ABSTRACT

Title of Dissertation: **THE ACQUISITION OF ADJUNCT CONTROL: GRAMMAR AND PROCESSING**

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This dissertation uses children's acquisition of adjunct control as a case study to investigate grammatical and performance accounts of language acquisition. In previous research, children have consistently exhibited non-adultlike behavior for sentences with adjunct control. To explain children's behavior, several different grammatical accounts have been proposed, but evidence for these accounts has been inconclusive. In this dissertation, I take two approaches to account for children's errors.

First, I spell out the predictions of previous grammatical accounts, and test these predictions after accounting for some methodological concerns that might have influenced children's behavior in previous studies. While I reproduce the non-adultlike behavior observed in previous studies, the predictions of previous grammatical accounts are not borne out, suggesting that extragrammatical factors are needed to explain children's behavior.

Next, I consider the role of two different types of extragrammatical factors in predicting children's non-adultlike behavior. With a new task designed to address the task demands in previous studies, children exhibit significantly higher accuracy than with previous tasks. This suggests that children's behavior has been influenced by task-specific processing factors. In addition to the task, I also test the predictions of a similarity-based interference account, which links children's errors to the same memory mechanisms involved in sentence processing difficulties observed in adults. These predictions *are* borne out, supporting a more continuous developmental trajectory as children's processing mechanisms become more resistant to interference.

Finally, I consider how children's errors might influence their acquisition of adjunct control, given the distribution in the linguistic input. I discuss the results of a corpus analysis, including the possibility that adjunct control could be learned from the input. The kinds of information that could be useful to a learner become much more limited, however, after considering the processing limitations that would interfere with the representations available to the learner.

THE ACQUISITION OF ADJUNCT CONTROL: GRAMMAR AND PROCESSING

by

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Dissertation submitted to the Faculty of the Graduate School of the
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Dedication

To my parents, Trudy Lionel and Steve Gerard.

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Ever since I started graduate school, the dissertation has seemed like a mountain somewhere in the distance that I would reach eventually, but not any time soon. Actually climbing the mountain was not even conceivable. It's easy to imagine that the last few months have really been a dream: I'll wake up again soon at the bottom of the dissertation mountain, still thinking about how to start the introduction.

200 pages in, I can be confident enough now that this isn't a dream, but there are so many people who helped to make it a reality. First, my advisor Jeff Lidz has supported me throughout the past 5 years, and I am incredibly grateful for all of his help and patience with designing, troubleshooting, analyzing, and presenting my work.

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Chapter 1: Introduction

Children are expert language learners: while adults can take several years or even decades to achieve fluency in a new language and require explicit attention to its grammatical features, children do so in just a few years, without instruction or direct attention to these features. Furthermore, children acquire a system that is much richer than their experience warrants: they exhibit sensitivity to phenomena that do not occur in the linguistic input, and do not make incorrect generalizations that are available in their experience. At the same time, children's errors persist well after they are able to produce and comprehend many of the complex structures in their language. Because these errors are relatively rare, the learning process is largely invisible. When they occur, children's errors therefore offer a unique window into children's language development and the learning mechanism, including how children process their linguistic input and how they converge on the adult grammar. Accounting for children's errors is therefore a major focus in language acquisition, and depending on the phenomenon, different explanations for these errors have led to many other types of questions about language acquisition and language processing.

If children have a non-adultlike grammar, for example, then this raises questions about why one particular non-adultlike grammar was selected over another, how the non-adultlike grammar is deployed differently from the adult grammar, and what kind of evidence is needed to discard the non-adultlike grammar in favor of the adult grammar, among others. Meanwhile, focusing on non-adultlike behavior that

results from an immature deployment system allows for questions about extragrammatical factors that affect children's behavior – for example, how the mechanisms responsible for online language processing might be more prone to parsing failure in children than in adults, and how these mechanisms develop over time.

Before addressing these types of questions, however, for a particular pattern of non-adultlike behavior it is necessary to spell out the predictions that are made by any grammatical accounts (which posit a non-adultlike grammar) or performance accounts (which point to a non-adultlike deployment system as the source of non-adultlike behavior). Identifying the source of children's errors is therefore a first step in answering further questions about how children's language develops over time.

This dissertation uses children's errors for adjunct control, as in (1), as a case study to address different predictions made by grammatical and performance accounts of language acquisition in children.

(1) John$_1$ bumped Mary$_2$ after PRO$_{1/*2/*3}$ tripping on the sidewalk.

In (1), the unpronounced subject of the adjunct clause is bound by the main clause subject, but not the object. While adults only allow a subject control interpretation for (1) (Chomsky, 1981), a number of studies have observed non-adultlike behavior for adjunct control in children (Goodluck, 1981; Hsu, Cairns, & Fiengo, 1985; McDaniel, Cairns, & Hsu, 1991; Cairns, McDaniel, Hsu, & Rapp, 1994; Broihier & Wexler, 1995; Goodluck, 2001; Adler, 2006), with some children accepting object control, some accepting a sentence internal interpretation, and some even allowing free reference for

PRO. Several different accounts have been proposed to explain children's behavior for adjunct control; however, the source of their errors is still unclear.

In this dissertation, I focus first on existing grammatical accounts, and on the methodology that has been used in studying the acquisition of adjunct control. The main concern in previous studies has been with describing the observed pattern of behavior and proposing a grammar (or series of grammars) that would best fit the data. Meanwhile, there has been less of a discussion about what further predictions are made by these grammatical accounts (Adler, 2006; Cairns et al., 1994), and few researchers have considered the task demands that may have influenced the patterns of behavior that were used to categorize children as having one grammar over another (Broihier & Wexler, 1995; McDaniel et al., 1991). Therefore in evaluating the existing grammatical accounts and the predictions that they make, this dissertation also considers how task-specific factors may have contributed to the observed patterns of behavior that motivated these accounts.

Next, I consider the processing demands that influence children's interpretations of sentences with adjunct control. This includes general task demands, as well as the processing load associated with retrieval of a linguistic antecedent during online sentence processing. Based on research on antecedent retrieval in adults, I argue that the deployment system in children makes use of the same parsing procedure as in adults, but that in children, the parser is more easily derailed. This raises questions about how, for the same constructions, parsing failures observed in children develop into reading time slowdowns in adults. I conclude with a discussion of the linguistic

input, and what information might be needed to learn a syntactic restriction on interpretation.

1.1 Introduction to adjunct control

In human language, non-adjacent linguistic elements enter into different types of grammatical dependencies. For example, these dependencies may be between a verb and its subject (2a), a pronoun and its antecedent (2b), or a wh-phrase and the verb that it is an argument of (2c).

(2) a. John usually walks to school.

b. John said that he walked to school.

c. Which school does John attend?

This dissertation focuses on referential dependencies, as in (2b), in which the interpretation of one element is determined via coreference with another. Different types of referential dependencies involve different restrictions on the set of possible antecedents. For example, the antecedent of a reflexive must be in the same clause, while a different set of restrictions determines the antecedent of a pronoun:

(3) a. John$_1$ said that Mary$_2$ should draw *himself/herself.

b. John$_1$ said that Mary$_2$ should draw him$_1$/her$_{*2}$.

Some linguistic dependencies are constrained by the syntactic relation between the two elements, whereas other dependencies reflect discourse relations. While discourse dependencies may cross sentence boundaries, syntactic dependencies are restricted to a single sentence, and depending on the type of dependency, can be subject to additional constraints as well, based on *binding* relations (Chomsky, 1981):

(4) A node α binds a node β iff:

a. α and β are co-indexed, and

b. α c-commands β

where α c-commands β iff:

a. neither node dominates the other, and

b. the first branching node dominating α dominates β.

For example, reflexives and quantifiers both enter into syntactic dependencies, within a single sentence. Reflexives must be bound by an antecedent in the same sentence (5a), and quantifiers can bind variables in the same sentence (5b):

(5) a. John$_1$ said that Mary$_2$ should draw herself$_2$.

b. Every girl$_1$ said that John$_2$ should draw her$_1$.

However, a reflexive cannot have a sentence-external antecedent (6a), and a quantifier cannot bind a variable across a sentence boundary (6b):

(6) a. Mary$_1$ called yesterday. *John$_2$ said that Bill$_3$ should draw herself$_1$.

b. Every girl$_1$ called yesterday. John$_2$ said that Bill$_3$ should draw her$_{*1}$.

Furthermore, both reflexives and quantifiers require c-commend within a sentence: a reflexive requires a c-commanding antecedent (7a), while a quantifier must c-command a variable in order to bind it (7b):

(7) a. *John$_1$ said that [the boy$_2$ who liked Mary$_3$] should draw herself$_3$.

b. [The boy$_1$ who liked every girl$_2$] said that John$_3$ should draw her$_{*2}$.

Meanwhile, pronouns can enter into discourse dependencies, and can have both a sentence-external antecedent (8a) and a non-c-commanding antecedent (8b):

(8) a. Mary$_1$ called yesterday. John$_2$ said that Bill$_3$ should draw her$_1$.

b. John$_1$ said that [the boy$_2$ who liked Mary$_3$] should draw her$_3$.

The existence of varieties of referential dependencies raises an interesting learning problem: how do children identify a given form as referentially dependent and what aspect of their experience tells them whether a referential dependency is sensitive to syntactic or discourse-based relations?

This question is especially pointed in cases where the dependent element is silent. This dissertation focuses on one such dependency – adjunct control – in (9):

(9) John bumped Mary after tripping on the sidewalk.

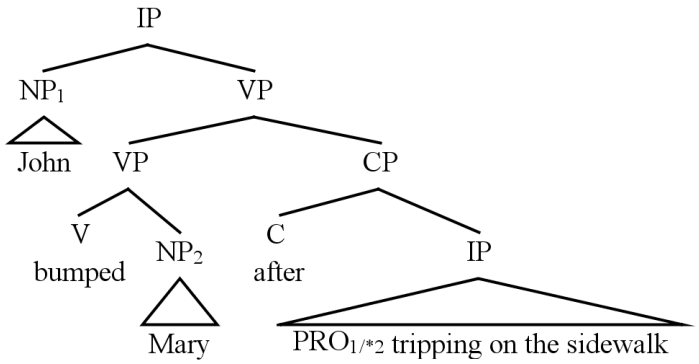
While verbs typically require subjects, there is no overt subject of *tripping* in (9). While the only interpretation in (9) is that *John*, the matrix subject, is the one who tripped, *John* is also thematically related to the main verb, *bumped*. NPs typically can bear only one thematic relation, which motivates positing a null referential element as the subject of *tripping*. This null element then has a thematic relation with *tripping*, and is referentially dependent on the matrix subject, *John*.

Here, I annotate the null element as PRO for concreteness, although the research presented in this dissertation does not depend on the precise syntactic representation of the control relation (see (Hornstein, 1999; O'Neil, 1995; Martin, 1996; Manzini & Roussou, 2000), among others, for alternative approaches):

(10) John$_1$ bumped Mary$_2$ after PRO$_{1/*2/*3}$ tripping on the sidewalk.

In (10), PRO is bound – or controlled – by the main clause subject, but not the object:

(11)



Like reflexives, adjunct PRO has a locality constraint – it must be bound by the subject of the next highest clause, without skipping clauses:

(12) $Bill_1$ said that [$John_2$ bumped $Mary_3$ after $PRO_{*1/\mathbf{2}/*3}$ tripping on the sidewalk]

(13) $Bill_1$ said that [$John_2$ bumped $Mary_3$] after $PRO_{\mathbf{1}/*2/*3}$ tripping on the sidewalk

In (12), the adjunct is attached to the embedded clause, such that the tripping happens after the bumping. With this attachment, the subject of the next highest clause is the subject of the embedded clause (*John*), and *John* is interpreted as both the tripper and the bumper.

In contrast, the adjunct is attached to the main clause in (13), such that the tripping happens after the saying. With this attachment, the subject of the next highest clause is the subject of the main clause (*Bill*), and *Bill* is interpreted as both the tripper and the sayer.

Although adjunct control is a syntactic dependency, it shares a number of features with discourse-based dependencies, raising questions about how children learn that adjunct PRO requires a syntactic antecedent.

For example, while the verb in most other non-finite clauses is preceded by the infinitive marker *to* (as in (14a-d)), the verb in non-finite adjunct clauses has a gerund form, similar to the form used in some types of discourse dependencies (as in (15a-b)).

(14) a. Bill_1 said that John_2 wanted $\text{PRO}_{*1/2}$ to leave.

b. Bill_1 told John_2 $\text{PRO}_{*1/2}$ to leave.

c. Bill_1 seemed to John_2 t_1 to be happy.

d. Bill_1 believed John_2 t_2 to be happy.

(15) a. Bill_1 talked to John_2. It was about $\text{PRO}_{1/2}$ getting the job.

b. PRO getting the job was an important step.

For the sentences in (15), the antecedent of PRO is not syntactically determined, and involves an arbitrary or free interpretation, based on the discourse. This contrasts with the syntactic dependency for adjunct control, despite the same form of the verb. Since the verb form therefore is not a reliable cue about syntactic versus discourse dependencies, other information must be available in order to learn the syntactic properties of adjunct control.

Another discourse dependency that bears a striking resemblance to adjunct control is observed with several of the complementizers that occur with adjunct PRO (e.g. *after, before, while*). In addition to a non-finite complement, these complementizers also allow a finite clause complement, which can have an overt subject whose interpretation is determined by the discourse:

(16) a. Bill$_1$ called yesterday. John$_2$ bumped Joe$_3$ after PRO$_{*1/2/*3}$ tripping on the sidewalk.

b. Bill$_1$ called yesterday. John$_2$ bumped Joe$_3$ after he$_{1/2/3}$ tripped on the sidewalk.

Although (16a) and (16b) have near identical interpretations when the dependency is between the adjunct subject and the main clause subject, in (16b) – with a finite adjunct and an overt pronoun – a discourse dependency is also available.

As demonstrated by the sentences in (15) and (16), both the complementizer and the verb inflection are needed to identify an adjunct control dependency, since each element alone is also present in other discourse dependencies. However, no particular aspect of the complementizer or the adjunct verb serves as an indication that adjunct PRO is syntactically bound, or that it requires a local antecedent. Therefore, even after identifying an adjunct control dependency as distinct from other types of dependencies, a learner is also tasked with determining the relationship between adjunct PRO and its antecedent.

Under ideal conditions, the linguistic input would not contain any noise about the antecedent of adjunct PRO – that is, any instances of adjunct control in the input should always involve a dependency between the main clause subject and adjunct PRO. Nevertheless, there are several factors that may affect a learner's ability to pick up on this correspondence. For example, because PRO is unpronounced, the learner must detect that there is a null element in the first place. Encountering a verb without a subject is a strong signal that null content has been encountered, but with no overt

signal to distinguish adjunct PRO from other types of null content, additional syntactic context is needed to correctly identify the dependency.

Additionally, if a learner is tasked with inferring a syntactic relation between the main clause subject and adjunct PRO, then other, non-syntactic information about the intended antecedent of PRO must also be available in the input. Otherwise, without any information about the antecedent, a learner might guess incorrectly, and infer the wrong relationship. In this case, noise is present in the *intake*, i.e. the learner's perception of the input (Omaki & Lidz, 2015; Gagliardi & Lidz, 2014), highlighting the importance of the learner's choice in resolving a dependency.

Despite (a) the grammatical similarities between adjunct control and different discourse dependencies and (b) the potential for a noisier signal if the learner retrieves the incorrect antecedent, adults have consistent judgments about a syntactic antecedent for adjunct PRO (Chomsky, 1981; Landau, 2003). It is not yet clear, however, when children acquire adultlike knowledge of adjunct control. Nor is it clear which of the potential issues outlined above, if any, might cause a problem for children who have yet to acquire the adult grammar.

In this dissertation, I focus primarily on the first issue: what do children know about adjunct control, and when do they acquire the adult grammar? While a number of studies have asked the same questions about children's acquisition of adjunct control, I take a different approach in accounting for why children make errors, based on research on sentence processing in adults. In later chapters, I consider how the factors discussed above might influence children's acquisition of adjunct control by examining the linguistic input that children receive. In the next section, I review the

approaches that previous researchers have taken in evaluating children's knowledge of adjunct control.

1.2 Previous studies on the acquisition of adjunct control

In previous studies, researchers have consistently observed that children allow non-adultlike interpretations for sentences with adjunct control. Operating under the assumption that children's errors are due to a non-adultlike grammar, these non-adultlike patterns of behavior have been used as evidence for one particular non-adultlike grammar over another. The consistency across studies ends there, however, with different patterns of behavior observed in different tasks, and different proposals for which non-adultlike grammar can best account for children's behavior.

1.2.1 Grammatical accounts of non-adultlike behavior

A central focus in previous studies on the acquisition of adjunct control has been on describing children's interpretations, and categorizing children individually as having a particular non-adultlike grammar, based on their response patterns. One of the main debates that emerged from this trend concerned the number of non-adultlike grammatical states that children pass through before converging on the adult grammar.

Under the Variable Attachment account (Goodluck, 1981; Hsu et al., 1985; McDaniel & Cairns, 1990; McDaniel et al., 1991; Cairns et al., 1994), children's non-adultlike behavior results from misattaching the adjunct to the main clause, with three distinct non-adultlike states that a child might pass through before acquiring the adult grammar:

1. Free interpretation of adjunct PRO is explained by attaching the adjunct too high, such that no argument in the main clause bind PRO and requiring a discourse-based interpretation.
2. Strict object control is explained by attaching the adjunct too low, such that the object can bind PRO.
3. Optional subject-object control, where children allow both a subject and an object interpretation of PRO but reject an external antecedent. For these children, it is proposed that their grammar includes both the adultlike and the low attachment structures, and that their interpretations are dependent upon which of the two structures is accessed at any given time.

For each of these three states, children access a non-adultlike interpretation as a result of misattaching the adjunct clause to the main clause, with transitions between states – including to the adult grammar – triggered by acquiring lexical and semantic information about the complementizers (e.g. *before, after, while*). Thus, all children converge on the adult grammar by virtue of acquiring adultlike knowledge of the relevant complementizers, which is assumed to include information about their attachment height.

Although the Variable Attachment account does descriptively cover the wide range of interpretations that were observed across studies, Wexler (Wexler, 1992) pointed out a number of concerns with Variable Attachment and the evidence for it, including small sample sizes to support each grammar type, not enough test items for reliable categorization into a single non-adultlike grammar, and the possibility that

children who allowed some but not all non-adultlike interpretations would have also allowed other interpretations with a larger number of trials.

Based on this last concern, Wexler (1992) and Broihier and Wexler (1995) argued instead that there is only one non-adultlike grammar for adjunct control, which does not place any syntactic restriction on the interpretation of adjunct PRO. In particular, they proposed that children's non-adultlike behavior results from an inability to represent PRO in temporal adjuncts, forcing children to represent the sentence in (10) with a nominal construction similar to the adjunct in (17).

(17) John bumped Mary after the tripping on the sidewalk.

In (17), the adjunct is underspecified for who tripped on the sidewalk, and the subject, object, and sentence-external interpretations are all available in the adult grammar. Under this Nominalization account, children with the non-adultlike grammar assign a similarly underspecified interpretation to sentences with adjunct control, and under appropriate experimental conditions, are predicted to allow any plausible interpretation for the antecedent (Broihier & Wexler, 1995; Wexler, 1992). Indeed, arguing in support of the Nominalization account, Broihier and Wexler (Broihier & Wexler, 1995) found that while all children allowed a subject (adultlike) interpretation of adjunct PRO, the same children who allowed an object interpretation in some trials also accepted an external interpretation in other trials.

In addition to the Variable Attachment and Nominalization accounts, it has also been proposed that children employ a strategy of linking adjunct PRO to the main clause agent, rather than the subject (Goodluck, 1998; Goodluck & Behne, 1992). This

account predicts adultlike behavior in sentences with an active main clause, where the agent is also the subject, in contrast to the more consistent finding that children accept non-adultlike interpretations even with an active main clause. Non-adultlike behavior is predicted, however, for sentences with a passive main clause, where the agent is not the subject.

In general, children's behavior in previous studies is *consistent* with the above grammatical accounts. However, a number of questions remain regarding the source of children's behavior in previous studies. First, although a pattern of behavior with only two groups of children – one adultlike, and one non-adultlike – as reported by Broihier and Wexler (1995) is consistent with the nominalization structure in (17), it is also consistent with the high attachment structure proposed by the Variable Attachment account: specifically, both structures predict free interpretation of PRO. Thus, while Wexler's (1992) argument against three *distinct* non-adultlike states as proposed in the Variable Attachment hypothesis is likely correct, Broihier and Wexler's (1995) study does not provide conclusive evidence against incorrect attachment of the adjunct altogether.

Second, neither Wexler's Nominalization account nor the Variable Attachment account make predictions about the rate at which a non-adultlike interpretation should be accessed in place of the adultlike interpretation. While both the nominal structure in (17) and the high attachment structure from the Variable Attachment account predict the free interpretation of PRO, in all of the studies to date, children accessed different interpretations at different rates. Although this variation is not inconsistent with either account, no explanation is offered for why, for example, uniform rates for each

interpretation of PRO were never observed – a result that would also have been consistent with these accounts. In sum, any pattern of behavior with non-zero rates of non-adultlike interpretations of (10) would be consistent with both the nominal and high attachment structures, since neither places a syntactic restriction on the interpretation of the adjunct subject.

Therefore, several questions remain about children's interpretations of adjunct control, including how the task and other extragrammatical factors might influence children's behavior, and what aspects of the linguistic input are responsible for a transition from one grammar to another. These issues are discussed in the following sections.

1.2.2 Task-related factors in previous studies

While some researchers have considered how task-specific factors may have influenced children's interpretations (McDaniel & Cairns, 1990; McDaniel et al., 1991; Broihier & Wexler, 1995), the variation observed across tasks does suggest that children's non-adultlike behavior was at least partly task-related. Task effects have been shown to influence children's performance on studies investigating phenomena like Principle B effects (Conroy, Takahashi, Lidz, & Phillips, 2009; Elbourne, 2005), one-substitution (Hamburger & Crain, 1984), relativization (Hamburger & Crain, 1982; Crain & Thornton, 2000), and quantifier spreading (Crain et al., 1996; Drozd & van Loosbroek, 1998; Drozd, 2001), and a number of aspects of previous studies on the acquisition of adjunct control suggest that similar concerns may be relevant for

children's interpretation of (10) – first, in the appropriate methodology for determining the source of children's behavior, and second, in the appropriate design.

The most commonly used methodology in the studies investigating the acquisition of adjunct control has been the Act Out Task (Hsu et al., 1985; McDaniel & Cairns, 1990; Goodluck, 1981, 1998, 2001; Goodluck & Behne, 1992), in which children are instructed to act out a test sentence with a set of toys. Necessarily, only one interpretation can be acted out at any one time. This would not present a problem for children who access only an adultlike interpretation of (10), where PRO is only bound by the main clause subject. However, if children have a non-adultlike structure that makes the adjunct subject in (10) ambiguous – as proposed in most studies that used the act out task – then the question arises of how a single interpretation would be selected to act out (Crain & McKee, 1985; Broihier & Wexler, 1995). In adults, a number of factors have been argued to influence the resolution of referential ambiguities, including first mention, recency, and syntactic parallelism (Arnold, 1998, 2001; Arnold, Brown-Schmidt, & Trueswell, 2007; Ariel, 1990; Gernsbacher, 1989; Gernsbacher & Hargreaves, 1988; Givón, 1983; Gordon, Grosz, & Gilliom, 1993; Grosz, Weinstein, & Joshi, 1995; Gundel, Hedberg, & Zacharski, 1993; Kehler & Rohde, 2013; Sanford & Garrod, 1981; Stevenson, Crawley, & Kleinman, 1994). However, children's sensitivity to these factors is inconsistent at best (Conroy et al., 2009; Thornton & Wexler, 1999; Arnold et al., 2007). Importantly, if children do have a structure that allows free reference of PRO in (10), then in an act-out task there may be any number of non-syntactic interpretation strategies involved in choosing one antecedent of PRO over another. It is therefore unclear how to interpret a pattern of

behavior with variation both within and across studies in which non-adultlike interpretations were reported for (10).

In contrast to the act-out task, the Truth Value Judgement Task (TVJT; Crain & McKee, 1985; Crain & Thornton, 1998) makes explicit predictions about children's – and adults' – interpretations of ambiguous sentences. In the classic TVJT, a context – specifically, the events of a story – is set up so that a test sentence containing the structure of interest can be uttered to describe the context. Under the adultlike interpretation of the test sentence, the context makes the test sentence false, while under a hypothesized non-adultlike interpretation, the context makes the test sentence true. However, a key methodological assumption of the TVJT is that, if multiple interpretations are *equally* available, then children (and adults) will obey the Principle of Charity (Crain & Thornton, 1998) – that is, if an interpretation that makes the test sentence true is available, children will access that interpretation, even if another interpretation is also available that makes the sentence false. Consequently, when a child answers that the test sentence is false (by telling a puppet who uttered the test sentence that it was incorrect), it is assumed that they did not have access to a true interpretation in the given context (Crain & Thornton, 1998).

