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Ambiguity resolution in sentence processing: the role of lexical and contextual information[1]

DESPINA PAPADOPOULOU & HARALD CLAHSEN

University of Essex

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This study investigates how the parser employs thematic and contextual information in resolving temporary ambiguities during sentence processing. We report results from a sentence-completion task and from a self-paced reading experiment with native speakers of Greek examining two constructions under different referential context conditions: relative clauses (RCs) preceded by complex noun phrases with genitives, [NP1 + $NP2_{Gen}$], and RCs preceded by complex noun phrases containing prepositional phrases, [NP1 + $_{PP}$[P NP2]]. We found different attachment preferences for these two constructions, a high (NP1) preference for RCs with genitive antecedents and a low (NP2) preference for RCs with PP antecedents. Moreover, referential context information was found to modulate RC attachment differently in the two experimental tasks. We interpret these findings from the perspective of modular theories of sentence processing and argue that on-line ambiguity resolution relies primarily on grammatical and lexical-thematic information, and makes use of referential context information only as a secondary resource.

1. Introduction

In sentence processing research, one question that has received considerable attention concerns the types of information used during the early stages of parsing. The existence of grammatically ambiguous sentences for which, in sentence comprehension, one of the possible interpretations is clearly favoured, e.g. *John said the man died yesterday*, where the adverb is preferably construed with the embedded clause (Kimball 1973), indicates that grammatical information alone is insufficient to predict preferences in sentence comprehension. Broadly speaking, we can distinguish three types of account of how different sources of information influence ambiguity resolution. First, syntax-first approaches argue that the initial parse is determined by phrase-structure-based parsing strategies such as Late

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Closure or Minimal Attachment (see e.g. Frazier & Fodor 1978, Frazier 1987 and subsequent work). Secondly, multiple-constraints accounts (MacDonald 1994, Thornton, Gil & MacDonald 1998, Thornton, MacDonald & Gil 1999) and the referential context hypothesis (Crain & Steedman 1985, Altmann & Steedman 1988, Steedman & Altmann 1989, Altmann, Garnham & Dennis 1992) argue that in addition to phrase-structure information, both lexical and discourse information influence the processing of (temporarily) ambiguous sentences at any given point during sentence comprehension. The third view has been postulated in the framework of Construal Theory (Frazier & Clifton 1996), according to which different subclasses of grammatical information are used differentially in sentence comprehension. Specifically, Construal Theory claims that complements and obligatory arguments are immediately assigned fully determinate syntactic structures by the parser, whereas adjuncts and modifiers (instead of being syntactically attached) are associated with the closest thematic domain. Thus, within this view, the role of discourse-level information in the early stages of sentence comprehension is limited, in that it may influence the initial parse only for adjuncts and modifiers, and only within a given thematic domain. Even though many studies have investigated the role of phrase-structure-based parsing strategies (Frazier 1978, 1987, Frazier & Fodor 1978, Frazier & Rayner 1982), of prosodic cues (Fodor 1998, 2002; Fernández & Bradley 1999), and of contextual information (Crain & Steedman 1985, Altmann & Steedman 1988, Steedman & Altmann 1989, Altmann et al. 1992) in comprehending ambiguous sentences, the question of which sources of information are available to the parser at early stages of processing remains controversial.

In the present study, we investigate how referential context information interacts with lexical cues for resolving relative clause (RC) attachment ambiguities in Greek. Two RC constructions of Greek were examined, (i) RCs preceded by complex noun phrases with genitives and (ii) RCs preceded by complex noun phrases containing prepositional phrases headed by the thematic preposition *me* 'with'. These two constructions were tested in different context conditions (with and without biasing context) in an untimed (= off-line) completion task and a timed (= on-line) self-paced reading experiment. With this design, we can test the three sentence-processing accounts mentioned above. From the perspective of syntax-first approaches to parsing, one would expect non-syntactic information to influence the final interpretation of a sentence, but not the on-line mechanism that guides RC attachment. If this is correct, we should find strong context and lexical effects in the off-line task but not in the on-line one. If, in contrast, all sources of information, including referential context and lexical information, affect all stages of parsing, as is claimed by multiple-constraints accounts, then we should find the same strong context and lexical effects in both experimental tasks. From the perspective of Construal Theory, on the other hand, we would expect that referential context information is more likely to affect

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attachment preferences in the genitive than in the PP construction. This is because according to Construal Theory, thematic information takes precedence over contextual information in ambiguity resolution. In the PP construction, [NP1 + PP[P NP2]], the thematic preposition *me* 'with' creates a local thematic domain with the second NP. In the genitive construction, [NP1 + NP2$_{Gen}$], however, both NPs belong to the same thematic domain and are potential hosts for the RC, and only in such cases is discourse-level information claimed to influence parsing decisions.

We will show that both syntax-first and multiple-constraints accounts of parsing provide only partial explanations for our findings, but that the predictions of Construal Theory are confirmed. Before turning to the empirical results, the following section will give a summary of previous experiments on the phenomenon under study.

2. Previous studies on relative clause ambiguities

2.1 *Lexical biases in RC attachment*

A series of studies indicates that lexical information affects the parsing of temporarily ambiguous sentences. Consider, for example, relative clause attachment ambiguities in sentences such as (1).

(1) The doctor recognized [the pupil]$_{NP1}$ with [the nurse]$_{NP2}$ who was feeling very tired.

Several studies found that when NP2 is introduced by a thematic preposition, the RC tends to be attached low, i.e. to NP2, the more deeply embedded of the two NPs – *the nurse* in (1). This preference was found for a range of languages, including English, Spanish, French, Italian and Greek (see e.g. De Vincenzi & Job 1993, 1995, Gilboy, Sopena, Clifton & Frazier 1995, Traxler, Pickering & Clifton 1998, Frenck-Mestre & Pynte 2000, Papadopoulou & Clahsen 2003).

By contrast, cross-linguistic differences in RC attachment were found for sentences such as (2), in which NP2 is headed by a functional preposition such as *of* or marked by genitive case.

(2) Someone shot [the servant]$_{NP1}$ of [the actress]$_{NP2}$ who was on the balcony.

Different languages exhibit different RC attachment preferences in this construction. An NP1 preference was, for example, obtained for Spanish (Cuetos & Mitchell 1988; Carreiras & Clifton 1993, 1999; Gilboy, Sopena, Clifton & Frazier 1995), French (Frenck-Mestre & Pynte 2000), German (Hemforth, Konieczny, Scheepers & Strube 1998), Dutch (Brysbaert & Mitchell 1996) and Greek (Papadopoulou & Clahsen 2003), while an NP2 preference was found, for example, for English (Cuetos & Mitchell 1988, Frazier & Clifton 1996), Italian (De Vincenzi & Job 1993, 1995), Swedish, Norwegian, Romanian (Ehrlich, Fernández, Fodor, Stenshoel & Vinereanu

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1999), Brazilian Portuguese (Miyamoto 1998) and Arabic (Abdelghany & Fodor 1999). Several accounts have been proposed to explain the cross-linguistic differences attested in RC attachment preferences. Gibson and colleagues (Gibson, Pearlmutter, Canseco-Gonzalez & Hickock 1996, Gibson, Pearlmutter & Torrens 1999) have attributed the cross-linguistic variation to the competition between two parsing principles, Recency and Predicate Proximity. The NP2 preference that is typically found in English can be accounted for by assuming that in highly configurational languages like English, ambiguous modifiers are integrated into the current parse in accordance with the locality principle of RECENCY, which favours attachment of ambiguous phrases to more recently processed syntactic constituents (and which is similar to the LATE CLOSURE strategy proposed earlier by Frazier 1978, Frazier & Fodor 1978). In languages whose speakers prefer NP1 disambiguation, on the other hand, the interacting locality principle of PREDICATE PROXIMITY is claimed to be strong enough to outrank the (supposedly universal) Recency preference. According to Predicate Proximity, threre will be a preference for attaching ambiguous modifiers to constituents as structurally close as possible to the predicate, or to the S/IP node, hence favouring attachment of the RC to the overall object NP in example (2) above; see Mitchell, Corley & Garnham (1992), Fodor (1998, 2002), Hemforth et al. (1998) for alternative accounts of the cross-linguistic differences in RC attachment, a detailed discussion of which is beyond the scope of this paper; see also Cuetos, Mitchell & Corley (1996), Papadopoulou (2002), Fernández (2003), Roberts (2003) for further discussion.

