Language Acquisition
Publication details, including instructions for authors and subscription information:
http://www.tandfonline.com/loi/hlac20

Children's Processing of Ambiguous Sentences: A Study of Relative Clause Attachment

Claudia Felser , Theodore Marinis & Harald Clahsen
Published online: 16 Nov 2009.

LANGUAGE ACQUISITION, *11*(3), 127–163

Children's Processing of Ambiguous Sentences: A Study of Relative Clause Attachment

Claudia Felser, Theodore Marinis, and Harald Clahsen
University of Essex

In this study, we investigate children's and adults' relative clause attachment preferences in sentences such as *The student photographed the fan of the actress who was looking happy.* Twenty-nine 6- to 7-year-old monolingual English children and 37 adult native speakers of English participated both in an auditory questionnaire study and in an online, self-paced listening experiment. Whereas the adult group's attachment preferences were influenced by the type of preposition joining the 2 potential antecedent noun phrases (NPs) (*of* vs. *with*), children's online attachment preferences varied depending on their listening span: Children with a relatively high listening span showed a preference for NP1 attachment irrespective of the type of preposition involved, whereas the children with a low span showed a general tendency toward NP2 disambiguation. We argue that (i) when resolving modifier attachment ambiguities during online processing, children primarily rely on structural information and (ii) the observed differences between children and adults, as well as those found between the two span groups, reflect working memory differences rather than differences in the parser.

1. INTRODUCTION

Whereas most first-language acquisition studies to date have investigated the development of children's linguistic competence, research on language processing has focused almost exclusively on adults. Language-processing routines, however, play a crucial role in linguistic development in that they enable language learners to assign structural representations to input strings, which in turn helps them to acquire the adult grammar (cf. Fodor (1998), Mazuka (1998), among oth-

Requests for reprints should be sent to Harald Clahsen, Department of Linguistics, University of Essex, Colchester CO4 3SQ, United Kingdom. E-mail: harald@essex.ac.uk

ers). Despite the importance of processing mechanisms for grammar construction, the details of a child's processing system are still largely unknown.

In the psycholinguistic literature, it is widely assumed that the human sentence-processing mechanism comprises a narrow set of universal parsing principles (Frazier (1979), Frazier and Fodor (1978)), some of which have been claimed to be subject to parametric variation (see, e.g., Frazier and Rayner (1988), Gibson, Pearlmutter, Canseco-Gonzalez, and Hickok (1996), Mazuka (1998), Mazuka and Lust (1990)). Common to all universalist approaches is the—explicit or implicit—prediction that there should be continuity in the development of language processing, that is, both children and adults are assumed to have access to the same set of structure-dependent processing routines (see Crain and Thornton (1998), Crain and Wexler (1999), Fodor (1998)).

One area of sentence processing that has been extensively studied with monolingual adults in the past is the way relative clause (RC) attachment ambiguities are resolved in sentences such as (1).

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

Individual languages vary with respect to whether speakers prefer to associate the RC with the first or the second potential host noun phrase (NP) (i.e., *the servant* vs. *the actress* in (1); Cuetos and Mitchell (1988), Cuetos, Mitchell, and Corley (1996), among others). In this study, we compare the way English-speaking children and adults process temporarily ambiguous sentences of the form *NP V [NP of/with NP] RC,* in which an RC is preceded by a complex NP providing two potential attachment sites. Children's offline comprehension of RCs has been extensively studied in the past. Results from various studies including Corrêa (1995), Goodluck and Tavakolian (1982), Fragman and Goodluck (2000), and Hamburger and Crain (1982) have demonstrated that children as young as 2;8 already possess adult-like competence in this area of grammar. The main empirical question we address in this study is whether, given the relevant grammatical knowledge, children employ the same sentence-processing routines as mature native speakers of English do.

2. STUDYING ONLINE SENTENCE PROCESSING IN CHILDREN

Results from adult sentence-processing studies indicate that although nonstructural information may not be able to affect the earliest stages in parsing (Frazier (1979), Frazier and Rayner (1982)), the adult processor is capable of utilizing and rapidly integrating both phrase structure and lexical-semantic information (B. Adams, Clifton, and Mitchell (1998), Garnsey, Pearlmutter, Myers, and Lotocky (1997), Trueswell, Tanenhaus, and Garnsey (1994), among others). Moreover, there is evidence that adult readers or listeners are also influenced by pragmatic or other contextual factors during sentence comprehension (Altmann and Steedman (1988), Tanenhaus, Spivey-Knowlton, Eberhard, and Sedivy (1995), Thornton, MacDonald, and Gil (1999)). Only recently, however, have researchers begun to investigate systematically the parsing mechanisms employed by children using online techniques such as word monitoring (Tyler and Marslen-Wilson (1981)), probe recognition (Mazuka (1998)), cross-modal priming (Love and Swinney (1997), McKee, Nicol, and McDaniel (1993)), eye tracking (Trueswell, Sekerina, and Logrip (1999), Hurewitz, Brown-Schmidt, Thorpe, Gleitman, and Trueswell (2000)), self-paced reading or listening (Booth, MacWhinney, and Harasaki (2000), Traxler (2002)), or brain-imaging techniques such as event-related brain potentials (Friederici and Hahne (2001)). One reason why so little is known about children's processing mechanisms is that many of the experimental techniques typically used to examine syntactic processing in adults rely on reading time measurements and thus are not suitable for younger children (see McKee (1996) for an overview of online methods appropriate for children). Children's reduced attention span and relatively limited vocabulary impose further restrictions on experimental design and choice of materials. Another important factor that needs to be taken into account when investigating language processing in children is their reduced cognitive abilities, specifically their relatively lower working memory (WM) span. Individual memory differences are known to affect language processing in both children and adults (A. Adams and Gathercole (2000), Booth et al. (2000), Just and Carpenter (1992), King and Just (1991), MacDonald, Just, and Carpenter (1992), Nakano, Felser, and Clahsen (2002), among others).

Tyler and Marslen-Wilson (1981) were among the first to investigate online sentence comprehension in children. In a word monitoring study, Tyler and Marslen-Wilson (1981) found that 5-, 7-, and 10-year-old children's ability to detect a word showed the same pattern of degradation as it did in adults when processing normal prose, semantically anomalous sentences, or syntactically anomalous ("scrambled") speech. This finding supports the view that children and adults analyze sentences in essentially the same way. In the category monitoring task, the 5-year-olds differed from the older children, however, in that the facilitating effect of normal prose was smaller than for the 7- and 10-year-olds at the earlier test points. According to Tyler and Marslen-Wilson (1981), this finding could be taken to indicate that the additional processing cost associated with semantic-attribute matching—possibly in conjunction with a more general problem with utilizing certain types of pragmatic cues during sentence comprehension—led to processor overload in the younger children.

Using lexical and semantic probe latency tasks, Mazuka (1998) found that children as young as 4 process complex sentences in a serial fashion similar to adults—a finding that is incompatible with models that predict qualitative differences between the way children and adults process multiclausal structures (Townsend, Ottavio, and Bever (1979), Tyler and Marslen-Wilson (1978)). Mazuka's results further suggest that during sentence comprehension, children, like adults, rapidly assign a semantic structure to main clauses, whereas this is claimed not to be the case in subordinate clauses. Results from cross-modal picture priming experiments moreover demonstrate that 4- to 6-year-old children are capable of establishing syntactic dependencies such as binding relationships (McKee et al. (1993)) and filler-gap dependencies (Love and Swinney (1997)) during sentence processing.

Children's online comprehension of relative clauses was recently investigated by Booth et al. (2000). Using both self-paced reading and self-paced listening tasks, Booth et al. examined 8- to 12-year-old children's processing of non-ambiguous sentences of the following types:

(2) a. The monkey that followed the frog left the tree in a hurry.
b. The deer that the tiger watched entered the field from the side.
c. The cat chased the rabbit and enjoyed the hunt in the yard.

In sentences such as (2a), both the antecedent NP and the relativized NP fulfill the grammatical function of subject (= Subject–Subject condition); example (2b) contains an object relative (= Subject–Object condition), and sentences of type (2c) involve conjoined verb phrases (= CVP condition). Previous offline comprehension studies have shown that children have considerably more difficulty comprehending Subject–Object sentences than those of the Subject–Subject type (see MacWhinney and Pleh (1988), for review). The slow down in both reading and listening times at the relative clause/main clause transition observed by Booth et al. (2000) confirms that this is also true for online processing.[1] Interestingly, the authors found that the degree of slow down was affected by the children's short-term memory span: In both the reading and the listening task, children with a high digit span produced relatively slower reaction times at the transition points than did children with a low digit span, which demonstrates that individual memory differences may influence online sentence comprehension in children (cf. also A. Adams and Gathercole (2000) for sentence production). Booth et al. hypothesized that the observed differences between the span groups may reflect differences in children's ability to store words effectively in short-term memory, with children with high digit span (but not those with low digit span) making use of their short-term memory store during the processing of "difficult" regions, which

[1]Booth et al. (2000) attribute the observed increase in reading/listening time in this region in the Subject–Object condition to the (multiple) "perspective shift" involved in Subject–Object sentences (compare MacWhinney (1982)). Note, however, that it could equally well reflect the processing cost of associating a filler (i.e., the head of the RC) with its subcategorizer (perhaps via a syntactic gap or trace).

was reflected in longer reaction times (RTs). Moreover, Booth et al. found that those children who they classified as "poor comprehenders" on the basis of their offline accuracy scores showed a tendency to follow a local attachment strategy. This strategy would frequently lead them to incorrectly interpret the second NP (e.g., *the frog* in (2a)) as the subject of the second verb (e.g., *left*), in particular in the Subject–Subject and CVP conditions.

Comparing children's and adults' electrophysiological brain responses to syntactically or semantically anomalous sentences, Friederici and Hahne (2001) found evidence that 7- and 8-year-old children's first-pass parsing processes are similar to those of adults. Children appear to need more time than adults, however, for secondary or "repair" processes, which Friederici and Hahne assume are reflected by the relatively longer latency of the P600 component elicited by syntactically incorrect stimuli. This, of course, presupposes that the P600 indexes the same processes in children and adults—an assumption that requires further study.

Few studies to date have addressed the question of how children resolve structural ambiguities in real time, however. In an eye-tracking study, Trueswell et al. (1999) examined the way children resolved temporary prepositional-phrase (PP) attachment ambiguities in sentences such as (3).

(3) Put the frog on the napkin in the box.

Children's eye movements were recorded as they responded to spoken instructions asking them to move objects around on a table. Trueswell et al. (1999) found that 5-year-old children preferentially interpreted the postverbal PP *on the napkin* as the Destination (or Goal) argument of the verb *put* rather than as a modifier of the NP *the frog,* even in the presence of disambiguating contextual information. This finding could be taken to indicate that when resolving temporary PP attachment ambiguities during online comprehension, the children relied primarily on lexical/structural information and largely failed to take into account the information provided by the visual context. Adults, on the other hand, appear to be able to integrate structural and contextual information much more rapidly during sentence comprehension (Altmann and Steedman (1988), Tanenhaus et al. (1995), among others). Results from Hurewitz et al.'s (2000) follow-up study to Trueswell et al. (1999), however, suggest that children's inability to utilize contextual cues may be task specific: In a corresponding production task, the children proved quite capable of making use of information supplied by the referential context.