To illustrate, for a test sentence that the context makes false under the adultlike interpretation *and* true under the non-adultlike interpretation, a child who answers that the test sentence is false is understood to only have access to the adultlike interpretation, since it is assumed that they would have answered that the sentence was true if the non-adultlike interpretation were available. Correspondingly, a child who answers that the test sentence is true is assumed to have accessed the non-adultlike interpretation. If, as

proposed in the Variable Attachment account and the Nominalization account, the structure that children have for (10) does not restrict the interpretation of the adjunct clause, then children should access both the adultlike and non-adultlike interpretations reported in previous studies.

Consider now a TVJT design (Table 1) with two conditions: one condition where the adultlike interpretation is false and the non-adultlike interpretation is true (ADULTLIKE-FALSE/NON-ADULTLIKE-TRUE) and one condition where the adultlike interpretation is true and the non-adultlike interpretation is false (ADULTLIKE-TRUE/NON-ADULTLIKE-FALSE). With these two conditions, the assumption about charitable behavior allows for specific predictions about behavior exhibited by children who allow free reference of PRO compared to those who only allow the adultlike interpretation. Those who only allow the adultlike interpretation of PRO should reject sentences in the ADULTLIKE-FALSE/NON-ADULTLIKE-TRUE condition *and* accept sentences in the ADULTLIKE-TRUE/NON-ADULTLIKE-FALSE condition. In contrast, those who allow free reference of PRO should access both non-adultlike and adultlike interpretations, and should accept sentences in both conditions.

	Condition	
Grammar	ADULTLIKE-FALSE/ NON-ADULTLIKE-TRUE	ADULTLIKE-TRUE/ NON-ADULTLIKE-FALSE
Adult grammar	reject	accept
Nominal/high attachment (both adultlike *and* non-adultlike interpretations allowed)	accept	accept

Table 1: Predictions of previous accounts for a TVJT, assuming the Principle of Charity (Crain & Thornton, 1998)

Although two studies to date – Broihier and Wexler (1995) and Adler (2006) – did use roughly the TVJT design described above to test children's interpretations of (10) there are concerns with both studies that must be addressed before concluding that non-adultlike knowledge, rather than other factors, was the source of children's behavior in previous studies.

First, in addition to true/false judgments, it is important in a TVJT to encourage justifications to both true and false responses (Lidz & Musolino, 2002; Syrett & Lidz, 2009) to confirm that the true/false answer was given based on the expected interpretation. Although children may not always provide them, justifications can confirm whether a non-adultlike true/false response was given based on the predicted non-adultlike interpretation of the test sentence, and whether an adultlike response was due to an adultlike interpretation (Syrett & Lidz, 2011). While Adler (2006) did elicit justifications, Broihier and Wexler (1995) did not, making it difficult to interpret the high variation observed among the children who gave non-adultlike responses. If, as Broihier and Wexler (1995) assume, children's interpretation of the adjunct subject in (10) was the only determining factor in their true/false responses, then accounting for the variation would involve additional independent processes. However, without justifications, even this assumption is weakened, since a true/false answer can misrepresent the actual interpretation if it is given for reasons unanticipated in the experimental design (Conroy et al., 2009; Syrett & Lidz, 2009).

Second, an argument that children allow free reference of PRO requires that each possible antecedent be made available in the discourse (Conroy et al., 2009).

Although Adler (2006) used the TVJT design above, the test sentences had the following form instead of the form in (10):

(18) Donald Duck went to the bank after PRO buying a truck.

As in (10), the main clause of (18) contains two NPs (*Donald Duck* and *the bank*), but unlike in (10), only one of them (*Donald Duck*) is a plausible antecedent for PRO. The contexts used by Adler (2006) did contain two possible referents for PRO – in the story for (18), both Donald Duck and Spiderman buy trucks. However, if children knew that the bank was not a plausible truck buyer, then (18) would not distinguish between an adultlike grammar and a bias for a sentence-internal referent over a sentence-external one, as observed by Goodluck (1987). Therefore, the task used by Adler (2006) did not distinguish between syntactic knowledge and a bias for interpretation at the discourse level.

In this dissertation, I take two different approaches in addressing the concerns with previous tasks as outlined above. First, I use a TVJT to show that by addressing these concerns, children show the same general pattern of behavior as adults, although with a higher error rate that cannot be explained by previous grammatical accounts. Next, I show that these errors can still be linked to task demands, by using a different task with reduced processing demands (Pinto & Zuckerman, 2015; Zuckerman, Pinto, Koutamanis, & van Spijk, 2015), resulting in significantly higher accuracy compared to the TVJT. To account for children's remaining errors, I consider other extragrammatical processes that have played a more central role in models of adult sentence processing.

1.3 Online antecedent retrieval and similarity-based interference

Aside from task-specific effects, there has been little discussion of the influence of other extragrammatical processes on the acquisition of adjunct control; in particular, whether children deploy the same parsing procedures as adults when resolving a dependency, and what kinds of differences in online processing abilities might explain the observed behavioral differences between children and adults.

One type of effect that has been observed for adults when retrieving an antecedent is similarity-based interference. Similarity-based interference, which is observed in adults as a slowdown in reading times or sometimes as reduced accuracy, occurs when an intervener matches in features with the antecedent, compared to when the features in question do not match. For example, it is consistently observed that reading times for object relative clauses (19) are delayed compared to reading times for subject relative clauses (20) (Caplan & Waters, 2002; Carpenter, Miyake, & Just, 1994; Gibson, 1998; Wanner, 1978); however, this difference is reduced when the relative clause subject, which intervenes between the head of relative clause and the gap site, is made less similar to the head of the relative clause, as in (19b).

(19) a. The banker that the lawyer admired ___ climbed the mountain.

b. The banker that Joe admired ___ climbed the mountain.

(20) The banker that ___ admired the lawyer climbed the mountain.

In (19a), both the relative clause head the banker and the relative clause subject the lawyer are full NPs, but varying the NP type (full NP vs. name) of the relative clause

subject has been observed to result in reduced reading times and increased accuracy in adults.

While this effect of NP type has been consistently observed for relative clauses, in general varying the features of an intervening NP (e.g. animacy, gender, number) has been reported to affect the processing of a number of different types of dependencies in adults (e.g. filler-gap dependencies (Gordon, Hendrick, & Johnson, 2004; Van Dyke & McElree, 2006; Xiang, Dillon, Wagers, Liu, & Guo, 2014), subject-verb agreement (Pearlmutter, Garnsey, & Bock, 1999; Wagers, Lau, & Phillips, 2009; Clifton, Frazier, & Deevy, 1999), and reflexive anaphors (Parker, 2014); for a review, see (Engelmann, Jäger, & Vasishth, 2015)). For all of these dependencies, difficulty is reported to increase (as measured by increased reading times or decreased accuracy) when a distractor or intervener shares features with some element in a dependency (e.g. when both the antecedent and the intervening NP are animate), compared to when the features are not shared. To account for this similarity-based interference, a number of models have been proposed in the adult psycholinguistics literature (Lewis & Vasishth, 2005; Van Dyke & Lewis, 2003; Gordon, Hendrick, & Johnson, 2001; Warren & Gibson, 2002). However, while similar effects have been observed in children, in general these models have received little attention in studies on language acquisition.

For example, a number of studies on relative clauses in preschool-aged children have found that children generally fail to show adultlike behavior for object relative clauses when the subject (e.g. the lawyer in (19a)) is a full NP; however, manipulating the relative clause subject by NP type as in (19b) (Kidd, Brandt, Lieven, & Tomasello, 2007; Brandt, Kidd, Lieven, & Tomasello, 2009; Arnon, 2009; Friedmann, Belletti, &

Rizzi, 2009; Haendler, Kliegl, & Adani, 2015), animacy (Kidd et al., 2007; Brandt et al., 2009; Bentea & Durrleman-Tame, 2013), number (Adani, Forgiarini, Guasti, & Van der Lely, 2014; Adani, Van der Lely, Forgiarini, & Guasti, 2010) or gender (Belletti, Friedmann, Brunato, & Rizzi, 2012) has resulted in increased accuracy overall. In general, the effect has tended to be much greater for children than for adults, which is consistent with a model where children are more susceptible to interference than adults (Omaki & Lidz, 2015).

Additional evidence for similarity-based interference in children comes from the observation of similar effects of feature overlap in constructions with raising over an experiencer (NP type: *John seems to {Mary/her} to be happy;* (Choe & Deen, 2015)), object fronting in German (NP type: *The tiger, {the pig/it} will tickle*; (Sauermann & Höhle, 2015)), and with non-reflexive pronouns (gender: {*He/she} watched as Mr. Jones bought a huge box of popcorn for him/her over the counter*; (Clackson, Felser, & Clahsen, 2011)). Although a few more recent studies have considered some of the adult models of similarity-based interference mentioned above (Conroy et al., 2009; Syrett & Lidz, 2011; Choe, 2012; Adani, 2011; Adani et al., 2010; Haendler et al., 2015), there is little discussion of the mechanism responsible for the amplified effect observed for children as compared to adults, and in the remaining cases researchers have opted for pragmatic (Clackson et al., 2011), usage based (Kidd et al., 2007; Brandt et al., 2009; Arnon, 2009), or grammar based (Friedmann et al., 2009; Belletti et al., 2012) explanations of children's behavior.

Like the above dependencies, sentences with adjunct control involve a *target* of retrieval (the main clause subject) and an *intervener* (the main clause object) between

the target and adjunct PRO. Some of the variation in previous studies may be due to task-related factors that did not make each possible antecedent available in the discourse (Conroy et al., 2009), but if children deploy the same parsing procedure as adults, then additional difficulty is predicted due to similarity-based interference from the main clause object. That is, the same interference effects discussed above should be observed by manipulating the similarity between the target (main clause subject) and the intervener (main clause object) in sentences with adjunct control. The results from the final experiments presented in this dissertation confirm this prediction, suggesting that children's difficulty with adjunct control can indeed be attributed to similarity-based interference. These results raise further questions about the role of the linguistic input in children's acquisition of adjunct control, as well as the developmental trajectory for interference effects.

1.4 Outline of the dissertation

The rest of the dissertation is organized as follows. Chapter 2 reexamines the methodological concerns with previous tasks, and presents the TVJT design outlined in §1.2.2 to address these concerns. This design is implemented first with sentences with adjunct control in Experiment 1, and next with ambiguous sentences in Experiment 2, to compare children's interpretations of sentences with adjunct control with discourse anaphora. In Experiment 1, I replicate children's non-adultlike behavior as observed in previous studies, but observe the same general pattern of behavior for children as for adults. Next, the results from Experiment 2 provide evidence against a discourse-based subject bias as the source of children's behavior in Experiment 1.

Chapter 3 tests the predictions of two proposed grammatical accounts. Under the Agent account (Goodluck & Behne, 1992; Goodluck, 1998), children correctly attach the adjunct to the main clause, but their interpretation of adjunct PRO is not restricted to the subject of the main clause. Instead, their interpretation is either (a) systematically determined by the main clause agent, by virtue of a non-adultlike grammatical restriction, or (b) variable depending on the other types of sentences in the surrounding context, with a greater likelihood of an agent interpretation in contexts with a higher number of passive sentences. While these two versions of the Agent account differ in their proposed source of children's interpretations, both predict non-adultlike behavior in contexts with a high proportion of passive sentences. Experiment 3 tests this prediction by using passive main clauses for both test sentences and controls. Rather than the inverse pattern as predicted by the Agent account, children's behavior again patterns with adults', providing evidence against both versions of the Agent account.

Next, Experiment 4 tests the predictions of low attachment – one of the non-adultlike grammars proposed under the Variable Attachment account to explain children's non-adultlike object control interpretations (Goodluck, 1981; Hsu et al., 1985; McDaniel & Cairns, 1990; McDaniel et al., 1991; Cairns et al., 1994). Low attachment predicts different binding relations between the main clause and the adjunct then the adult grammar. Instead, children in Experiment 4 exhibit the same interpretations as adults, including the interpretation predicted not to be available with the low attachment grammar, providing evidence against low attachment as the source of children's non-adultlike behavior. The experiments in Chapter 3 demonstrate that

previous grammatical accounts cannot fully explain children's behavior, and that extragrammatical factors are needed to provide a complete picture. Chapters 4 and 5 consider two potential factors.

Chapter 4 first spells out the task-specific processing demands associated with the TVJT, and considers how these may have influenced children's behavior in previous studies and the experiments presented thus far. To reduce these demands, I present a new task (Pinto & Zuckerman, 2015) which addresses many of the concerns with previous TVJT studies on the acquisition of adjunct control. Experiment 5a compares children's behavior on this new task with the TVJT design from Experiment 1, and observes significantly improved behavior on the new task. Next, Experiment 5b evaluates children's performance with this task in a younger age range, and finds that children's performance is strongly correlated with age. These results provide strong evidence that children's grammars are adultlike by age 4, and that their behavior was influenced by the task-specific factors in previous studies. Meanwhile, the non-adultlike pattern in younger children is compatible with both grammatical and processing accounts. Chapter 5 considers how other processing factors might influence children's behavior, while Chapter 6 further explores the grammatical accounts.

The discussion in Chapter 5 begins with a review of the memory mechanisms involved in similarity-based interference, and considers how these mechanisms might be involved in the parallel effects observed in children and adults, as discussed in §1.3. To test whether the same effects can account for children's non-adultlike behavior for adjunct control, Experiments 6 and 7 manipulate the feature mismatch between the main clause subject (the target) and the main clause object (the intervener) in gender

and number, respectively. In both experiments, children exhibit the predicted pattern of behavior for similarity-based interference, supporting a broader account of interference effects, with the same general source of interference for both children and adults.

In Chapter 6, I consider what information would be needed in the linguistic input for children to acquire the adult grammar of adjunct control. Different accounts in previous studies have taken different approaches in assuming what aspects of adjunct control must be learned from the linguistic input, from a maturation account with minimal to no effect of the input (Wexler, 1992; Broihier & Wexler, 1995) to the restriction on PRO itself, given the correct attachment height (Goodluck & Behne, 1992). I discuss how children might make use of the size principle (Tenenbaum & Griffiths, 2001; Xu & Tenenbaum, 2007) to converge on the adult grammar, and present the results of a corpus analysis with data collected from transcripts of parent-child interactions from CHILDES (MacWhinney, 2000). While the linguistic input does contain instances of adjunct control, the experiments presented in this dissertation raise an important question about their utility for the learning problem: if children's interpretations are influenced by various processing factors independent of their grammars, how much noise can a statistical learning mechanism cope with before converging on the wrong grammar? Depending on how much noise is introduced into the *intake*, there will be a greater advantage for learning accounts that do not depend directly on the interpretation of adjunct PRO.

I conclude in Chapter 7 by summarizing the key findings of the dissertation, and discussing some remaining questions and their implications.

Chapter 2: Addressing concerns with a TVJT

This chapter addresses the concerns outlined in the previous chapter about the tasks used in previous studies on the acquisition of adjunct control. Doing so will establish a baseline pattern of behavior for children's interpretations of adjunct control with a TVJT. Although I find that children exhibit non-adultlike behavior even after these concerns are addressed, determining this baseline allows for a comparison with truly ambiguous sentences. The results from two experiments comparing children's interpretations of adjunct control with truly ambiguous sentences suggest that despite children's errors for adjunct control, they do not interpret sentences with adjunct control as ambiguous.

2.1 Concerns to address

As discussed in the previous chapter, the tasks from previous studies on the acquisition of adjunct control may have influenced children's interpretations, resulting in a higher rate of non-adultlike responses. Concerns with the availability of interpretations, relevance of the test sentence, and other aspects of the design in previous studies motivate the methodological choices implemented in the current study.

In order to compare multiple interpretations in a judgment task, all relevant interpretations must be equally available (Crain & McKee, 1985; Conroy et al., 2009). That is, the context should not provide a bias towards one type of interpretation over another. In previous studies on the acquisition of adjunct control, the adultlike interpretation was always available, but the non-adultlike interpretations may have

been more salient, depending on the task. For example, in the judgment of reference task (Cairns et al., 1994; McDaniel et al., 1991), children were asked for their first interpretation, but were then asked whether other characters could also be interpreted as the antecedent of adjunct PRO. By asking about each interpretation individually, this type of follow-up question singles out one potential antecedent over the others, making an ungrammatical antecedent more salient than a grammatical one.

To avoid this potential confound, the experiments in chapters 2 and 3 use the TVJT. In the TVJT, a context is set up that allows for two different interpretations, where one interpretation is made true by the context, and the other is made false (Crain & Thornton, 1998). If children have the adult grammar, it is assumed that they will always reject a non-adultlike interpretation in favor of the adultlike one. However, the availability of each interpretation is still a concern for the TVJT: if a non-adultlike interpretation is much more salient than the adultlike one, children will often select the non-adultlike interpretation, overriding any relevant grammatical constraints (Conroy et al., 2009).

Conversely, if the context favors the adultlike interpretation, then children's behavior may not be as informative about their linguistic competence. For example, as discussed in the previous chapter, the test sentences used by Adler (2006) compared an adultlike interpretation of adjunct control with a sentence-external interpretation of adjunct PRO:

(18) Donald Duck went to the bank after PRO buying a truck.

Although a sentence-external referent was provided by the context, children have been shown to exhibit a non-syntactic bias for sentence-internal antecedents (Goodluck, 1987). In (18), the only plausible sentence-internal antecedent is *Donald Duck*, the main clause subject. Therefore, if children's bias for a sentence-internal antecedent supported the adultlike interpretation, then children might not have considered the non-adultlike interpretation in the first place.

One factor that can drastically affect the availability of an interpretation is the relevance of the test sentence with respect to the story context. In a TVJT, a test sentence will be true under one interpretation and false under another; additionally, the difference between the true and false interpretations must be a central focus in the story. Otherwise, a child might relate the test sentence to a different, unintended aspect of the story in order to give a truth value.

For example, in the studies that used a TVJT to investigate children's interpretations of adjunct control (Broihier & Wexler, 1995; Adler, 2006), the relevant aspect of the test sentences is whether they mention the events in the correct order. For example, if (10) were false, the reason would be that John's tripping happened *before* the bumping, rather than after.

(10) John$_1$ bumped Mary$_2$ after PRO$_{1/*2/*3}$ tripping on the sidewalk.

However, the stories do not make both the non-adultlike and the adultlike interpretations relevant with respect to the story. For example, in (18), the link between Donald Duck going to the bank and buying a truck is clear in the story, and the reverse order of Donald Duck going to the bank and buying a truck is also considered.

Meanwhile, the sentence-external referent, Spiderman, did not go to the bank, or even consider going, providing little motivation to link Spiderman with a statement about Donald going to the bank. Since the order of Donald Duck going to the bank and Spiderman buying a truck is not a source of conflict in the story, a statement with Spiderman as the antecedent is not expected. Rather, a statement about the order of events is only relevant with Donald Duck as the antecedent. This makes an interpretation with a sentence-internal antecedent (Donald Duck) more available than with a sentence-external one (Spiderman), independent of the grammar. Designing the context to make both interpretations relevant in the test sentence is therefore critical for determining which interpretations are grammatically licit.

Finally, justifications are needed to verify that children's responses are given for the expected reasons, for both false and true responses (Lidz & Musolino, 2002; Syrett & Lidz, 2009). Justifications are especially important with a high proportion of non-adultlike responses or when the task is not tested with adults, to determine whether any particular aspects of the task may have influenced children's behavior. Neither of studies that used the TVJT to investigate the acquisition of adjunct control elicited justifications for both true and false responses: Adler (2006) elicited justifications to false answers only, which can risk introducing a bias for true responses, while Broihier and Wexler (1995) did not report any justifications. To address these concerns, the TVJT experiments in this dissertation include justifications for both true and false answers, from children and from adult controls.

In Experiment 1, I address the above concerns about the availability and relevance of both interpretations, and replicate children's non-adultlike interpretations.

Experiment 2 confirms that both interpretations were indeed available, and that children's interpretations of adjunct control are different from truly ambiguous sentences involving discourse anaphora. These results suggest that children's interpretations of adjunct control are not discourse-driven, and that extragrammatical factors are the source of their non-adultlike behavior.

2.2 Experiment 1: a replication study, after addressing concerns with previous tasks

Experiment 1 was designed to address the methodological concerns outlined in the previous section, to serve as a baseline for children's interpretations of sentences with adjunct control. If, as proposed in previous studies, most four-year-old children do not have adultlike knowledge of adjunct control, the overall pattern of behavior for children should contrast with the pattern for adults, and children should either exhibit an inverse pattern or they should be at chance. However, if non-adultlike performance in previous studies was related to previous methods, then by addressing the concerns outlined above we should observe the same pattern of behavior for children as for adults.

2.2.1 Participants

Participants were 40 children (24 males) ages 4;0-5;3 (M = 4;7.29) who were recruited through the University of Maryland Infant and Child Studies Database or participated at their local preschools; and 20 undergraduate students in introductory Linguistics classes at the University of Maryland, College Park. An additional 5

children were excluded from the final sample for failure to complete the training portion (2) or inattention (3). Adults received course credit for their participation.

2.2.2 Design and Materials

We used a TVJT to set up contexts that made both a subject interpretation and an object interpretation of PRO available and relevant (Conroy et al., 2009). Factors were CONTEXT (ADULTLIKE-TRUE/ADULTLIKE-FALSE, within-subject), and AGE (CHILD/ADULT, between-subject) with the truth conditions for context spelled out in Table 2.

	Interpretation	
CONTEXT	PRO = subject (adultlike)	PRO = object (non-adultlike)
ADULTLIKE-TRUE	true	false
ADULTLIKE-FALSE	false	true

Table 2: Factors and truth values for context in Experiment 1

Context either made the subject interpretation of PRO true and the object interpretation false (ADULTLIKE-TRUE) or the subject interpretation false and the object interpretation true (ADULTLIKE-FALSE). For a given story, both interpretations were always available, and so a single item appeared in both conditions (ADULTLIKE-TRUE and ADULTLIKE-FALSE) in different lists.

Test stories had a format like the following (important events underlined):

(21) Dora and Diego are going outside to play in the snow but neither of them has a jacket. Diego wants to get a jacket and asks Dora if she wants one too, but Dora doesn't because she thinks she won't be cold if they play tag. Diego gets a jacket anyway, and tries to hide from Dora behind a snowman. Dora sees Diego hide, so she tags him and he falls down in the snow. Dora realizes that she's

cold now too, and asks Diego if he's cold since he's covered in snow. Diego says he's not since he already had a jacket on, so Dora gets a jacket too so she won't be cold anymore either.

ADULTLIKE-TRUE: 'Dora tagged Diego before getting a jacket.'

ADULTLIKE-FALSE: 'Dora tagged Diego after getting a jacket.'

For the test sentences in (21), the subject control (adult) interpretation is available because Dora got a jacket after the tagging event. At the same time, the object control (non-adultlike) interpretation is also available for both sentences, because Diego got a jacket before the tagging event.

The stories were designed so that a statement about the order of events would be a felicitous description of the story. This was achieved by establishing the possibility of alternate orders throughout the story, making a true statement about an order that was ultimately realized, and a false one about one that was possible at one point in the story. Additionally, boxes with pictures of the three main events appeared at the end of each story as reminder of the order in which they had occurred, and to make sure children had followed the entire story, they were asked to resummarize the story just before the test sentence to "help the puppet remember" (all children could do this).

2.2.3 Procedure

Since the difference between the subject and the object interpretation of PRO depended on awareness of the temporal order events in the stories, the training session was designed not just to ensure that children could correctly judge if a puppet's statement was true or false (by indicating that a puppet "got it right"), but also that:

(a) children knew the meanings of *before* and *after*

(b) they could correctly judge the puppet's statements when they included *before* and *after* to describe everyday routines, and the events in two warmup stories

Children received feedback for incorrect responses, and those who judged the puppet to always be correct or to always be incorrect for all training items despite the feedback did not proceed to the test portion. Stimuli included 4 easy training items without visuals, 2 training items with visuals similar to the test items, 4 test items, and 3 control items with an overt subject and a finite adjunct. The training items focused exclusively on the ordering of events, to focus children's attention on the relevance of *before* and *after* to the truth value of the test sentences. No features of control were included in the training trials.

Two orders were constructed, with two lists for each order. Truth value of the sentence, whether the sentence contained *before* or *after*, and the correct antecedent of PRO were all counterbalanced across items and lists. In order to balance the salience of both potential antecedents of PRO, the puppet uttered a preamble directly before each test sentence that consisted of a short (one clause) description of the story and contained both names of the potential antecedents of PRO in a conjunct:

(22) Dora and Diego were both playing tag outside, and oh, I know: [test sentence]

The order of mention for the potential antecedents was also counterbalanced across items and lists. Test sentences were all sentences with a structure like in (21), and visual stimuli were presented to children with the PowerPoint app on an iPad2, and to adults on a 13 inch laptop. Adults were not presented with the four easy training items. Each

participant was tested in a single session that lasted from 20 to 25 minutes for the children, and from 10 to 15 minutes for the adults.

2.2.4 Predictions

For children with the adult grammar that only allows the subject interpretation of PRO, only the subject interpretation should be accessible. These children should therefore accept sentences that make the subject interpretation of PRO true and the object interpretation false (ADULTLIKE-TRUE) and reject the sentences that make the subject interpretation false and the object interpretation true (ADULTLIKE-FALSE).