With respect to the issue of lexical biases in RC attachment and the contrast observed between sentences such as (1) and (2), consider the results of Papadopoulou & Clahsen (2003) on RC attachment preferences in Greek in some more detail. They examined sentences such as those in (3) that contained complex NPs followed by a temporarily ambiguous RC introduced by the complementizer *pu* 'that'. The second potential host NP either carried morphological genitive case (*tis kathighitrias* 'the-gen teacher-gen' in (3a) and (3b)) or was the complement of the thematic preposition *me* 'with' (cf. (3c), (3d)). The disambiguating information forcing either NP1 or NP2 attachment was provided by gender marking on the participle.

(3) (a) *Condition Gen-high* (*gh*)

Enas	kirios		fonakse	ton
a-MASC-SG-NOM	man-MASC-SG-NOM		called	the-MASC-SG-ACC
fititi		tis	kathighitrias	
student-MASC-SG-ACC		the-F-SG-GEN	teacher-F-SG-GEN	

pu itan apoghoitevmenos apo to neo ekpedheftiko sistima.
that was disappointed-MASC by the new educational system.
'A man called the student (masc) of the teacher (fem) who was disappointed (masc) by the new educational system.'

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(b) *Condition Gen-low* (*gl*)
Enas kirios fonakse ton fititi tis kathighitrias pu itan apoghoitevmeni apo to neo ekpedheftiko sistima.
'A man called the student (masc) of the teacher (fem) who was disappointed (fem) by the new educational system.'

(c) *Condition PP-high* (*ph*)
Enas kirios fonakse ton fititi me tin kathighitria pu itan apoghoitevmenos apo to neo ekpedheftiko sistima.
'A man called the student (masc) with the teacher (fem) who was disappointed (masc) by the new educational system.'

(d) *Condition PP-low* (*pl*)
Enas kirios fonakse ton fititi me tin kathighitria pu itan apoghoitevmeni apo to neo ekpedheftiko sistima.
'A man called the student (masc) with the teacher (fem) who was disappointed (fem) by the new educational system.'

Papadopoulou & Clahsen (2003) found that in both off-line and on-line tasks, native speakers of Greek showed a high-attachment preference in sentences with genitive antecedents, (3a) vs. (3b). In sentences with PP antecedents, (3c) vs. (3d), on the other hand, they obtained a low-attachment preference for the RC, both off-line and on-line. This latter finding replicates previous findings from other languages showing that when the second NP is introduced by a thematic preposition, the RC tends to be attached low, even in languages that prefer high-attachment in corresponding constructions without a thematic preposition. Thus, the presence of a thematic preposition seems to affect RC attachment preferences, indicating that lexical-thematic cues influence the parsing of (temporary) ambiguities. The low-attachment preference in sentences with PP antecedents is compatible with Construal Theory, according to which non-obligatory constituents such as RC adjuncts are construed or associated with the closest thematic processing domain. That is, when the NP2 receives a theta-role from a preposition (as in (3c) and (3d), from *me*), the RC is processed within this thematic domain and is consequently attached low. However, in sentences such as (3a) and (3b) the closest thematic processing domain is the entire NP (*ton fititi tis kathighitrias* 'the student of the teacher'), which includes both NP1 and NP2. In this way, Construal Theory accounts for the fact that in sentences such as (3c) and (3d) low-attachment is preferred across languages, even in languages such as Greek, which otherwise (i.e. in cases such (3a) and (3b)) prefer high-attachment.

2.2 *Context effects on RC ambiguities*

There are two studies examining context effects on RC attachment preferences in the NP-*of*-NP construction, Zagar, Pynte & Rativeau (1997) for

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French and Desmet, De Baecke & Brysbaert (2002) for Dutch. Their results seem to indicate that referential context information is unavailable to the parser, at least during the initial (first pass) parse.

Zagar et al. (1997) tested sentences such as (4), in which the RC *qui semblait plus* 'who seemed more' could be interpreted either as a modifier of the first NP (*l'avocat*) or the second one (*la chanteuse*).

(4) Un journaliste aborda l'avocat de la chanteuse qui semblait plus …
'A journalist approached the barrister of the singer who seemed more …'

According to the referential context hypothesis, one would expect that the RC should be more likely to be attached to a host that has several possible referents in a preceding discourse context. Hence, in order to bias participants towards high or low attachment, several referents were introduced for the first or the second noun, respectively. Zagar et al. obtained a context effect only with respect to the accuracy of responses to comprehension questions following the experimental sentences; specifically, accuracy was greater when the contextual bias was consistent with the attachment. The eye-tracking measures, however, did not produce any effect of context. Instead, Zagar et al. found an overall high-attachment preference regardless of context, similarly to what has been found when constructions such as (4) are presented to native speakers of French in isolation (cf. Mitchell, Cuetos & Zagar 1990, Frenck-Mestre & Pynte 2000). Zagar et al. (1997) concluded that contextual information influences the final interpretation of a sentence but does not influence the on-line mechanism that guides early RC attachment.

However, one potential problem with Zagar et al.'s study is that high- and low-attachment biasing contexts were not properly balanced in their materials in that, while the high-attachment contexts contained several potential referents for the first noun and only one for the second, the low-attachment contexts contained several potential referents for both nouns. Moreover, Zagar et al.'s pre-test completion experiment revealed only a very small context effect (p. 427), suggesting that the contexts may not have been sufficiently biased to affect the participants' attachment preferences in the on-line task.

Nevertheless, the absence of context effects on RC attachment preferences has been replicated by a later study on Dutch. Desmet et al. (2002) investigated the influence of referential context on RC attachment preferences in Dutch in a sentence-completion study and an eye-tracking experiment. They studied Dutch sentences such as *De agenten verhoren de adviseur van de politici die spreekt* (*spreekt/spreken*) *met een zachte stem* 'The police interrogate the advisor of the politicians who speaks (speaks/speak) with a soft voice'. Previous studies examining this kind of construction in isolation found an NP1 preference for Dutch (Brysbaert & Mitchell 1996, Mitchell &

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Brysbaert 1998, Mitchell, Brysbaert, Grondelaers & Swanepoel 2000). Like Zagar et al. (1997), Desmet et al. presented these sentences in different referential context conditions, with a preceding neutral context, a preceding high-attachment biasing context, and a preceding low-attachment biasing context. Desmet et al. found that while in the off-line study the participants' preferences were strongly influenced and indeed reversed by the preceding referential context, in the on-line (eye-tracking) experiment they were only slightly modulated by context information. Most importantly, the reading times revealed a significant high-attachment preference independent of the preceding context. Desmet et al. conclude from these findings that referential context does not influence early attachment decisions, but plays a role in later phases of sentence processing.

Desmet et al.'s (2002) results are consistent with those of Zagar et al. (1997). However, both studies have examined only RCs headed by complex NPs containing non-thematic (*of*-type) RC antecedents and were not designed to examine how discourse-level information interacts with lexical cues in RC attachment ambiguity resolution. The lack of studies examining the interaction of discourse-level information and lexical cues for processing ambiguous sentences motivated the present study.

3. Experiment 1: sentence-completion study

The purpose of this experiment was to examine the role of lexical and contextual information in ambiguity resolution IN AN OFF-LINE TASK. Three context conditions were examined: a neutral condition in which the experimental sentences were presented in isolation without any preceding context, a high-attachment biasing context, and a low-attachment biasing context. In the neutral condition, we would expect to replicate Papadopoulou & Clahsen's (2003) results on Greek RC attachment, i.e. a high-attachment preference for $NP+NP_{genitive}$ and a low-attachment one for NP+PP. Context effects would be evident if the initial NP1 preference for genitives is magnified by a high-attachment biasing context and neutralized or reversed by a low-attachment biasing context. Likewise, the initial NP2 preference for PP antecedents should be strengthened by a low-attachment biasing context and wiped out or reversed in a high-attachment biasing context.

3.1 *Participants*

Forty adult native speakers of Greek (mean age: 20,03; females: 25; males: 15), all students of the University of Athens, participated voluntarily in the experiment. There were twenty participants in the no-context version (in which sentences were presented in isolation) and twenty participants in the version with preceding context; no one participated in both versions.

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3.2 *Materials and design*

Twenty-four experimental sentences were constructed. The experimental sentences contained an RC with two possible antecedents. The RCs were always subject-RCs introduced by the complementizer *pu* 'that'. The two NPs preceding the RC were always animate (see Desmet et al. 2002), had different gender (either feminine or masculine) and involved a functional/professional relationship. Two versions of each experimental sentence were constructed that differed only with respect to the form of the complex NP that preceded the RC. In one version, NP2 appeared in genitive case, in the other, the second NP contained a PP introduced by the lexical preposition *me* 'with'; see (5) and (6) for examples. A complete list of all experimental stimuli for each task can be found in Papadopoulou (2002) and can be made available upon request.