The results obtained by Traxler (2002) in a self-paced reading study are compatible with Trueswell et al.'s (1999) in that they also suggest that structural factors may override semantic or pragmatic plausibility. Materials included sentences like (4a), which are known to produce a clear garden-path effect in adults; sentences like (4b) in which the postverbal NP is a semantically implausible object of the verb; and sentences like (4c) that contained intransitive verbs.

(4) a. When Sue tripped the girl fell over and the vase was broken.
b. When Sue tripped the table fell over and the vase was broken.
c. When Sue fell the policeman stopped and helped her up.

Traxler found that 8- to 12-year-old children tended to misanalyze the postverbal NP in all three conditions as a direct object, indicating that the structurally simpler analysis was preferred irrespective of plausibility or thematic properties of the verb. The effect was less strong in the intransitive condition (4c), however, suggesting that subcategorization information may have been partially utilized.

To the extent that any general conclusion at all can be drawn from the rather small body of published research, most of the existing studies of syntactic processing in children appear to be compatible with the view that children and adults employ similar parsing mechanisms but that in the online comprehension of (temporarily) ambiguous sentences, children rely predominantly on structural information and largely disregard contextual information such as semantic or pragmatic fit. In this study, we built on the existing research on children's processing of structurally ambiguous sentences and focused on the question of how children resolve RC attachment ambiguities in two-site contexts.

3. RELATIVE CLAUSE ATTACHMENT PREFERENCES IN ADULTS

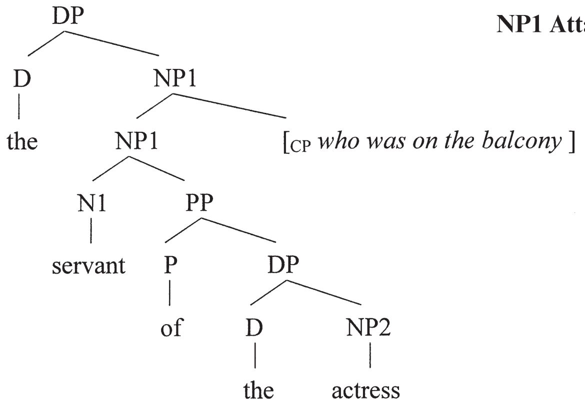
Adult speakers' RC attachment preferences in sentences such as (1), repeated next, have been frequently studied in the past.

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

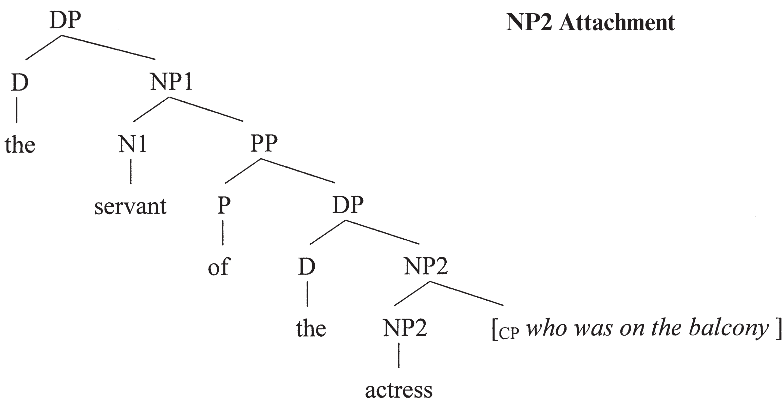
Although the grammar of English allows for the RC to be associated with either NP1 or NP2 (cf. (5) and (6)), several offline and online studies on adult native speakers have revealed a preference for the relative clause to be attached to NP2 (i.e., to *the actress,* cf. (6)) (Carreiras and Clifton (1999), Cuetos and Mitchell (1988), Frazier and Clifton (1996), Roberts (2003), among others).[2]

[2]Not all studies have been able to replicate this NP2 preference, though. In a self-paced reading study, Carreiras and Clifton (1993), for instance, found no consistent attachment preferences for NPs linked by *of,* and results from an eye-tracking study by Traxler et al. (1998) provide evidence that English readers initially attempt NP1 attachment. Results from Gilboy et al.'s (1995) questionnaire study moreover demonstrate that depending on the specific kind of semantic relationship between the two NPs, certain types of NP-*of*-NP constructions do in fact elicit a majority of NP1 responses. We return to these issues in the discussion in section 6.

(5) **NP1 Attachment**



(6) **NP2 Attachment**



This preference for NP2 attachment has been argued to follow from a supposedly universal parsing principle dubbed Recency by Gibson et al. (1996), which is similar (although not identical) to previously proposed principles such as Right Association (Kimball (1973)) and Late Closure (Frazier (1979)) and which biases the parser toward integrating new incoming material with the most recently processed phrase.

(7) *Recency*
Preferentially attach structures for incoming lexical items to structures built more recently.
(Gibson et al. (1996, 26))

Like other cross-linguistically, well-attested parsing strategies such as Minimal Attachment (Frazier and Fodor (1978)) or the Minimal Chain Principle (De

Vincenzi (1991)), the Recency principle is thought to reflect the parser's effort to minimize processing cost (cf. also Fodor (1998)).

Cross-linguistic studies of RC attachment preferences indicate, however, that the Recency strategy does not apply universally. A preference for NP1 attachment has been observed for corresponding constructions in numerous other languages including Spanish (Carreiras and Clifton (1993), Gilboy, Sopena, Clifton, and Frazier (1995)), Dutch (Brysbaert and Mitchell (1996)), German (Hemforth, Konieczny, and Scheepers (2000)), French (Frenck-Mestre and Pynte (1997), Zagar, Pynte, and Rativeau (1997)), and Greek (Papadopoulou and Clahsen (2003)). Gibson et al. (1996) showed that for complex NPs providing three possible attachment sites (cf. (8)), English speakers also violate Recency in that they show a preference for NP1 attachment over NP2 attachment.

(8) a. *the lamp* near the paintings of the houses that *was* damaged in the flood
b. the lamps near *the painting* of the houses that *was* damaged in the flood
c. the lamps near the paintings of *the house* that *was* damaged in the flood

The fact that the participants had the least difficulty with complex NPs of the type shown in (8c), which force NP3 attachment, confirms that the Recency principle is operative. The observed preference for NP1 (cf. (8a)) over NP2 attachment (cf. (8b)), however, is unexpected under the assumption that Recency should be the only structural parsing principle determining English speakers' RC attachment preferences. Instead, Gibson et al. proposed that the universal Recency preference interacts with a second parsing principle dubbed Predicate Proximity that favors attachment of the RC to the NP closest to the S/IP node (cf. Gibson et al. (1996, 41)).

(9) Predicate Proximity
Attach as structurally close as possible to the head of a predicate phrase.

Results from Gibson, Pearlmutter, and Torrens' (1999) study of three-site ambiguities in Spanish provide further support for the Recency–Predicate-Proximity interaction. Gibson et al. (1996) argued that the relative strength of the Predicate Proximity principle is variable, which makes it possible for it to outrank Recency in some languages or in situations where computational resources are short.[3]

Moreover, a questionnaire study by Gilboy et al. (1995) revealed that RC attachment preferences are not only influenced by structural principles but also by semantic factors such as the particular role that the preposition assigns to its com-

[3]Whereas Gibson et al. (1996) found an NP3 > NP1 > NP2 preference hierarchy for both English and Spanish, results from a reading-time study by Wijnen (1998) indicate that Dutch speakers prefer NP1 over NP3 attachment in three-site contexts.

plement or by the semantic relationship between the two potential antecedent NPs. Specifically, they found that the NP1 preference reported for languages such as Spanish holds for certain types of genitive constructions only. If, on the other hand, the second NP is the complement of a thematic preposition such as *con/with,* NP2 attachment tends to be the preferred option across languages. One attempt to account for these differences has been made within the framework of Construal theory (Frazier and Clifton (1996)), according to which nonprimary phrases such as RCs or adjunct predicates are initially associated with local thematic domains rather than being attached syntactically and are then construed with an antecedent on the basis of both structural and semantic/pragmatic information. Under this view, the NP most likely to be construed as the host of an ambiguous RC will be one that is contained within the extended maximal projection of the most recent theta assigner. The construal hypothesis thus correctly predicts that cross-linguistically, NP2 disambiguation should be preferred if the two potential host NPs are linked by a thematic-role assigning preposition such as *with.* Results from eye-tracking studies by Traxler, Pickering, and Clifton (1998) and Frenck-Mestre and Pynte (2000) indicate that the choice of the linking preposition also affects online processing in adults. If the second NP is a genitive-marked or prepositional object of the first NP, however, the current thematic processing domain is the overall NP so that from the point of view of the Construal hypothesis, either NP may serve as the antecedent for an ambiguous RC. To the extent that speakers exhibit any attachment preference in contexts containing *of*-type or genitive NPs at all, these will be determined by the interaction of phrase-structure based locality principles and other factors that may influence attachment.

Other factors that have been claimed to affect the way RC attachment ambiguities are resolved in a given language include prosody (Fodor (1998), Schafer, Carter, Clifton, and Frazier (1996)), the availability of alternative structures such as the Saxon genitive (Frazier and Clifton (1996)), the type of relativizing element used (Hemforth et al. (2000)), pragmatic factors such as NP-modifiability (Thornton et al. (1999)), and the frequency of past exposure to each attachment pattern, the so-called Tuning Hypothesis (Cuetos et al. (1996), Mitchell and Cuetos (1991)).

Moreover, there is evidence that individual differences in WM capacity may also influence syntactic ambiguity resolution (MacDonald et al. (1992), Mendelsohn and Pearlmutter (1999)). In a free-choice questionnaire study, Mendelsohn and Pearlmutter found that adult speakers of English who had a relatively low verbal WM capacity (scoring lower than 4 in Daneman and Carpenter's (1980) Reading Span Test) showed a marked preference for NP1 over NP2 attachment for NPs linked by the preposition *of.* Participants with a high span, by contrast, showed no clear preference for either attachment type.[4] This finding could be taken to suggest

[4]In a second experiment, Mendelsohn and Pearlmutter (1999) also tested attachment preferences for prepositions other than *of.* Although no overall NP1 preference was found for the preposition *with* for either of the two groups, the proportion of NP1 responses was again higher for the low-WM group than for the high-WM group for this condition.

that participants with a low span—who, according to Mendelsohn and Pearlmutter, may have difficulty keeping both potential antecedents equally active in working memory—tend to rely on the Predicate Proximity strategy.

In summary, it appears that mature speakers' RC attachment preferences are determined by at least two interacting parsing strategies: a universal Recency preference and a principle such as Predicate Proximity that favors attachment to the initial NP. In addition, there is evidence from both offline and online studies that semantic properties of the linking preposition affect adult speakers' attachment decisions in two-site contexts. The findings from Gibson et al.'s (1996) and Gibson, Pearlmutter, and Torrens' (1999) studies indicate, however, that these "preposition effects," or lexical biases, can be overridden if the complexity of the overall NP is increased.

4. METHOD

4.1. Participants

To investigate children's RC attachment preferences, 29 monolingual English children (*M* age = 6;8, range = 6;2–7;5) recruited from primary schools in the Colchester area of Essex, United Kingdom, and 37 adult native speaker controls (*M* age = 23;6, range = 18;8–50;9) participated in an offline questionnaire study and in an online segment-by-segment, self-paced listening experiment. All participants had normal or corrected-to-normal hearing and vision and were naïve with respect to the purpose of the experiments. Parental consent was obtained prior to the testing of the children. The adults and an original pool of 38 children (*M* age = 6;8) initially underwent a grammaticality judgment test, the main purpose of which was to ensure that the participants were sensitive to number agreement violations between an antecedent NP and the auxiliary in an RC modifying it, as number agreement was later used to disambiguate the experimental sentences in the online task. To control for possible effects of the children's WM capacity on processing, the children additionally underwent a listening-span test (Gaulin and Campbell (1994)).