However, if children have a non-adultlike grammar that allows both a subject and an object control interpretation, as predicted by the Nominalization and Variable Attachment analyses, then the test sentences will be ambiguous. Under the Principle of Charity (Crain & Thornton, 1998), these children should access the true interpretation in each condition. Thus, since a true interpretation is available in both conditions (the subject interpretation in the ADULTLIKE-TRUE condition, and the object interpretation in the ADULTLIKE-FALSE condition) these children should accept sentences in both conditions.

Finally, a child with the non-adultlike grammar that only allows the object interpretation of PRO (strict object control, predicted by the low attachment analysis) should exhibit the inverse pattern of behavior to that expected for the adult grammar. That is, they should reject sentences in the ADULTLIKE-TRUE condition and accept sentences in the ADULTLIKE-FALSE condition. These predictions are outlined in Table 3.

	grammar		
CONTEXT	adult (strict subject)	optional subject-object	strict object
ADULTLIKE-TRUE	accept	accept	reject
ADULTLIKE-FALSE	reject	accept	accept

Table 3: Predictions for acceptance of the test sentence by context and grammar

Crucially, both conditions are needed to distinguish between the adult and non-adultlike grammars - adultlike behavior is characterized by a pattern of accepting sentences in the subject-true context *and* rejecting sentences in the object-true context.

2.2.5 Justifications

In addition to judging whether a test sentence was true or false, children and adults were asked to justify their answers. Children generally gave justifications to their answers with little prompting, and the vast majority of justifications given cited order of events as the reason for rejection or acceptance.

Justifications were coded as CLEAR, UNCLEAR, or IRRELEVANT (Syrett & Lidz, 2011). IRRELEVANT justifications were primarily observed when a child was distracted or forgot the test sentence, while UNCLEAR justifications tended to include all three events in the story, making it unclear which of the characters, if either, had been selected as the antecedent of PRO. CLEAR justifications cited two of the three main events, and made it clear which character had been interpreted as PRO. Examples of CLEAR justifications to the test sentences in (21) are given in Table 4.

Of the 80 responses by adults to the test sentences, 78 (98%) were CLEAR, and 2 (2%) were IRRELEVANT. Of the 156 responses by children, 133 (85%) were CLEAR, 20 (13%) were UNCLEAR, and 3 (2%) were IRRELEVANT. Since most of the time children

gave clear justifications to their answers, and including the answers without clear justifications does not significantly affect the data, all data is included in the analysis.

ADULTLIKE-TRUE: 'Dora tagged Diego before getting a jacket'
"Yes, because she was cold *after* she tagged him behind the snowman."
(PRO = Dora)
"No, because Diego put on a jacket then Dora tagged Diego."
(PRO = Diego)
ADULTLIKE-FALSE: 'Dora tagged Diego after getting a jacket'
"No, because he should have said Dora tagged Diego *before* she got a jacket."
(PRO = Dora)
"Yes, because he got a jacket before they played tag."
(PRO = Diego)

Table 4: Examples of CLEAR justifications to the test sentences in (21)

2.2.6 Results

Results for Experiment 1 are presented in Figure 1. We used R (R Core Team, 2015) and *lme4* (Bates, Maechler, Bolker, & Walker, 2015) to perform a mixed-effects logistic regression analysis of the relationship between acceptance, and AGE and CONTEXT. As fixed effects, we entered AGE and CONTEXT into the model, and subjects and items were entered as random effects. A likelihood ratio test confirmed that the full model with the interaction outperformed the model with the fixed effects and no interaction term ($\chi^2(1) = 3.71$, $p < .001$), suggesting that the interaction between AGE and CONTEXT was a significant predictor for acceptance.[1]

The fitted model revealed a main effect of CONTEXT ($\beta = .94$, $Z = 2.69$, $p = .007$), a main effect of AGE ($\beta = -2.71$, $Z = -3.31$, $p < .001$), and a significant interaction between CONTEXT and AGE ($\beta = 4.90$, $Z = 4.59$, $p < .001$).

[1] See Appendix A for the R code used for these analyses

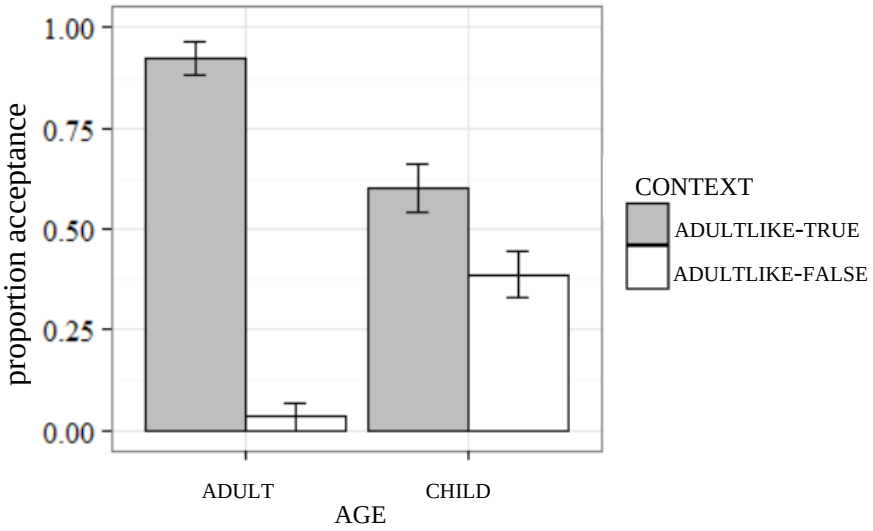


Figure 1: Proportion acceptance of the test sentence by CONTEXT and AGE in Experiment 1

Based on the results in Figure 1, the main effect of AGE is likely due to the variation in responses for children (Figure 2), compared to adults. The main effect of CONTEXT, meanwhile, is clear from a visual inspection of Figure 1, and while the pattern of results for children is not 100% adultlike, it is in the same direction as the pattern for adults: both children and adults accepted sentences in the ADULTLIKE-TRUE condition and rejected sentences in the ADULTLIKE-FALSE condition, with a significant difference in CONTEXT for adults (β = 14.85, Z = 3.11, p = .002) as well as for children (β = .91, Z = 2.68, p = .007). There was also no correlation for the children between overall accuracy and age (r(39) = .20, p = .22).

While previous studies have reported distinct patterns of responses in a single population (e.g. object control, optional subject-object), the distribution of responses for both conditions in Experiment 1 did not clearly reveal any such patterns (Figure 2, see Goodluck, 2001). With only 1 child accepting only the object interpretation (strict

object) and only 4 children accepting both the subject *and* the object interpretation (optional subject-object), the distribution in Figure 2 is not consistent with the predictions for the non-adultlike grammar accounts in previous studies.

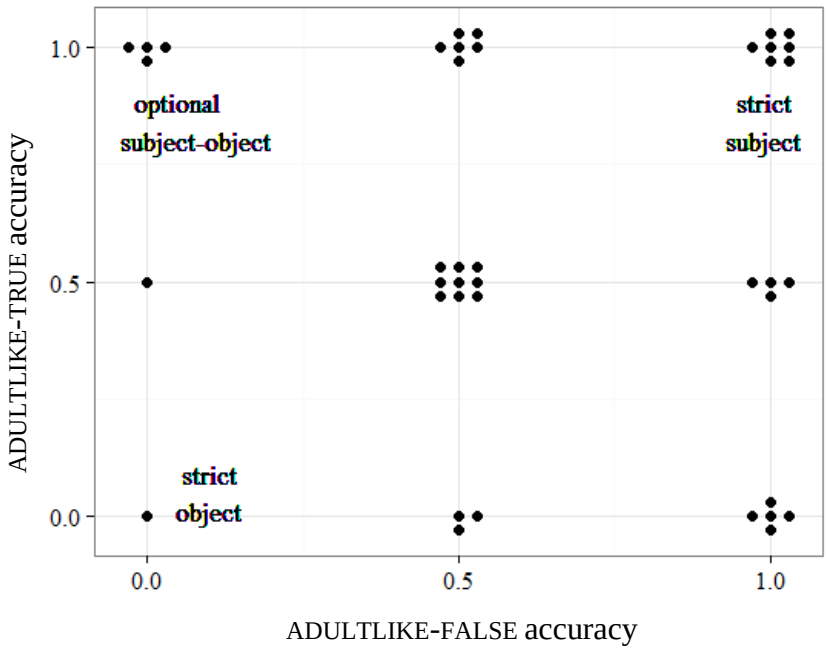


Figure 2: Distribution of responses by accuracy in Experiment 1, children only.

At the same time, the distribution in Figure 2 does not clearly confirm that children have an adultlike grammar. Specifically, the distribution is also consistent with a general bias to interpret PRO as the subject, as opposed to strict subject control in the adult grammar. This type of bias is seen for pronouns, as in (23):

(23) John$_1$ bumped Bill$_2$ after he$_{1/2}$ tripped on the sidewalk.

In (23), the pronoun *he* is ambiguous and can refer to either *John* or *Bill*, but a bias is exhibited for the subject interpretation *John* over the object interpretation *Bill* when both interpretations are made available (Gordon & Hendrick, 1998; Grober, Beardsley,

& Caramazza, 1978; Sheldon, 1974; Crawley, Stevenson, & Kleinman, 1990; Frederiksen, 1981; Smyth, 1994). Such a bias is consistent with both the Nominalization and the Variable Attachment analyses, which appeal to discourse factors to account for the interpretations of children with a grammar that does not pick out a single antecedent for PRO.

2.2.7 Discussion

Experiment 1 investigated whether addressing the methodological concerns with previous studies would result in the same pattern of non-adultlike behavior observed in previous studies or in an adultlike pattern of behavior. Indeed, children exhibited the same pattern of behavior as adults – both were more likely to accept the subject-true sentences and reject the object-true sentences. However, children still allowed a substantial number of non-adultlike interpretations. The higher error rate in for children than for adults raises the possibility that children's responses were due to a subject discourse bias, rather than a syntactic restriction as observed for the adults. To address this alternative analysis of the results in Experiment 1, we repeated the design in Experiment 1 with an ambiguous pronoun, as in (23).

2.3 Experiment 2: a comparison with discourse anaphora using ambiguous sentences

In Experiment 2, we addressed the alternative discourse-based analysis of children's behavior described above. In particular, if children's responses were due to a subject bias from the discourse, then this may have produced the same pattern of behavior as a syntactic restriction in the adult grammar. In Experiment 2, we used test

sentences with a fully ambiguous pronoun (as in (23)), which allows us to address the proposal that children's interpretations with a non-adultlike grammar (with a nominal structure or with the adjunct attached too high) are discourse-driven. If children's responses were driven by discourse factors rather than a syntactic restriction, then the same bias should be observed for (23); otherwise, discourse factors cannot fully account for the pattern of behavior in Experiment 1.

2.3.1 Participants

Participants were 33 children (15 males) ages 4;6-5;4 (M = 4;11.11) who were recruited through the University of Maryland Infant and Child Studies Database or participated at their local preschools; and 24 undergraduate students in introductory Linguistics classes at the University of Maryland, College Park. An additional 5 children were excluded from the final sample for failure to complete the training portion (2), inattention (2), or a language delay (1). Adults received course credit for their participation.

2.3.2 Design, Materials, and Procedure

As in Experiment 1, we used a TVJT that made both a subject interpretation and an object interpretation possible for the adjunct subject. The same design, materials, and procedure were used as in Experiment 1, but with test sentences containing a finite adjunct and a pronoun subject. In addition to the form of the test sentences, the stories were slightly modified to have two male characters (Diego and Mickey) so that the pronoun was ambiguous:

(24) a. Mickey tagged Diego before he got a jacket (SUBJECT-TRUE)

b. Mickey tagged Diego after he got a jacket (SUBJECT-FALSE)

2.3.3 Predictions

In Experiment 1, adultlike behavior was to accept subject-true sentences and reject object-true sentences. In contrast, for the sentences in (24), both the subject (*Mickey*) and the object (*Diego*) interpretations of the pronoun are grammatically licit in the adult grammar. With no syntactic restriction on the interpretation of the pronoun subject, accepting or rejecting either condition involves retrieving an antecedent from the discourse.

If children's interpretations in Experiment 1 were similarly discourse-driven, then the same pattern of behavior for children in Experiment 1 should also be observed for Experiment 2. However, if children's interpretations in Experiment 1 did not involve discourse anaphora, then they should exhibit a different pattern of responses for the test sentences in Experiment 2, with a truly ambiguous pronoun.

2.3.4 Justifications

The same coding criteria were used for Experiment 2 as in Experiment 1. Of the 96 responses by adults to the test sentences, 90 (94%) were CLEAR, and 6 (6%) were IRRELEVANT. Of the 130 responses by children, 100 (77%) were CLEAR, 28 (21%) were UNCLEAR, and 2 (2%) were IRRELEVANT. Since most of the time children gave clear justifications to their answers, and including the answers without clear justifications does not significantly affect the data, all data is again included in the analysis.

2.3.5 Results

Results for Experiment 2 are presented in Figure 3. We used R (R Core Team, 2015) and *lme4* (Bates et al., 2015) to perform a mixed-effects logistic regression analysis of the relationship between acceptance, and AGE and CONTEXT. As fixed effects, we entered AGE and CONTEXT into the model, and subjects and items were entered as random effects. A likelihood ratio test found that the full model with the interaction performed marginally better than the model with the fixed effects and no interaction term ($\chi^2(1) = 2.89$, $p = .089$). The model with both fixed effects performed marginally better than the model without CONTEXT ($\chi^2(1) = 4.68$, $p = .051$), but no better than the model without AGE ($\chi^2(1) = .12$, $p = .73$) suggesting CONTEXT and the interaction were marginal predictors for acceptance, but that AGE was not a predictor.

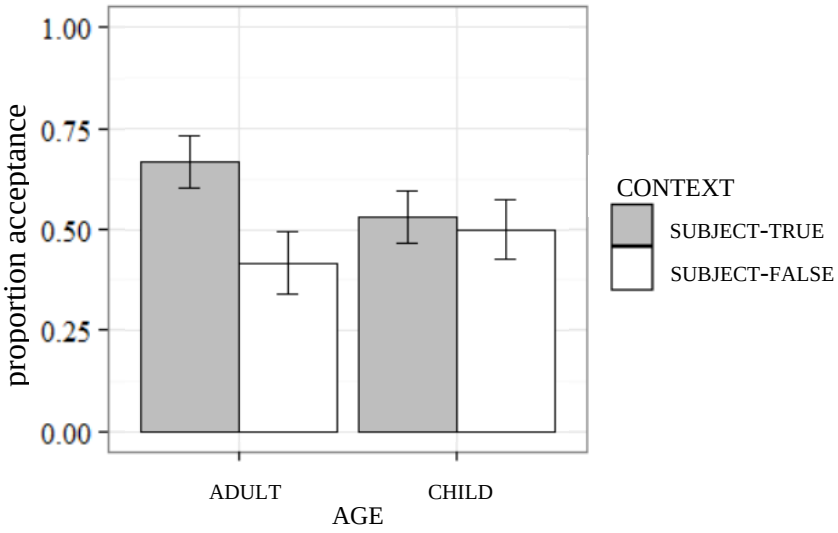


Figure 3: Proportion acceptance of the test sentence by CONTEXT and AGE in Experiment 2

The fitted model including the interaction term revealed a marginal interaction ($\beta = 0.97$, $Z = 1.69$, $p = .09$), but no effect of AGE ($\beta = -0.36$, $Z = -.86$, $p = .39$), and no effect of CONTEXT ($\beta = .14$, $Z = .39$, $p = .70$). The fitted model without the interaction

term also revealed no effect of AGE (β = 0.11, Z = .35, p = .73), and although removing the interaction term resulted in a marginal effect of CONTEXT (β = .55, Z = 1.94, p = .053), the results in Figure 3 suggest that this was driven by the adults (β = 1.05, Z = 2.45, p = .01), rather than the children (β = .15, Z = .39, p = .70).

In contrast to Experiment 1, children in Experiment 2 showed no preference for a subject interpretation of the adjunct subject, and adults showed a much weaker preference. Also inconsistent with the Nominalization and Variable Attachment analyses, the chance performance for children did not result from two different distributions. Rather, children (and adults) as a group were more likely than in Experiment 1 to accept an object interpretation and to reject a subject interpretation (

Figure *4*).

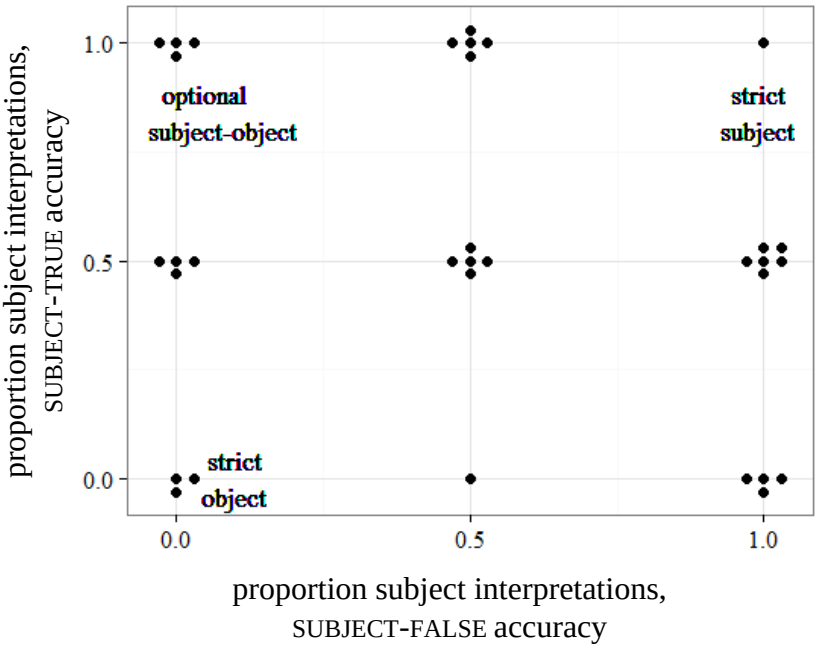


Figure 4: Distribution of responses by subject preference in Experiment 2, children only.

2.3.6 Discussion

With the same design as in Experiment 1, we observed that with sentences with a truly ambiguous pronoun as in (23), both children and adults exhibited a different pattern of behavior than they had shown for adjunct control. Specifically, adults showed a much weaker preference for the subject with an ambiguous pronoun than for object control, while children showed no preference in interpretation. Since children's responses for an ambiguous pronoun contrasted with their responses for adjunct PRO, their interpretations for adjunct control are unlikely to be entirely discourse-driven, and are more likely sensitive to the syntactic restriction in the adult grammar.

2.4 General discussion

Experiments 1 and 2 addressed the concerns in previous studies about the availability of all relevant interpretations, and the reliability of children's true/false responses in the TVJT. In Experiment 1, contexts were constructed so that both the adultlike and the non-adultlike interpretations of the test sentence would be equally available, and so that the test sentences would be relevant statements about the stories. Both children's true/false responses and their justifications to their responses indicated that they preferred the adultlike (subject control) interpretation of the test sentences. Nevertheless, children still accessed the non-adultlike interpretation at much higher rates that the adults, so Experiment 2 was designed to address whether children's preference in Experiment 1 could be attributed to a non-syntactic, discourse-based preference.

Children (and adults) showed a different pattern of behavior in Experiment 2 when the antecedent was not syntactically constrained, suggesting that the preference exhibited in Experiment 1 was not entirely due to the discourse status of the possible antecedents. The source of children's errors in Experiment 1 remains unresolved, however.

Under the Nominalization and Variable Attachment accounts, children who allow a free interpretation of adjunct PRO resolve the control dependency by retrieving an antecedent from the discourse, because their grammar does not place any syntactic restriction on the interpretation of adjunct control. Although the discourse-based accounts make predictions about children's interpretations of sentence-internal *and* sentence-external antecedents, Experiment 1 tested only whether children allow a non-adultlike internal antecedent of adjunct PRO. Whether they also allow an external interpretation was not addressed, and so the results do not rule out the possibility that children's non-adultlike object control interpretations were due to a different non-adultlike grammar (e.g. optional low attachment, which predicts that both internal, but not external interpretations should be grammatical), or to a different type of strategy, independent of the discourse. This option is addressed in Experiments 3 and 4, in the next chapter.

Another possible source of children's non-adultlike behavior in Experiment 1, however, is that the processing load that was associated with the task may have influenced how well children were able to retrieve an antecedent for adjunct PRO. Even if both interpretations are available, there is a processing load associated with keeping both the story context and the test sentence in memory in order to assign a truth value

to the test sentence. It is not clear exactly which processing resources that are involved in producing a response would be depleted by this type of load: for example, children might have difficulty retrieving the antecedent itself. Alternatively, they might instead have trouble after retrieving the antecedent, since resolving the dependency is only the first step in determining whether the test sentence contained the correct order of events. If children's non-adultlike behavior is related to the processing load associated with evaluating the order of events, then improved accuracy is predicted with a task that does not focus on temporal ordering. This prediction is further discussed in chapter 4, and serves as the basis for Experiment 5.

The results in Experiments 1 and 2 suggest that children's non-adultlike interpretations for sentences with adjunct control are not due to a non-syntactic discourse bias. These results therefore provide evidence against the grammatical accounts that argue for a non-adultlike state in which the interpretation of adjunct PRO is not syntactically constrained. In the next chapter, I test the predictions of two other grammatical accounts, which posit that children's interpretations of adjunct PRO are subject to different restrictions than in the adult grammar.

Chapter 3: Testing predictions of previous grammatical accounts

The previous chapter described some key methodological concerns in previous studies. In a TVJT that addressed these concerns, children's behavior patterned in the same direction as adults, but with a much higher error rate. Experiment 2 showed that these errors cannot be attributed to a non-syntactic discourse bias. The experiments in the present chapter test the predictions of two non-adultlike grammatical accounts that have been proposed to explain children's errors. These predictions are not borne out, suggesting that children's knowledge is adultlike, and that their errors are instead due to difficulty with deploying their knowledge.

3.1 The Agent account

Under the Agent account of children's interpretation of adjunct control, children use an agent strategy, linking adjunct PRO to the main clause agent (Goodluck & Behne, 1992; Goodluck, 1998). Using this strategy, children's interpretations of adjunct control will pattern with adults' interpretations when the main clause is active, as in (10), because the main clause agent is the main clause subject, *John*.

(10) John$_1$ bumped Mary$_2$ after PRO$_{1/*2/*3}$ tripping on the sidewalk.

However, this strategy picks out a different NP if the main clause is passive:

(25) John$_1$ was bumped by Mary$_2$ after PRO$_{1/*2/*3}$ tripping on the sidewalk.

In (25), the antecedent of adjunct PRO is still *John* for the adult grammar; however, the agent is *Mary* in the by phrase. If children use an agent strategy, then their behavior is predicted to diverge from adults for (25), since the agent is not the subject.

This strategy is consistent with the results in Experiment 1 in that it accounts for the finding that children's behavior patterned in the same way as observed for adults. How well it predicts children's behavior, though, depends on whether the agent strategy is a considered a preference for interpretation, which predicts some non-adultlike behavior even with an active main clause, or as a hard constraint, that does not involve any variation in interpretation.

In the previous studies that proposed the Agent account, children's accuracy for sentences with an active main clause was much higher compared to other studies, with only 10-20% errors. In contrast, children's performance was much less accurate for sentences with a passive main clause, with 40-60% errors (with higher accuracy for older children). This difference is interpreted as indicative of an agent strategy, which Goodluck and Behne (1992) propose to be a variable preference depending on the proportion of passive sentences in the experiment. That is, children whose grammar is not adultlike do not restrict their interpretation of adjunct PRO to the main clause subject, and instead exhibit different preferences depending on the context of the experiment. With a high proportion of passive sentences in a particular context, Goodluck and Behne (1992) argue, children are more likely to adopt an agent strategy for that context, supporting a version of the agent strategy as a general preference for the main clause agent, rather than a hard constraint.

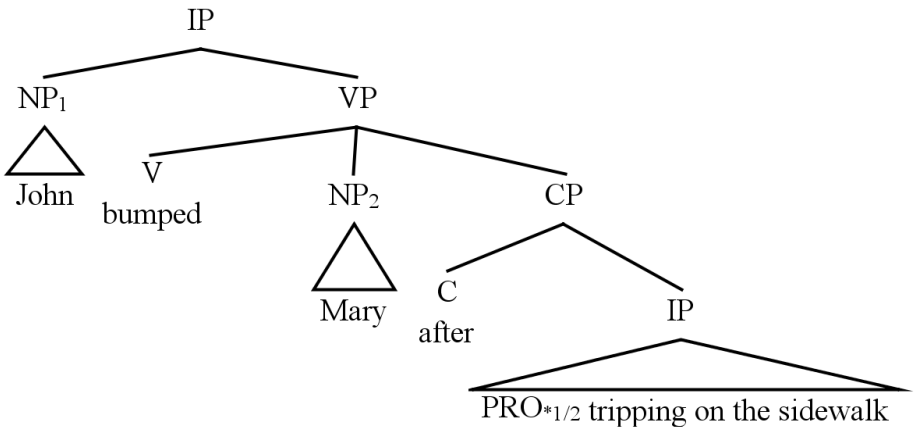
While the difference between active and passive sentences is consistent with an agent strategy, there may be other explanations available for the results observed by Goodluck and Behne (1992), and Goodluck (1998). Because both experiments used an act out task, it is difficult to determine a criterion for chance performance, and 20% of children's responses to the sentences with a passive main clause were coded as not scorable for the referent of adjunct PRO. Furthermore, the test sentences with a passive main clause contained *be*-passives, which children may have had trouble with, independent of the control dependency (Baldie, 1976; Bever, 1970; Brooks & Tomasello, 1999; Gordon & Chafetz, 1990; Horgan, 1978; Lempert, 1990; Maratsos, Fox, Becker, & Chalkley, 1985; Messenger, Branigan, & McLean, 2012; Pinker, Lebeaux, & Frost, 1987; Sudhalter & Braine, 1985; Turner & Rommetveit, 1967; a.o). In the present chapter, I use a TVJT to test children's interpretations of sentences with adjunct control with a passive main clause. Despite the high proportion of passive sentences throughout the experiment, children's behavior again patterns with adults' behavior, suggesting that children's errors do not result from an agent strategy of interpretation.