Participants were presented with sentence fragments such as (5a) or (5b) and had to choose between a low (6a) and a high (6b) attachment continuation of the sentence fragment. Note that the sentence fragments are ambiguous up to the auxiliary *itan* 'was', and that in the sentence continuations, the ambiguity is resolved by means of gender information on a past participle, which agrees with either the first or the second noun, resulting in either high or low RC attachment.[2] In addition to the experimental sentences, there were forty-eight filler sentences involving a variety of constructions. Half of the fillers were ambiguous and half were unambiguous.

[2] One *JL* referee raised the question of whether the PPs in sentences like (5b) could modify the preceding verb, as in sentences such as *He looked at the man with the binoculars*, in which the PP *with the binoculars* could denote the instrument and modify the verb *looked*. This possibility is not available in our critical sentences because the complement of the PP was always an animate referent. Note, however, that the English translation equivalents of the PP sentences (e.g. (5b)), but not of the genitives, allow for an additional attachment ambiguity in which the PP (*with the teacher*) is attached to the verb, so that (5b) could be interpreted to mean that the journalist and the teacher looked at the pupil together. This possibility is also available in Greek but is less plausible when the complement of the PP is animate. To verify these intuitions, we gave all 24 experimental sentences with the PPs but without the RCs (e.g. *Enas dhimosioghrafos kitakse ti mathitria me to dhaskalo* 'A journalist looked at the pupil with the teacher') to 13 native speakers of Greek and asked them to rate which of two interpretations, one based on verb attachment of the PP (e.g. 'A journalist together with the teacher looked at the pupil') versus one based on NP attachment (e.g. 'A journalist looked at the pupil who was with the teacher'), was more plausible. It turned out that the reading in which the PP is attached to the NP received an 81.83% plausibility score, whereas the verb-attachment reading received a much lower plausibility score, 30.16%. One-sample *t*-tests showed that both scores were significantly different from 50% (NP attachment: $t1(12) = 7.110$, $p < 0.001$; $t2(23) = 24.994$, $p < 0.001$; verb attachment: $t1(12) = 3.367$, $p < 0.01$; $t2(23) = 12.040$, $p < 0.001$), which confirmed that the additional verb-attachment ambiguity is not very plausible for the kinds of sentences we tested. In addition, most of the subjects participating in this plausibility test reported that the NP-attachment reading was the most natural interpretation of the sentences and the one that first came to their mind when reading the sentences.

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(5) (a) Enas dhimosioghrafos kitakse ti mathitria tu dhaskalu pu itan …
'A journalist looked at the pupil-FEM the-GEN teacher-MASC-GEN that was …'

(b) Enas dhimosioghrafos kitakse ti mathitria me to dhaskalo pu itan …
'A journalist looked at the pupil-FEM with the teacher-MASC that was …'

(6) (a) … nevriasmenos eksetias tis kathisterisis
angry-NOM-SG-MASC because-of the-GEN-SG-FEM delay-GEN-FEM

(b) … nevriasmeni eksetias tis kathisterisis
angry-NOM-SG-FEM because-of the-GEN-SG-FEM delay-GEN-FEM

To investigate context effects, seventy-two texts were constructed, twenty-four to precede the experimental sentences and forty-eight for the filler sentences. For the experimental sentences, referential context and focus were manipulated to bias participants towards high or low attachment. The biasing contexts constructed were properly balanced in that low- and high-attachment biasing contexts had two possible referents for the second and the first noun respectively. In high-attachment biasing contexts (7a), the text preceding each experimental sentence contained two potential referents for the first antecedent of the RC and focus was put on the referent of the first NP in the last sentence of the text. In low-attachment biasing contexts (7b), there were two potential discourse referents for the second RC antecedent, and focus was put on the second NP in the last sentence before the target; see (7b). The filler sentences were also preceded by texts of the same length as was the case with the experimental sentences. For half of the filler texts, only one completion of the target sentence was appropriate given the semantic and pragmatic information provided in the preceding text. For the other half, the context biased the participants towards one of the two completions.

(7) (a) *Context biased towards high-attachment*
The schoolyard was crowded. Children, parents and teachers were waiting for the celebration to start. It was 10.30 and the celebration was supposed to have started at 10. Two pupils were talking with their teacher. The teacher and one of the pupils were really upset. The other pupil was listening to the conversation sceptically.
EXPERIMENTAL SENTENCE: 'A journalist looked at the pupil with the teacher that was …'

(b) *Context biased towards low-attachment*
The schoolyard was crowded. Children, parents and teachers were waiting for the celebration to start. It was 10.30 and the celebration was supposed to have started at 10. One pupil was talking with two of her teachers. The pupil and one of the teachers were really upset. The other teacher was listening to the conversation sceptically.

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EXPERIMENTAL SENTENCE: 'A journalist looked at the pupil with the teacher that was …'

To examine whether both of the NPs introduced in the two context conditions preceding the experimental sentence were equally plausible hosts for an RC, all experimental contexts used in the main experiments were given to ten adult native speakers of Greek (none of whom participated in any of the main experiments), who were asked to rate the plausibility of the continuations on a five-point scale. Continuations were sentences that contained one of the two referents introduced in the context paragraphs followed by an RC, e.g. *A journalist looked at the pupil that was angry*. We also added an infelicitous continuation in which the continuation sentence contained an NP modified by an RC that was not introduced in the context paragraph. Infelicitous continuations yielded low plausibility ratings across the two referential context conditions (M = 1.29, s.d. = 0.44), whereas continuations with one of the two NPs introduced in the contexts received high plausibility ratings. In the contexts biasing towards NP1, the plausibility ratings were M = 4.0, s.d. = 0.57 for NP1; M = 3.68, s.d. = 0.51 for NP2; and M = 1.26, s.d. = 0.47 for infelicitous continuations. The infelicitous continuations were statistically less preferred than both NP1 ($t1(9) = 11.520$, $p < 0.001$; $t2(23) = 13.286$, $p < 0.001$) and NP2 continuations ($t1(9) = 12.688$, $p < 0.001$; $t2(23) = 9.765$, $p < 0.001$). In the contexts biasing towards the second NP, the scores were M = 4.19, s.d = 0.47 for NP1; M = 3.67, s.d. = 0.53 for NP2; and M = 1.31, s.d. = 0.43 for infelicitous continuations. In this context condition, NP1 continuations ($t1(9) = 13.466$, $p < 0.001$; $t2(23) = 12.459$, $p < 0.001$) and NP2 continuations ($t1(9) = 11.488$, $p < 0.001$; $t2(23) = 11.347$, $p < 0.001$) were also significantly more preferred than infelicitous ones. As can be seen, the mean plausibility ratings were parallel for continuations that contained NP1 and for those that contained NP2, thus indicating that both NPs presented in the contexts are plausible hosts for the RCs we employed.

We also manipulated the form of the complex NP that preceded the RC, parallel to our earlier study (see (3) above), thus yielding six experimental conditions:

(8)

RC ANTECEDENT	CONTEXT		
$NP + NP_{genitive}$	High-attachment biasing	Low-attachment biasing	No-context
NP + PP	High-attachment biasing	Low-attachment biasing	No-context

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3.3 *Procedure*

Two experimental versions were constructed, one in which the critical (and the filler) sentences were presented in isolation, i.e. without any preceding context, and one with preceding context. In the no-context version of the experiment, the participants were presented with two booklets of seventy-two sentences each, with each sentence fragment together with two possible continuations typed on a separate sheet of paper. Each booklet contained the same number of fillers and experimental sentences, of which twelve had $NP + NP_{gen}$ and twelve had NP + PP antecedents for the RCs, and the same sentence was not seen more than once by any participant. In half of the experimental sentences, the NP1 attachment interpretation was shown as the first completion, and in the other half it was shown as the second one. The participants were instructed to read the sentences only once and to circle the option that seemed most appropriate to them as a completion of the sentence. In the experimental version with preceding contexts, booklets with the same seventy-two sentences were constructed in which the critical (and filler) sentences were preceded by short texts. Each short text was printed on a separate sheet of paper followed (on the same page) by an experimental or filler sentence. The participants' task was again to circle the option that seemed most appropriate to them as a completion of the sentence. Four different booklets were constructed, ensuring that each one contained all the conditions tested and that each participant was exposed to all conditions. Participants were tested in two sessions, in each of which the same experimental sentences were presented with different preceding contexts (biased towards high- or low-attachment). There was a two-week interval between the two sessions.

3.4 *Results*

Some subjects did not provide an answer on a small number of trials and others chose both options. These ambiguous or unanswered responses were left out so that the means add up to 100%. Figure 1 presents percentages of high-attachment (= NP1) and low-attachment (= NP2) continuations provided by the participants.