4.2. Materials

The experimental materials used in the grammaticality judgment task and in the two main experiments were similar but not identical. They all involved a main clause headed by a transitive verb in the past tense whose complex NP object was followed by a subject RC.[5] The materials used for the grammaticality judgment

[5]The experimental materials were specifically designed to be used with children, that is, although our experimental sentences were (necessarily) structurally similar to the kind of materials previously used in adult studies, the vocabulary items were selected to be appropriate for 6- to 7-year-old chil-

task comprised 58 sentences, including 10 practice sentences, 24 experimental sentences (12 grammatical, 12 ungrammatical), and 24 filler sentences. In half of the critical items, both potential antecedent NPs were in the singular, and in the other half, both NPs were in the plural, yielding the following four sentence types:[6]

(10) a. Singular—Grammatical
The doctor recognized *the nurse* of *the pupil* who *was* feeling very tired.
b. Plural—Grammatical
The doctor recognized *the nurses* of *the pupils* who *were* feeling very tired.
c. Singular—Ungrammatical
* The doctor recognized *the nurse* of *the pupil* who *were* feeling very tired.
d. Plural—Ungrammatical
* The doctor recognized *the nurses* of *the pupils* who *was* feeling very tired.

In half of the grammatical and half of the ungrammatical sentences, the two postverbal NPs were joined by the preposition *of* and in the other half by the preposition *with* (Appendix A provides a complete list of the materials used in the grammaticality judgment test). The relationship between the two NPs in the *of* condition was of the functional/occupational type throughout (cf. Gilboy et al. (1995)).

The auditory questionnaire materials included 20 sentences (10 experimental sentences, 10 fillers). Of the fillers, half were ambiguous and half unambiguous. All experimental sentences were ambiguous, with both NPs and the auxiliary in the RC appearing in the singular. There were two versions of each sentence, one using the preposition *of* to link the two critical NPs and the other one using *with,* as shown in (11a) and (11b), respectively (see Appendix B for a list of the experimental items used in the questionnaire study).

---

dren. As regards the structure of the sentences we used, there is evidence that shows that 6- to 7-year-old children process complex sentences containing subject RCs in a qualitatively similar way to adults (see, e.g., Weighall and Altmann (2001)). Processing right-branching structures (which were also used in this study) proved to be easier than processing center-embedded ones, which has been found to be the case for children as well as adults (see, e.g., Bates, Devescovi, and D'Amico (1999), Booth et al. (2000), MacWhinney and Pleh (1988)).

[6]As one reviewer noted, sentences of the type (10d) may in fact be grammatical under an extraposition reading in which the RC is taken to modify the subject NP, which may have affected the results from the grammaticality judgment task. As the children (as well as the adults, albeit only for sentences containing complex genitive NPs) did indeed reject sentences of this type less often than sentences such as (10c), this may at least in part account for the children's relatively low accuracy rate in this task.

(11) a. The doctor recognized the nurse *of* the pupil who was feeling very tired.
b. The doctor recognized the pupil *with* the nurse who was feeling very tired.

To ensure that the experimental sentences sounded equally natural in both the *of* and the *with* conditions, we reversed the relative ordering of NP1 and NP2 in the *with* conditions in all experimental materials.[7] Two different versions of the questionnaire were created, and the sentences in each of the two sets were pseudo-randomized. Each set contained one version of each experimental sentence only and an equal number of *of* and *with* sentences.

The stimulus materials for the self-paced listening task comprised 89 sentences, including 17 practice, 24 experimental, and 48 filler sentences.[8] The experimental sentences were temporarily ambiguous and contained an RC modifying either the overall object NP (= NP1 Attachment) or the embedded one (= NP2 Attachment). Disambiguation always occurred on the auxiliary (*was* vs. *were*). The two nouns appearing in the NP complex both had human referents and were matched for frequency. The two critical NPs were linked either by functional/occupational *of* or by "accompaniment" or attributive *with,* yielding the following four experimental conditions (Appendix C provides a complete list of the experimental items used in the online task):

(12) a. *Of*-NP1
The doctor recognized *the nurse* of the pupils who *was* feeling very tired.
b. *Of*-NP2
The doctor recognized the nurse of *the pupils* who *were* feeling very tired.
c. *With*-NP1
The doctor recognized *the pupils* with the nurse who *were* feeling very tired.
d. *With*-NP2
The doctor recognized the pupils with *the nurse* who *was* feeling very tired.

[7]Results from both offline and online experiments by Roberts (2003) suggest that NP order by itself does not influence attachment decisions. Roberts found the same attachment preferences for NPs linked by the preposition *next to* irrespective of the relative ordering of the two potential antecedent NPs, indicating that adult speakers' attachment preferences are not affected by NP order per se.

[8]A somewhat lower filler-to-target ratio was used in both the questionnaire (1:1) and the self-paced listening experiment (2:1) than is normally used in adult processing studies to keep the total number of stimulus sentences the children are exposed to as small as possible, taking into account their relatively shorter concentration span. Note that this is common practice in child processing studies; Traxler (2002), for example, used equal numbers of filler and target sentences in his self-paced reading study, and Booth et al.'s (2000) materials comprised 16 filler and 12 target sentences for both their self-paced reading and listening experiments.

To neutralize any possible effects of number, the relative ordering of singular and plural NPs was counterbalanced across all four conditions. Two different experimental sets were created, each containing two maximally different versions of each experimental sentence (either (a) and (d) or (b) and (c)), and the experimental items in each set were pseudo-randomized.

All auditory materials were read by a female native speaker of English and prerecorded on a digital tape recorder. To the materials used in the online task, splicing was applied so as to reduce as far as possible potential effects of prosody. The initial NPs of each NP complex were replaced by the same NP from a different sentence read separately. In the *of* conditions, NP1 was replaced by an NP from a sentence in which this NP was followed by a locative PP, whereas NP1 in the *with* conditions was replaced by the initial NP from an NP-*of*-NP complex. In addition, the segments containing *who, was,* and *were* were replaced by the same words read separately so that these segments were identical in all conditions and not phonologically reduced as it might happen in continuous speech.

4.3. Procedures

The experiments with the children were carried out in a dedicated room in their school. Prior to the main experimental tasks, the children were given a short vocabulary test to make sure that they knew the vocabulary items that were used in the main experiments and to familiarize them with the pictures they had to respond to in the online task. Further details of procedures are given next.

4.3.1. Listening-span task. The materials and procedure for the listening-span task were adopted from Gaulin and Campbell (1994), which is an adaptation of Daneman and Carpenter's (1980) reading-span task for children. The task involved listening to sets of one to six sentences, providing a truth–value judgment for each sentence, and then recalling the last word of each of the sentences at the end of each set.

4.3.2. Grammaticality judgment task. The design of the grammaticality judgment test was based on McDaniel and Smith Cairns (1996). Participants were instructed to listen carefully to a set of prerecorded sentences presented to them through headphones and then to indicate for each sentence whether or not it contained a grammatical error. The children were asked once every couple of sentences to correct sentences they had judged as bad by asking them "Could you make it sound good?" The end of each sentence was indicated by a tone. Participants were allowed to listen to each sentence as many times as they wanted to before making their decision.

4.3.3. Questionnaire study. Participants were instructed to listen carefully to a set of sentences through headphones. The end of each sentence was indicated by a tone. After each sentence, a content question was presented through the headphones. The question following the experimental sentences was always a *who* question of the type shown in (13).

(13) Who was feeling very tired?

On presentation of the question, two NPs appeared on the screen representing two possible answers—for example, *the nurse* and *the pupil.* Nouns were always preceded by the definite article. One NP appeared on the left side of the screen and the other on the right side. The order of the two possible answers was counterbalanced relative to the order of the nouns in the test sentences. To compensate for some of the children's difficulty with reading, we read the phrases out loud as they appeared on the screen. Participants were allowed to listen to each sentence, the corresponding question, and the two answer options twice. They were instructed to answer the question after either the first or the second time.

4.3.4. Self-paced listening experiment. For the online task, we used the auditory moving window technique described by Ferreira, Henderson, Anes, Weeks, and McFarlane (1996) in which the participants listen to sentences by pressing a pacing button to receive successive words or phrasal segments. This technique, which has been used successfully with both adults (Ferreira, Anes, and Horine (1996), Ferreira, Henderson, et al. (1996), Heredia and Vaid (2002), Waters, Yampolsky, and Caplan (2002), among others) and children (Booth et al. (2000)) in the past, provides a segment-by-segment measure of processing time. Self-paced listening tasks have been shown to be sensitive to the same effects that have been observed in corresponding tasks using visual stimuli (see, e.g., Booth et al. (2000), Ferreira, Henderson, et al. (1996)). The basic rationale underlying the moving window technique is that increased RTs to a particular segment (relative to the same segment in a control condition) indicate a relatively higher processing difficulty at that point in the sentence.

Participants were seated in front of a 17-in. monitor and instructed to listen carefully to the prerecorded sentences over headphones. The sentences were presented in a segment-by-segment fashion, with each sentence being divided into five segments as indicated in (14). The disambiguating auxiliary always appeared in the fourth segment.

(14) The doctor recognized / the nurse of the pupils / who / was / feeling very tired.

After listening to each segment, the participants were asked to press either button on a dual push-button box as quickly as possible to receive the next segment. The end of each sentence was indicated by a tone. The computer recorded the time between the onset of each segment and the next button press. The presentation of the stimuli and the recording of RTs was controlled by the NESU software package (Baumann, Nagengast, and Klaas (1993)). To ensure that the participants paid attention to the task, all experimental sentences and half of the fillers were followed by a comprehension question of the type shown in (15), which was also presented auditorily.

(15) Who was feeling very tired?

Immediately after the question was presented, two pictures appeared on the computer screen—one on the left and one on the right side of the screen. Each picture represented one of the two potential antecedent NPs. For half of the questions, the correct picture appeared on the left side of the screen, and for the other half of the questions, the correct picture appeared on the right side. The order of the two pictures was counterbalanced relative to the order of the corresponding nouns in the stimulus sentences. To answer the question, the participants had to press either the left or the right button of a dual push-button box, which corresponded to the left or right picture on the screen. The online experiment lasted approximately 30 min and was divided into two 15-min sessions by a short break. The first session was preceded by 11 practice sentences and the second session by a further 6 practice sentences. Each participant heard 2 different sentences from each sentence quadruplet, 1 in the first session and the other in the second session.