3.2 Erroneous attachment of the adjunct to the main clause: low attachment

Experiment 2 in the previous chapter addressed the proposal that children's non-adultlike behavior results from attaching the adjunct too high, resulting in a discourse-based interpretation of adjunct PRO. However, we have not yet addressed whether children pass through a separate stage proposed under the Variable Attachment account, that children attach the adjunct too low. With a low attachment structure, both

the subject and the object c-command the adjunct, but since the object is the closest c-commanding NP, it is the object that binds PRO (26).

(26)



An important distinction between the low attachment structure in (26) and the non-adultlike high attachment structure that requires a discourse antecedent for adjunct PRO is that in (26), the antecedent of PRO is syntactically constrained. For children who only access the low attachment structure, only an object control interpretation should be allowed. Indeed, a few children were reported by McDaniel, Cairns, and Hsu (1991) and Cairns, McDaniel, Hsu, and Rapp (1994) to only allow this interpretation, and to reject a subject and a sentence-external interpretation of PRO. However, Wexler (Wexler, 1992; Broihier & Wexler, 1995) questioned whether these children would have allowed a wider range of interpretations with a larger number of trials. Moreover, Broihier and Wexler (1995) showed that all children who allowed an object control interpretation also allowed an external interpretation, suggesting that if children do access the low attachment structure in (26), they must also have access to other structures as well, in order to account for the subject and external interpretations.

Although the study by Broihier and Wexler (1995) tested whether children allow a wider range of interpretations for adjunct PRO, it did not provide conclusive evidence regarding the grammatical structures that children assign to sentences with adjunct control. For example, since the object c-commands the adjunct in (26), but not in the adult structure, specific predictions are available regarding the binding relations between the object of the main clause and an NP in the adjunct, depending on which structure is assigned to a sentence with adjunct control. I test these predictions in Experiment 4, and find that children's preferences for the relevant binding relations match the preferences of adults. This result suggests that children have access to the same structure as adults.

In both experiments in the present chapter, children's behavior patterns with adults', suggesting that previous grammatical accounts cannot fully explain children's errors for sentences with adjunct control, as observed in Experiment 1. Alternative approaches, including the influence of the task itself, are discussed in the final section of this chapter.

3.3 Experiment 3: testing an agent strategy using passive sentences

Experiment 3 used sentences with a passive main clause in order to test the predictions of the Agent analysis, which posits that children have the wrong strategy for interpreting adjunct PRO: instead of selecting the main clause subject as the antecedent of PRO, they prefer the main clause agent. In doing so, children use the thematic structure, rather than the structural environment of PRO to determine its interpretation. There are two ways that this kind of strategy could be realized as a non-

adultlike grammar. One option is that children's grammars select the thematic structure for deriving the interpretation of adjunct PRO, with a grammatical rule to interpret adjunct PRO as the main clause agent. Another, as proposed by Goodluck and Behne (1992), is that the interpretation of PRO is not restricted by the grammar, but is sensitive the other types of structures in the discourse (or the task). As a result, under this proposal, agent interpretations are more likely in contexts with a higher proportion of passive sentences.

Under both versions of the Agent account, children's agent interpretations of adjunct PRO will pattern with adults' when the main clause is active, as in (10), because the main clause agent is the main clause subject, *John*.

(10) John$_1$ bumped Mary$_2$ after PRO$_{1/*2/*3}$ tripping on the sidewalk.

However, both versions pick out a different NP if the main clause is passive:

(25) John$_1$ was bumped by Mary$_2$ after PRO$_{1/*2/*3}$ tripping on the sidewalk.

In (25), the antecedent of adjunct PRO is still *John* for the adult grammar; however, the agent is *Mary* in the by phrase. If children use an agent strategy, then their behavior is predicted to diverge from adults for (25), since the agent is not the subject.

On the one hand, children's behavior in Experiment 1 might argued to be consistent with either version of the Agent account. At the same time, both versions raise questions about the developmental trajectory. If children have a grammatical rule that selects the agent of the main clause as the antecedent of PRO, then a transition to the adult grammar will depend on the availability of sentences in the linguistic input like (25). However, if children assign a non-adultlike interpretation to these sentences,

then it is not clear what other type of information would motivate a transition to the adult grammar. Meanwhile, for a grammar in which the antecedent of PRO is sensitive to the other types of sentences in the discourse, converging on the adult grammar will depend on acquiring the correct restriction on adjunct PRO, based on information in the linguistic input. This form and availability of this information will be discussed in detail in Chapter 6. However, it is less clear how children would develop an agent bias in the context of a high proportion of passive sentences, and what kinds of problems such a bias would cause in converging on the adult grammar.

Importantly, both agent strategies (grammatical and context-driven) may be problematic when it comes to accounting for how children converge on the adult grammar of adjunct control. Determining whether these strategies accurately predict children's behavior is therefore important in constructing an acquisition story. While sentences with an active main clause predict the same pattern for an agent strategy and the adult grammar, in contexts with a high proportion of passive sentences, both strategies predict a non-adultlike pattern of behavior for sentences like (25) with a passive main clause. In contrast, if children have access to adultlike knowledge of adjunct control, then the same similar pattern as in Experiment 1 should be observed for children and for adults.

3.3.1 Participants

Participants were 49 children (30 males) ages 3;11-5;5 (M = 4;9.12) who were recruited through the University of Maryland Infant and Child Studies Database or participated at their local preschools; and 24 undergraduate students in introductory

Linguistics classes at the University of Maryland, College Park. An additional 14 children were tested but were excluded from the final sample for failure to complete the training portion (6), answering passive control sentences incorrectly (6), and experimenter error (2). Adults received course credit for their participation.

3.3.2 Design, Materials, and Procedure

The same design and procedure were used as in Experiments 1 and 2, but with new contexts that better supported the use of a passive test sentence rather than an active one. Since all test sentences had a full passive in the main clause (as in (25), comprehension of the passive was required for completing the task; because of this we took a number of measures to make sure that children could pass this criterion.

First, we used *get*-passives, which children have exhibited higher accuracy for compared to *be*-passives (Crain, Thornton, & Murasugi, 1987; Crain & Fodor, 1993; Crain, 1991). Next, we used verbs that occurred most frequently in *get*-passive constructions in the CHILDES North American English database (MacWhinney, 2000).

For the stories in Experiment 3, we were careful to set up both the context and the discourse so that a passive construction in the test sentence would be felicitous. For the context, the events that were described with a passive were accidental, de-emphasizing the role of the agent in order to more felicitously describe the event from the perspective of the patient. To further satisfy the discourse requirements of a passive construction, the preamble was uttered by the experimenter instead of the puppet, with the form:

(27) Okay [puppet], what happened to [patient] in that story?

This preamble was intended to promote an expectation that the test sentence would mention the patient first, i.e. in the subject position. Passive controls with a full passive main clause but no adjunct were also included as an exclusion criterion in addition to the training criterion in Experiment 1.

The same design was used as in Experiments 1 and 2, with factors adjusted for the passive main clause (Table 5).

	interpretation	
CONTEXT	PRO = subject (adultlike)	PRO = agent (non-adultlike)
SUBJECT-TRUE	true	false
AGENT-TRUE	false	true

Table 5: Factors and truth values for context in Experiment 3

Test stories had a format like the following (important events underlined):

(28) Dora and Diego are going trick or treating on Halloween. Dora is dressed as a cat, and Diego is dressed as a bee. Dora gets hungry and decides to eat some of their Halloween candy. She offers some to Diego, but when he reaches for it, he accidentally stings her with the stinger on his costume. So, Dora decides to throw some candy to Diego instead so he doesn't sting her again, and then Diego eats some candy too.

SUBJECT-TRUE: 'Dora got stung by Diego after eating some candy.'

AGENT-TRUE: 'Dora got stung by Diego before eating some candy.'

3.3.3 Predictions

For children with the adult grammar, which only allows the subject interpretation of PRO, only the subject interpretation should be accessible. These children should therefore accept the SUBJECT-TRUE sentences and reject the AGENT-TRUE sentences. However, if children's behavior in Experiment 1 was driven by an agent strategy, then for passive sentences they should reject sentences the SUBJECT-TRUE sentences and accept the AGENT-TRUE sentences – the inverse of the predicted adultlike pattern.

3.3.4 Justifications

The same coding criteria were used for Experiment 3 as in Experiments 1 and 2. Of the 96 responses by adults to the test sentences, 94 (98%) were CLEAR, and 2 (2%) were IRRELEVANT. Of the 196 responses by children, 144 (73%) were CLEAR, 48 (25%) were UNCLEAR, and 4 (2%) were IRRELEVANT. Inter-rater reliability for justifications was 88% for whether a justification was clear and 90% for the referent of PRO. As in Experiments 1 and 2, CLEAR justifications were provided for most answers, and including the answers without clear justifications does not significantly affect the data, so all data is again included in the analysis.

3.3.5 Results

Results for Experiment 3 are presented in Figure 5. We used R (R Core Team, 2015) and *lme4* (Bates et al., 2015) to perform a mixed-effects logistic regression analysis of the relationship between acceptance, and AGE and CONTEXT. As fixed effects, we entered AGE and CONTEXT into the model, and subjects and items were entered as

random effects. A likelihood ratio test confirmed that the full model with the interaction outperformed the model with the fixed effects and no interaction term ($\chi^2(1) = 39.22$, $p < .001$), suggesting that the interaction between AGE and CONTEXT was a significant predictor for acceptance.

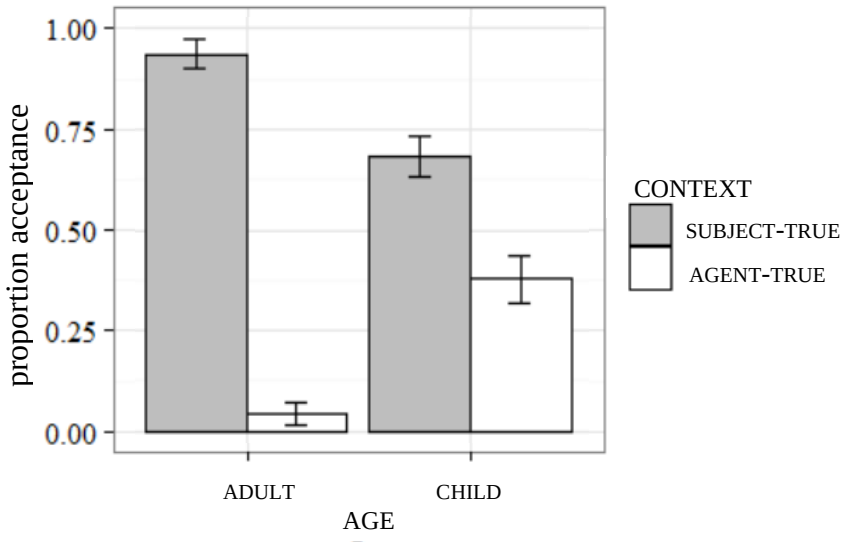


Figure 5: Proportion acceptance of the test sentence by CONTEXT and AGE in Experiment 3.

The fitted model revealed a main effect of CONTEXT (β =1.67, Z = 4.43, p < .001), a main effect of AGE (β =-2.89, Z = -3.58, p < .001), and a significant interaction between CONTEXT and AGE (β =5.18, Z = 4.86, p < .001).

As in Experiment 1, the main effect of AGE is not apparent from Figure 5, and is likely due to the variation in responses for children, compared to adults (Figure 6). The main effect of CONTEXT, meanwhile, is clear from a visual inspection Figure 5, with a significant difference between the SUBJECT-TRUE and the AGENT-TRUE conditions for adults (β = 5.84, Z = 6.24, p < .001), as well as for children (β = 1.90, Z = 4.45, p < .001).

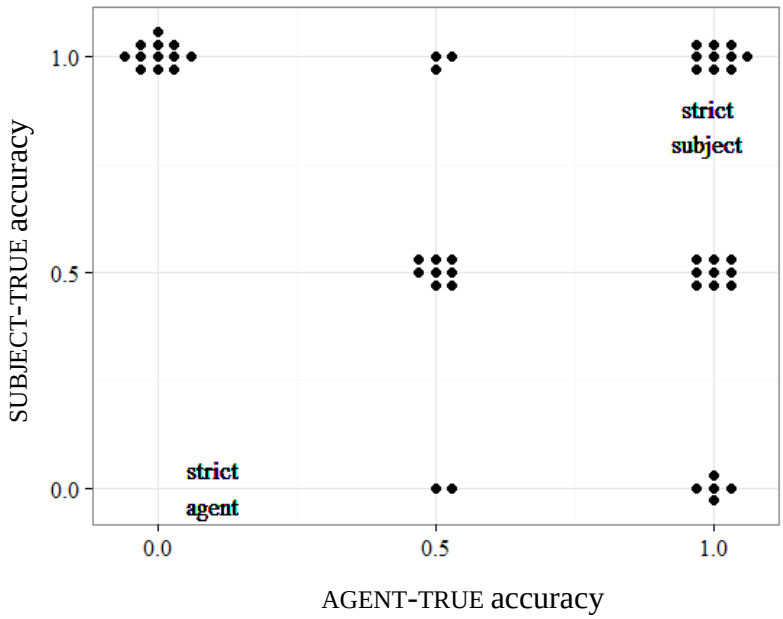


Figure 6: Distribution of responses by accuracy in Experiment 3, children only.

Finally, the distribution of responses in Experiment 3 did not reveal different populations, with no children accepting only the agent interpretation of PRO (Figure 6).

Since children did not exhibit the inverse pattern of behavior as predicted by the Agent analysis, an agent strategy cannot account for their behavior in Experiment 1. Instead, children's behavior is most consistent with the predictions for the adultlike behavior, although their non-adultlike interpretations remain unaccounted for.

3.3.6 Discussion

Experiment 3 investigated whether the results of Experiment 1 could be attributed to an agent strategy of interpretation as predicted by the Agent analysis. Under the Agent analysis, children interpret PRO as the main clause agent rather than the main clause subject, which predicts adultlike behavior for sentences with an active

main clause but non-adultlike behavior for sentences with a passive main clause. Since Experiment 1 used only active sentences, Experiment 3 used passive sentences to provide the crucial test case for evaluating the Agent analysis. Although children again exhibited some non-adultlike behavior, their patterns of acceptance in both conditions were in the same direction as the patterns for adults – the opposite of the pattern predicted by the Agent account.

The combined results of Experiments 1, 2 in Chapter 2, and Experiment 3 in the present chapter strongly suggest that children's errors are not entirely due to a non-adultlike grammar as proposed in previous studies, and instead point to the task, if not also additional performance factors, as the source of children's errors. Still, although Experiment 2 speaks to the high attachment component of the Variable Attachment analysis (by comparing children's interpretations of adjunct PRO with discourse anaphora), we have not yet addressed the proposal that children attach the adjunct too low. Experiment 4 therefore tests the predictions of low attachment, by probing binding relations between the main clause and the adjunct. In particular, if children's behavior is due to an adult grammar of adjunct control, then children should show the same preferences as adults for additional binding relations (other than adjunct control), which should contrast with the binding relations predicted by a non-adult grammar with low attachment.

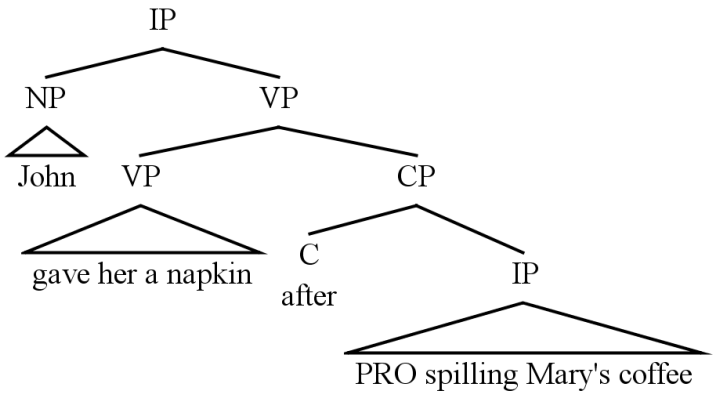
3.4 Experiment 4: testing attachment height using Principle C

Experiment 4 used a TVJT to set up a context that made two interpretations available for a sentence like (29):

(29) John gave her a napkin after PRO spilling Mary's coffee.

In (29), the pronoun *her* cannot bind PRO in the adult grammar because the object (*her*) in the adult structure does not c-command the adjunct (30):

(30)



Consequently, the pronoun *her* in object position does not c-command *Mary* in the adjunct. Co-reference is therefore grammatically licit, since Principle C (R-Expressions must not be bound) does not apply (Chomsky, 1981).

Meanwhile, Principle C would apply if the adjunct were attached low, such that the object does bind PRO, as in the low attachment grammar proposed in the Variable Attachment analysis. We predict, then, that for children with the non-adultlike grammar, co-reference between *her* and *Mary* in (29) should be blocked by Principle C.

3.4.1 Participants

Participants were 50 children (23 males) ages 4;4-5;6 (M = 4;11.09) who were recruited through the University of Maryland Infant and Child Studies Database or participated at their local preschools; and 37 undergraduate students in introductory

Linguistics classes at the University of Maryland, College Park. An additional 19 children were tested but were excluded from the final sample for failure to complete the training portion (16)[2], general inattention (2), or experimenter error (1). Adults received course credit for their participation.

3.4.2 Design, Materials, and Procedure

We used a TVJT with a similar design and procedure as in Experiments 1-3, but with materials that allowed for test sentences with the form in (29), with a pronoun in the main clause object position. The pronoun was ambiguous between a sentence-internal reading, i.e. with the pronoun co-referring with the R-expression in the adjunct (grammatical with the adult grammar only), and a sentence-external reading (grammatical with adult and non-adult grammars). As in Experiments 1-3, the factors were CONTEXT and AGE, but with CONTEXT modified to compare the sentence-internal and sentence-external interpretations of the ambiguous pronoun, rather than the possible antecedents of PRO (Table 6), and with CONTEXT as a between-subjects factor.

	interpretation:	
CONTEXT	pronoun = internal referent (adult grammar only)	pronoun = external referent (adult or non-adult grammar)
SENTENCE-INTERNAL-TRUE	true	false
SENTENCE-EXTERNAL-TRUE	false	true

Table 6: Factors and truth values for context in Experiment 4. As in Experiments 1-3, the truth values are based on order of events.

[2] It is not clear why more children were unable to complete the training portion in Experiment 4, compared to Experiments 1-3. One possibility is that the training items were different in the different experiments, and were more difficult in Experiment 4; more likely is that while the stories (including the training stories) in Experiments 1-3 had only two characters, Experiment 4 had three different characters, which may have introduced additional difficulty.

Test stories had a format like the following (important events underlined):

(31) Dora, Diego and Boots are going to pick apples. Dora gets bored, but she doesn't want to leave yet. So, she picks an apple for Diego. He is very happy that Dora picked him an apple, but he doesn't have anywhere to put it because he lost his basket! So Diego asks Dora to help him find his basket. Dora finds Diego's basket behind the bushes, but suddenly Boots runs up to Dora and asks her to pick him an apple too, since he's too short to reach any of them. So, Dora picks Boots an apple too.

SENTENCE-INTERNAL-TRUE:

Dora picked him an apple before PRO finding Diego's basket.

SENTENCE-EXTERNAL-TRUE:

Dora picked him an apple after PRO finding Diego's basket.

In the test sentences in (31), the internal referent is Diego, while the external referent is Boots, although these roles were counterbalanced across items. The format of the stories and the procedure were otherwise comparable to the format used in Experiments 1-3.

Balancing the availability of both interpretations (internal and external) is necessary to avoid two potential confounds:

(a) the sentence-internal referent being too salient, which might force a violation of Principle C due to a 'grammatical override' – i.e. children with low attachment only allow a sentence-external reading of the pronoun, but the

higher salience of the sentence-internal referent might block access to the sentence-external reading. In this case, the salient sentence-internal referent is selected despite the violation of Principle C.

(b) the sentence-external referent being too salient, such that the sentence-internal referent is not considered as the antecedent of the pronoun. In this case, the test of co-reference does not distinguish between the adult and non-adultlike grammars, since both allow the sentence-external referent as the antecedent.

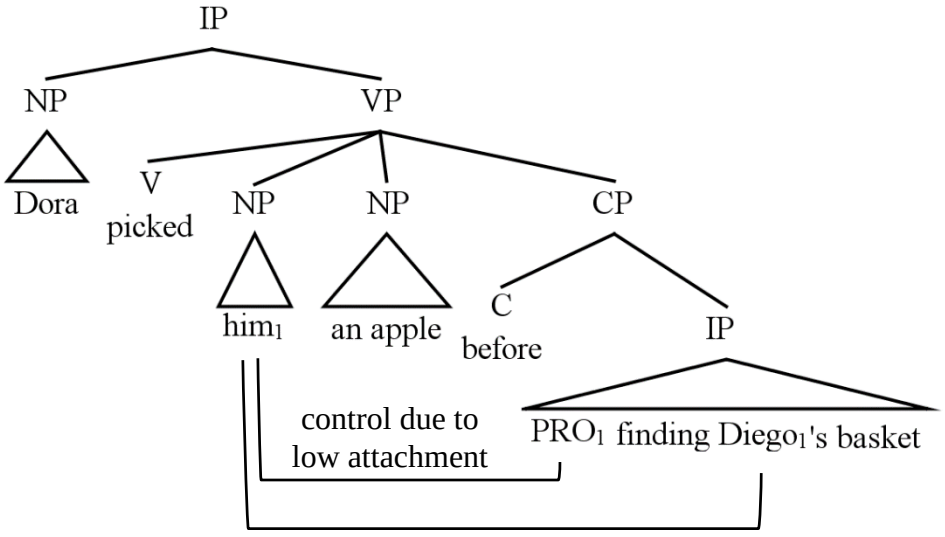
The stories were designed to make both interpretations of the pronoun equally available, and a preamble was included to balance the salience of both referents directly before the test sentence.

3.4.3 Predictions

While a true interpretation is grammatically licit in both conditions (sentence-internal-true and sentence-external-true) for the adult grammar, the predictions for a low attachment grammar are different due to the interpretation of PRO as the main clause object rather than as the subject (due to low attachment of the adjunct).

First, consider the possibility that the adjunct clause is attached low (32):

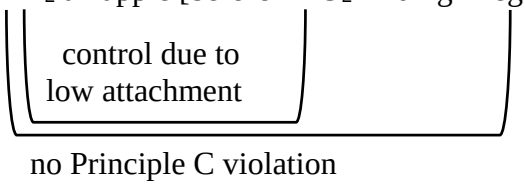
(32)



In this case, the object pronoun *him* would be the closest c-commanding NP to the adjunct subject. Consequently, the sentence should be interpreted as object control. Moreover, because the pronoun would c-command everything in the adjunct clause, it should be interpreted as disjoint in reference from all overt NPs in the adjunct clause. Hence, *him* in (32) could not be coreferential with *Diego* and therefore must be interpreted as taking a sentence-external antecedent. Additionally, because PRO c-commands *Diego,* coreference is ruled out between PRO and *Diego.* Since co-reference is ruled out between *Diego* and *him,* and PRO is bound by *him* with a low attachment structure, coreference between *Diego* and *him* is ruled out by virtue of the control relation.

This external interpretation is schematized in (33):

(33) Dora picked him$_2$ an apple [before PRO$_2$ finding Diego$_1$'s basket]



In (33), as in (32), the object pronoun *him* would be the closest c-commanding NP to the adjunct subject, resulting in object control. Unlike (32), though, *Diego* is not co-indexed with any c-commanding NPs (*him* or PRO). Since (33) therefore does not involve a Principle C violation, a grammatical interpretation of the test sentences in (31) is possible when *him* is interpreted as taking a sentence-external antecedent.

However, we also predict different responses in each condition for the low attachment grammar, due to the object control interpretation of PRO. Specifically, in (31), an object control interpretation is made false by the context (because Boots did not find Diego's basket). Therefore, children with low attachment should reject sentences in both conditions and give justifications referencing the antecedent of PRO, rather than the order of events in the story. These predictions are outlined in Table 7:

	interpretation (acceptance by grammar)	
CONTEXT	adult grammar	low attachment
SENTENCE-INTERNAL-TRUE	pronoun = internal referent (accept)	pronoun = external referent (reject, based on referent of PRO)
SENTENCE-EXTERNAL-TRUE	pronoun = external referent (accept, based on event order)	pronoun = external referent (reject, based on referent of PRO)

Table 7: Predictions by CONTEXT, grammar, and interpretation of the pronoun.