In the condition in which the experimental sentences were presented in isolation, figure 1 shows a high-attachment preference (69.16%) for genitives and a low-attachment preference (75%) in the PP condition. More importantly, figure 1 shows that the low-attachment preference for PPs is wiped out in the high-attachment biasing context condition, and that in this context condition the high-attachment preference for genitives is stronger than in sentences presented in isolation. Likewise, in the low-attachment biasing condition, the high-attachment preference for genitives seen in the no-context condition is strongly reduced, whereas the low-attachment preference for PPs is still present. In order to examine these results statistically,

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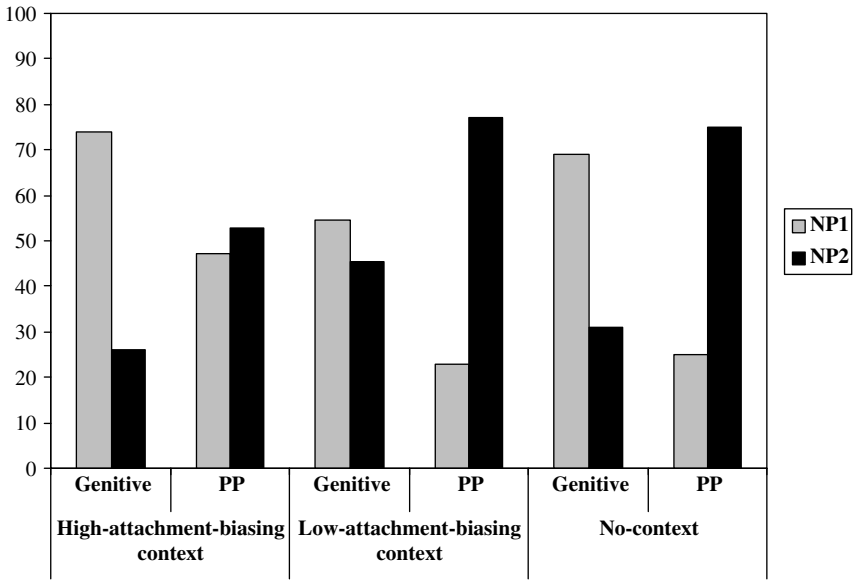


Figure 1
Percentages of continuations

we ran repeated-measures ANOVAs on the subjects' NP1 responses. In the items analysis, within-items ANOVAs were performed, because the same items were used in all context conditions. The two within-items factors were Context, which had three levels (no context vs. high-biasing vs. low-biasing contexts), and Antecedent, which had two levels (genitives vs. PPs). In the subjects analysis, we used a between-subjects design, because one group of people saw the no-context condition and another group saw the biasing context conditions. We compared each biasing context condition with the no-context condition and treated Context (no context vs. either high- or low-biasing contexts) as a between-subjects factor and Antecedent as a within-subjects factor.

The statistical analyses confirmed the modulating role of a biasing referential context on RC attachment. In the items analysis, there were significant main effects of Context ($F_2(2, 46) = 26.761$, $p < 0.001$) and Antecedent ($F_2(1, 23) = 187.272$, $p < 0.001$), as well as a significant interaction between Context and Antecedent ($F_2(2, 46) = 5.895$, $p < 0.01$). Separate comparisons of the no-context condition with each biasing context condition also revealed main effects of Context (high-biasing vs. no-context conditions: $F_1(1, 38) = 3.314$, $p = 0.077$; $F_2(1, 23) = 7.352$, $p < 0.02$; low-biasing vs. no-context conditions: $F_1(1, 38) = 1.863$, $p = 0.180$; $F_2(1, 23) = 5.470$, $p < 0.03$) and Antecedent (high-biasing vs. no-context conditions: $F_1(1, 38) = 65.737$, $p < 0.01$; $F_2(1, 23) = 129.222$, $p < 0.001$; low-biasing vs. no-context conditions: $F_1(1, 38) = 78.697$, $p < 0.001$; $F_2(1, 23) = 105.010$, $p < 0.001$), and a significant

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Context × Antecedent interaction (high-biasing vs. no-context conditions: $F_1(1, 38) = 4.256$, $p < 0.05$; $F_2(1, 23) = 8.395$, $p < 0.01$; low-biasing vs. no-context conditions: $F_1(1, 38) = 1.676$, $p = 0.203$; $F_2(1, 23) = 4.243$, $p = 0.051$). Furthermore, one-sample *t*-tests confirmed that in the no-context condition, the high-attachment preference for genitives ($t_1(19) = 4.945$, $p < 0.001$; $t_2(23) = 4.258$, $p < 0.001$) and the low-attachment preference for NP + PP antecedents ($t_1(19) = 4.199$, $p < 0.001$; $t_2(23) = 7.460$, $p < 0.001$) were significantly different from chance level; for all one-sample *t*-tests chance level was set at 50%. Finally, in the high-attachment biasing context, there was an NP1 advantage in the genitive condition ($t_1(19) = 4.381$, $p < 0.001$; $t_2(23) = 7.433$, $p < 0.001$) and no NP2 advantage in the PP condition ($t_1(19) = 0.395$, $p = 0.697$; $t_2(23) = 0.150$, $p = 0.882$). On the other hand, in the low-attachment biasing context there was an NP2 advantage in the PP condition ($t_1(19) = 5.804$, $p < 0.001$; $t_2(23) = 7.924$, $p < 0.001$) and no NP1 advantage in the genitive condition ($t_1(19) = 0.630$, $p = 0.536$; $t_2(23) = 1.311$, $p = 0.203$).

3.5 *Discussion*

We found that when ambiguous RCs are presented in isolation, native speakers of Greek prefer NP1 attachment in cases in which the RC is headed by a complex NP containing a genitive phrase, whereas they prefer NP2 attachment for complex RC antecedents with thematic PPs. These results replicate those of Papadopoulou & Clahsen (2003) and suggest that lexical cues, such as the presence of a theta-role assigning preposition, influence RC attachment preferences in Greek.

We also found that an appropriately biased context plays a role in the way RC attachment ambiguities are resolved in Greek, in that there were more NP1-responses when the sentences were preceded by a high-biasing context than when they were presented in isolation, and there were more NP2-responses in the low-biasing contexts than in the no-context condition. Our materials revealed a significant interaction between Context and Antecedent, indicating that the contexts we created were strong enough to influence the interpretation of the RC. Specifically, the biasing contexts were found to modulate the different (NP1 vs. NP2) attachment preferences for both genitive and PP antecedents. The low-attachment preference for PPs that is evident in the no-context condition is wiped out in the high-attachment biasing context condition. Likewise, in the low-attachment biasing condition, the high-attachment preference for the genitives seen in the no-context condition is reduced.

The results of this experiment are compatible not only with multiple-constraints accounts and with Construal Theory but also with syntax-first approaches, because even the latter allow for context effects in off-line tasks, as these may reflect final (rather than early) parsing processes.

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4. Experiment 2: self-paced reading

The main purpose of this experiment was to investigate how in an on-line task, referential context information and lexical cues influence ambiguity resolution. Experiment 1 revealed different RC attachment preferences for the two antecedent types and an effect of referential context, which means that the contexts used in our materials were sufficiently biased to affect RC attachment preferences in an off-line task. If EARLY parsing preferences are also affected by context information and lexical cues, we would expect parallel results in the on-line (self-paced reading) task.

4.1 *Participants*

Fifty-eight adult native speakers of Greek (mean age: 23,66; females: 34; males: 24), all students at the University of Essex, participated in the experiment. Twenty of them were presented with experimental and filler sentences in isolation, and thirty-eight participants read the same materials preceded by short texts to test potential context effects. The participants were Greek nationals studying for Masters degrees at the University of Essex who, at the time of testing, had been in the UK for less than six months. Most participants form part of a network of Greek students in which Greek is used as a common language on a daily basis. English is clearly a second language for them, acquired and used mainly in classroom settings. None of the participants was a simultaneous bilingual having learned two languages in parallel. Note also that the entire experiment, including all instructions, was performed in Greek by a native speaker of Greek. We therefore assume that in our experiment the participants are processing Greek as a native language, i.e. in 'monolingual mode' (Grosjean 1997); see Fernández (2003) for RC attachment preferences in bilinguals.

4.2 *Materials and design*

Twenty-four experimental sentences were tested in four conditions as illustrated in (9).

(9) (a) *Gen-high*
Enas theatis kituse ton proponiti tis athlitrias pu fenotan poli stenohorimenos apo tin apofasi tis epitropis.
'A spectator was looking at the trainer (masc) of the athlete (fem) who seemed very upset (masc) because of the decision of the committee.'