5. RESULTS

5.1. Listening-Span Task

Listening-span scores were calculated using the scoring procedure originally described by Daneman and Carpenter (1980). On the basis of their scores in this task, we divided the children into two groups—those with a relatively low listening span (span ≤ 1.5) and those with a high listening span (span ≥ 2). Of the 29 children who took part in the main experiments, 19 were identified as high-span (*M* age = 6;8, range = 6;2–7;5) and 10 as low-span participants (*M* age = 6;8, range = 6;4–7;2).[9]

5.2. Grammaticality Judgment Task

Both the children and the adults were better at accepting grammatical sentences as correct than they were at rejecting the ungrammatical ones. This tendency was stronger for the children who overall exhibited a fairly strong bias toward a "yes" response. The mean overall accuracy rate for the adult group was 88%, and the children's mean overall accuracy rate was 62%. The main purpose of the

[9]Results from a Pearson correlation test showed that the children's scores in the listening span test were not correlated with age ($r = .243$, $n = 29$, $p = .203$).

grammaticality judgment task was to identify children who failed to demonstrate any sensitivity to number agreement errors in the auditorily presented sentences of the type under investigation and to exclude any such children from the analysis of the two main experiments.[10] Of the 38 children who originally underwent this task, we excluded from all subsequent analyses those who accepted all sentences as grammatical (8 children) as well as 1 child whose overall response accuracy rate was below chance level. Given that the children appeared to be biased toward a "yes" response, we also calculated correctness scores using the A′ statistic (Grier (1971)) that isolates the factor bias from the measure of sensitivity to the grammaticality of the sentences. When we applied Grier's formula[11] to the uncorrected scores, the children's mean accuracy score rose to 77% (high-span children = 80.5%, low-span children = 71.7%). The A′-corrected score of the child who was excluded on the basis of her low uncorrected accuracy score remained below chance level, though. Thus, 29 children and 37 adults went on to participate in the questionnaire study and the self-paced listening experiment.[12]

5.3. Questionnaire Study

The mean percentages of NP2 responses produced by each of the three participant groups in the offline task were as follows: adults, *of* = 41%, *with* = 67%; children with a high span, *of* = 47%, *with* = 58%; children with a low span, *of* = 46%, *with* = 48%.

Overall, the *with* condition elicited more NP2 responses than did the *of* condition, particularly for the adults. One-sample *t* tests revealed that the number of NP2 responses provided for *with* by the adult group differed reliably from chance, $t_1(36) = 3.508$, $p < .01$; $t_2(9) = 3.449$, $p < .01$, whereas the adult participants' bias toward an NP1 response for the *of* condition proved marginally significant in the subjects analysis only, $t_1(36) = 1.790$, $p < .1$. Although the pattern of responses for children with a high span resembles that of the adults, the number of NP2 responses remained within chance level for both groups of children and for both conditions. There were also no statistically reliable differences between the two conditions in either of the two child groups.

[10]There is ample evidence from the acquisition literature that normally developing English-speaking children have mastered tense and agreement by about age 4 (cf. e.g., Rice, Wexler, and Hershberger (1998)). The fact that some of our 6- to 7-year-old children failed to detect number agreement violations in the auditory grammaticality judgment task suggests that they had problems with this task rather than lacked grammatical knowledge in this domain.

[11]$A' = 0.5 + (y - x)(1 + y - x) / 4y(1 - x)$, where x = proportion of false alarms, and y = proportion of hits.

[12]To determine whether the children's performance in the grammaticality judgment task was linked to their listening span, we performed a Pearson correlation analysis on the two sets of (uncorrected) scores. The results indicate that the children's scores in the two tasks were not correlated ($r = .048$, $n = 29$, $p = .805$).

TABLE 1
Mean Reaction Times per Condition for All Segments and All Groups

Condition	*Segment 1*	*Segment 2*	*Segment 3*	*Segment 4*	*Segment 5*
Adults					
of-NP1	1,764	1,931	680	610	2,199
of-NP2	1,806	1,970	714	665	2,183
with-NP1	1,715	1,902	664	667	2,231
with-NP2	1,762	1,906	642	609	2,314
Children with high span					
of-NP1	2,044	2,100	967	863	4,221
of-NP2	2,254	2,160	934	964	4,840
with-NP1	2,199	2,120	826	749	4,471
with-NP2	1,987	2,055	915	807	4,956
Children with low span					
of-NP1	2,322	2,325	1,067	874	4,821
of-NP2	2,515	2,263	857	807	4,044
with-NP1	2,847	2,447	1,031	916	5,045
with-NP2	2,106	2,214	990	836	3,588

Note. All reaction times are given in milliseconds.

5.4. Self-Paced Listening Task

Following common practice in studies of this type, only data from trials that were responded to correctly were included in the statistical analysis of the reaction time data. For each condition, RTs beyond 1.5 *SD*s from each participant's mean were corrected to that value, affecting 9.8% of the data.[13] We also eliminated trials in which the participants had pressed the button before listening to the entire segment. To remove extreme outliers, we also excluded RTs greater than 2,000 ms to the critical segment (*was/were*), that is, data points that were more than twice as long as the average RTs. In addition, we excluded the data from 1 child whose answer accuracy was at or below chance level for all conditions and the data from 1 adult participant whose data set was incomplete. Finally, one item was excluded from the adult data (Item 10 in Appendix C) and two items from the child data (Items 4 and 11 in Appendix C) because the relevant data sets were incomplete. The remaining data from 18 high-span children, 10 low-span children, and 36 adults were included in the statistical analysis of the RT data.

Table 1 presents an overview of all participant group's mean RTs to each segment for the four conditions. Here and in the following, all RTs are given in milliseconds.

[13]We used a correction window of ±1.5 *SD*s (rather than the usual 2 or 2.5 *SD*s) because the children's listening times showed a relatively high degree of variation as is typically the case in online RT studies with children (cf. McKee (1996)).

5.5. Adult Group

Overall, the adult group produced shorter RTs than did the children. The adult group's mean RTs to the segment containing the disambiguating auxiliary (= Segment 4) are plotted in Figure 1.

The adult group produced shorter RTs to the critical segment for sentences forcing NP1 disambiguation for the *of* conditions but shorter RTs for forced NP2 disambiguation if the two critical NPs were joined by the preposition *with.* Two-way analyses of variance (ANOVAs) with the variables preposition and attachment revealed that the Preposition × Attachment interaction was significant in both the subjects and the items analysis, $F_1(1, 35) = 13.308$, $p < .01$; $F_2(1, 10) = 5.021$, $p < .05$. Subsequent pairwise comparisons using paired-samples t tests showed significant differences between NP1 and NP2 attachment both for the *of* conditions, $t_1(35) = 2.268$, $p < .05$; $t_2(10) = 2.298$, $p < .05$, and for the *with* conditions, $t_1(35) = 2.638$, $p < .05$; $t_2(10) = 1.828$, $p < .1$. For both Segments 2 and 3 preceding the disambiguating region, there was a main effect of preposition in the subjects analysis, which reflects shorter reading times for the *with* sentences: Segment 2, $F_1(1, 35) = 8.229$, $p < .01$; $F_2(1, 10) = 1.235$, $p > .1$; Segment 3, $F_1(1, 35) = 10.149$, $p < .01$; $F_2(1, 10) = 0.992$, $p > .1$. Crucially, however, there was no interaction between preposition and attachment on these earlier segments.

5.6. Children

At Segments 2 and 3 preceding the disambiguating auxiliary, there were no statistical effects or interactions for either group of children. The results from the children with a high span and low span at Segment 4 are plotted in Figures 2 and 3.

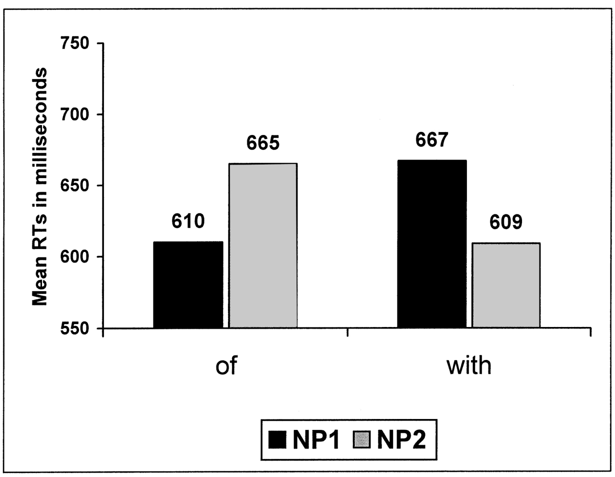


FIGURE 1 Mean reaction times to Segment 4–Adults ($N = 36$).

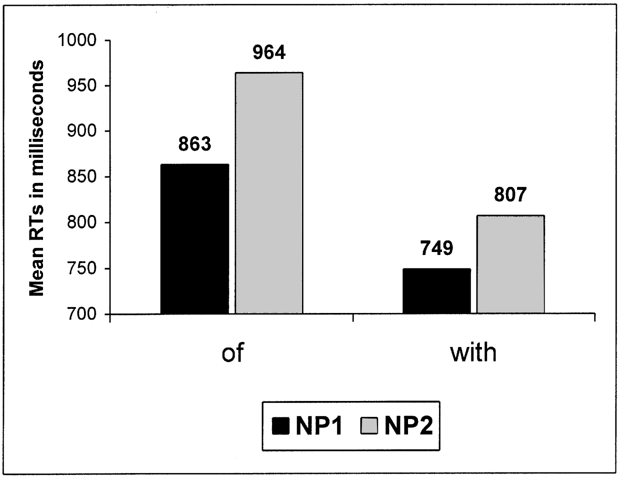


FIGURE 2 Mean reaction times to Segment 4–High-span children (N = 18).

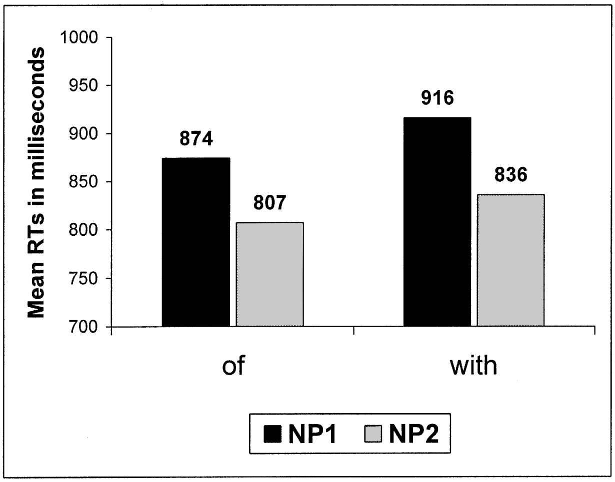


FIGURE 3 Mean reaction times to Segment 4–Low-span children (N = 10).

Whereas for the high-span group the conditions forcing NP1 attachment elicited shorter RTs at the disambiguating segment than the conditions forcing NP2 attachment for both *of* and *with* antecedents, the low-span group showed the opposite pattern. To find out whether this difference between the two span groups was statistically reliable, we performed a preliminary 2 × 2 × 2 ANOVA with the variables preposition (*of* vs. *with*), attachment (NP1 vs. NP2), and group (high-span vs. low-span) as between-subject factor for the critical segment. This analysis revealed a significant Preposition × Group interaction in the subjects analysis that was marginally significant in the items analysis, $F_1(1, 26) = 6.936$, $p < .05$; $F_2(1, 18) = 3.752$, $p < .1$, and a significant Attachment × Group interaction in both the subjects and the items analysis, $F_1(1, 26) = 13.924$, $p < .01$; $F_2(1, 18) = 6.874$, $p < .05$, confirming that the two groups of children differed reliably with respect to their online disambiguation preferences. As the observed interactions indicate that the two span groups exhibited different patterns of attachment preferences, we subsequently analyzed the results from each group on the critical Segment 4 separately.