3.4.4 Justifications

As in Experiments 1-3, children and adults were asked to justify their answers. The same categories were used, but justifications were marked as CLEAR when the referent of the pronoun was made obvious rather than PRO, UNCLEAR, when the

referent of the pronoun was not obvious from the justification, and IRRELEVANT based on the same criteria as before. Of the 293 responses to test sentences by adults, 276 (94%) were CLEAR, 17 (6%) were UNCLEAR, and 0 were IRRELEVANT. Of the 188 relevant responses by children, 91 (48%) were CLEAR, 80 (43%) UNCLEAR, and 17 (9%) were IRRELEVANT. Inter-rater reliability for justifications was 91% for whether a justification was clear and 96% for the referent of the pronoun. All justifications given by children and most of the justifications by adults cited order of events as the reason for rejection or acceptance.

While children gave CLEAR justifications for most of their answers in Experiments 1-3, only half of their justifications were clear in Experiment 4. The source of this difference is not entirely clear, since the test sentences in both Experiment 2 and Experiment 4 contained an ambiguous pronoun, but children were more likely in Experiment 4 than in Experiment 2 to notice the ambiguity. While this observation can be taken as anecdotal evidence against the low attachment grammar, the analysis for Experiment 4 will first present the results with all answers included, as in Experiments 1-3. Then, we will consider the results when only a CLEAR justification was provided, and the implications of this contrast for our predictions.

3.4.5 Results and discussion

Results for Experiment 4 are presented in Figure 7. We used R (R Core Team, 2015) and *lme4* (Bates et al., 2015) to perform a mixed-effects logistic regression analysis of the relationship between acceptance, and AGE and CONTEXT. As fixed effects, we entered AGE and CONTEXT into the model, and subjects and items were

entered as random effects. A likelihood ratio test found that the full model with the interaction performed marginally better than the model with the fixed effects and no interaction term ($\chi^2(1) = 3.74$, $p = .053$). The model with both fixed effects outperformed the model without AGE ($\chi^2(1) = 4.68$, $p = .03$), as well as the model without CONTEXT ($\chi^2(1) = 17.44$, $p < .001$) suggesting that AGE and CONTEXT were both significant predictors for acceptance, with the interaction as a marginal predictor.

The fitted model including the interaction term revealed a main effect of AGE ($\beta = 0.95$, $Z = 3.19$, $p = .001$), a marginal interaction ($\beta = -0.76$, $Z = -1.93$, $p = .054$), and no significant effect of CONTEXT ($\beta = -0.36$, $Z = -1.21$, $p = .23$). The fitted model without the interaction term also revealed a main effect of AGE ($\beta = 0.53$, $Z = 2.65$, $p = .008$), but removing the interaction term resulted in a main effect of CONTEXT as well ($\beta = -0.81$, $Z = -4.03$, $p < .001$).

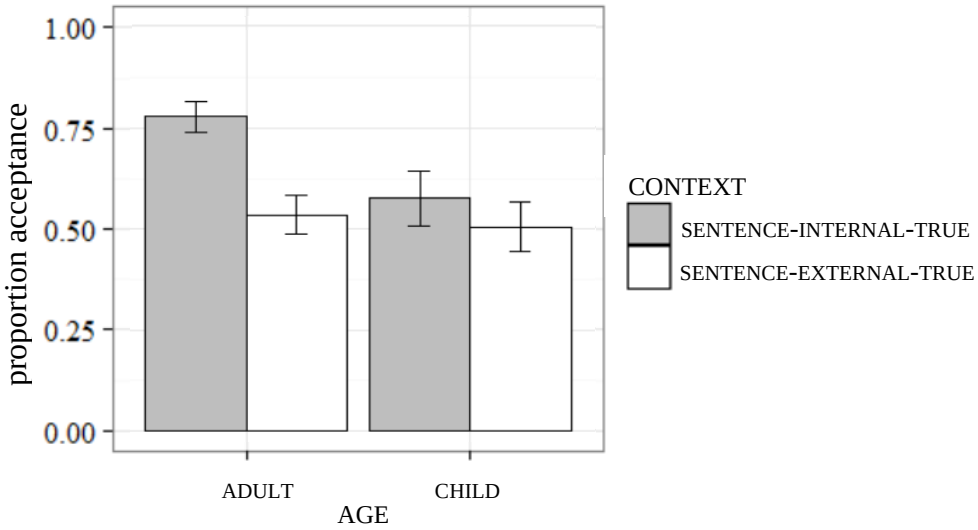


Figure 7: Proportion acceptance of the test sentence by CONTEXT and AGE in Experiment 4

A visual inspection of the results in Figure 7 suggests that children performed at chance in both conditions, in contrast with the adults, who were more likely to accept

the sentence-internal-true sentences than the sentence-external-true sentences (β = -1.22, Z = -3.95, p < .001). However, examining just the CLEAR justifications provides a different picture (Figure 8). In particular, when we include only the answers to which a CLEAR justification was provided (94% of adults' answers, and 48% of children's answers, with 5 additional children excluded for giving no CLEAR justifications) children show the same pattern as adults, with no advantage for the full model with the interaction term over the model without just the fixed effects ($\chi^2(1) = 2.56$, p = .11). With only CLEAR justifications, the fitted model without the interaction term revealed a main effect of CONTEXT (β = -1.06, Z = 1.77, p < .001) and, in contrast with the model including UNCLEAR justifications, only a marginal effect of AGE (β = 0.56, Z = 1.77, p = .08).

This contrast between the two patterns of results suggests that compared to Experiments 1-3, where the same pattern of results emerged with or without the UNCLEAR and IRRELEVANT justifications included, the task in Experiment 4 was more demanding, such that children were more likely overall to exhibit guessing behavior. This is supported by the observation that responses with UNCLEAR justifications were at chance, whereas the adultlike pattern was observed for answers with CLEAR justifications. That is, children's guessing behavior obscured the effect of context for the cases where children were able to provide a CLEAR justification, and so excluding children's UNCLEAR and IRRELEVANT answers was therefore necessary to identify the effect for Experiment 4, in contrast to Experiments 1-3.

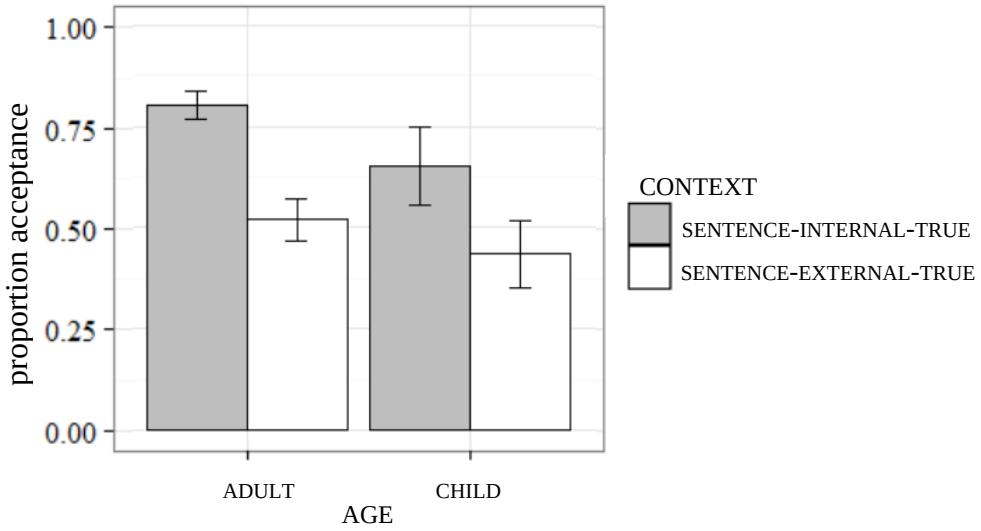


Figure 8: Proportion acceptance of the test sentence by CONTEXT and AGE in Experiment 4, CLEAR justifications only

After excluding the UNCLEAR and IRRELEVANT justifications, the overall pattern of acceptance in Figure 8 is largely identical for children and adults: consistent with the predictions of a grammar with high attachment, both children and adults accepted sentences that were true with an internal antecedent (SENTENCE-INTERNAL-TRUE). While the acceptance rate for the external antecedent condition (SENTENCE-EXTERNAL-TRUE) is not as high as for the SENTENCE-INTERNAL-TRUE condition, it clearly demonstrates that the external referent was also available. Only 3 children in the SENTENCE-INTERNAL-TRUE condition rejected all of the test sentences, and, consistent with the predictions for adultlike attachment, all justifications to rejected test sentences cited the order of events in the story as the reason for rejection rather than the referent of PRO.

Finally, neither children nor adults were at floor or at ceiling for acceptance in either condition, suggesting that both interpretations were available in both conditions. The justifications confirm this: for both children and adults and in each condition, both

interpretations (sentence-internal and sentence-external) were accessed at rates that differed significantly from 0 (Table 8). In contrast, since the low attachment structure allows only the external interpretation, children must have access to a grammar with high attachment.

AGE	CONTEXT	difference from 0 (one-tailed)	difference from 1 (one-tailed)
ADULT	INTERNAL-TRUE	$t(36) = 22.35$, $p < .001$	$t(36) = -5.53$, $p < .001$
	EXTERNAL-TRUE	$t(36) = 9.24$, $p < .001$	$t(36) = -10.02$, $p < .001$
CHILD	INTERNAL-TRUE	$t(17) = 7.06$, $p < .001$	$t(17) = -4.15$, $p < .001$
	EXTERNAL-TRUE	$t(22) = 11.65$, $p < .001$	$t(22) = -4.67$, $p < .001$

Table 8: Significance values for proportion interpretation of the pronoun as the sentence-internal referent in terms of difference from 0 (no interpretations as the sentence-internal referent) and 1 (all interpretations as the sentence-internal referent). All values differ significantly from 0 and 1, indicating that the pronoun was indeed ambiguous, while ceiling or floor effects are predicted for an unambiguous pronoun.

3.4.6 Optional vs. obligatory low attachment

By citing the order of events rather than the referent of PRO, the answers to clear justifications all clearly indicate a high attachment structure rather than a low attachment structure. However, the data for Experiment 4 are not inconsistent with an optional attachment analysis. Under this analysis, children may have been unable to give clear justifications in the cases where they attached the adjunct low (requiring an object interpretation of PRO when the context did not provide one). This contrasts with children's behavior in Experiment 1, where children were able to give justifications for an object interpretation of PRO most of the time it was accessed, but in Experiment 1 both a subject and an object interpretation of PRO were made available by the context. If children did access an object control interpretation in Experiment 4 but the availability of an interpretation in the context affected children's ability to give a clear

justification, then the absence of any justifications citing the interpretation of PRO in Experiment 4 might be related to the lack of an object interpretation in the context.

Importantly, children's answers and justifications clearly indicate that they have access to a high attachment structure and that the low attachment structure is not obligatory. One potential option for future research might be to investigate whether the low attachment structure is possible. However, in order to explain the results from Experiments 1 and 3 with an optional subject-object analysis of children's non-adultlike behavior, the analysis should also account for individual differences; that is, why low attachment would be observed at different rates in different children.

3.5 General discussion

Experiments 3 and 4 tested the predictions of the Agent account and the low attachment structure from the Variable Attachment account. Specifically, these experiments tested whether children would show different patterns of behavior from adults for sentences with a passive main clause, and for binding relations between the main clause object and an NP in the adjunct, respectively. In both experiments, children's behavior patterned with adults' behavior, suggesting that (a) children do not use an agent strategy of interpretation for sentences with a passive main clause, and (b) children have access to the correct attachment site of the adjunct to the main clause.

If children's non-adultlike behavior for sentences with adjunct PRO cannot be explained by grammatical accounts, then extragrammatical factors must play a role in determining children's behavior. First, although the TVJT might be better suited than an act out task for investigating children's interpretations of adjunct control, the

demands associated with producing a truth value response may still have affected children's performance on the task, even after addressing the concerns discussed in Chapter 2. As mentioned previously, retrieving the antecedent of PRO was only the first step in producing a response for the TVJT studies discussed here; after resolving the control dependency, children needed to compare multiple events from the story in order to determine whether the test sentence had described the events in the correct order. If children found it difficult to make this comparison, then they may have exhibited non-adultlike behavior, independent of their ability to resolve the control dependency.

One sign that this concern is on the right track is that especially in the training portion, children who had difficulty giving judgments about the temporal relations exhibited *yes* or *no*-biases, i.e. they would give the same response to every question. This type of bias is often observed when the demands of the task are too high, or when the test sentence is not comprehensible (Fritzley & Lee, 2003; Fritzley, Lindsay, & Lee, 2013). While the TVJT per se is not too demanding of a task for preschool-aged children, it is important to consider the type of response involved for the experiments presented here. In most cases, the test sentence in a TVJT depends on a single event, without referring to event ordering. Producing a truth value, then, involves evaluating whether the event occurred, rather than comparing its ordering with another event in the story. If comparing the ordering of multiple events adds an additional processing load relative to a task where the truth of the test sentence depends on a single event, then a noisier pattern of behavior might be expected in the former case, where the test sentence involves multiple events.

One way to test this prediction is with a task that does not rely on event ordering. The TVJT experiments depended on the complementizer in the adjunct to determine whether the events were mentioned in the correct order, i.e. whether the main clause event happened *before* or *after* the adjunct clause event. However, it is also possible to manipulate the truth value of the sentence by changing other elements in the test sentence – for example, the adjunct object:

(34) Dora washed Diego before PRO eating {a cookie/an apple}.

In (34), both possible test sentences contain the same ordering (the main clause event occurred *before* the adjunct clause event). Meanwhile, the adjunct object may be manipulated, independent of the order of events. In the following chapter, I take this approach, with the goal of reducing the task demands that may have previously contributed to children's non-adultlike behavior.

Chapter 4: Adultlike behavior with a new comprehension task

The experiments in the previous chapters used a Truth Value Judgment paradigm to argue that previous accounts of adjunct control in children cannot fully explain the observed patterns of behavior. In the present chapter, I discuss how children's behavior may have been influenced by task-specific demands. Using a new task, I demonstrate how these demands may be reduced, resulting in significantly higher accuracy compared to Experiment 1. This new task also presents the opportunity to consider adjunct control in a younger age group. While 4-year-olds exhibit high accuracy for sentences with adjunct control, accuracy in 3-year-olds does not differ significantly from chance. This contrast raises questions about learnability and the linguistic input, which are discussed further in Chapter 6.

4.1 Revisiting task factors in the TVJT

Although children have exhibited non-adultlike behavior with the TVJT for sentences with adjunct control (Broihier & Wexler, 1995; Adler, 2006), the TVJT has successfully been used to demonstrate adultlike behavior in children in the same age range for numerous other phenomena (e.g. Principle C (Crain & McKee, 1985; Crain & Thornton, 1998), Principle B (Conroy et al., 2009), Quantifier Raising (Musolino & Lidz, 2006; Viau, Lidz, & Musolino, 2010), Quantifier spreading (Crain et al., 1996; Drozd & van Loosbroek, 1998; Sugisaki & Isobe, 2001), Antecedent-contained Deletion (Syrett & Lidz, 2009, 2011), and others). If, as assumed in a TVJT design, both the adultlike and the non-adultlike interpretations were equally available, and the

test sentences were relevant in the given context, then this contrast may be cited in support of the proposed grammatical accounts in previous studies on the acquisition of adjunct control. Another possibility, however, is that these assumptions were not always met, and children's behavior was not indicative of their grammatical competence. The experiments in the previous chapters were designed to address this concern; nevertheless, the high proportion of non-adultlike responses in Experiment 1 raises the possibility that both interpretations were not always available, despite the methodological choices discussed in Chapter 2.

As mentioned in the previous chapter, another difference between the TVJT studies on the acquisition of adjunct control and TVJTs that observed adultlike performance for other phenomena is in the evaluation of event order (but see Lidz et al., 2004). The extra step of comparing two events in the story after retrieving the antecedent of adjunct PRO highlights extra processing costs that can be introduced into the task of producing a true/false response. For example, a true/false response in a TVJT involves:

1. Parsing the test sentence (assigning both structure and meaning),
2. Holding the parse and the story in memory in order to compare the test sentence to the events in the story, and
3. Based on this comparison, judging whether the final interpretation of the test sentence is consistent with the events in the story.

Any of these factors can affect the likelihood of a non-adultlike response.

Children's initial interpretation of the test sentence may differ from the adultlike interpretation, either because their grammar is non-adultlike, or because of factors having to do with extralinguistic contributors to parsing. These factors may involve immature parsing abilities, independent of the context (e.g., as seen in children's difficulty with revising an initial parse; (Trueswell, Sekerina, Hill, & Logrip, 1999; Omaki & Lidz, 2015). Depending on the availability of different interpretations, however, children may also "override" a grammatical constraint, based on pragmatic pressures from the context to access a non-adultlike interpretation (Crain & Thornton, 1998; Conroy et al., 2009).

After forming an initial interpretation, children's representation of the test sentence may become degraded with the cost of keeping the test sentence and the context in memory to judge the truth value. For example, for the adjunct control test sentences, children may correctly retrieve the antecedent of PRO in their initial parse of the test sentence, but their representation of the antecedent or the complementizer (*before/after*) may become degraded due to later processing demands. Alternatively, children may experience difficulty when comparing the order of the events in the test sentence to the order of events in the story. While children's behavior may have been influenced during any of these steps, the type of design in the experiments presented so far is not set up to identify which ones.

4.2 Coloring Book: a new comprehension method to address task demands

To address the extent to which children's behavior was influenced by task demands in the TVJT, the experiments in the present chapter take three steps to reduce

the task demands from previous studies. First, to avoid any pragmatic bias for one interpretation over another, the stories were replaced with standalone pictures, with minimal context. If children's responses were influenced by the processing costs associated with holding the interpretation in memory to compare with the events in the story, then simplifying the context should result in improved accuracy overall.

Second, as mentioned in the previous chapter, the context was also simplified by reducing the relevance of the event ordering in the test sentence. This change allowed for more focus to be placed on other elements in the adjunct clause, i.e. the direct object, which provided information to contrast the antecedent of PRO with another referent.

(35) Dora washed Diego before PRO eating an apple.

For example, in (35), the antecedent of PRO in the adult grammar is *Dora*. For a context containing Dora with a cookie and Diego with an apple (Figure 9), this contrast is captured by the adjunct clause in (35), which is false with *Dora* as the antecedent of PRO (the adultlike interpretation), but true with *Diego* as the antecedent (because Diego is the one eating an apple).

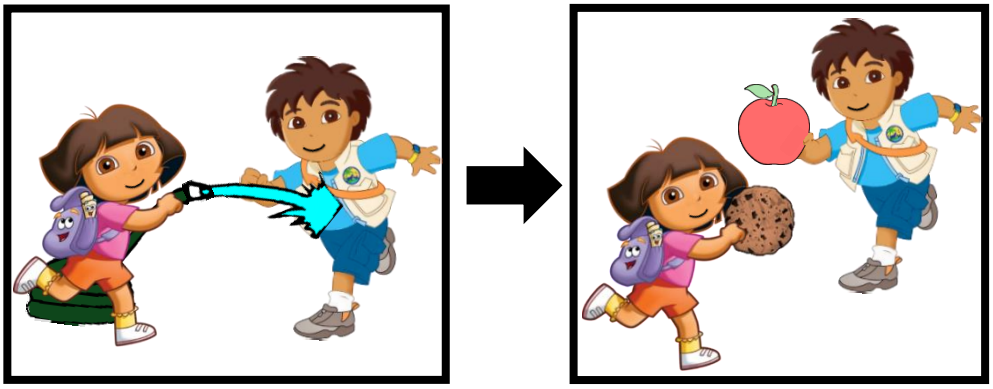


Figure 9: Context for:
(35) Dora washed Diego before PRO eating an apple.

Finally, while the context in Figure 9 makes both an adultlike (*Dora*) and a non-adultlike (*Diego*) interpretation of PRO in (35) available, this design does not fully address the concerns outlined above about the processing demands associated with comparing the test sentence to a context in order to determine a *truth value*. Instead, the experiments in the current chapter use the Coloring Book task, a coloring paradigm in which children indicate their interpretation by coloring in one of the objects in the context (Pinto & Zuckerman, 2015; Zuckerman et al., 2015). With a black and white version of the context in Figure 9, but where Dora and Diego each have an apple (Figure 10), children are prompted to color in a single item using test sentences as in (36):

(36) Dora washed Diego before PRO eating the red apple.

By coloring either Dora or Diego's apple, children indicated their interpretation of adjunct PRO for (36), without evaluating the truth value of the test sentence. Rather, the task involves coloring in a picture – an activity that preschool-aged children are especially familiar with. If children's grammars are adultlike, then the test sentences should indicate unambiguously which item should be colored in. Otherwise, since the task does not involve a true/false judgment, no clear preference is predicted for one interpretation over another (in contrast with the TVJT, where a preference for the true interpretation is predicted by the Principle of Charity (Crain & Thornton, 1998)).

4.3 Experiment 5a: Coloring Book with 4-year-olds

4.3.1 Participants

Participants for the coloring task were 33 children (16 males) ages 4;0-5;3 (*M* = 4;8.54) who were recruited through the University of Maryland Infant and Child

Studies Database or participated at their local preschools. An additional 9 children were excluded from the final sample for answering too many control sentences incorrectly (6), failure to complete the training portion (1), inattention (1), or equipment failure (1). Additionally, to compare children's performance on the coloring task with performance on the TVJT, we repeated the design in Experiment 1, with 40 children (18 males) ages 4;0-5;6 (M = 4;9.01). An additional 7 children were excluded from the final sample for failure to complete the training portion (3) or to inattention (4).

Adult controls (n=6) were also tested on the coloring task. They performed at 100% accuracy for all items with no variation, and their results are not included in further analyses. The adults were undergraduate students in introductory Linguistics classes at the University of Maryland, College Park, and they received course credit for their participation.

4.3.2 Design

We used the Coloring Book task introduced in §4.2, which allowed children to show their interpretation of the test sentence by coloring in a black and white picture (Pinto & Zuckerman, 2015; Zuckerman et al., 2015). In Experiment 1, an adultlike response in the TVJT varied depending on the condition (ADULTLIKE-TRUE or ADULTLIKE-FALSE). Because one goal of the coloring book task was to eliminate the extra step of determining a truth value for the test sentence, a response in the coloring book task only involved coloring in one of two objects. For example, for the test sentence in (36), the adultlike interpretation of the adjunct clause is that Dora ate the red apple (with no color specified for Diego's apple). However, if PRO is interpreted

as the main clause object, then the interpretation of (36) would be that Diego ate the red apple. Based on their choice of which object to color in, children's answers can therefore be categorized based on whether an ADULTLIKE response was given.

Without two distinct conditions in the coloring task, comparing the coloring task with the TVJT required collapsing the conditions in the TVJT to allow for the same ADULTLIKE measure for both tasks (Table 9). Because children's proportion of ADULTLIKE responses did not differ across conditions in Experiment 1, averaging across these two conditions in the present experiment was not predicted to miss any contrasts that are needed when comparing the TVJT to the coloring task.[3]

	proportions (between 0 and 1)	
CONTEXT	acceptance (from Figure 1)	ADULTLIKE responses
ADULTLIKE-TRUE	0.60	0.60
ADULTLIKE-FALSE	0.39	0.61
significance between conditions	$\beta = 0.91$, $Z = 2.68$, $p = .007$	$\beta = 0.07$, $Z = .21$, $p = .83$

Table 9: conversion of factors in Experiment 1 (ADULTILKE-TRUE and ADUTLIKE-FALSE) to proportion of ADULTLIKE responses. These data are not included in Experiment 5a; instead, the design was repeated with the same materials as a comparison with the coloring task.

With criteria in both tasks for categorizing children's responses as adultlike or non-adultlike, children's performance in the TVJT can be compared with performance on the coloring task, with TASK (TVJT/COLORING) as a between-subjects factor.

[3] This stands in contrast to the intended comparisons in Experiment 1, between the adult grammar, an optional subject-object grammar, and a strict object grammar. These three grammars made different predictions about children's responses in the two different conditions, motivating the use of both conditions in Experiment 1. This difference is not relevant for the coloring task, which does not include truth values by design.

4.3.3 Materials

The materials and procedure for the TVJT were identical to those in Experiment 1. For the coloring task, each item had the form described in §4.2 (Figure 10), with test sentences as in (36). The main clause event was depicted in one picture (Dora washing Diego), while the other picture contained both characters performing the action described in the adjunct clause (eating an apple).

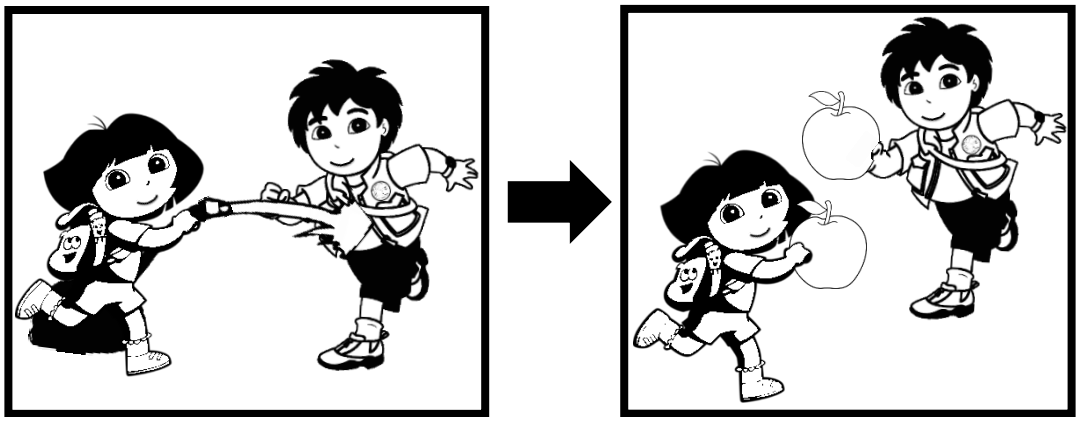


Figure 10: Example item for Experiment 5a:
(36) Dora washed Diego before PRO eating the red apple.