(b) *Gen-low*
Enas theatis kituse ton proponiti tis athlitrias pu fenotan poli stenohorimeni apo tin apofasi tis epitropis.
'A spectator was looking at the trainer (masc) of the athlete (fem) who seemed very upset (fem) because of the decision of the committee.'

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(c) *PP-high*
Enas theatis kituse ton proponiti me tin athlitria pu fenotan poli stenohorimenos apo tin apofasi tis epitropis.
'A spectator was looking at the trainer (masc) with the athlete (fem) who seemed very upset (masc) because of the decision of the committee.'

(d) *PP-low*
Enas theatis kituse ton proponiti me tin athlitria pu fenotan poli stenohorimeni apo tin apofasi tis epitropis.
'A spectator was looking at the trainer (masc) with the athlete (fem) who seemed very upset (fem) because of the decision of the committee.'

The experimental sentences were similar[3] to those in experiment 1. In the self-paced reading task, the auxiliary form *itan* was replaced by a finite form of the verb *fenome* 'to seem'. This was done so as to avoid a temporal ambiguity that might result from the fact that *itan* is a syncretic form meaning either 'was' or 'were'. The verb *fenome* has distinct forms for singular (*fenotan*) and plural (*fenodan*) in the past continuous and thus avoids this ambiguity. The syncretism of the *itan* form is less problematic for the off-line completion task, as in this task the participants were asked to choose between two possible continuations which disambiguated the sentences in favour of either NP1 or NP2 attachment. The self-paced reading task, however, provides a continuous on-line measure of reading. A temporary ambiguity resulting from the *itan* form should therefore be avoided.

The experimental sentences ranged in length from 14 to 16 words. The sentences across the four conditions were minimal pairs, in the sense that they included the same words and they differed only in the form of antecedent (genitive vs. preposition) and the type of attachment (high vs. low). The two antecedents in the complex NP had different gender, either feminine or masculine, and they also indicated functional or professional relationships exactly like in the off-line task. In half of the materials the first NP was masculine and the second feminine, whereas in the other half the first NP was feminine and the second masculine. The resolution of the ambiguity is rendered by gender information in the same way as in the off-line task.

Participants read these sentences in a non-cumulative segment-by-segment fashion, with the presentation of each new segment being triggered by the participants' pressing a pacing button. The times between button presses

[3] The items used in the two experiments were identical, with the exception of two items (item 12 and item 24). When reconsidering the materials of the on-line study, we thought that the contents of the relative clauses in these two items might bias the participants towards NP2 (item 12) and NP1 (item 24), and for this reason we changed their contents so that they would be more neutral.

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provide the crucial experimental measure. The sentences were divided into five segments, as shown in (10).

(10) Enas theatis kituse / ton proponiti tis athlitrias (me tin athlitria) / pu fenotan / poli stenohorimenos(i) / apo tin apofasi tis epitropis.
'A spectator was looking at / the trainer-MASC of the athlete-FEM (with the athlete-FEM) / who seemed / very upset (MASC/FEM) / because of the decision of the committee.'

To ensure that participants paid attention to what they were reading, they were also required to answer a content question after having read each sentence, e.g. 'Was the trainer upset because of the decision of the committee?' The correct response to the questions was either a simple 'YES' or a simple 'NO'. 'YES' and 'NO' questions were evenly distributed across the four conditions.

Participants' reading times were compared. The critical segment is the fourth one, since at this point the attachment of the RC is disambiguated. At this segment, a low-attachment preference would be evident from shorter reading times of (9b) and (9d) relative to (9a) and (9c), because in the former sentences the form of the gender marking on the adjective is compatible with low-attachment, whereas in (9a) and (9c) it is not. If, on the other hand, participants prefer to attach the relative clause to the first of the two NPs, reading times should be shorter for (9a) and (9c) than for (9b) and (9d) on the fourth segment.

Seventy-two filler items were included to divert participants' attention from the structure of the materials. The filler sentences made use of different kinds of syntactic constructions. Like the experimental items, they were divided into five segments and followed by a content question. The answer to these questions was either a simple 'YES' or a simple 'NO'; the 'YES' and 'NO' questions were evenly distributed across the fillers. Moreover, there were ten practice sentences at the beginning of the experiment to familiarize the participants with the task.

To examine the role of referential context, the experimental sentences and fillers were presented to one group of participants without any preceding context and to another as the final sentence of a short text. The texts used for the experimental and filler sentences were the same as those for experiment 1, yielding six experimental conditions (see (8) above).

4.3 *Procedure*

The experiment was designed using the NESU software package (Baumann, Nagengast & Klaas 1993). The stimuli were presented in Greek script on a TFT computer monitor in white letters (Arial 24pt) on a dark background. The participants reacted by pressing a button on a dual box after reading each segment.

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Participants reading the sentences in isolation were instructed to read the sentences as quickly and as carefully as they could. After having read a sentence in a segment-by-segment fashion, a yes–no question appeared on the screen, which participants answered by pressing one of the two buttons on a dual box. The green button on the right side was for 'YES' and the red button on the left side was for 'NO'. After the participants pressed a marked key on the keyboard, the next sentence was presented for (self-paced) reading. At this point they could take a break for as long as they wanted to, if they felt tired.

For participants who read the sentences with preceding context, the texts and the target sentences were also presented on a TFT computer monitor in white letters (Arial 24pt) on a dark background. In each trial, participants first saw the biasing context (see examples (7a) or (7b)), which appeared in full on the screen and remained on the screen to ensure that they could read it at their own pace. Participants were instructed to press a button as soon as they had read the text. Immediately after they pressed the button, the target sentences appeared on the screen divided into five segments, as illustrated in (10). Again, the participants were instructed to press the button as soon as they had read each segment. After they had read a set of texts and sentences, a message appeared on the screen instructing them to answer questions, in order to ensure that the participants paid attention to both the texts and the target sentences. The questions always referred either to the content of the filler sentences or to the texts preceding them. There were eight questions per participant, each of which appeared after they had read different numbers of target sentences and texts, to prevent them from developing expectations. This set of questions was different from the one used in the no-context condition. The questions were typed on paper and the participants had to circle the correct answer, which was either a simple 'YES' or a simple 'NO'. Each sheet of paper contained the questions of one section and there was an equal number of 'YES' and 'NO' questions. The sentences were counterbalanced so that each participant read equal numbers of high- and low-attachment sentences and genitive and PP constructions in a high- or low-attachment biasing context. All participants were exposed to all conditions and no participant read the same item in more than one condition. Each participant was given written instructions that explained the tasks. Before the experiment, each participant was familiarized with seven practice trials.

4.4 *Results*

The percentage of correct responses to questions for the filler items was 92.2% in the experimental version, in which sentences were presented in isolation, and 80.7% in the versions with preceding context, indicating that the participants did indeed pay attention to the task. Any trials in which the

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Segment	Attachment	High-attachment-biasing context		Low-attachment-biasing context		No-context	
		Genitive	PP	Genitive	PP	Genitive	PP
First	NP1	843.04	815.96	760.73	804.91	873.38	816.12
	NP2	791.68	840.25	809.85	848.88	900.74	840.18
Second	NP1	918.46	1054.51	1183.03	935.06	1419.36	1594.88
	NP2	986.19	989.50	1012.60	1010.62	1516.41	1618.11
Third	NP1	738.72	709.06	682.83	704.86	970.58	1000.27
	NP2	756.48	733.55	765.66	772.48	1011.80	1086.73
Fourth	NP1	856.48	807.49	911.87	851.90	882.64	938.38
	NP2	1023.11	739.62	955.82	721.08	1222.12	864.32
Fifth	NP1	726.44	735.94	676.57	756.91	875.77	1022.00
	NP2	835.61	675.99	738.42	689.18	961.17	872.11

Table 1
Mean reading times (in ms) per segment and conditions

comprehension question was answered incorrectly were not included in the analysis, which resulted in the elimination of 8.54% of the data set. Reading times (RTs) that were two standard deviations above the mean for each condition were excluded from the present analysis. This resulted in the elimination of 4.58% of the data set in the version with isolated sentences and 5% in the versions with context. We ran separate analyses for 'subjects' and 'items' in the on-line task as we did in the off-line task. As the same sentences were used in all context conditions, we performed repeated-measures ANOVAs for items with the factors Antecedent (PP vs. Gen), Attachment (high vs. low) and Context (high, low, no) as within-items factors. In the subjects analysis, we treated Context as a between-subjects factor, because one group of people saw the sentences in isolation and a different group saw the sentences preceded by the biasing contexts. Thus, in the subjects analysis the between-subjects factor Context refers to the comparison of the no-context condition to either the high- or the low-attachment biasing context conditions. Antecedent and Attachment were treated as within-subjects factors. Items analyses are also reported when the no-context condition is compared to the high- and the low-attachment biasing conditions. In that case, a series of repeated 2x2x2 ANOVAs was performed with Context (no context vs. either high- or low-attachment biasing context), Antecedent (genitives vs. PPs) and Attachment (NP1 vs. NP2 sentences) as within-items factors. The mean reading times (RTs) per segment and for the different conditions are presented in Table 1.