5.4. High-Span Children

Figure 3 shows that for the high-span group, NP1 attachment elicited faster RTs at Segment 4 than did NP2 attachment for both *of* and *with.* Moreover, RTs to the critical segment were shorter for the *with* conditions. Two-way ANOVAs with the variables preposition and attachment revealed significant main effects of both preposition, $F_1(1, 17) = 10.450$, $p < .01$; $F_2(1, 9) = 5.963$, $p < .05$ and attachment, $F_1(1, 17) = 11.279$, $p < .01$; $F_2(1, 9) = 6.474$, $p < .05$ for this group of children. Crucially, though, the two variables did not interact. The effect of preposition found on the critical segment reflects the fact that overall, this group of children produced shorter RTs to the *with* conditions than to the *of* conditions (778 ms vs. 915 ms). The fact that this tendency, although not statistically significant, is already visible on the preceding Segment 3 (871 ms vs. 951 ms) suggests that the children with high span found complex NPs joined by *with* easier to process than those joined by *of.* The effect of attachment, on the other hand, confirms the preceding observation that this participant group preferred NP1 attachment irrespective of the type of preposition.

5.5. Low-Span Children

For this group of children, it was disambiguation toward NP2 attachment that produced faster RTs for both the *of* and the *with* conditions. Two-way ANOVAs with the variables preposition and attachment showed a significant main effect of attachment in the subject analysis, $F_1(1, 9) = 4.926$, $p = .05$. Although contrary to the children with high span, the children with a low span produced somewhat longer response latencies to the critical segment in the *with* conditions than in the *of* conditions, no statistically reliable effect of preposition was found for this group.

5.6. Child–Adult Comparisons

To explore the extent to which the children's attachment patterns differed from that of the adult group, we performed further ANOVAs comparing the results from each of the span groups with those from the adult group. When comparing the adult group and the high-span group, a mixed 2 × 2 × 2 ANOVA with the variables preposition, attachment, and group showed significant main effects of preposition, $F_1(1, 52) = 16.054$, $p < .01$; $F_2(1, 19) = 5.622$, $p < .05$; attachment, $F_1(1, 52) = 7.792$, $p < .01$; $F_2(1, 19) = 6.355$, $p < .05$; and group, $F_1(1, 52) = 42.988$, $p < .01$; $F_2(1, 19) = 67.171$, $p < .01$, as well as significant Preposition × Group, $F_1(1, 52) = 15.404$, $p < .01$; $F_2(1, 19) = 5.382$, $p < .05$; and Attachment × Group interactions, $F_1(1, 52) = 12.861$, $p < .01$; $F_2(1, 19) = 5.544$, $p < .05$. A parallel ANOVA comparing the results from the low-span group with those from the adult group revealed a significant main effect of attachment in the subjects analysis, $F_1(1, 44) = 6.361$, $p < .05$; a main effect of group in both the subjects and the items analysis, $F_1(1, 44) = 26.671$, $p < .01$; $F_2(1, 19) = 50.752$, $p < .01$; a significant Preposition × Attachment interaction in the subjects analysis, $F_1(1, 44) = 4.253$, $p < .05$; and a marginally significant Attachment × Group interaction in the subjects analysis, $F_1(1, 44) = 3.380$, $p < .1$. Taken together, these results confirm that neither group of children showed the same pattern of attachment preferences as the adult group.

5.7. Analysis of Response Accuracy

Overall, the mean response accuracy rates of the three participant groups in the online task were relatively low, possibly reflecting the fact that due to the transitory nature of the stimulus segments, auditory comprehension is a more demanding task than reading comprehension. Whereas the adult group answered 75% of the questions following the experimental and filler items correctly, the children with a high span had an overall correctness score of 66%, and the low-span group had 58%. Table 2 provides an overview of the mean percentages of correct responses to the questions following the experimental sentences.

As can be seen from Table 2, the participants' patterns of response accuracy are similar to their online attachment preferences as demonstrated by the analyses of the RTs results. The adult group's response accuracy rate was higher for NP1 than NP2 questions for the *of* conditions but higher for NP2 than NP1 questions for the *with* conditions. The answer accuracy rate for children with a high span was higher for NP1 questions than for NP2 questions for both prepositions, whereas the children with a low span showed the opposite pattern. The 2 × 2 ANOVAs with the variables preposition and attachment on the adult group's accuracy data

TABLE 2
Mean Percentages of Correct Responses to Questions Following Experimental Items

Group	*of-NP1 (%)*	*of-NP2 (%)*	*with-NP1 (%)*	*with-NP2 (%)*
Adults	77	60	57	67
Children with high span	64	59	56	53
Children with low span	55	68	47	53

showed a significant main effect of preposition in the subjects analysis, $F_1(1, 35) = 4.531, p < .05$; $F_2(1, 10) = 0.458, p > .1$ and a significant Attachment × Preposition interaction, $F_1(1, 35) = 17.345, p < .001$; $F_2(1, 10) = 6.798, p < .05$, confirming that the adult participants' response accuracy pattern did indeed match their online attachment preferences. The analyses of the children's accuracy data revealed a main effect of preposition for the high-span group, $F_1(1, 17) = 4.533, p < .05$; $F_2(1, 9) = 7.364, p < .05$, reflecting the fact that for this group, questions to *of* sentences elicited more correct responses than questions to *with* sentences, and a significant main effect of attachment for the low-span group in the subjects analysis, $F_1(1, 9) = 25.138, p < .01$; $F_2(1, 9) = 2.928, p > .1$, reflecting the fact that for this group, NP2 questions yielded higher response accuracies than NP1 questions.

5.8. Additional Analyses

As some of the children's response accuracy rates were close to chance level, it is possible that these children did not make an active enough effort to comprehend the experimental sentences. To find out whether low-accuracy children processed the experimental items any differently from their high-accuracy peers, we performed an additional analysis of the children's RTs to the critical segment in which the children were divided into two groups on the basis of their response accuracy rather than their listening span as in the earlier analysis (see Figures 2 and 3). Children were assigned to Groups 1 and 2 using the median of the response accuracy scores. A mixed 2 * 2 * 2 ANOVA with the variables preposition, attachment, and group revealed a significant main effect of preposition, $F_1(1, 26) = 5.958, p < .05$; $F_2(1, 18) = 7.835, p < .05$ only, reflecting the fact that, overall, the children produced shorter RTs for the *with* conditions than for the *of* conditions. Crucially though, there was no Attachment × Group interaction, confirming that the children's overall response accuracy rate was not related to their online attachment preferences.

We also determined whether the children's response accuracy in the online task was dependent on their listening-span scores. It might, for example, be the case that children with relatively low listening spans achieved poorer accuracy scores than children with high listening spans. The results of a Pearson correlation test between accuracy scores and listening spans showed that this was not the case ($r = .141$; $n = 28$; $p = .474$). Taken together, the results from the preceding analyses indicate that the children's answers to the control questions were affected by factors other than those that influenced their attachment preferences, including the possibility that they occasionally confused the two buttons or failed to take into account the number marking on the auxiliary when attempting to reconstruct the sentences' meaning at the end of the trial.

In online experiments such as the one performed for this study, it is common practice to include only those trials for which the participants answered the accompanying comprehension questions correctly. This is indeed the way we analyzed the self-paced listening data previously. However, the children's relatively low offline response accuracy scores in this task forced us to exclude a considerable amount of data from the statistical analysis. To include a larger amount of data, we performed an additional analysis on the children's RTs to the critical segment for both correctly and incorrectly answered trials. The rationale for this additional analysis was as follows. On the assumption that trials in which an initial attachment is revised yield relatively longer RTs to the critical segment than those in which the initial attachment is maintained, we hypothesized that RTs to Segment 4 should generally be shorter for trials to which the children gave their preferred answer—regardless of whether this answer was in fact accurate. That is, for the children with a high span (who, as shown previously, preferred NP1 attachment), RTs should be shorter for trials that elicited an NP1 response than for those trials in which they gave an NP2 response. The opposite should hold for the children with a low span (who prefer NP2 attachment), that is, trials eliciting an NP2 response should yield shorter RTs than those eliciting an NP1 response.

To test these predictions, we performed additional analyses on both correct and incorrect trials combined. For the high-span children, RTs to Segment 4 were indeed shorter overall for sentences that elicited an NP1 answer than for those that elicited an NP2 answer (818 ms vs. 895 ms), irrespective of accuracy. A one-way ANOVA with the variable answer (NP1 vs. NP2) showed a significant main effect, $F_1(1, 17) = 7.109, p < .05$; $F_2(1, 9) = 9.893, p < .05$, indicating that the aforementioned difference between the NP1-response and NP2-response RTs for children with a high span was reliable. For the low-span group, we found the opposite pattern, with sentences eliciting an NP2 answer showing significantly shorter RTs to the critical segment than sentences eliciting an NP1 answer (850 ms vs. 953 ms), $F_1(1, 9) = 9.636, p < .05$; $F_2(1, 9) = 5.146, p < .05$. These results provide additional evidence that the 6- to 7-year-old children we tested fell into two groups with respect to their RC attachment preferences.

6. DISCUSSION

Our results have revealed differences between the way children and adults process structurally ambiguous input. Specifically, our findings indicate that whereas adult native speakers' offline and online RC attachment preferences are influenced by semantic properties of the preposition joining the two potential antecedent NPs, children's online attachment preferences interact with their listening span: Whereas the children with a high span showed a preference for NP1 attachment for both prepositions, the low-span group showed a general tendency toward NP2 attachment.

In the following, various linguistic and nonlinguistic factors that may have affected our results are discussed in turn, as are the implications of our findings for theories of language acquisition and processing.

6.1. Structural Versus Nonstructural Information in Online Processing

The results from the adult group confirm Traxler et al.'s (1998) finding that the type of preposition joining the two potential host NPs (*of* vs. *with*) affects online ambiguity resolution in adult comprehenders. The results from the children, by contrast, indicate that children's attachment preferences were not influenced by semantic properties of the preposition or by the particular semantic relation between the two critical NPs that the preposition signals. Instead, the children appeared to be guided primarily by structure-based locality principles during parsing: Whereas the children with a low span appeared to follow a general Recency strategy favoring NP2 attachment, the high-span group relied on a strategy such as Predicate Proximity that favors NP1 attachment.[14] The observation that the children effectively ignored the attachment cues provided by the preposition during sentence processing is compatible with findings from other studies of children's online ambiguity resolution strategies (compare section 2). The results from Traxler's (2002) reading-time study of temporary subject–object ambiguities also suggest that children's parsing decisions are determined primarily by structural factors. Specifically, he found that children would preferentially pursue the structurally simpler analysis irrespective of plausibility or subcategorization information. Together with our findings, these results indicate that the use of semantic or contextual information during online processing may be developmentally delayed with respect to the use of structural information.

Further support for this view comes from an ongoing study with a group of older (10- to 11-year-old) children. Thus far, we have tested 34 children (*M* age = 10;7, range = 10;1–11;2) using the same tasks as for the younger children reported in this study. On the basis of their scores in the Gaulin and Campbell (1994) test, 30 of these children had a high listening span and are in this regard comparable to our subgroup of high-span 6- to 7-year-olds.[15] Here, we briefly report some preliminary results from these 30 children. As one might have expected, the older children's performance is closer to the performance of adult control group than the younger children's. Interestingly, however, this was only the case for their

[14]One reviewer suggested that rather than being guided by Predicate Proximity, the children with high span might simply prefer to modify as few NPs as possible, which would also account for the results obtained from this group in the online task. However, why should this only be the case for the children with high-span? An explanation along these lines seems unlikely and ad hoc, as neither the adult group nor the low-span group appear to be sensitive to such a constraint on modification. Moreover, it is unclear what the possible source(s) of this constraint might be and how children should eventually come to abandon it in favor of adult-like processing strategies. Given the results from the low-span group, limited processing resources are unlikely to give rise to any such restrictions on modification.