For each item, coloring in one of the two objects corresponded to an adultlike interpretation of PRO (Dora's apple in (36)), while the other object corresponded to a non-adultlike interpretation (Diego's apple in (36)), with the correct antecedent of PRO (*Dora* or *Diego*) counterbalanced across items. Because interpreting the responses depended on children coloring only one of the objects, the task was administered on a touchscreen computer and programmed so that only the two relevant objects could be colored in. Additionally, children learned during the training session that only one object should be colored in for each trial.

Two orders were constructed, with two lists for each order. The correct antecedent of PRO, character position on the screen, and whether the sentence contained *before* or *after* were all counterbalanced across items and lists. Although the order of events was not a main feature of the design, test sentences still described sequences of events. To support the use of a temporal adjunct, an arrow between the two pictures indicated the order of events, with the first event always in the left picture. This ordering allowed us to counterbalance which picture contained the main clause event, and which contained the adjunct clause event. In sentences with *before* (e.g. in (36)), the main clause event appeared on the left, while in sentences with *after*, the main clause event appeared on the right.

Finally, to make sure that children's interpretations were due to the adjunct control dependency, we included control sentences with a finite adjunct that had an overt subject, as in (37):

(37) a. Dora washed Diego before she ate the red apple. (subject pronoun)

b. Dora washed Diego before he ate the red apple. (object pronoun)

High performance on the control items serves as an indication that both the subject interpretation (in (37a)) and the object interpretation (in (37b)) are available without a syntactic restriction. Adultlike behavior on the test sentences, then, can be interpreted as a preference that is specific to sentences with adjunct control, despite the availability of both interpretations in sentences with no control dependency.

4.3.4 Procedure

The training session for the coloring task was designed to familiarize children with coloring in a single object based on a sentence with a temporal adjunct. The pictures were presented with an array of colored squares, and to color in an object children were instructed to "tap the color, and then tap the thing." After an initial warm up to practice coloring with the touchscreen, two additional training items focused on coloring in a single object based on a sentence describing a sequence of pictures. All sentences used in the training session had overt subjects, and no features of control were included in the training trials. All children could color the objects by the end of the training session.

In addition to the training items, the stimuli included 4 test items, 4 control items with a pronoun referring to the main clause subject (as in (37a)), and 4 control items with a pronoun referring to the main clause object (as in (37b)). Children who responded incorrectly to more than control item with a subject pronoun *or* to more than one item with an object pronoun were excluded from the analysis.

To familiarize the children with the pictures, the actions were introduced at the beginning of each new trial:

(38) In this picture we have Dora washing Diego, but first there's Dora eating an apple, and there's Diego eating an apple too.

Next, to balance the salience of both potential antecedents of PRO, a preamble was included before each test sentence that contained both names of the potential antecedents of PRO in a conjunct:

(39) So here's how we should color this picture of Diego and Dora: [test sentence]

The order of mention of the characters in the picture introductions (38) and the preamble (39) was counterbalanced across items and lists. Test sentences all had the structure like in (36), with emphasis on the color, and the stimuli were presented to children with the Coloring Book app (Pinto & Zuckerman, 2015) on a Dell touchscreen PC. Each participant was tested in a single session that lasted from 10 to 15 minutes for the children, and less than 5 minutes for the adults.

4.3.5 Predictions

With no differences between the two groups in terms of age or demographics, any differences in accuracy can be attributed to the task. If the processing demands associated with the TVJT influenced children's behavior in Experiment 1, then the same high rate of non-adultlike responses should be observed for the TVJT in Experiment 5a. If these demands were related to judging the truth value of the test sentence or to the relevance of temporal order, then the absence of these factors in the should result in increased accuracy for the coloring book task, compared to the TVJT.

4.3.6 Results

Results for Experiment 5a are presented in Figure 11. We used R (R Core Team, 2015) and *lme4* (Bates et al., 2015) to perform a mixed-effects logistic regression analysis of the relationship between the proportion of ADULTLIKE responses and the independent variable, TASK. We entered subjects and items into the model as random effects, with TASK as a fixed effect. A likelihood ratio test confirmed that the model with TASK outperformed the null model that included only random effects ($\chi^2(1) = 7.20$,

p =.007), suggesting that TASK was a significant predictor for the proportion of ADULTLIKE responses.

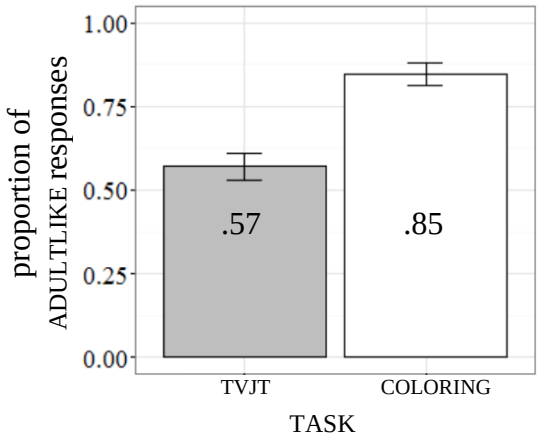


Figure 11: ADULTLIKE responses by TASK in Experiment 5a

The fitted model revealed a main effect of TASK (β =1.56, Z = 3.16, p = .002), with a higher proportion of ADULTLIKE responses for the COLORING task (0.85) than for the TVJT (0.57). The proportion of correct answers for the control items averaged 0.96 (out of 1) for both the subject pronoun sentences (as in (37a)) and the object pronoun sentences (as in (37b)), indicating that both the subject and the object interpretations were available when there was no syntactic restriction on the adjunct subject.

While the pattern of behavior in Experiment 1 alone did not clearly indicate whether children's grammars are adultlike, the pattern in Figure 11 provides much stronger evidence for task effects as the source of children's errors in previous studies. As the coloring task involves *reduced* processing demands compared to the TVJT, and does not eliminate them, children still made some errors with the coloring task; importantly, the pattern is largely adultlike. This contrast with the TVJT suggests that

children's knowledge of adjunct control is adultlike by age 4, but was obscured by the task in previous studies[4].

4.3.7 Discussion

In Experiment 5a, children's performance was significantly more accurate on the coloring task compared to the TVJT. What can be concluded from this result is that children's behavior for sentences with adjunct control was likely influenced by task demands in previous studies. These demands may be linked to providing an explicit true/false judgment, the additional step involving the order of events after resolving the control dependency, or the pragmatics of the context, which may not have fully balanced the availability of the potential antecedents in previous tasks. The coloring book task allows us to address these concerns, providing a clearer picture regarding the source of children's errors for sentences with adjunct control.

Importantly, the results from Experiment 5a do *not* constitute evidence that the coloring book task categorically eliminates the difficulties associated with the TVJT, regardless of the linguistic phenomena. As discussed in §4.1, the influence of these difficulties can vary widely depending on the specific design of the experiment, and preschool-aged children have exhibited adultlike behavior for many other structures with a TVJT. In cases where children do not exhibit adultlike behavior with a TVJT, the coloring book task provides an alternative means of evaluating children's

[4] Ideally, further support for this conclusion would be provided by an additional experiment analogous to Experiment 2, with ambiguous pronouns. This would offer additional evidence for a distinction between (unambiguous) sentences with adjunct control and minimally different sentences with an ambiguous pronoun.

performance, with the potential to demonstrate improved performance in a context that avoids some of the difficulties associated with the TVJT (Pinto & Zuckerman, 2015; Zuckerman et al., 2015).

With children's high accuracy on the coloring task in Experiment 5a, a new set of questions arises about children's knowledge of adjunct control: if four-year-old children's grammars are adultlike, at what age do children learn that adjunct PRO is controlled by the main clause subject, and what does this learning involve? Two different approaches are needed for answering these questions. First, we need to know how younger children treat sentences with adjunct control in the same conditions as older children. If evidence for the adult grammar is available at even younger ages, then this further limits what kind of information can be used to converge on the adult grammar, given the shorter time frame. Second, we need to know what kind of information is available in the linguistic input that could be used to learn about the adjunct control dependency. The first question is addressed in the next section, while issues related to learning and the linguistic input are discussed further in Chapter 6.

4.4 Experiment 5b: Coloring Book with 3-year-olds

Experiment 5b used the same materials as in Experiment 5a, but except with 3-year-olds as well as 4-5 year olds, and with only the coloring condition. The same procedure was also used for the 3-year-olds, as well as the same exclusion criteria.

4.4.1 Participants

In addition to the 4-year-olds from Experiment 5a, participants in Experiment 5b were 32 children (12 males) ages 3;3-3;11 (M = 3;7.03) who were recruited through

the University of Maryland Infant and Child Studies Database or participated at their local preschools. An additional 17 children were excluded from the final sample for answering too many control sentences incorrectly (12), failure to complete the training portion (4), or failure to complete the task (1).

4.4.2 Design, materials, and procedure

The focus in Experiment 5b was on how younger children's behavior for sentences with adjunct control compared with behavior in older children. The data from Experiment 5a for the COLORING condition are therefore presented again in Experiment 5b to represent behavior in older children, with AGE (THREE-YEAR-OLDS/FOUR-YEAR-OLDS) as a between-subjects factor. The materials and procedure used for the THREE-YEAR-OLDS were the same as in Experiment 5a.

4.4.3 Predictions

If younger children's grammars are not yet adultlike, then accuracy for THREE-YEAR-OLDS will be lower than observed in FOUR-YEAR-OLDS. There are two different patterns of behavior that are consistent with this prediction: first, a preference for the main clause object as the antecedent of adjunct PRO (i.e. systematic non-adultlike behavior), is suggestive of a strict object grammar (Cairns et al., 1994; Hsu et al., 1985; McDaniel et al., 1991).

Alternatively, children may exhibit no preference between the main clause subject and the main clause object, resulting in chance performance. With no available external referent, chance performance is consistent with:

1. A non-adultlike grammar that places no syntactic restriction on the antecedent of PRO, requiring a discourse-based interpretation (e.g. Nominalization (Wexler, 1992; Broihier & Wexler, 1995; Goodluck, 2001) or high attachment (Goodluck, 1981; Hsu et al., 1985; McDaniel & Cairns, 1990; McDaniel et al., 1991; Cairns et al., 1994; Adler, 2006)), or
2. A non-adultlike grammar which disallows an external antecedent but does not distinguish between the subject and the object (e.g. low attachment (Goodluck, 1981; Hsu et al., 1985; McDaniel & Cairns, 1990; McDaniel et al., 1991; Cairns et al., 1994), or a nonsyntactic preference for an internal antecedent (Goodluck, 1987)).

Chance performance should not necessarily be interpreted, however, as evidence for a non-adultlike grammar. In addition to the grammatical accounts, chance performance is also consistent with adultlike knowledge, if the task demands are too high for the younger children. Chance performance can therefore be taken as evidence that either children's knowledge of adjunct control, their parsing abilities – or both – are not yet adultlike.

It should be noted that no account considered here predicts the exact same (overwhelmingly adultlike) pattern of behavior for THREE-YEAR-OLDS as was observed for the FOUR-YEAR-OLDS. This is because the FOUR-YEAR-OLDS still made some errors, suggesting that difficulty of the coloring task still affected their behavior to some degree. If language processing abilities become more sophisticated with age, then any processing difficulties experienced by the FOUR-YEAR-OLDS should have an even

greater effect on performance for THREE-YEAR-OLDS. Nevertheless, if THREE-YEAR-OLDS have adultlike knowledge of adjunct control and the processing demands associated with parsing the test sentences and producing a response is sufficiently reduced in the coloring task, then performance in THREE-YEAR-OLDS should be significantly above chance, albeit with a higher error rate than observed for FOUR-YEAR-OLDS.

4.4.4 Results

Results for Experiment 5b are presented in Figure 12. We used R (R Core Team, 2015) and *lme4* (Bates et al., 2015) to perform a mixed-effects logistic regression analysis of the relationship between the proportion of ADULTLIKE responses and the independent variable, AGE. We entered subjects and items into the model as random effects, with AGE as a fixed effect. A likelihood ratio test confirmed that the model with AGE outperformed the null model that included only random effects ($\chi^2(1) = 21.65$, $p < .001$), suggesting that AGE was a significant predictor for the proportion of ADULTLIKE responses.

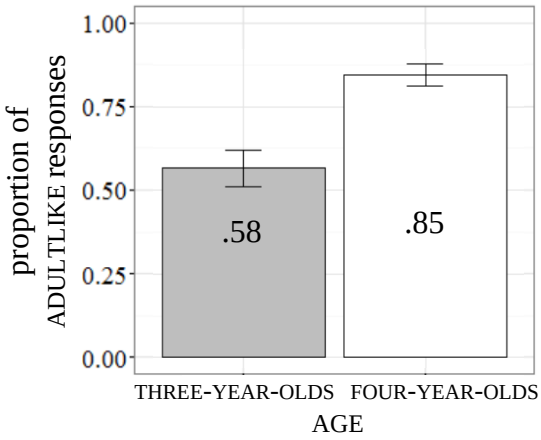


Figure 12: ADULTLIKE responses by AGE in Experiment 5b

The fitted model revealed a main effect of AGE (β = -1.42, Z = -4.82, p < .001), with a higher proportion of ADULTLIKE responses for the FOUR-YEAR-OLDS (0.85) than for the THREE-YEAR-OLDS (0.58).

Like the FOUR-YEAR-OLDS, the THREE-YEAR-OLDS showed high accuracy for the control items, with an average proportion correct of 0.92 (out of 1) for the subject pronoun sentences (as in (37a)), and an average of 0.88 for the object pronoun sentences (as in (37b)). The high accuracy for the control items indicates that the lower performance in THREE-YEAR-OLDS did not result from a general misunderstanding of the task, and instead points to difficulty with the test sentences with adjunct control as the relevant difference between THREE-YEAR-OLDS and FOUR-YEAR-OLDS.

A finer-grained analysis of the dependent variable AGE supports this conclusion: in addition to a binned binary variable, children's proportion of adultlike responses was also highly predicted by their age coded as a continuous variable (β =.02, t(60.9) = 5.44, p < .001). This relationship is reflected in Figures 13a and 13b, which show the proportion of ADULTLIKE responses by AGE as a continuous variable, and as a categorical variable binned into four different age groups (based on a median split of the two groups in Figure 12).

4.4.5 Discussion

The high accuracy exhibited by four-year-olds in Experiment 5a shifted the focus in Experiment 5b to younger children's behavior for sentences with adjunct control. While accuracy in four-year-olds was largely adultlike, three-year-olds

exhibited significantly lower accuracy in the exact same context. Although a strict object control grammar can easily be ruled out in accounting for the difference between three and four-year-olds, several other hypotheses must be addressed before identifying the source of the errors in three-year-olds.

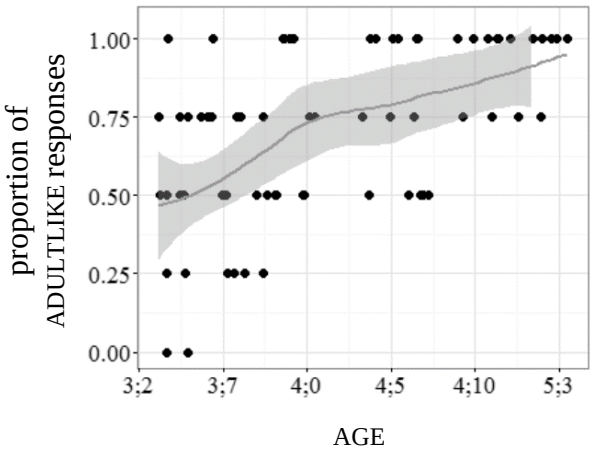


Figure 13a: ADULTLIKE responses by AGE, as a continuous variable

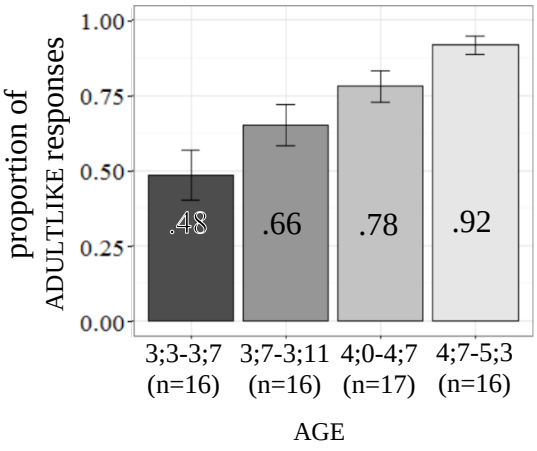


Figure 13b: ADULTLIKE responses by AGE, binned into four groups

While the difference between three and four-year-olds might be due to a change in grammatical knowledge, the steady increase in accuracy by age in Figures 13a and 13b is also consistent with changes in processing capacity as the source of the pattern observed in Experiment 5b. While Experiment 5a showed that the task-specific processing demands associated with the coloring task were lower than for the TVJT with adjunct control, the processing cost associated with the coloring task must be considered in the context of the three year olds, who are not predicted to have the same processing abilities as the four year olds. In the following section, we will consider how the processing cost specific to the coloring task influenced children's behavior, and

why this children's performance varied by age, despite high performance on the control items.

4.5 General discussion

Experiments 5a and 5b tested the prediction that simplifying the context, removing the relevance of temporal ordering, and removing the truth value judgment component would lower the processing cost of the task for sentences with adjunct control. While four-year-olds exhibited significantly higher accuracy with these changes to the task, accuracy in three-year-olds did not differ significantly from chance. This result offers strong evidence for adultlike knowledge in four-year-olds. However, the source of non-adultlike behavior for three-year-olds remains unclear.

One possible explanation for the chance performance is that three-year-olds have a non-adultlike grammar that does not restrict the interpretation of PRO to the main clause subject. If so, then an explanation is needed for how three-year-olds might acquire the adult grammar by age four.

There are at least two potential sources in addition to the grammar, however, that offer an explanation for the chance performance in three-year-olds, as well as the errors in four-year-olds. First, while the processing costs associated with the coloring task may have been lower compared to previous studies on the acquisition of adjunct control, it is important to consider how they may have still influenced children's behavior. In particular, these costs are comparable to those associated with the act out tasks that have been used in previous studies, in that both types of tasks involve planning and executing two distinct actions: in the act out tasks, children were asked to

act out both the main clause and the adjunct clause (e.g. in (36), Dora fanning Diego, and Dora eating the red apple). Similarly, in the coloring task, coloring in the correct object involved first selecting the correct color from the array of colored squares below the picture sequence from Figure 10, and then coloring in the correct object.

In both the act out task and the coloring task, it is the second of these actions – acting out the adjunct clause, and coloring in the correct object in the adjunct clause, respectively – that most clearly indicates the interpretation of adjunct PRO. The first action in both tasks (acting out the main clause, or selecting the correct color) can be a useful measure of understanding for the sentence as a whole – for example, in cases where a child reverses the roles of the characters in the main clause while acting it out, or selects the wrong color. However, for both tasks, these first actions introduce an additional memory load: the second action, indicating the antecedent of PRO, must be held in memory while the first action is carried out. If carrying out the first action interferes with the representation of the test sentence, then this may result in higher rates of non-adultlike behavior, independent of the grammar.

Next, children's errors may also result from the parsing procedures involved in online retrieval of an antecedent. For some types of dependencies, online retrieval mechanisms have been shown to be sensitive to the presence of an intervening element between two other elements in the dependency. When the intervening element matches in features (e.g. gender, number, animacy) with an element with the dependency, reading time differences are observed for adults compared to when the same features do not match, with parallel effects observed for accuracy in children (Table 10).

As discussed in Chapter 1, sentences with adjunct control contain a syntactic dependency which allows for an intervener between the two elements in the dependency:

(10) John$_1$ bumped Mary$_2$ after PRO$_{1/*2}$ tripping on the sidewalk.

construction	studies	age group(s)
relative clauses	Gordon, Hendrick, & Johnson (2001, 2004), Warren & Gibson (2002, 2005), Kidd, Brandt, Lieven, & Tomasello (2007), Brandt, Kidd, Lieven, & Tomasello (2009), Arnon, (2009), Friedmann, Belletti, & Rizzi (2009), Haendler, Kliegl, & Adani (2015), Bentea & Durrleman-Tame (2013) Adani, Forgiarini, Guasti, & Van der Lely (2014), Adani, Van der Lely, Forgiarini, & Guasti (2010), Belletti, Friedmann, Brunato, & Rizzi (2012)	adults and children
filler-gap dependencies	Gordon et al. (2004), Van Dyke & McElree (2006), Xiang, Dillon, Wagers, Liu, & Guo (2014)	adults
subject-verb agreement	Pearlmutter, Garnsey, & Bock (1999), Wagers, Lau, & Phillips (2009), Clifton, Frazier, & Deevy (1999), a.o.	adults
reflexive anaphors	Parker (2014)	adults
adjunct control	Parker, Lago, & Phillips (2015)	adults
subject-to-subject raising	Kwon & Sturt (2014), Sturt & Kwon (2015), Choe & Deen (2015)	adults and children
object fronting	Sauermann & Höhle (2015)	children
non-reflexive pronouns	Clackson, Felser, & Clahsen (2011)	children

Table 10: Interference effects observed in previous studies

In (10), the main clause object (*Mary*) intervenes between adjunct PRO and its grammatical antecedent, the main clause object (*Mary*). Test sentences in previous studies on the acquisition of adjunct control, as well as the experiments presented so far, have used sentences with this general form. Importantly, the main clause subject – the target of retrieval to link with adjunct PRO, overlaps with the main clause object –

the intervener – in animacy, number, and NP type (in (10), both the subject and the object are names, as opposed to full NPs, pronouns, etc). Test sentences in previous studies have consistently involved overlap in these features, raising the possibility that similarity-based interference might account for some of the observed non-adultlike behavior, in addition to the task effects demonstrated in the present chapter. This hypothesis is explored further in the following chapter for children's interpretations of adjunct control, by manipulating the feature overlap between the target and the intervener.

Chapter 5: Similarity-based interference

The previous chapter demonstrated how children's behavior may be influenced by task specific processing factors. While children exhibited a high proportion of non-adultlike responses with the TVJT, their errors were significantly reduced with the coloring task (Pinto & Zuckerman, 2015; Zuckerman et al., 2015), which addressed several of the ways that the TVJT may have influenced children's behavior for sentences with adjunct control. In the present chapter, I consider another potential source of children's non-adultlike behavior: similarity-based interference, in which a grammatically inaccessible constituent interferes with the grammatically accessible antecedent in online processing. In two experiments, I show that children's accuracy for sentences with adjunct control is modulated by similarity-based interference, suggesting that children deploy the same parsing procedures as adults, but are more susceptible to interference.

5.1 Review of similarity-based interference

Similarity-based interference is observed when a grammatically inaccessible element matches in features with the grammatically accessible antecedent in a linguistic dependency. For example, interference has been reported for object relative clauses (Gordon, Hendrick, & Johnson, 2001, 2004; Gordon, Hendrick, Johnson, & Lee, 2006; Warren & Gibson, 2002, 2005; for a review see Gordon & Lowder, 2012):

(19) a. The banker that the lawyer admired ___ climbed the mountain.

b. The banker that you/Joe admired ___ climbed the mountain.

In (19), there is a dependency between the head of the relative (*the banker*) and the object gap, after *admired*. In both (19a) and (19b), the relative clause subject intervenes between the head of the relative and the object gap, but in (19a) the head and the subject match in the feature NP type (both full NPs), while in (19b) the head (*the banker*) mismatches with the subject (*you* or *Joe*) in NP type. For relative clauses where the head and the subject match in features (as in (19a)), more interference is reported compared to when these features mismatch (as in (19b)). Interference effects have been reported in adults in terms of reading or reaction times, and have been observed for several different types of linguistic dependencies (Table 10; see Engelmann, Jäger, & Vasishth (2015) for a review).

Much of the work on similarity-based interference has focused on interference during retrieval of a target, based on specific cues for retrieval. For example, when linking a verb to its subject, the verb can be marked in English for number. In the ungrammatical case where the number feature on the subject does not match with the cue specified on the verb, but there is a grammatically inaccessible NP which does match the cue (as in (40)), illusions of grammaticality are observed, due to the grammatically inaccessible NP (Bock & Miller, 1991; Eberhard, Cutting, & Bock, 2005; Pearlmutter, Garnsey, & Bock, 1999; Clifton, Frazier, & Deevy, 1999; Häussler & Bader, 2009; see Wagers, Lau, & Phillips, 2009 for a review).

(40) *[The key$_{SG}$ [to the cabinets$_{PL}$]] are$_{PL}$ on the table.