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4.4.1 *Reading times before the critical segment*

To see whether any NP1/NP2 preferences arise before the critical experimental manipulation, consider the RTs pertaining to the first three segments. For the first segment, no statistically reliable differences were found. Table 1 shows that for the other segments, RTs in the no-context condition are overall slower than in the two conditions with preceding contexts, yielding significant main effects of Context on the second segment (no-context vs. high-attachment biasing context condition: $F_1(1, 56) = 28.268$, $p < 0.001$; no-context vs. low-attachment biasing context condition: $F_1(1, 56) = 19.631$, $p < 0.001$; $F_2(2, 46) = 112.082$, $p < 0.001$), the third segment (no-context vs. high-attachment biasing context condition: $F_1(1, 56) = 40.622$, $p < 0.001$; no-context vs. low-attachment biasing context condition: $F_1(1, 56) = 32.040$, $p < 0.001$; $F_2(2, 46) = 42.008$, $p < 0.001$), as well as on the fifth segment (no-context vs. high-attachment biasing context condition: $F_1(1, 56) = 12.025$, $p < 0.01$; no-context vs. low-attachment biasing context condition: $F_1(1, 56) = 15.613$, $p < 0.001$; $F_2(2, 46) = 66.269$, $p < 0.001$). Moreover, table 1 shows that in segment 2, genitives were read faster than PPs, yielding a significant main effect of Antecedent in the subjects analysis ($F_1(1, 56) = 5.195$, $p < 0.03$). Importantly, however, there were no interactions between Antecedent, Attachment, or Context, confirming that the attachment preferences did not arise before the critical manipulation.

4.4.2 *Reading times for the critical segment*

To see the results for the critical fourth segment, i.e. the point of disambiguation, more clearly, figure 2 presents a graph of the mean reading times in the various experimental conditions. This shows that parallel to what was found for the previous segments, the no-context conditions were read more slowly than the two referential context conditions and that sentences involving genitives were read more slowly than those with PPs. This was statistically confirmed in the repeated-measures ANOVA for items by main effects of Context ($F_2(2, 46) = 7.876$, $p < 0.01$) and Antecedent ($F_2(1, 23) = 15.673$, $p < 0.01$). More importantly, however, figure 2 suggests that in segment 4 (unlike in previous segments), the biasing context conditions affected sentences with genitives differently from sentences with PP antecedents. Consider genitive antecedents. In the no-context condition, there is a significant advantage for NP1 attachment of 339ms (1222.12–882.64: $t_1(19) = 4.568$, $p < 0.001$; $t_2(23) = 4.558$, $p < 0.01$), which is significantly reduced to a mere 44ms (955.82–911.87) advantage in the low-attachment biasing context ($t_1(56) = 1.857$, $p = 0.069$; $t_2(23) = 2.993$, $p < 0.01$). This is different for sentences with PP antecedents. In the no-context condition, there is a significant 74ms advantage for NP2 attachment (938.38–864.32: $t_1(19) = 2.315$, $p < 0.05$; $t_2(23) = 1.55$, $p = 0.135$) in sentences with PPs, and

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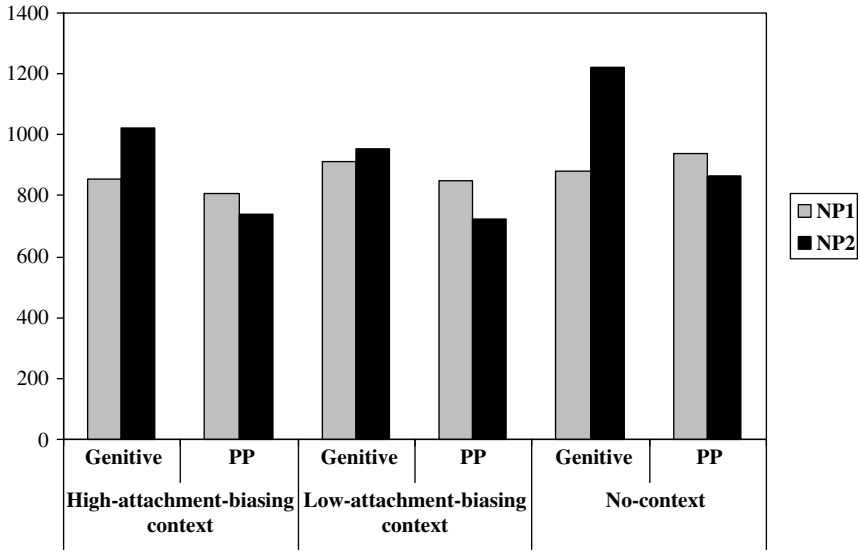


Figure 2
Mean reading times (in ms) for the critical (4th) segment

in the high-attachment biasing context, there is still an NP2 advantage of 68ms (807.49–739.62); the 6ms difference between these two is not significant.[4] What these results suggest is that even though biasing contexts are unable to wipe out or reverse the different attachment preferences for genitives and PPs, an appropriate context may significantly reduce the NP1 advantage for genitives but not the NP2 advantage for PPs.

The statistical analyses confirmed these observations. In the repeated-measures ANOVA for items, there were significant interactions between Antecedent and Attachment ($F_2(1, 23) = 19.697$, $p < 0.001$) and between Context and Attachment ($F_2(2, 46) = 6.969$, $p < 0.01$) in segment 4. The former interaction indicates that RC attachment preferences were modulated by the type of antecedent, and the latter that context had an effect on RC attachment. The second set of ANOVAs (the 'subjects' analyses)

[4] Given the design of our study, the no-context condition functioned as a baseline to compare the effects of the referential context, and in the statistical analyses, referential context was found not to affect the attachment preferences for PPs. A *JL* referee pointed out that a more direct comparison of the two context conditions might perhaps reveal significant effects, even for the PP conditions. To address this possibility, we performed an additional ANOVA with Attachment (NP1/NP2) and Context (high-attachment biasing/low-attachment biasing) on the mean reading times in region 4 for PPs. This analysis revealed an effect of Attachment ($F1(1, 37) = 3.773$, $p = 0.06$; $F2(1, 23) = 7.606$, $p < 0.02$), but no Context × Attachment interaction ($F1(1, 37) = 0.8626$, $p = 0.369$; $F2(1, 23) = 0.359$, $p = 0.555$), confirming that the two context conditions did not affect the attachment bias for PPs.

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revealed parallel results.[5] To explore these interactions further, planned comparisons were performed in which we ran separate ANOVAs for the genitive and the PP conditions. The items analysis confirmed the modulating role of context for genitives, but not for PPs. There was a significant Attachment × Context interaction for genitives ($F_2(2, 46) = 5.307$, $p < 0.02$), but not for PPs ($F_2(2, 46) = 0.511$, $p = 0.607$). Moreover, for genitives, there was a significant Context × Attachment interaction when the no-context condition was compared to the high-context ($F_1(1, 56) = 2.361$, $p = 0.130$; $F_2(1, 23) = 4.029$, $p = 0.057$) and to the low-context condition ($F_1(1, 56) = 3.450$, $p = 0.069$; $F_2(1, 23) = 8.956$, $p < 0.01$). In contrast, for the PPs, the interaction between Context and Attachment was not significant in either statistical comparison.[6]

Recall that for the analyses reported above, incorrect responses and outliers (i.e. reading times that were two standard deviations above the mean for each condition) were excluded, due to which approximately 18.2% of the experimental data had to be eliminated. To determine whether this led to any distortions after data elimination, we performed an additional analysis of the reading times on the critical segment which was based on THE WHOLE DATA SET, including data points that yielded incorrect responses. Moreover, instead of excluding outliers using standard deviations, this new analysis was based on the (subjects') medians of the RTs on the critical segment. The results of this new analysis were parallel to those reported above[7] and we therefore conclude that data elimination in the above analysis has not led to any artefacts or distortions.