[15]We are currently trying to recruit more 10- to 11-year-olds with a relatively low listening span to allow for comparisons with our subgroup of 6- to 7-year-olds with low span.

offline performance but not with respect to online ambiguity resolution as revealed by their RTs to the critical segment in the self-paced listening task. In the grammaticality judgment task, the older children scored more than 80% correct, which is similar to the adult group's mean score of 88%. In the auditory questionnaire, the older children showed a clear tendency toward NP1 disambiguation for sentences containing *of* antecedents but not for sentences containing *with* antecedents. In terms of their response accuracy to the comprehension questions in the self-paced listening task, the older children also achieved similar scores (of more than 60%) as the adult control group. Response accuracy was higher for NP1 than NP2 questions for the *of* conditions but higher for NP2 than NP1 questions for the *with* conditions—the same pattern that was observed in the adults. Despite these similarities, however, the crucial online measure (= listening times to Segment 4) revealed differences between the older children and the adult group. Recall that in the online task, the adults showed an NP1 preference for the *of* conditions and an NP2 preference for *with* antecedents. By contrast, the older (high-span) children produced faster RTs in conditions forcing NP1 attachment than in conditions forcing NP2 attachment, irrespective of the type of antecedent. This replicates the pattern that was found for the younger children with high span and indicates that even the older children's online ambiguity resolution is not influenced by the type of preposition linking the two critical NPs.

The observation that in the questionnaire task the older children treated the two conditions differently shows that, in the offline task at least, these children were sensitive to semantic properties of the linking preposition. Note that the 6- to 7-year-old children with a high span showed a similar tendency in the offline task (cf. section 5, questionnaire study). The contrast between the questionnaire and the listening-time data suggests that children are capable of making use of semantic cues in principle but that this ability has not yet become sufficiently automatized to influence the initial stages in parsing. In other words, what seems to distinguish sentence processing in children and adults is not a general inability to use semantic information on the part of the children but rather the fact that children need more time for integrating structural and semantic or contextual information during sentence processing than adults do. Possible differences between adults and children in the extent to which semantic information can influence initial parsing preferences apart, then, our results are consistent with the hypothesis that the language processor does not undergo any qualitative changes from childhood to adulthood (Crain and Wexler (1999), Fodor (1998), among others).

6.2. The Role of Prosody in Ambiguity Resolution

Given that most previous studies investigating RC attachment ambiguities in adult speakers of English have found an NP2 attachment preference for *of,* the fact that our adult group showed a preference for NP1 attachment for this preposition was somewhat unexpected (cf. Mendelsohn & Pearlmutter (1999) and Traxler et al. (1998) for similar findings).[16] As the materials in both of our main experiments were presented auditorily, it is conceivable that prosodic factors have influenced the participants' attachment decisions. Prosodic factors are known to influence syntactic ambiguity resolution in adults (Fodor (1998), Price, Ostendorf, Shattuck-Hufnagel, and Fong (1991), Schafer et al. (1996), among others). Recall, however, that we found an NP1 preference for *of* both in the offline and in the online task. That is, although it may be the case that during the recording of the materials, an "NP1 intonation" (cf. Schafer et al. (1996)) was unintentionally imposed on the stimulus sentences used in the offline task, this is unlikely to be true for the materials used in the self-paced reading task, which had undergone splicing. What may have biased speakers toward NP1 attachment in the online task, though, is the fact that the complex NP was presented as one segment and that this segment was necessarily followed by a pause—the time it took the participants to press the button triggering the presentation of the next segment. As was shown by Price et al. (1991), introducing prosodic breaks before an ambiguous region may indeed influence listeners' attachment decisions during the processing of structurally ambiguous input. Schafer et al. (1996) suggested that the presence of a major prosodic boundary after the complex NP is likely to bias listeners toward NP1 attachment of a following RC.

Although we cannot rule out the possibility that prosody may be responsible for the adult participants' NP1 preference for *of,* prosodic factors alone can hardly explain why adult speakers' attachment preferences should vary depending on the type of preposition linking the two NPs. What is more, the assumption that listeners' attachment decisions are affected by prosody cannot by itself explain the results from the children, in particular, the differences in attachment preferences between the two span groups or the absence of any interaction of preposition type and attachment site in the two groups. As to the former observation, it is conceivable that the NP1 preference for the children with a high span was due to their being influenced by prosodic cues more than the children with a low span. This possibility is rendered unlikely, however, by the results from an offline study by Smyth (2001) on the influence of prosodic breaks on children's and adults' comprehension of ambiguous relative clauses. Smyth found that although 3- to 6-year-old children produced a similar (or even higher) number of NP1 responses as the adults to sentences spoken without pauses, introducing a pause after NP2 did not lead to a higher proportion of NP1 attachments in either the adults or the children. Studies by Choi and Mazuka (2002) and Snedeker, Thorpe, and Trueswell (2001) provide further evidence that children make limited or no use of prosodic cues when processing ambiguous sentences. To conclude, even if it were the case that our high-span group differed from the low-span group in that the former but not

---

[16]Note that in their questionnaire study, Gilboy et al. (1995) also found that complex NPs of the type we used in our experiments—that is, NPs linked by functional/occupational *of*—elicited more NP1 than NP2 responses.

the latter were sensitive to prosodic cues during online processing (a possibility that we are unable to verify), the possible influence of prosody alone does not account for our overall pattern of results.

6.3. Frequency of Exposure

An influential account in the adult sentence-processing literature is the so-called Tuning Hypothesis (Cuetos et al. (1996), Mitchell and Cuetos (1991)), according to which comprehenders' attachment preferences reflect the relative frequency of NP1 versus NP2 attachment patterns in the input. Preliminary evidence supporting the influence of past exposure on children's RC disambiguation preferences comes from a training study with 7-year-old Spanish-speaking children reported by Cuetos et al. (1996). The results from Cuetos et al.'s study show that systematically increasing the number of NP1 disambiguations in the input led to a significant increase in the strength of the children's NP1 attachment bias in a posttraining, offline test. The children "trained" on the NP2 attachment pattern, on the other hand, failed to show any increase in their proportion of NP2 responses.

Probabilistic approaches to the development of parsing preferences such as the Tuning Hypothesis have difficulty accounting for our child data, however. On the assumption that all children tested had been exposed to roughly the same proportions of NP1 and NP2 attachments in the past, the Tuning Hypothesis predicts that our children should have behaved in a uniform way. Given that the children's listening span was not correlated with their age, their grammaticality judgment scores, or their answer accuracy in the online task, it seems unlikely that their listening-span scores should have reflected differences in the children's linguistic development. Furthermore, given the likely predominance of the NP2 attachment pattern for NPs linked by "local" prepositions such as *with* in the input, both groups of children should have exhibited at least a tendency toward NP2 attachment for *with.* Our results disconfirm this prediction. Instead, we found an overall NP1 attachment preference for the children with a high span in the online task, even for the *with* condition.

6.4. The Role of Working Memory

Although our results suggest that children's use of lexical-semantic information during parsing is developmentally delayed with respect to their use of structural information, this by itself does not explain our second main result: the observation that the children's online attachment preferences differed depending on their listening span. More specifically, we found that children with a relatively high listening-span score showed a preference for NP1 attachment as predicted by the Predicate Proximity principle, whereas the children with a low span showed a general tendency toward NP2 disambiguation, thus obeying Recency. As it is unlikely that the two groups of children have different parsers, we suggest that the observed differences in parsing performance between the two span groups are best attributed to nonlinguistic differences. On the assumption that listening-span scores provide a measure of the children's verbal WM capacity, individual WM differences are the most likely source of the observed pattern of variation. Note also that a number of previous studies have found that individual differences in WM influence ambiguity resolution in adults (MacDonald et al. (1992), Mendelsohn and Pearlmutter (1999), Pearlmutter and MacDonald (1995), among others) and affect sentence processing in normally developing children (A. Adams and Gathercole (2000), Booth et al. (2000)).

From a WM perspective, it is conceivable that listeners will attach an ambiguous relative clause to whichever potential host NP is more active in their immediate memory. Our results indicate that the relative saliency of the two NPs differed depending on a child's listening span. This idea is further supported by the results of the two child groups' answer accuracy in the self-paced listening task. Whereas the children with a high span responded more accurately to questions in which NP1 was the correct answer than to those in which NP2 was correct, the reverse tendency was observed for the children with a low span. On the assumption that the Recency strategy is the more memory-friendly option in that it favors the NP that the participants had heard last, it is perhaps not surprising that it was the low-span group who preferred this strategy.

The NP1 attachment exhibited by the high-span group, on the other hand, indicates that for these children, the initial NP seemed to be the more active one. One possible reason for this might be that the high-span group prioritized on determining hierarchical relationships among the constituents of the sentences they heard or focused on the processing of "primary phrases" in the sense of Frazier and Clifton (1996). From this point of view, NP1 would be a more salient antecedent for the RC than the more deeply embedded NP2. There is independent evidence that the relative strength of the Predicate Proximity strategy increases where WM or processing resources are short. Recall, for example, Gibson et al.'s (1996) finding that if the number of potential antecedents for an ambiguous RC were increased to three, comprehenders would violate Recency in that they preferred high over middle attachment. Evidence that adult speakers' offline RC attachment preferences are influenced by their WM capacity is provided by the results from Mendelsohn and Pearlmutter's (1999) questionnaire study: They obtained a higher number of NP1 responses from their low-WM participants than they did from their high-WM participants. Mendelsohn and Pearlmutter hypothesized that due to their relatively limited processing resources, their participants with a low span may have focused primarily on the verb and its arguments—an idea that is similar to what we are suggesting for the children with a high span. If processing resources are even scarcer, though—as was very likely the case for our children with a low span—then NP saliency will be determined primarily by Recency, leading the children's parser to preferentially attach an ambiguous modifier to the second potential host NP.

7. CONCLUSION

This study has yielded two main findings. First, our results from the self-paced listening task show that adults' but not children's online attachment decisions are influenced by the type of preposition involved, indicating that the ability to use lexical-semantic cues to disambiguation is developmentally dissociated from the use of structure-based parsing principles. This conclusion is in line with previous findings by Traxler (2002) and others to the effect that during online sentence comprehension, children pursue the structurally simpler analysis irrespective of the presence of disambiguating semantic or contextual information. We argued that rather than being absent altogether, children's sensitivity to lexical biases does not (yet) influence their online parsing decisions. That children's parsing should be primarily guided by structural information during sentence processing may be due to the fact that children's WM capacity is more limited than that of adults, on the assumption that the online integration of nonstructural information requires additional processing resources. Determining the exact age or developmental stage at which children begin to behave like adults in this regard will be left as a matter for future research.

Second, we found that children's online parsing strategies differed depending on their verbal WM capacity. Whereas children with a relatively low listening span predominantly applied a more memory-friendly Recency strategy, the children with a high span followed a principle such as Predicate Proximity that is based on the hierarchical structure of sentences. This result suggests that individual WM capacity may affect the way in which these two parsing principles interact. In our view, then, the observed differences between the children's and the adults' performance in the online task are best interpreted as resulting from cognitive differences outside the language system proper, specifically, from children's relatively limited WM spans.