In cases like (40) with explicit retrieval cues, reading time differences may be attributed to interference with the retrieval mechanism, by a grammatically inaccessible

but matching intervener. The effects observed for object relative clauses in (19), however, suggest that similarity-based interference is not always dependent on retrieval cues, because NP type is not specified as a cue for retrieval (but see Van Dyke & McElree (2006) regarding the specificity of semantic properties of different NP types). That is, while the form of the verb is marked for agreement with the number of the subject (and the form of a pronoun or reflexive specifies the number and gender of the antecedent), NP type is not specified on the verb in (19) in the same way that number is explicitly specified on the verb in (40). Instead, similarity-based interference in (19a) must arise from the initial encoding of the target and intervener, or while storing both elements in memory.

Research on similarity-based interference in language processing has discussed the effects primarily in terms of a storage account (but see Johnson, Lowder, and Gordon (2011)). Meanwhile, extensive evidence is provided for interference during encoding the domain of visual processing (discussed further below). With interference effects observed in other domains in addition to language, the question arises of how much of the general phenomenon – interference with similar items – is due to properties of domain general memory mechanisms, which then interface with domain specific systems. With effects of similarity-based interference observed for features like NP type, at least some aspects of interference in sentence processing must be domain specific, since values like "name" and "definite description" do not provide a meaningful distinction in other, non-linguistic domains. Analogously, interference in visual processing has been observed for objects that share features related to shape and

orientation in space, i.e. features that are meaningful in the visual domain, but not, for example, in the linguistic domain.

One possibility is that these effects are completely unrelated, with no overlap between the memory mechanisms that are involved in encoding and storing linguistic representations and the mechanisms that are deployed in visual processing. An advantage of this is that it provides an intuitive way to explain the different ways that similarity-based interference is realized in different domains: in general, interference effects are observed for representations that match in features compared to ones that mismatch, but there are domain specific differences in how the effects are modulated by other factors (e.g. timing, additional items). A disadvantage of this model, though, is that it involves redundancy. Specifically, it requires multiple unrelated mechanisms to account for interference effects in different domains, which fails to capture the *general* observation that encoding and storing similar items results in interference.

An alternative approach appeals to general properties of the memory architecture to explain this observation – in particular, that the architecture is feature-driven. Meanwhile, domain specific properties are responsible for the variation in interference effects across domains. As a consequence of the memory architecture, similar representations will interfere with each other in memory; however, the features that make up these representations will be largely domain specific. Furthermore, the kinds of features that determine similarity vary widely across domains – an expected source of variation, given the range in perceptual channels through which the representations are generated. Differences in the ways that interferences effects are realized in different domains therefore result from differences in the specific properties

of the representations that are stored in memory: interference effects in language processing, for example, are sensitive to a linguistic features, while interference effects observed for visual processing are sensitive to constraints in the visual system.

To further explore interference effects under this approach, the following sections consider the factors involved in interference resulting from maintaining similar items in memory (§5.1.1), and from initial encoding of similar items (§5.1.2).

5.1.1 Interference in storage

In the studies by Gordon and colleagues, interference is observed as a slowdown in reading times in the region composed of the relative clause subject and verb (*the lawyer admired* ___ and *Joe admired* ___). When the head of the relative (*the banker* in (19)) matches in NP type with the relative clause subject (*the lawyer*), slower reading times are observed for the relative clause region than when the head of the relative mismatches with the subject in NP type (*Joe*). While this effect might be accounted for in terms of word length alone (i.e. *the lawyer admired* is longer, and should therefore be read slower, all things equal, than *Joe admired*), two additional observations support an interpretation of this effect as due to similarity-based interference. First, the same pattern was observed for relative clauses at the main clause verb (*climbed*), which was held constant across all conditions, independent of NP length. This suggests that interference occurs not only in resolution of the dependency in the relative clause, but also in the processing operations that take place upon integrating the relativized NP with the main clause verb. These operations may be susceptible to interference because

the intervening subject of the relative clause must be ignored in order to link the verb in the main clause to the head of the relative.

Additionally, the same pattern of reading times is observed with cleft structures (41), which allow for the word length to be controlled (Gordon et al., 2001; Warren & Gibson, 2005):

(41) a. It was the barber that the lawyer saw __ in the parking lot. (full NP/full NP, match)

b. It was the barber that Bill saw __ in the parking lot. (full NP/name, mismatch)

c. It was John that the lawyer saw __ in the parking lot. (full NP/name, mismatch)

d. It was John that Bill saw __ in the parking lot. (name/name, match)

Unlike the relative clauses in (19), which do not allow names to function as the head of the relative, the cleft structures in (41a-d) do not place any restriction on the clefted NP. This allows the type of NP (name vs. description) to be fully crossed with the placement of the NP, resulting in the four options in (41a-d) with just the two types of NP.

As in (19a), with two definite descriptions, the sentence in (41a) with two definite descriptions is read more slowly than when the intervening subject is a name (*Bill* in (41b)), to mismatch with the first NP in NP type. The critical comparisons which tease apart a word length effect from an interference effect, however, are the ones between (41a) and (41c), and between (41b) and (41d). If the faster reading times were due to word length alone, then the type of NP for the first NP in the cleft should not affect reading time for the region containing the second NP and the verb (*the lawyer saw*___ or *Bill saw*). Meanwhile, slower reading times due to interference in the region

with the subject and the verb are predicted for (41a) compared to (41c) (in *the lawyer saw* __), and for (41d) compared to (41b) (in *Bill saw* __), since the NPs in (41a) and (41d) match in NP type, while the NPs in (41b) and (41c) mismatch in NP type. Consistent with the predictions of a similarity-based interference account, slower reading times were observed in the sentences with matching NPs ((41a) and (41d)) compared to the sentences with mismatching NPs ((41c) and (41b), respectively), in addition to a word length effect (Gordon et al., 2001; Warren & Gibson, 2005).

To account for the observed effects of NP type, Gordon and colleagues have proposed that interference arises as a result of storing items in memory with overlapping features. In support of this account, object relative clauses are compared with subject relative clauses (20), which do not require the first NP to be maintained in memory after an intervening NP in encountered.

(20) The banker that ___ admired the lawyer climbed the mountain.

In (20), the head of the relative (*the banker*) overlaps in NP type with the relative clause object, but interference is not observed. In contrast with the object relative clause structures in (19), the second NP in (20) (*the lawyer*) is not encountered until after the dependency has been discharged. Thus, when the object is encountered, no dependency information is being maintained in working memory. This contrasts with object relative clauses, where the object gap occurs after the relative clause subject. As a result, the head of the relative is still maintained in working memory when the subject is encountered.

Under the storage account described by Gordon and colleagues, maintaining both the head of the relative to link up to the gap *and* the subject of the relative clause to incorporate with the verb causes them to interfere with each other in memory. This interference results in slower reading times in the region with the relative clause verb, in addition to lower accuracy in comprehension questions, suggesting that the interference persists, to the final representation of the sentence.

In support of this account, Gordon, Hendrick, and Levine (2002) showed that the same slowdown in reading times are observed when participants memorized a list of items that overlapped in features with the NPs in a cleft structure. That is, if the NPs in the cleft were full NPs (e.g. *It was the barber that the lawyer saw…*), then participants were slower to read the region containing the subject NP and the verb (*the lawyer saw* __) when they memorized a list containing three full NPs than when they memorized a list containing three names. Meanwhile, if the NPs in the cleft were names (e.g. *It was John that Bill saw…*), then participants were slower to read the region containing the subject NP and the verb (*Bill saw* __) when they memorized a list containing three names than when they memorized a list containing three full NPs. This result suggests that the slowdown in reading times results from difficulty with linking the filler to the gap. Furthermore, greater difficulty is experienced when more items are stored in memory that overlap in features with the filler than when there are fewer items stored in memory that overlap in features. When more items are stored in memory that overlap in features with the filler, these items interfere with the representation of the filler in memory, including the non-overlapping features (e.g. features containing syntactic or ordering information) that allow the filler to be linked with the gap.

While the interference effects observed for clefts and relative clauses are consistent with a storage account of similarity-based interference, they are also consistent with an encoding account. In particular, items that overlap in features might interfere with each other in memory (under a storage account), but they may also interfere with each other during initial encoding, causing them to be stored as less distinguishable in memory than items without overlapping features. This account is explored in the following section.

5.1.2 Interference in encoding

The observed reading time slowdowns in contexts with feature-matching items are consistent with an account in which similarity-based interference occurs while the matching items are maintained in memory. However, another possibility is that interference occurs when an item is *encoded*, when the item matches in features with an item that is already stored in memory.

For example, in the object relative clause structures in (19), the head of the relative (*the banker*) is already stored in memory at the time when the relative clause subject is encountered. Under an encoding account, encoding the subject in the sentence where the subject matches with the head of the relative in NP type (*the lawyer*) is predicted to cause more interference than when the subject mismatches in NP type (*you/Joe*). As a result, encoding the matching NP (*the lawyer*) causes interference with the representation of the stored NP (*the banker*) such that the syntactic and semantic features that do distinguish them may be displaced, with a greater likelihood of feature displacement as the overlap in features increases (Nairne, 1988, 1990; Dillon, 2011).

This type of encoding account is supported by Johnson et al. (2011), who showed that retrieval is facilitated by more complete encoding of the target, compared to when less attention is allocated during initial encoding. Furthermore, extensive evidence is provided for interference during encoding in the domain of visual processing, in tasks that manipulate the feature overlap of a target and a distractor (Luck & Vogel, 2001; Luck, Girelli, McDermott, & Ford, 1997; Luck & Ford, 1998; Lavie, 1995; Hopf, Boelmans, Schoenfeld, Heinze, & Luck, 2002; Treisman, 1996; Treisman & Gormican, 1988; Alvarez & Franconeri, 2007; for a review, see Brady, Konkle, & Alvarez, 2011). In these tasks, participants must give a response for some feature of a target while keeping their gaze in the center of the screen; for example, by indicating whether a "T" appeared upright (T) or inverted (⊥), or whether a "T" occurred in a string of rapidly presented letters. In these tasks, the target and distractor might be mismatched on several features, e.g. in the case where the target is a green "T," where there is a red "T" in a different location of the screen. In these cases, there is little interference when encoding the target, and participants are quick to identify the orientation of the target "T." In contrast, slower reaction times are observed when there are multiple distractor "Ts," with one of the distractors placed directly adjacent to the target in the reverse orientation and with a similar luminance (although with a difference color). With a higher number of distractors in the visual array, encoding the target and binding the features to the target that distinguish it from the distractors involves more attention – resulting in slower reaction times – than with fewer distractors in the array (Luck et al., 1997; Luck & Ford, 1998; Treisman, 1996). While the mechanisms involved in visual binding may be specific to the visual system, the

effects are consistent with the approach outlined in §5.1, which appeals to the feature-driven memory architecture as a general source of interference.

The task of detecting the orientation of a "T" speaks to the difficulty with encoding a target in the presence of a distractor with overlapping features. Further evidence about the timecourse of encoding is offered by the tasks involving detection of a specific letter within a string of rapidly presented random letters (Luck & Vogel, 2001). In particular, these tasks tease apart whether interference prevents a target from being detected at all, or from being encoded in memory, despite being detected.

In this task, participants are instructed to detect and recall two targets in a string of letters, with the number of distractor items that appear between the two targets as the dependent variable. After the string of letters is presented, the first target is typically recalled quickly and with high accuracy. In contrast, the speed and accuracy of recall for the second target is observed to vary as a function of the number of distractor items separating the first target from the second target, with fewer intervening items resulting in lower accuracy and higher response times (Luck & Vogel, 2001; Broadbent & Broadbent, 1987; Raymond, Shapiro, & Arnell, 1992; Reeves & Sperling, 1986). This result, termed the *attentional blink* due to the failure to encode the second target, is attributed to interference from the first target which causes encoding failure for the second target. When the second target is presented too soon after the first target, the resources required for encoding the second target are not available, with attention still allocated to encoding the first target (Luck & Vogel, 2001; Jolicœur, 1999, 1998; Jolicœur & Dell'Acqua, 1998). Meanwhile, higher accuracy and faster reaction times are observed in trials with more items separating the first target from the second target.

In these cases, the delay between the first and second target provides enough time for resources to be allocated separately to encode the first target, followed by the second target.

While the above tasks are designed to measure processing in vision rather than language, they support a general model of interference based on the availability of processing resources, under the framework outlined in §5.1. For both vision and language, interference is observed when manipulating an item in memory calls on resources that are already occupied (Van Dyke & Lewis, 2003; Van Dyke & McElree, 2006). Additionally, there are consistent limits on how many items may be manipulated in memory in both adults and children (for reviews, see Feigenson (2007) and Cowan (2001)). In contexts involving a distractor and a target with matching features, increased attention is required for encoding the items as distinct, resulting in increased response times compared to when the same features to not match.

If the interference observed for sentences with a matching target and intervener arises due to difficulty at the encoding stage, then the resource-based models from the vision tasks discussed above can also inform our predictions for interference in language processing. In the vision tasks, subjects were slower to respond in contexts that placed a higher demand on processing resources, either because more attention was required to distinguish the target from a distractor (in the case of the orientation detection task), or because more resources were needed to encode the second target directly after detecting the first target (in the case of the target detection task). Similarly, under an encoding account of similarity-based interference in sentence processing, reading time differences are predicted for the intervener. Because the target is already

stored in memory when the intervener is encountered, increased effort is predicted in order to encode a matching intervener as distinct from the target, compared to when the target and intervener mismatch in features. Meanwhile, no difference in reading times is predicted for the intervener by the storage account, because interference effects are explained as arising later on, after both items have been encoded.

In the studies discussed above on interference in sentence processing, differences in reading times are reported for the region including both the intervening NP and the verb (*the lawyer saw* or *Joe saw*), but not for the intervening NP alone. These times are reported in order to compare the times for object relative clauses and object clefts with the reading times in the same region in subject relative clauses and subject clefts, respectively. Since the order of the NP and the verb is reversed in subject relative clauses and subject clefts (*the lawyer saw* ___ in object relative clauses and clefts, but ___ *saw the lawyer* in subject relative clauses and clefts), comparing reading times for e.g. *the lawyer* in an object relative clause would *the lawyer* in a subject relative clause does not allow for a balanced comparison, since *the lawyer* does not occur in the same context across conditions.

Meanwhile, in both object and subject relative clauses and clefts, the region containing the NP and the verb (*the lawyer saw*__ or __ *saw the lawyer*) does occur in the same context: as the content of the relative clause or cleft, and before the main clause verb (e.g. *climbed* in (19)). At the same time, reporting reading times for the entire region collapses any slowdowns at the intervener – as predicted by an encoding account alone – with the slowdowns at the first verb (*saw*). Since slowdowns at the verb are predicted under both the storage and the encoding accounts (due to difficulty

linking the filler to the gap in match contexts, compared to mismatch contexts), the reported differences in reading times therefore do not clearly distinguish between storage and encoding accounts.

Since the reading times do not definitively point to storage or encoding as the source of similarity-based interference in cases where there is no explicit cue for retrieval, both options may be considered when evaluating children's knowledge of linguistic dependencies. While the paradigms used with children are much more varied than those used with adults, a general finding is that children exhibit lower accuracy in the same contexts that adults exhibit slowdowns in reading time. The following section discusses the implications of these parallel effects for how children encode linguistic dependencies, including adjunct control.

5.2 Interference effects in children

A number of studies on language acquisition in children have manipulated the feature match between a target and intervener (Table 11).

construction	studies
relative clauses	Kidd, Brandt, Lieven, & Tomasello (2007), Brandt, Kidd, Lieven, & Tomasello (2009), Arnon (2009), Friedmann, Belletti, & Rizzi (2009), Haendler, Kliegl, & Adani (2015), Bentea & Durrleman-Tame (2013), Adani, Forgiarini, Guasti, & Van der Lely (2014), Adani, Van der Lely, Forgiarini, & Guasti (2010), Belletti, Friedmann, Brunato, & Rizzi (2012)
subject-to-subject raising	Choe & Deen (2015), Choe & O'Grady (2016)
object fronting	Sauermann & Höhle (2015)
non-reflexive pronouns	Clackson, Felser, & Clahsen (2011)

Table 11: Interference effects observed in previous studies with children. The effects are realized as differences in accuracy, with lower accuracy observed when target and intervener match in features than when they mismatch.

The majority of the studies in Table 11 used a picture selection task, but a few of them a TVJT (Choe & Deen, 2015; Choe & O'Grady, 2016; Sauermann & Höhle, 2015) or a visual world paradigm (Clackson et al., 2011). In addition to NP type, researchers have varied the animacy (Kidd et al., 2007; Brandt et al., 2009; Bentea & Durrleman-Tame, 2013), the number (Adani et al., 2014, 2010), and the gender (Belletti et al., 2012; Adani et al., 2014, 2010) of the target and intervener.

The effects of NP type and animacy, which are not explicitly marked in any of the structures in Table 11, suggest that the interference effects observed for children have the same source as those observed for adults with clefts and relative clauses. However, conflicting results in previous experiments, as well as different assumptions about the source of children's errors have resulted in several different perspectives regarding interference effects in children, as opposed to adults.

For example, while effects of NP type and animacy have consistently been observed without any explicit retrieval cues, interference effects for gender have only been observed when gender is explicitly marked on the verb, with no interference observed the verb is not marked for gender agreement (Adani et al., 2014, 2010; Belletti et al., 2012). While this difference is accounted for by appealing to the difference in the availability of gender cues, there are a number of task-related factors that may have contributed to the lack of an effect when the verb was not marked for gender agreement (e.g. minimal context before the test sentence, unbalanced items across conditions).

In addition to the role of the specific features, researchers have also disagreed about the source of the effects in the first place. While a few studies have considered a similarity-based interference account of children's errors for linguistic dependencies

(Choe & Deen, 2015; Choe & O'Grady, 2016), more commonly cited accounts are child Relativized Minimality, which posits that children have a non-adultlike grammar that is overly restrictive in cases with overlapping features (Friedmann et al., 2009), and input accounts, which cite the frequencies of relative clauses in the input as determining which features will be preferred where (Kidd et al., 2007; Brandt et al., 2009).

5.2.1 A Relativized Minimality account

In the adult grammar, Relativized Minimality disallows a dependency between two constituents when an intervener c-commands the lower constituent and overlaps completely with the higher constituent in features that trigger movement (Rizzi, 1990, 2004; Chomsky, 1995). This restriction is not specific to any one type of dependency, and also allows for a unified explanation for wh-island effects (42b) and *super-raising* (43b):

(42) a. What$_{+Q}$ did you say John read ~~what~~?

b. *What$_{+Q}$ did you say who$_{+Q}$ read ~~what~~?

(43) a. John seems ~~John~~ to be likely ~~John~~ to win.

b. *John seems that it is likely ~~John~~ to win.

In (42a), there is an A-bar dependency between the final position of the wh-word *what* in the main clause and its initial position in the embedded clause. With no intervening elements in an A-bar position that overlap in features with *what* in (42a), there is no minimality violation. In contrast, the same dependency is disallowed in (42b), because

the wh-word *who* intervenes in an A-bar position, and bears the same +Q feature as *what*.

Similarly, the same analysis is available for the contrast in (43), but with A-movement rather than A-bar movement: in (43a), there the main clause subject *John* raises from an A-position in the most embedded clause, to an A-position in the intermediate clause, to an A-position in the main clause, without crossing any other constituents in an A-position. In contrast, the dependency in (43b) is ruled out by Relativized Minimality because the expletive *it* intervenes in an A-position, and overlaps in features with *John*.

Furthermore, minimality effects are relative to a particular type of dependency for any given instance of minimality; for example, A-movement does not affect the acceptability of A-bar movement in the same sentence:

(44) Who does John seem [~~John~~ to like ~~who~~]?

A-bar A

Finally, Relativized Minimality has been proposed by some to extend to sentences like (45), which are judged to be more acceptable than (42b) (Pesetsky, 1987; Cinque, 1990).

(45) ? [Which book$_{+Q}$] did you say who$_{+Q}$ read ~~which book~~?

In (45), there is a +Q feature on *which problem* and *who*, but these constituents are distinguished from each other because *which problem* is D-linked, while *who* is not, resulting in improved acceptability of (45) compared to when neither wh-phrase is D-linked as in (42b). In accounts of child Relativized Minimality, this distinction is referred a difference in *lexical NP restriction* (Friedmann et al., 2009).

While the adult grammar only prohibits sentences with complete feature overlap, the non-adultlike grammar under a Relativized Minimality account is much more restrictive. While children do exhibit sensitivity to overlap in +Q feature, the non-adultlike grammar also disallows structures with partial overlap, which are not ruled out by the adult grammar. This account explains children's poor performance with object relative clauses like (19a), for example, because *the banker* and *the lawyer* overlap in NP type, even though only one bears the +Q feature. Meanwhile, the conditions for adultlike performance are not as clear, the proposal for child Relativized Minimality is explicit that the non-adultlike grammar only allows structures "in which the target and the intervener do not share any feature" (Friedmann et al., 2009). While +NP is further included as one of the relevant features, increased accuracy is nevertheless predicted in cases with *reduced* overlap between two NPs. For example, object relative clauses like (19b) would be permitted in the non-adultlike grammar because *the banker* and *Joe* do not overlap in NP type or on the +Q feature, correctly predicting that the majority of children will show chance performance for object relative clauses when the target and intervener match in features, but adultlike performance when they mismatch in features (Friedmann et al., 2009).

5.2.2 An interference account

While the results observed in previous studies with relative clauses in children are consistent with a Relativized Minimality account, they can also be explained by similarity-based interference. In some of the studies where an interference pattern has been observed, the structures have included an explicit cue that may have contributed

to the effect – for example, in relative clauses with number or gender marking on the verb (Adani et al., 2010, 2014; Belletti et al., 2012), or with gender on pronouns and reflexives (Clackson et al., 2011).

For example, Adani et al. (2014, 2010) have observed effects of gender interference in Italian, with sentences containing a verb that is marked for agreement with gender:

(46) a. Il gatto che il topo sta lavando é salito sullo sgabello
The cat-M that the mouse-M is washing has climbed-M onto the stool

b. Il gatto che la capra sta lavando é salito sullo sgabello
The cat-M that the goat-F is washing has climbed-M onto the stool

c. La capra che la mucca sta lavando é salita sullo sgabello
The goat-F that the cow-F is washing has climbed-F onto the stool

d. La capra che il gatto sta lavando é salita sullo sgabello
The goat-F that the cat-M is washing has climbed-F onto the stool

In (46), the head of the relative either matches ((46a) and (46c)) or mismatches ((46b) and (46d)) with the relative clause subject in gender. At the same time, the main clause verb (*salito/salita*) agrees with the head of the relative in gender, serving as a cue to retrieval. When the intervening subject matched in gender with the head of the relative, Adani et al. (2014, 2010) observed lower accuracy than when they mismatched, suggesting that children had more difficulty retrieving the target when the intervener matched with the retrieval cue than when it mismatched.

For studies like these, the cue may have contributed to interference effects in children that were parallel to the effects observed in adults for sentences like (40), repeated below, where interference is observed when a feature on the intervener matches with the retrieval cue. However, the remainder of the studies have manipulated NP type and animacy, which were not explicit retrieval cues.

(40) *[The key$_{SG}$ [to the cabinets$_{PL}$]] are$_{PL}$ on the table.

As discussed in §5.1, this type of interference in adults may occur while matching items are stored in memory prior to retrieval, but also during encoding when an item matches in features with another item that is already stored in memory. If similarity-based interference is responsible for interference effects in children as well as in adults, then one issue faced by this account is how to explain the differences between children and adults; that is, why reading time differences in adults would be realized as differences in accuracy in children. Given that executive function, including the ability to access and manipulate information in memory, is slower to develop overall (Omaki & Lidz, 2015; Courage & Cowan, 2008; Mazuka, Jincho, & Oishi, 2009; Novick, Trueswell, & Thompson-Schill, 2010), different explanations are available under the storage and encoding accounts discussed in §5.1.

For example, lower accuracy in match conditions is predicted under a storage account if the representations of the target and intervener in memory are quicker to decay over time in children than in adults (Courage & Cowan, 2008). If the features distinguishing the target and intervener become less accessible over time, then a higher rate of retrieval failure is predicted in contexts where fewer features distinguish the

target from the intervener (i.e. match contexts). In contrast, with more features available to discriminate between the target and the intervener in mismatch contexts, differences between the target and intervener take longer to decay. As a result, retrieval failure is predicted to be less likely in a mismatch context at the same point in time as for a match context.

Under an encoding account, lower accuracy in match conditions is predicted if children are less competent than adults at encoding the target and intervener as sufficiently distinct in memory. When fewer features distinguish the target from the intervener (in a match context), they are less likely to be encoded as distinct compared to when more features are available to distinguish the target from the intervener (in a mismatch context). Additionally, items that are encoded as less distinct from each other may be more susceptible to feature displacement for features that are distinctive (Engelmann et al., 2015), increasing the likelihood that an incorrect item will be retrieved in match contexts, compared to mismatch contexts.