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[5] The comparison of the no-context condition and the high-attachment biasing context condition revealed a main effect of Context ($F1(1, 56) = 2.365$, $p = 0.130$; $F2(1, 23) = 7.899$, $p < 0.01$), an Antecedent effect ($F1(1, 56) = 14.569$, $p < 0.001$; $F2(1, 23) = 8.813$, $p < 0.01$), an Attachment effect ($F1(1, 56) = 6.522$, $p < 0.02$; $F2(1, 23) = 4.730$, $p < 0.04$) – due to an advantage for sentences disambiguated towards NP1 – and an Attachment×Antecedent interaction ($F1(1, 56) = 17.188$, $p < 0.001$; $F2(1, 23) = 15.113$, $p < 0.01$), showing that attachment preferences are modulated by antecedent type. The comparison of the no-context condition and the low-attachment condition also revealed a main effect of Context ($F1(1, 56) = 2.911$, $p = 0.094$; $F2(1, 23) = 15.263$, $p < 0.01$), an Antecedent effect ($F1(1, 56) = 10.634$, $p < 0.01$; $F2(1, 23) = 10.406$, $p < 0.01$) and an Antecedent×Attachment interaction ($F1(1, 56) = 10.783$, $p < 0.01$; $F2(1, 23) = 18.810$, $p < 0.001$). Moreover, the interaction between Attachment and Context was also significant ($F1(1, 56) = 4.116$, $p < 0.05$; $F2(1, 23) = 12.757$, $p < 0.01$), indicating context effects on attachment preferences.

[6] Furthermore, all statistical comparisons showed a significant main effect of Attachment for both the genitives (high- vs. low- vs. no-context (items analysis): $F2(1, 23) = 11.481$, $p < 0.01$; high-context vs. no-context: $F1(1, 56) = 20.244$, $p < 0.001$; $F2(1, 23) = 13.977$, $p < 0.001$; low- vs. no-context: $F1(1, 56) = 5.807$, $p < 0.02$; $F2(1, 23) = 10.039$, $p < 0.01$) and the PPs (high- vs. low- vs. no-context (items analysis): $F2(1, 23) = 6.653$, $p < 0.02$; high-context vs. no-context: $F1(1, 56) = 2.070$, $p = 0.156$; $F2(1, 23) = 7.606$, $p < 0.02$; low-context vs. no-context: $F1(1, 56) = 7.227$, $p < 0.01$; $F2(1, 23) = 6.651$, $p < 0.02$), which signifies that in the sentences with genitives, the NP1 sentences were read faster than the NP2 ones, whereas in the PP conditions the NP1 sentences were read more slowly than the NP2 ones.

[7] The median-based analysis of the no-context condition with the high-attachment biasing context condition revealed effects of Antecedent ($F1(1, 56) = 5.843$, $p < 0.02$), Attachment

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4.4.3 *Reading times after the critical segment*

Finally, to determine whether the experimental effects seen in the critical region lasted to the next segment, we performed the same statistical analyses for the fifth segment. These analyses revealed that the different attachment preferences for genitive and PP antecedents were also present in segment 5. There was a significant Antecedent × Attachment interaction in all statistical comparisons (high- vs. low- vs. no-context (items analysis): $F_2(1, 23) = 12.100$, $p < 0.01$; no-context vs. high-context: $F_1(1, 56) = 7.839$, $p < 0.01$; $F_2(1, 23) = 8.899$, $p < 0.01$; no-context vs. low-context: $F_1(1, 56) = 9.311$, $p < 0.01$; $F_2(1, 23) = 6.948$, $p < 0.02$). The NP1 advantage for the genitives was also evident on the fifth segment (high- vs. low- vs. no-context (items analysis): $F_2(1, 23) = 4.591$, $p < 0.05$; no-context vs. high-context: $F_1(1, 56) = 4.079$, $p < 0.05$; $F_2(1, 23) = 4.206$, $p = 0.052$; no-context vs. low-context: F_1 & F_2: n.s.), even though it did not reach significance in all statistical comparisons. Finally, the NP2 attachment preference for PPs on the critical segment was also seen on the fifth segment (items analysis: $F_2(1, 23) = 6.647$, $p < 0.02$; no-context vs. high-context: $F_1(1, 56) = 6.358$, $p < 0.02$; $F_2(1, 23) = 6.206$, $p < 0.03$; no-context vs. low-context: $F_1(1, 56) = 7.489$, $p < 0.01$; $F_2(1, 23) = 4.515$, $p < 0.05$).

5. General discussion

The present study examined the role of lexical cues and referential context information in the processing of temporarily ambiguous sentences. We investigated RC attachment in Greek sentences in which the RC can be attached either high, to the first NP, or low, to the second one, of a complex NP. In two experiments, an off-line sentence-completion task and an on-line self-paced reading task, RCs in sentences with two kinds of complex NPs, a 'genitive antecedent' ($NP1 + NP2_{Gen}$) and a 'PP-antecedent' condition ($NP1 + [_{PP}\ [NP2]]$) were tested in different context conditions.

Our results indicate that even early parsing decisions are sensitive to lexical cues and influenced by the referential context. That modifier ambiguity resolution is influenced by lexical information is evident from our finding that in Greek, a language that exhibits an overall NP1 attachment

($F1(1, 56) = 3.609$, $p < 0.063$), a significant Antecedent × Attachment interaction ($F1(1, 56) = 7.631$, $p < 0.01$), as well as an interaction of Attachment × Context ($F1(1, 56) = 4.133$, $p < 0.05$). These effects and interactions (except for the latter) were also seen in the corresponding analysis reported in the main text. Likewise, the comparison of the no-context condition and the low-attachment biasing context condition revealed the same effect of Antecedent ($F1(1, 56) = 6.831$, $p < 0.02$), and the same interactions of Attachment × Context ($F1(1, 56) = 5.535$, $p < 0.03$) and of Antecedent × Attachment ($F1(1, 56) = 3.852$, $p = 0.05$), that were seen in the main analysis.

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preference for complex NPs containing genitives, RCs headed by NPs linked by thematic prepositions elicited a robust NP2 attachment preference in both the off-line sentence-completion and the self-paced reading task. This finding replicates previous results on other languages (Gilboy et al. 1995, Traxler et al. 1998, Frenck-Mestre & Pynte 2000, among others) and suggests that this type of lexical bias is strong enough to override any phrase-structure-based locality principle that might otherwise favour NP1 attachment. We also found context effects on RC attachment in both the off-line and the on-line tasks. Specifically, the presence of a supporting context was found to significantly magnify overall (i.e. no-context) attachment preferences, and for genitive antecedents a low-attachment biasing context eliminated the NP1 preference that is otherwise seen in this type of construction. These results suggest that discourse-level information does indeed influence early parsing decisions. It should be noted, however, that these findings contrast with the results from two previous studies (Zagar et al. 1997, Desmet et al. 2002) that have examined context effects on RC attachment preferences and failed to find main effects or interactions with Context in their on-line measures. Desmet et al. (2002), for example, obtained only an effect of Attachment (reflecting an NP1 advantage), even in the low-attachment biasing context. In the following, we will first explore possible reasons for these discrepancies and then discuss the wider implications of our findings for the architecture of the human sentence processor.

5.1 *Context effects in ambiguity resolution: a comparison with previous studies*

Given our results, one might wonder why two previous studies (Zagar et al. 1997, Desmet et al. 2002) examining the role of referential context for RC attachment preferences did not obtain any context effects in their on-line measures, even though the kinds of materials used were similar to the ones we used. It is always hard to decide why an experiment did NOT produce a particular kind of effect, and we can only speculate about possible reasons. One possibility might be that the discrepancies are due to the different methodologies used. Recall that both Zagar et al. (1997) and Desmet et al. (2002) used eye-tracking, a technique that tends to result in faster reading than is the case for self-paced reading. Hence, it might be the case that the slower self-paced reading times relative to reading under eye-tracking allowed discourse factors to come into play and affect parsing decisions. Note, however, that if this were correct, we should have found context effects IN ALL CONDITIONS, as was indeed the case in the off-line task, and not just for sentences with genitives, as was the case in the self-paced reading experiment. An additional factor could be differences in the local biases that any context effect has to overcome. Supposing the NP1 bias for

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genitives to be relatively weak in Greek, then it could be the case that context effects act rapidly enough to overcome a relatively weak bias under the (slower) conditions of self-paced reading; not at the higher rates of reading examined in eye-tracking studies, and hence the discrepancy between our results and those of Zagar et al. (1997) and Desmet et al. (2002). Note, however, that there is a STRONG bias for genitives in Greek, as can be seen from the 339ms advantage for NP1 attachment in the no-context condition (see figure 2). The bias for genitives is substantially stronger than the one for PPs, for which there was only a 74ms advantage for the preferred attachment in the no-context condition. Thus, if 'strength of attachment bias' was a crucial factor for the presence of context effects in the self-paced reading task, then we should have found stronger context effects for PPs than for genitives, and this is just the opposite of what the data showed. We can therefore rule out this possibility and maintain that the context effect obtained in the self-paced reading task is not due to methodological artefacts.