ACKNOWLEDGMENTS

This research was supported by the Leverhulme Trust (Grant F/213B to Harald Clahsen, Claudia Felser, and Roger Hawkins), which is gratefully acknowledged. We thank Martin Atkinson, Bob Borsley, Christian Fiebach, Janet Fodor, Angela Friederici, Ted Gibson, Peter Gordon, Roger Hawkins, Ian Hocking, Mike Jones, Dana McDaniel, Don Mitchell, Despina Papadopoulou, Matthias Schlesewsky, Herbert Schriefers, Carson Schütze, Ron Smyth, the audiences at the Max-Planck-Institute for Cognitive Neuroscience, Leipzig, Germany and at the 15th Annual CUNY Conference on Human Sentence Processing, New York, and two anonymous *Language Acquisition* reviewers for helpful comments and discussion. We are grateful to Ricardo Russo and Phil Scholfield for providing statistical advice; Roger Hawkins and Leah Roberts for helping with the design and the construction of the materials; and Emma Hopper, Ritta Husted, Annemarie Kerkhoff, and Leah Roberts for helping to collect the data. Finally, we thank the children at Broomgrove Primary School, Kirby-Cross County Primary School, Monkwick Primary School, and Millfields Primary School for their participation, and the teachers and parents for their support.

REFERENCES

Adams, A. and S. Gathercole (2000) "Limitations in Working Memory: Implications for Language Development," *International Journal of Language & Communication Disorders* 35, 95–116.

Adams, B., C. Clifton, and D. Mitchell (1998) "Lexical Guidance in Sentence Processing?," *Psychonomic Bulletin and Review* 5, 265–270.

Altmann, G. and M. Steedman (1988) "Interaction With Context During Human Sentence Processing," *Cognition* 30, 191–238.

Bates, E., A. Devescovi, and S. D'Amico (1999) "Processing Complex Sentences: A Crosslinguistic Study," *Language and Cognitive Processes* 14, 69–123.

Baumann, H., J. Nagengast, and G. Klaas (1993). "New Experimental Setup (NESU)," ms., Max-Planck Institute for Psycholinguistics, Nijmegen, The Netherlands.

Booth, J., B. MacWhinney, and Y. Harasaki (2000) "Developmental Differences in Visual and Auditory Processing of Complex Sentences," *Child Development* 71, 981–1003.

Brysbaert, M. and D. Mitchell (1996) "Modifier Attachment in Sentence Parsing: Evidence From Dutch," *Quarterly Journal of Experimental Psychology* 49, 664–695.

Carreiras, M. and C. Clifton (1993) "Relative Clause Interpretation Preferences in Spanish and English," *Language and Speech* 36, 353–372.

Carreiras, M. and C. Clifton (1999) "Another Word on Parsing Relative Clauses: Eyetracking Evidence From Spanish and English," *Memory and Cognition* 27, 826–833.

Choi, Y. and R. Mazuka (2002) "Young Children's Use of Prosodic Cues in Sentence Processing," paper presented at the 15th Annual CUNY Conference on Human Sentence Processing, New York.

Corrêa, L. (1995) "An Alternative Assessment of Children's Comprehension of Relative Clauses," *Journal of Psycholinguistic Research* 24, 183–203.

Crain, S. and R. Thornton (1998) *Investigations in Universal Grammar: A Guide to Experiments on the Acquisition of Syntax and Semantics,* MIT Press, Cambridge, Massachusetts.

Crain, S. and K. Wexler (1999) "Methodology in the Study of Language Acquisition: A Modular Approach," in W. Ritchie and T. Bhatia, eds., *Handbook of Child Language Acquisition,* Academic Press, San Diego, California.

Cuetos, F. and D. Mitchell (1988) "Cross-Linguistic Differences in Parsing: Restrictions on the Use of the Late Closure Strategy in Spanish," *Cognition* 30, 73–105.

Cuetos, F., D. Mitchell, and M. Corley (1996) "Parsing in Different Languages," in M. Carreiras, J. Garcia-Albea, and N. Sebastian-Galles, eds., *Language Processing in Spanish,* Lawrence Erlbaum Associates, Inc., Mahwah, New Jersey.

Daneman, M. and P. Carpenter (1980). "Individual Differences in Working Memory and Reading," *Journal of Verbal Learning and Verbal Behavior* 19, 450–466.

De Vincenzi, M. (1991) *Syntactic Parsing Strategies in Italian,* Kluwer, Dordrecht, The Netherlands.

Ferreira, F., M. Anes, and M. Horine (1996) "Exploring the Use of Prosody During Language Comprehension Using the Auditory Moving Window Technique," *Journal of Psycholinguistic Research* 25, 273–290.

Ferreira, F., J. Henderson, M. Anes, P. Weeks, and D. McFarlane (1996) "Effects of Lexical Frequency and Syntactic Complexity in Spoken Language Comprehension: Evidence From the Auditory Moving Window Technique," *Journal of Experimental Psychology: Learning, Memory and Cognition* 22, 324–335.

Fodor, J. D. (1998) "Learning to Parse?" *Journal of Psycholinguistic Research* 27, 285–319.

Fragman, C. and H. Goodluck (2000) "Child and Adult Construal of Restrictive Relative Clauses: Knowledge of Grammar and Differential Effects of Syntactic Context," ms., University of Ottawa, Ottawa, Ontario, Canada.

Frazier, L. (1979) *On Comprehending Sentences: Syntactic Parsing Strategies,* Doctoral dissertation, University of Connecticut, Storrs, Connecticut.

Frazier, L. and C. Clifton (1996) *Construal,* MIT Press, Cambridge, Massachusetts.

Frazier, L. and J. D. Fodor (1978) "The Sausage Machine: A New Two-Stage Parsing Model," *Cognition* 6, 291–326.

Frazier, L. and K. Rayner (1982) "Making and Correcting Errors During Sentence Comprehension: Eye Movements and the Analysis of Structurally Ambiguous Sentences," *Cognitive Psychology* 14, 178–210.

Frazier, L. and K. Rayner (1988) "Parameterizing the Language Processing System: Left- vs. Right-Branching Within and Across Languages," in J. Hawkins, ed., *Explaining Language Universals,* Blackwell, Oxford, England.

Frenck-Mestre, C. and J. Pynte (1997) "Syntactic Ambiguity Resolution While Reading in Second and Native Languages," *Quarterly Journal of Experimental Psychology* 50A, 119–148.

Frenck-Mestre, C. and J. Pynte (2000) "Resolving Syntactic Ambiguities: Cross-Linguistic Differences?," in M. De Vincenzi and V. Lombardo, eds., *Cross-Linguistic Perspectives on Language Processing,* Kluwer, Dordrecht, The Netherlands.

Friederici, A. and A. Hahne (2001) "Development Patterns of Brain Activity," in J. Weissenborn and B. Höhle, eds., *Approaches to Bootstrapping: Phonological, Lexical, Syntactic and Neurophysiological Aspects of Early Language Acquisition, Vol. 2,* John Benjamins, Amsterdam, The Netherlands.

Garnsey, S., N. Pearlmutter, E. Myers, and M. Lotocky (1997) "The Contribution of Verb Bias and Plausibility to the Comprehension of Temporarily Ambiguous Sentences," *Journal of Memory and Language* 37, 58–93.

Gaulin, C. and T. Campbell (1994) "Procedure for Assessing Verbal Working Memory in Normal School-Age Children: Some Preliminary Data," *Perceptual and Motor Skills* 79, 55–64.

Gibson, E., N. Pearlmutter, E. Canseco-Gonzalez, and G. Hickok (1996) "Cross-Linguistic Attachment Preferences: Evidence From English and Spanish," *Cognition* 59, 23–59.

Gibson, E., N. Pearlmutter, and V. Torrens (1999) "Recency and Lexical Preferences in Spanish," *Memory and Cognition* 27, 603–611.

Gilboy, E., J. M. Sopena, C. Clifton, and L. Frazier (1995) "Argument Structure and Association Preferences in Spanish and English Compound NPs," *Cognition* 54, 131–167.

Goodluck, H. and S. Tavakolian (1982) "Competence and Processing in Children's Grammar of Relative Clauses," *Cognition* 11, 1–27.

Grier, J. (1971) "Nonparametric Indexes for Sensitivity and Bias: Computing Formulas," *Psychological Bulletin* 75, 424–429.

Hamburger, H. and S. Crain (1982) "Relative Acquisition," in S. Kuczaj, ed., *Language Development: Syntax and Semantics,* Lawrence Erlbaum Associates, Inc., Mahwah, New Jersey.

Hemforth, B., L. Konieczny, and C. Scheepers (2000) "Syntactic Attachment and Anaphor Resolution: Two Sides of Relative Clause Attachment," in M. Crocker, M. Pickering, and C. Clifton, eds., *Architectures and Mechanisms for Language Processing.* Cambridge University Press, Cambridge, England.

Heredia, R. and J. Vaid (2002) "Processing Code-Switched Sentences: Effects of Semantic Constraint, Guest Word Phonology and Guest Word Frequency," poster presented at the 15th Annual CUNY Conference on Human Sentence Processing, New York.

Hurewitz, F., S. Brown-Schmidt, K. Thorpe, L. Gleitman, and J. Trueswell (2000) "One Frog, Two Frog, Red Frog, Blue Frog: Factors Affecting Children's Syntactic Choices in Production and Comprehension," *Journal of Psycholinguistic Research* 29, 597–626.

Just, M. and P. Carpenter (1992) "A Capacity Theory of Comprehension: New Frontiers of Evidence and Arguments," *Psychological Review* 99, 122–149.

Kimball, J. (1973) "Seven Principles of Surface Structure Parsing in Natural Language," *Cognition* 2, 15–47.

King, J., and M. Just (1991) "Individual Differences in Syntactic Processing: The Role of Working Memory," *Journal of Memory and Language* 30, 580–602.

Love, T. and D. Swinney (1997) "Real Time Processing of Object Relative Constructions by Pre-School Children," poster presented at the 10th Annual CUNY Conference on Human Language Processing, Santa Monica, California.

MacDonald, M., M. Just, and P. Carpenter (1992) "Working Memory Constraints on the Processing of Syntactic Ambiguity," *Cognitive Psychology* 24, 56–98.

MacWhinney, B. (1982) "Basic Syntactic Processes," in S. Kuczaj, ed., *Language Acquisition: Vol. 1. Syntax and Semantics,* Lawrence Erlbaum Associates, Inc., Hillsdale, New Jersey.

MacWhinney, B. and C. Pleh (1988) "The Processing of Restrictive Relative Clauses in Hungarian," *Cognition* 29, 95–141.

Mazuka, R. (1998) *The Development of Language Processing Strategies. A Cross-Linguistic Study Between Japanese and English,* Lawrence Erlbaum Associates, Inc., Hove, England.

Mazuka, R. and B. Lust (1990) "On Parameter Setting and Parsing: Predictions for Cross-Linguistic Differences in Adult and Child Processing," in L. Frazier and J. de Villiers, eds., *Language Processing and Language Acquisition,* Kluwer, Dordrecht, The Netherlands.

McDaniel, D. and H. Smith Cairns (1996) "Eliciting Judgements of Grammaticality and Reference," in D. McDaniel, C. McKee, and H. Smith Cairns, eds., *Methods for Assessing Children's Syntax,* MIT Press, Cambridge, Massachusetts.

McKee, C. (1996) "On-line Methods," in D. McDaniel, C. McKee, and H. Smith Cairns, eds., *Methods for Assessing Children's Syntax,* MIT Press, Cambridge, Massachusetts.

McKee, C., J. Nicol, and D. McDaniel (1993) "Children's Application of Binding During Sentence Processing," *Language and Cognitive Processes* 8, 265–290.

Mendelsohn, A. and N. Pearlmutter (1999) "Individual Differences in Attachment Preferences," poster presented at the 12th Annual CUNY Conference on Human Sentence Processing, New York.

Mitchell, D. and F. Cuetos (1991) "The Origins of Parsing Strategies," in C. Smith, ed., *Current Issues in Natural Language Processing,* Center for Cognitive Science, University of Austin, Austin, Texas.

Nakano, Y., C. Felser, and H. Clahsen (2002) "Antecedent Priming at Trace Positions in Japanese Long-Distance Scrambling," *Journal of Psycholinguistic Research* 31, 531–571.

Papadopoulou, D. and H. Clahsen (2003) "Parsing Strategies in L1 and L2 Sentence Processing: A Study of Relative Clause Attachment in Greek," *Studies in Second Language Acquisition* 25, 501–528.

Pearlmutter, N. and M. MacDonald (1995) "Individual Differences and Probabilistic Constraints in Syntactic Ambiguity Resolution," *Journal of Memory and Language* 34, 521–542.

Price, P., S. Ostendorf, S. Shattuck-Hufnagel, and C. Fong (1991) "The Use of Prosody in Syntactic Disambiguation," *Journal of the Acoustical Society of America* 90, 2956–2970.

Rice, M., K. Wexler, and S. Hershberger (1998) "Tense Over Time: The Longitudinal Course of Tense Acquisition in Children With Specific Language Impairment," *Journal of Speech, Language, and Hearing Research* 41, 1412–1431.

Roberts, L. (2003) *Second Language Sentence Processing: The Processing of Relative Clause Attachment Ambiguities and Long-Distance Wh-Dependencies by Adult L2 Learners of English,* Doctoral dissertation, University of Essex, England.

Schafer, A., J. Carter, C. Clifton, and L. Frazier (1996) "Focus in Relative Clause Construal," *Language and Cognitive Processes* 11, 135–163.

Smyth, R. (2001) "Prosody, Overt Number Markers, and Late Closure in the L1 and L2 Acquisition of Subject-Verb Agreement," ms., University of Toronto, Toronto, Ontario, Canada.

Snedeker, J., K. Thorpe, and J. Trueswell (2001) "On Choosing the Parse With the Scene: The Role of Visual Context and Verb Bias in Ambiguity Resolution," in J. D. Moore and K. Stenning, eds., *Pro-*

ceedings of the 23rd Annual Conference of the Cognitive Science Society, Lawrence Erlbaum Associates, Inc., Mahwah, New Jersey.

Tanenhaus, M., M. Spivey-Knowlton, K. Eberhard, and J. Sedivy (1995) "Integration of Visual and Linguistic Information in Spoken Language Comprehension," *Science* 268, 1632–1634.

Thornton, R., M. MacDonald, and M. Gil (1999) "Pragmatic Constraints on the Interpretation of Complex Noun Phrases in Spanish and English," *Journal of Experimental Psychology: Learning, Memory, and Cognition* 25, 1347–1365.

Townsend, D., D. Ottavio, and T. Bever (1979) "Immediate Memory for Words from Main and Subordinate Clauses at Different Age Levels," *Journal of Psycholinguistic Research* 8, 83–101.

Traxler, M. (2002) "Plausibility and Subcategorization Preference in Children's Processing of Temporarily Ambiguous Sentences: Evidence From Self-Paced Reading," *Quarterly Journal of Experimental Psychology* 55A, 75–96.

Traxler, M., M. Pickering, and C. Clifton (1998) "Adjunct Attachment Is Not a Form of Lexical Ambiguity Resolution," *Journal of Memory and Language* 39, 558–592.

Trueswell, J., I. Sekerina, N. Hill, and M. Logrip (1999) "The Kindergarden-Path Effect: Studying On-Line Sentence Processing in Children," *Cognition* 73, 89–134.

Trueswell, J., M. Tanenhaus, and S. Garnsey (1994) "Semantic Influence on Parsing: Use of Thematic Role Information in Syntactic Disambiguation," *Journal of Memory and Language* 33, 285–318.

Tyler, L. and W. Marslen-Wilson (1978) "Some Developmental Aspects of Sentence Processing and Memory," *Journal of Child Language* 5, 113–129.

Tyler, L. and W. Marslen-Wilson (1981) "Children's Processing of Spoken Language," *Journal of Verbal Learning and Verbal Behavior* 20, 400–416.

Waters, G., S. Yampolsky, and D. Caplan (2002) "Syntactic Processing Under Load and Noise Interference," poster presented at the 15th Annual CUNY Conference on Human Sentence Processing, New York.

Weighall, A. and G. Altmann (2001) "When Two Cats Are Better Than None: Children's Interpretation of Relative Clauses (Revisited)," poster presented at the 7th Annual Conference on Architectures and Mechanisms for Language Processing, Saarbrücken, Germany.

Wijnen, F. (1998) "Dutch Relative Clause Attachment in Two- and Three-Site Contexts," poster presented at the 11th Annual CUNY Conference on Human Sentence Processing, New Brunswick, New Jersey.

Zagar, D., J. Pynte, and S. Rativeau (1997) "Evidence for Early-Closure Attachment on First-Pass Reading Times in French," *Quarterly Journal of Experimental Psychology* 50A, 421–438.

APPENDIX A

Critical Sentences Used in the Grammaticality Judgment Task

Grammatical

1. The reporter phoned the boss of the secretary who was reading a book.
2. The cleaning lady noticed the chief of the player who was working very late.
3. The nurse trusted the doctor of the teacher who was preparing to go home.
4. A reporter interviewed the bodyguard with the prince who was wearing a smart black suit.
5. The man spoke to the secretary with the manager who was about to move to a new office.

6. The little girl envied the princess with the maid who was eating chocolates.
7. The headmaster smiled at the pupils of the teachers who were standing in the hall.
8. The inspector watched the assistants of the policemen who were watching the report of the crime on TV.
9. The journalist hated the soldiers of the colonels who were sitting down.
10. The photographer liked the artists with the models who were smiling all the time.
11. The young man noticed the singers with the guitarists who were reading the music.
12. The coach looked at the football players with the fans who were very happy.

Ungrammatical

13. The director noticed the hairdresser of the actress who were wearing a green dress and a yellow hat.
14. The director congratulated the instructor of the schoolboy who were looking very serious.
15. The doctor recognised the nurse of the patient who were feeling very tired.
16. The cameraman spoke to the actor with the cameraman who were preparing the next scene.
17. The young girl favoured the player with the driver who were talking to an old woman.
18. The cameraman adored the actor with the director who were wearing round glasses.
19. I watched the fans of the singers who was dancing about throughout the concert.
20. The reporter watched the lawyers of the criminals who was speaking to the judge.
21. The woman knew the photographers of the singers who was reading a book.
22. A strange woman called to the travellers with the guides who was about to cross the dangerous river.
23. The doctor contacted the lawyers with the nurses who was talking on the phone.
24. The woman blamed the hairdressers with the apprentices who was smiling all the time.

APPENDIX B

Experimental Sentences Used in the Auditory Questionnaire Study

1a. The doctor recognised the nurse of the pupil who was feeling very tired.

1b. The doctor recognised the pupil with the nurse who was feeling very tired.

2a. The young girl favoured the driver of the player who was talking to an old woman.
2b. The young girl favoured the player with the driver who was talking to an old woman.

3a. The journalist criticised the coach of the runner who was drinking too much.
3b. The journalist criticised the runner with the coach who was drinking too much.

4a. The cleaning lady noticed the chief of the player who was working very late.
4b. The cleaning lady noticed the player with the chief who was working very late.

5a. The woman knew the photographer of the singer who was reading a book.
5b. The woman knew the singer with the photographer who was reading a book.

6a. The student photographed the fan of the actress who was looking happy.
6b. The student photographed the actress with the fan who was looking happy.

7a. The doctor contacted the nurse of the lawyer who was talking on the phone.
7b. The doctor contacted the lawyer with the nurse who was talking on the phone.

8a. The photographer liked the model of the artist who was smiling all the time.
8b. The photographer liked the artist with the model who was smiling all the time.

9a. The nurse trusted the doctor of the teacher who was preparing to go home.
9b. The nurse trusted the teacher with the doctor who was preparing to go home.

10a. The journalist hated the soldier of the colonel who was sitting down.
10b. The journalist hated the colonel with the soldier who was sitting down.

APPENDIX C

Experimental Sentences Used in the Self-Paced Listening Task

1a. The doctor recognised the nurse of the pupils who was feeling very tired.
1b. The doctor recognised the nurse of the pupils who were feeling very tired.
1c. The doctor recognised the pupils with the nurse who were feeling very tired.

1d. The doctor recognised the pupils with the nurse who was feeling very tired.

2a. The director congratulated the instructor of the schoolboys who was looking very serious.
2b. The director congratulated the instructor of the schoolboys who were looking very serious.
2c. The director congratulated the schoolboys with the instructor who were looking very serious.
2d. The director congratulated the schoolboys with the instructor who was looking very serious.

3a. The young girl favoured the driver of the players who was talking to an old woman.
3b. The young girl favoured the driver of the players who were talking to an old woman.
3c. The young girl favoured the players with the driver who were talking to an old woman.
3d. The young girl favoured the players with the driver who was talking to an old woman.

4a. The journalist criticised the coach of the runners who was drinking too much.
4b. The journalist criticised the coach of the runners who were drinking too much.
4c. The journalist criticised the runners with the coach who were drinking too much.
4d. The journalist criticised the runners with the coach who was drinking too much.

5a. The cleaning lady noticed the chief of the players who was working very late.
5b. The cleaning lady noticed the chief of the players who were working very late.
5c. The cleaning lady noticed the players with the chief who were working very late.
5d. The cleaning lady noticed the players with the chief who was working very late.

6a. The woman knew the photographer of the singers who was reading a book.
6b. The woman knew the photographer of the singers who were reading a book.
6c. The woman knew the singers with the photographer who were reading a book.
6d. The woman knew the singers with the photographer who was reading a book.

7a. The student photographed the fans of the actress who were looking happy.
7b. The student photographed the fans of the actress who was looking happy.
7c. The student photographed the actress with the fans who was looking happy.
7d. The student photographed the actress with the fans who were looking happy.

8a. The doctor contacted the nurses of the lawyer who were talking on the phone.
8b. The doctor contacted the nurses of the lawyer who was talking on the phone.
8c. The doctor contacted the lawyer with the nurses who was talking on the phone.
8d. The doctor contacted the lawyer with the nurses who were talking on the phone.

9a. The photographer liked the models of the artist who were smiling all the time.
9b. The photographer liked the models of the artist who was smiling all the time.
9c. The photographer liked the artist with the models who was smiling all the time.
9d. The photographer liked the artist with the models who were smiling all the time.

10a. The nurse trusted the doctors of the teacher who were preparing to go home.
10b. The nurse trusted the doctors of the teacher who was preparing to go home.
10c. The nurse trusted the teacher with the doctors who was preparing to go home.
10d. The nurse trusted the teacher with the doctors who were preparing to go home.

11a. The journalist hated the soldiers of the colonel who were sitting down.
11b. The journalist hated the soldiers of the colonel who was sitting down.
11c. The journalist hated the colonel with the soldiers who was sitting down.
11d. The journalist hated the colonel with the soldiers who were sitting down.

12a. The little girl envied the maids of to the princess who were eating chocolates.
12b. The little girl envied the maids of to the princess who was eating chocolates.
12c. The little girl envied the princess with the maids who was eating chocolates.
12d. The little girl envied the princess with the maids who were eating chocolates.