Another possibility is that the discrepancies in the results are due to linguistic differences between the heads of the RCs tested in the three studies. In the Zagar et al. and Desmet et al. studies, complex NPs with prepositions, [NP1 + PP[P NP2]], were used as RC antecedents, e.g. *de adviseur van de politici* 'the advisor of the politicians' and *l'avocat de la chanteuse* 'the barrister of the singer', whereas in our study the corresponding condition had two bare case-marked NPs without a preposition, e.g. *ton proponiti tis athlitrias* 'the trainer-acc. (of) the athlete-gen'. Thus it could be that an attachment bias for a construction with a free-standing lexical element (i.e. a preposition) is harder to overcome by contextual information than for a corresponding construction with bound morphemes. Evidence that this is indeed a relevant factor for RC attachment comes from Lovric's (2003) study of Serbo-Croatian, which found that RC attachment is lower when the two NPs are linked with the functional preposition *od* 'of' than when the second NP is marked for genitive case. That contextual information does not affect RC attachment preferences in cases in which the two NPs are linked by a preposition is also evident from our findings for the NP + PP condition, for which we did not obtain any effects of context, similarly to Zagar et al. (1997) and Desmet et al. (2002). Perhaps the presence of the preposition (irrespective of its thematic properties) in the constructions tested by Zagar et al. and Desmet et al. leads to more deterministic parsing decisions that are harder to overcome by discourse-level information than the corresponding constructions with purely case-marked RC antecedents that we tested.

Looking beyond RC attachment ambiguities, there is evidence from studies of other kinds of ambiguity by van Berkum, Brown & Hagoort (1999) and van Berkum, Hagoort & Brown (2000) for strong context effects on early parsing decisions. Van Berkum and colleagues examined

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complement/relative clause ambiguities in sentences in which a function word such as *that* could either be a complementiser (*John told the girl that he was having trouble with his car*) or a relative pronoun (*John told the girl that had been calling …*) in a reading study measuring event-related brain potentials (ERPs). The critical sentences were preceded by a complementiser-favouring context (with one referent for *the girl*) or a relative-clause-favouring context (with two possible referents for *the girl*). Van Berkum et al. found an effect on the disambiguating word following *that*, but only when the continuation of the target sentence went against the preceding context. This, they argued, indicates that discourse-level information strongly influences early sentence parsing.

5.2 *Implications for the structure of the human sentence processor*

We referred to three broad accounts of sentence processing in the introduction: syntax-first approaches, multiple-constraints accounts/referential context hypothesis, and Construal Theory. Consider the predictions derived from these accounts in the light of our findings.

From the perspective of syntax-first approaches (see e.g. Frazier 1987), we would have expected to see non-syntactic effects on ambiguity resolution in the off-line task, but not in the on-line self-paced reading experiment. This is because non-syntactic information is said to influence the final interpretation of a sentence, but not early parsing decisions. This prediction was not confirmed. We found that lexical-thematic cues affected RC attachment preferences in BOTH experimental tasks, indicating that parsing decisions are not purely syntax-driven, even at early stages of parsing.

Multiple-constraints models of sentence processing (e.g. Thornton et al. 1999) and the referential context hypothesis (e.g. Altmann & Steedman 1988) claim that all sources of information are accessed in parallel and are available at all levels of parsing. This would mean that in our study we should have found the same strong context and lexical effects in both experimental tasks. Our results show that this was not the case. It is true that in the off-line task, an appropriately biased context affected the way RC attachment ambiguities were resolved. More NP1 continuations were obtained in high-attachment biasing contexts and more NP2 continuations in low-attachment biasing contexts. In the self-paced reading task, however, we found an overall Antecedent×Attachment interaction that did not interact with Context. Instead, a low-attachment-favouring context significantly reduced the NP1 advantage in sentences with genitives, whereas the NP2 preference for RCs headed by complex NPs linked by thematic prepositions could not be overridden by a high-attachment-favouring context. These differences between off-line and on-line measures and between different RC antecedents do not receive a straightforward

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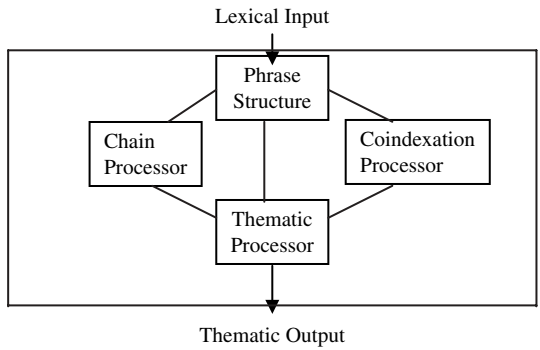
explanation from the idea that lexical information and discourse-level information are accessed in parallel at all levels of parsing. We conclude that neither syntax-first nor multiple-constraints accounts of parsing provide a full account of our findings.

Construal Theory (Frazier & Clifton 1996) claims that adjuncts and modifiers, instead of being syntactically attached, are associated with the closest thematic domain using both syntactic and non-syntactic information. According to this account, discourse-level information may influence early parsing decisions, but only for adjuncts and modifiers that occur within a given thematic domain. From this, we would expect that referential context information is more likely to affect RC attachment preferences in sentences with genitives than in sentences with PP antecedents, because in the PP construction, [NP1 + PP[P NP2]], the thematic preposition *me* 'with' creates a local thematic domain with the second NP, which makes NP1 unavailable for RC attachment. By contrast, in the genitive construction, [NP1 + $NP2_{Gen}$], both NPs belong to the same thematic domain and are thus potential hosts for the RC; in such cases, discourse-level information may also affect early parsing decisions. Our results confirm these predictions. We found an NP2 attachment preference for the PP construction in the self-paced reading task across the three context conditions, which was not significantly affected by contextual manipulations. This is consistent with the idea that modification (e.g. by RCs) of constituents OUTSIDE the current thematic domain is computationally costly, and hence dispreferred (see Frazier & Clifton 1996). Thematic prepositions such as *me* 'with' create a local thematic domain of their own and, therefore, the ambiguous RC is preferably associated with the second (lower) NP. In the genitive construction, however, no such thematic cue is present, and both NPs are potential hosts for the RC. In this case the parser is affected by discourse-level information, hence the context effects obtained for the genitive construction in the self-paced reading task.

More generally, the results of the present study indicate that the parser has immediate access to both syntactic information and lexical-thematic properties, and that discourse-level information is a secondary resource that is employed in cases in which sentence- and/or word-level information is insufficient for ambiguity resolution. This is compatible with modular theories of sentence processing. Frazier (1990), for example, proposed a theta-predication module that operates in parallel with the module responsible for creating constituent analysis, and Crocker (1996) argued that the syntactic processor consists of four components, as shown in (11).

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(11) *Crocker's (1996) syntactic processor*



In this model, the syntactic processor has an internally modular structure in which each component is specialised for particular representations, but is allowed to access the representations generated by the other processors. Lexical items are the input to the syntactic processor, and the output is a representation of an utterance's thematic interpretation. Our results are consistent with the idea that lexical-thematic information is processed in parallel with other syntactic information and that discourse-level information becomes available at the output of the thematic processor, as shown by the differential effects of context for the genitive and the PP conditions.

6. Conclusion

The results of the present study indicate that lexical-thematic information and referential context information affect RC attachment preferences in on-line sentence processing, a finding that goes against the view that early parsing decisions are exclusively guided by phrase-structure-based information. The results of our self-paced reading experiment also show that in sentences in which thematic cues are available for ambiguity resolution, the role of contextual influences is reduced, indicating that thematic information and discourse-level information are not accessed in parallel during early parsing. Instead, we argued that the primary resource for parsing is sentence-level information (available from a sentence's syntactic structure and lexical items) and that discourse-level information is a secondary resource that is employed in cases in which sentence-level information is insufficient for ambiguity resolution.

Our results also indicate that early and later stages of parsing differ with respect to how contextual information is accessed for ambiguity resolution. In contrast to the on-line experiment, the off-line sentence-completion task elicited significant overall effects of referential context for both of the

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constructions tested. Off-line tasks are likely to reflect final interpretation processes, and these seem to be fed by all available sources of information. Crucially, however, this is not the case for early parsing decisions, as testified by the limited effects of referential context seen in the self-paced reading task.

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Authors' address: *Department of Language & Linguistics, University of Essex, Colchester C04 3SQ, U.K.*
E-mail: depapa@enl.auth.gr, harald@essex.ac.uk

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