While the encoding and storage accounts provide different explanations for children's non-adultlike behavior, both accounts predict a higher rate of non-adultlike interpretations in match contexts (i.e. when the target and intervener match in features) than in mismatch contexts. Furthermore, under both accounts, non-adultlike interpretations arise from failing to retrieving the target (retrieval failure), and retrieving the intervener instead. For object relative clauses like (19a), the adultlike interpretation is to link the object gap with the head of the relative clause; meanwhile, retrieving the intervener instead of the target would cause the object gap to be linked to the relative clause subject, rather than the head of the relative:

(47) The banker that the lawyer admired ~~the lawyer~~ climbed the mountain.

The resulting interpretation is a reading in which the lawyer would have both the subject and the object θ-roles. While this interpretation is predicted in cases of retrieval failure for object relative clauses, it has not typically been included as an option in previous studies on the acquisition of relative clauses. Many of the studies have used a picture selection task, with a choice between e.g. a lawyer admiring a banker and a banker admiring a lawyer. Since both choices are only a partial match for the interpretation in (47) (i.e., one picture has the lawyer as the agent and other has the lawyer as patient), chance performance is predicted when the object gap is linked to the intervener rather than the target.

While the nature of children's final interpretations for object relative clauses after retrieval failure is not entirely clear, other structures for which interference effects have been demonstrated allow for more straightforward predictions. For example, children have been reported to exhibit non-adultlike interpretations for sentences with raising from the subject position of the embedded clause to the subject position of the main clause (48):

(48) John seems to Mary [~~John~~ to be happy].

In (48), the subject of the embedded clause is not pronounced, but must be linked to the subject of the main clause to receive an interpretation. However, children have been reported to show chance interpretation for the embedded subject in (48) between an adultlike interpretation and an interpretation with the intervening experiencer (*Mary*) as the antecedent of the embedded subject. This non-adultlike interpretation is

predicted by similarity-based interference (Choe & Deen, 2015; Choe & O'Grady, 2016), where the intervening experiencer (*Mary*) is more likely to be retrieved in place of the target (*John*) when they interfere with each other due to feature overlap, compared to when they do not overlap in features. Indeed, (Choe & Deen, 2015) showed that children were less likely to retrieve the intervening experiencer when the target and intervener mismatched in NP type than when they matched.

Like the subject raising dependency in (48), sentences with adjunct control (10) also involve a syntactic dependency between the main clause subject (*John*) and an unpronounced subject in a separate clause:

(10) John$_1$ bumped Mary$_2$ after PRO$_{1/*2}$ tripping on the sidewalk.

Additionally, both sentences have an intervener (*Mary*), such that retrieving the intervener rather than the target results in a specific non-adultlike interpretation of the unpronounced subject.

Meanwhile, unlike sentences with subject raising (in which the antecedent is specified as a feature of the selectional criteria for the main clause verb) but similar to relative clauses, the antecedent of adjunct PRO is determined based on the structure of the sentence: in relative clauses, the target is the head of the relative clause, while in sentences with adjunct control, the target is the main clause subject.

One source of debate about the interference effects observed for object relative clauses concerns the role of agreement on the relative clause verb, which may be used as a cue for retrieval for some features (gender, number), but not for others (animacy, NP type). While the effects observed for animacy and NP type suggest that similarity-

based interference occurs independent of retrieval in both children and adults, the results for gender and number are less clear.

Sentences with adjunct control, with a non-finite verb that is not marked for agreement, present the opportunity to investigate similarity-based interference in a context without any explicit retrieval cues. One caveat is that interference effects for animacy have been observed for sentences with adjunct control in adults, with the argument that animacy may be used as a retrieval cue despite the lack of any explicit agreement marking (Parker et al., 2015). Furthermore, an animate antecedent for adjunct PRO was preferred over an inanimate antecedent even for grammatical sentences. If the adjunct verb was more strongly associated with an animate NP subject than an inanimate NP subject, then this may have promoted a bias for an animate antecedent. However, another option is that a learned association is developed for the structurally defined antecedent of adjunct PRO, due to the higher probability of an animate subject over an inanimate on (i.e. cue confusion from (Engelmann et al., 2015)).

If children's non-adultlike interpretations arise from similarity-based interference between the target and the intervener in encoding or in storage, then the same interference effects for NP type and animacy should also be observed for gender and number. Moreover, if children exhibit interference effects for sentences with adjunct control, then children's non-adultlike behavior in previous studies on the acquisition of adjunct control may be attributed to similarity-based interference, in addition to the processing load associated with the task as discussed in Chapter 5.

In the following sections, I present two experiments that manipulate the feature match between the target and intervener for sentences with adjunct control. In both experiments, children exhibit higher accuracy when the target and intervener mismatch in features than when they match. These results suggest the same parsing procedures that result in interference in adults are also deployed by children, and that children differ from adults in the resources at their disposal to deploy these procedures.

5.3 Experiment 6: gender manipulation

Experiment 6 adapted the coloring book task (Pinto & Zuckerman, 2015; Zuckerman et al., 2015) from the previous chapter to investigate whether interference would be observed when the target and intervener matched in gender, compared to when they mismatched in gender. Gender is not marked for agreement on the verb in sentences with adjunct control (or in English at all), and so no interference effects are predicted under the Relativized Minimality account outlined in (Belletti et al., 2012). However, under the storage and encoding accounts outlined in §5.1, items that overlap in gender should be more similar, and therefore more likely to interfere with each other prior to retrieval than items that are distinguished by gender, with all other features equal.

Additionally, in previous studies on the acquisition of adjunct control, the main clause subject and object in many of the test sentences overlapped in gender. If interference effects are observed in Experiment 6, then this overlap may have played a role in the observed non-adultlike behavior, independent of children's grammars.

5.3.1 Participants

Participants were 24 children (7 males) ages 3;11-5;3 (*M* = 4;8.6) who were recruited through the University of Maryland Infant and Child Studies Database or participated at their local preschools. An additional 6 children were excluded from the final sample for answering too many control sentences incorrectly (5) or failure to complete the task (1).

Adult controls (n=6) were also tested on the coloring task. They performed at 100% accuracy for all items with no variation, and their results are not included in further analyses. The adults were undergraduate students in introductory Linguistics classes at the University of Maryland, College Park, and they received course credit for their participation.

5.3.2 Design, materials, and procedure

The design for Experiment 6 was based on the experiments in Chapter 5, with additional items to allow for the gender manipulation. The gender feature was manipulated on the main clause subject and on the main clause object, allowing for a balanced manipulation of FEATURE MATCH (MATCH/MISMATCH) as a within-subjects factor.

In addition to the items from Experiment 5a with Dora the Explorer and Diego (36), new test items were constructed containing Mickey Mouse, allowing for test items where both the subject and the object of the main clause were male (49).

(36) Dora$_{\text{FEMALE}}$ washed Diego$_{\text{MALE}}$ before PRO eating the red apple.

(49) Mickey$_{\text{MALE}}$ washed Diego$_{\text{MALE}}$ before PRO eating the red apple.

Furthermore, to balance the number of times each character appeared throughout the experiment, new control items were constructed with Mickey and Dora. This allowed for an unambiguous overt pronoun, which was used to confirm that children could access both a subject and an object interpretation in sentences with no syntactic restriction, as in Experiment 5a. This resulted in 3 training items, 4 gender match test items with Mickey and Diego, 4 gender mismatch test items with Dora and Diego, 4 control items with Dora and Mickey, and 4 control items with Dora and Diego. Control items alternated with test items, and no items were included with Diego and Mickey with an overt pronoun; these would have been syntactically ambiguous, and might have influenced children's interpretations on the unambiguous items.

All of the items were counterbalanced across items and lists, and children who responded incorrectly to more than one control item with a subject pronoun *or* to more than one item with an object pronoun were excluded from the analysis. The procedure was exactly the same as in Experiments 5a and 5b, described in §4.3.4.

5.3.3 Predictions

If more interference occurs for items that share the same gender feature than for items that differ in gender, then greater accuracy is predicted for MISMATCH items than for MATCH items. A difference in accuracy is only predicted, however, if there is a large enough difference in the likelihood of retrieval failure when the target and intervener match in features compared to when they mismatch.

For example, in some contexts the interference between a gender matching target and intervener might not significantly affect their representations in memory,

beyond any other factors that might *also* interfere with the representations of a target and intervener that don't match in gender. Such factors may include the general demands of the task, interference for other features that overlap in both conditions (e.g. animacy, NP type, and number), or the rate of decay for items in memory, independent of any interference effects for gender. Observing a difference in accuracy therefore requires that the processing load of the task is low enough that children are able to exhibit accurate behavior in the MISMATCH condition. Otherwise, if performance in the MISMATCH condition is too close to chance, then differences due to interference in the MATCH condition will be too small to detect.

Meanwhile, Relativized Minimality does not predict any interference effects for adjunct control, because the intervener does not c-command adjunct PRO. Furthermore, since Relativized Minimality only predicts interference effects when the feature is explicitly marked for agreement (Belletti et al., 2012), gender effects are only predicted for languages with gender marking on the verb.

Finally, if the gender feature does not influence the similarity in memory between the target and the intervener, then no difference is predicted between the MATCH and MISMATCH conditions, at any level of accuracy.

5.3.4 Results

Results for Experiment 6 are presented in Figure 14. We used R (R Core Team, 2015) and *lme4* (Bates et al., 2015) to perform a mixed-effects logistic regression analysis of the relationship between the proportion of ADULTLIKE responses and the independent variable, FEATURE MATCH. We entered subjects and items into the model

as random effects, with FEATURE MATCH as a fixed effect. A likelihood ratio test confirmed that the model with FEATURE MATCH outperformed the null model that included only random effects ($\chi^2(1) = 3.96$, $p = .047$), suggesting that FEATURE MATCH was a significant predictor for the proportion of ADULTLIKE responses.

Additionally, since the dependent variable depended on the gender of the characters, we evaluated a model with FEATURE MATCH and participant gender as fixed effects. A likelihood ratio test confirmed that participant gender did *not* reliably predict children's accuracy, with no advantage for the model with both FEATURE MATCH and participant gender as fixed effects over the model with only FEATURE MATCH as a fixed effect ($\chi^2(1) = .18$, $p = .67$).

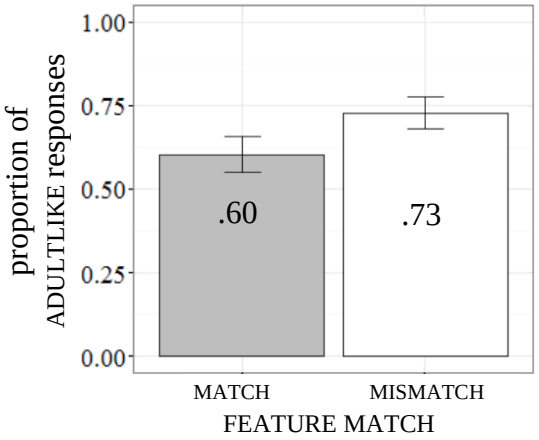


Figure 14: ADULTLIKE responses by FEATURE MATCH in Experiment 6

The fitted model revealed a main effect of FEATURE MATCH ($\beta = -.67$, $Z = -1.98$, $p = .048$), with a higher proportion of ADULTLIKE responses in the MISMATCH condition (0.73) than for the MATCH condition (0.60).

Consistent with the predictions of a similarity-based interference account, children exhibited greater accuracy when the target and intervener mismatched in gender (36) than when they matched in gender (49). Furthermore, while accuracy in the MISMATCH condition was significantly higher than chance (two-tailed one sample t-test, $t(23) = 4.84$, $p < .001$), accuracy in the MATCH condition was only marginally higher than chance (two-tailed one sample t-test, $t(23) = 1.93$, $p = .067$).

5.3.5 Discussion

In Experiment 6, children's performance was significantly more accurate when the target and intervener mismatched in gender than when they matched in gender. This pattern of results is consistent with a similarity-based interference account, where children's non-adultlike interpretations result from a failure to retrieve the correct antecedent. With shared features between the target and intervener in both conditions (e.g. number, animacy, and NP type), non-adultlike interpretations are still observed in mismatch contexts as well as match contexts. However, with one *less* feature available to distinguish between the target and the intervener, the likelihood of a retrieval failure is greater in match contexts than in mismatch contexts. Furthermore, these results are not consistent with an account of child Relativized Minimality, which do not predict any effect of gender for sentences with adjunct control.

With a reliable effect of gender interference for sentences with adjunct control, the question arises of whether interference is observed only for gender, or for other features as well. If interference effects are observed only for gender, then this is problematic for an account of similarity-based interference. Since the account predicts

that interference should be observed based on the similarity of the target and the intervener, no particular advantage is predicted for gender per se, especially when the dependency itself is not sensitive to the gender of the antecedent – as is the case for adjunct control. Therefore, it is important to confirm these results with other features to demonstrate that the interference effects observed in Experiment 6 are due to similarity-based interference, rather than a specific aspect of the gender feature.

In Experiment 7, the same feature match manipulation with sentences with adjunct control is repeated for number. As with gender, children exhibit higher accuracy when the target and intervener mismatch in number than when they match, supporting the evidence from Experiment 6 for similarity-based interference as a source for children's errors with adjunct control.

5.4 Experiment 7: number manipulation

5.4.1 Participants

Participants were 48 children (20 males) ages 4;0-5;5 (*M* = 4;10.28) who were recruited through the University of Maryland Infant and Child Studies Database or participated at their local preschools. An additional 20 children were excluded from the final sample for answering too many control sentences incorrectly (18), equipment failure (1), or a speech delay (1).

Adult controls (n=4) were also tested, and performed at 100% accuracy for all of the test items with no variation. Although two of the adults responded incorrectly to a control item, we believe that additional factors might have been at play for these particular control items, which were not relevant for the current study. The adults were

undergraduate students in introductory Linguistics classes at the University of Maryland, College Park, and they received course credit for their participation.

5.4.2 Design, materials, and procedure

The design for Experiment 7 was largely the same as in Experiment 6, with a few key modifications. The modifications were made to allow for a manipulation of the number on the main clause subject and object in the test sentences with adjunct control, as well as in the control sentences with an overt pronoun.

First, to manipulate the number of the target and the intervener while still keeping word length as even as possible across conditions, the characters in Experiment 7 were two generic girls and two generic boys. This change allowed for a straightforward manipulation of the number on the main clause subject and object. As in Experiment 6, the independent variable was FEATURE MATCH (MATCH/MISMATCH), but with a singular target and intervener for the MATCH items (50), and a plural target *or* intervener for the MISMATCH items (51):

(50) The girl$_{\text{SINGULAR}}$ washed the boy$_{\text{SINGULAR}}$ before PRO eating the red apple.

(51) The girl$_{\text{SINGULAR}}$ washed the boys$_{\text{PLURAL}}$ before PRO eating the red apple.

Items had the same form as in Experiments 5a and 6, but with two characters performing a single action when the test sentence included a plural NP (Figure 15).

Next, in contrast with Experiment 6, the manipulation of FEATURE MATCH in Experiment 7 was designed to be between-subjects, due to the number of items needed to fully counterbalance the roles across all four characters. As a result, each child saw the same number of test and control items as in Experiment 6; however, instead of

seeing four test items in each condition, children were assigned to the MATCH condition or the MISMATCH condition, and saw test items only from their assigned condition. Assignment of children to conditions was random, except to balance the age ranges in each condition.

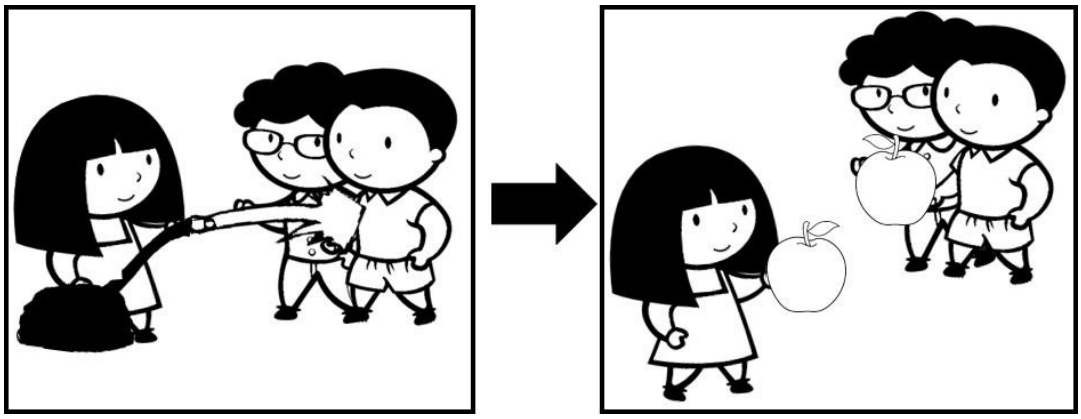


Figure 15: Example MISMATCH item for Experiment 7, to go with (51)

Finally, to avoid promoting a bias for or against coloring the objects corresponding to a single action with two characters, half of the 8 control items had the form in Figure 15, where one of the NPs was plural (*the boys* and *the girl*), while the other half had a form like in Figure 10, with two characters each performing an action (*the boy* and *the girl*). As a result of this ratio for the control items, 75% of the items in the MISMATCH lists had a plural NP (all 8 test items and 4 controls), and 25% had two singular NPs (4 controls). Meanwhile, 25% of the items in the MATCH condition had a plural NP (4 controls), and 75% had two singular NPs (all 8 test items and 4 controls). This design is schematized in Table 12, with the items with a plural NP shaded in grey.

The procedure was the same as in Experiments 5 and 6.

MISMATCH test items	MATCH test items	control items (same for both lists)
1.girls V boy after…	girl$_1$ V boy$_1$ after…	girl$_1$ V boy$_1$ after she… (subj)
2.girl V boys after…	girl$_2$ V boy$_2$ after…	girl$_2$ V boys after they… (obj)
3.girls V boy before…	girl$_1$ V boy$_2$ before…	girls V boy$_2$ before they… (subj)
4.girl V boys before…	girl$_2$ V boy$_1$ before…	girl$_2$ V boy$_1$ before he… (obj)
5.boy V girls after…	boy$_1$ V girl$_2$ after…	boy$_1$ V girls after he… (subj)
6.boys V girl after…	boy$_2$ V girl$_1$ after…	boy$_2$ V girl$_1$ after she… (obj)
7.boys V girl before…	boy$_1$ V girl$_1$ before…	boys V girl$_1$ before she… (obj)
8.boy V girls before…	boy$_2$ V girl$_2$ before…	boy$_2$ V girl$_2$ before he… (subj)

Table 12: lists in Experiment 7, where "V" = verb. The control items were the same in MISMATCH and MATCH conditions, and additional lists were created in both conditions to counterbalance the pronoun antecedent in the control items. Items with a plural NP are shaded grey.

5.4.3 Predictions

If the differences in accuracy observed in Experiment 6 were due to similarity-based interference, then the same differences between the MATCH and MISMATCH conditions are also predicted for other features, including number. As such, the same factors at play in Experiment 6 are also relevant for Experiment 7: if encoding and storing two singular NPs in memory raises the likelihood of retrieval failure by virtue of the two NPs sharing a number feature, then higher accuracy should be observed when the number feature is not shared (in the MISMATCH condition). Otherwise, if interference is only observed for number with an explicit retrieval cue, then no difference should be observed between the MATCH and MISMATCH conditions (since the adjunct verb is not marked for number agreement).

5.4.4 Results and discussion

Results for Experiment 7 are presented in Figure 16. We used R (R Core Team, 2015) and *lme4* (Bates et al., 2015) to perform a mixed-effects logistic regression

analysis of the relationship between the proportion of ADULTLIKE responses and the independent variable, FEATURE MATCH. We entered subjects and items into the model as random effects, with FEATURE MATCH as a fixed effect. A likelihood ratio test confirmed that the model with FEATURE MATCH outperformed the null model that included only random effects ($\chi^2(1) = 4.38$, $p = .036$), suggesting that FEATURE MATCH was a significant predictor for the proportion of ADULTLIKE responses.

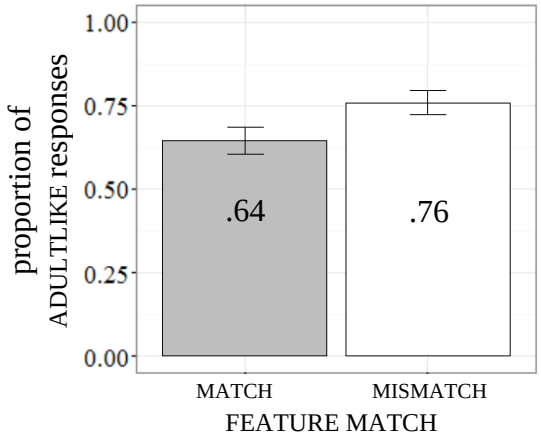


Figure 16: ADULTLIKE responses by FEATURE MATCH in Experiment 7

The fitted model revealed a main effect of FEATURE MATCH ($\beta = -.58$, $Z = -2.12$, $p = .034$), with a higher proportion of ADULTLIKE responses in the MISMATCH condition (0.76) than for the MATCH condition (0.64).

As in Experiment 6, and consistent with the predictions of a similarity-based interference account, children were more accurate in the MISMATCH condition than in the MATCH condition. Unlike in Experiment 6, two-tailed t-tests revealed that children's accuracy was significantly greater than chance in *both* conditions, rather than just the MISMATCH condition (MISMATCH: $t(23) = 7.08$, $p < .001$; MATCH: $t(23) = 3.62$, $p = .001$). However, this difference is expected, given that the target and intervener in Experiment

6 overlapped in both gender *and* number; meanwhile, the MATCH condition in Experiment 7 (with *the girl* and *the boy*) was more comparable to the MISMATCH condition in Experiment 6 (with *Dora* and *Diego*), since the target and intervener in both overlapped in number, but not in gender. The difference in accuracy between the MATCH condition in Experiment 7 (.64) and the MISMATCH condition in Experiment 6 (.73) is therefore unexpected, since they differ only in the NP type of the target and intervener. The implications of this difference will be explored further in the following section.

5.5 General discussion

Experiments 6 and 7 tested the prediction that similarity-based interference plays a role in predicting children's non-adultlike interpretations of adjunct control. Previous studies have produced mixed results regarding the role of explicit cues in predicting interference effects. Furthermore, for features that are often realized with explicit agreement marking like gender and number, interference effects have only been observed in contexts where these features are in fact marked for agreement. Nevertheless, reliable effects were observed in both experiments in the present chapter for gender and number, despite the lack of any explicit retrieval cues on the adjunct verb. This suggests that children's errors in previous studies on the acquisition of adjunct control were likely due in part to interference from the intervening object.

From the results from Experiments 6 and 7, a number of question arise about how children represent linguistic dependencies, from encoding to retrieval, and about

additional sources of non-adultlike behavior. These questions are addressed in the following sections.

5.5.1 How would the grammatically inaccessible antecedent be retrieved when it contrasts with the target on the relevant structural features?

In adults, interference effects are realized as slowdowns in reading time, which are taken to indicate temporary consideration of an ungrammatical antecedent. At the same time, studies with adults are not consistently designed to probe whether the grammatical antecedent was ultimately retrieved, despite the consideration of a matching distractor. This raises the possibility that consideration of the ungrammatical antecedent might even lead to an ungrammatical interpretation even in adults. However, when there are structural cues to distinguish the grammatical antecedent from other partially matching items (e.g. main clause subject, for sentences with adjunct control), a cue-based retrieval mechanism should not be expected to retrieve an ungrammatical antecedent that does not match the structural cues (for sentences with adjunct control: any non-subject distractor).

Importantly, this depends on the availability of the relevant structural features upon deployment of the retrieval mechanism: to retrieve the main clause subject, the representation of the subject in memory must still be tagged as the subject, in contrast with the representations of non-subject elements. Meanwhile, if structural information decays over time, then at some point the grammatical antecedent may no longer bear the relevant structural features. If so, then structural cues for retrieval will be less

effective as more time elapses between encountering the target and deploying the retrieval mechanism.

In adults, structural information has been shown to decay much more quickly than semantic information. In studies testing recall of structural and semantic properties of sentences, accuracy rates are high for both types of properties immediately after a test sentence is presented. However, after a delay, both for sentence recall and for change detection, accuracy rates are much higher for a sentence's meaning than for its particular structure, including information about the subject (Sachs, 1967; Mehler, 1963; Jarvella, 1971).

Although the reduced accuracy for structural information is observed in adults after a number of sentences, individual differences in recall accuracy are also observed (Gernsbacher, 1990). If these differences are related to differences in domain general memory processes – e.g. differences in overall memory capacity or decay rate – then structural information should decay much more quickly in children than in adults. Thus, at high decay rates, the structural information about the main clause may no longer be available by the time that the retrieval mechanism is deployed in the adjunct clause, especially if children are less competent than adults at encoding the structural information in the first place. As memory processes mature, structural information will then be retained for longer periods of time. Furthermore, if retrieval failure is due to the decay of structural information in memory, then imposing a working memory load with adults should also be predicted to result in a greater likelihood of retrieving an ungrammatical antecedent (e.g. in a dual task paradigm).

5.5.2 Which features are relevant for similarity-based interference in language?

The experiments presented in the present chapter found that children show similarity-based interference effects for gender and number, even when these features are not realized as explicit retrieval cues. This result is consistent with the effects observed in other studies that were also modulated by linguistic features; however, there were other features in addition to gender and number that differentiated the characters in the experiments from each other, particularly in Experiment 6. For example, the MISMATCH condition in Experiment 6 included Dora and Diego (who mismatch in gender), while the MATCH condition included Mickey and Diego (who match in gender). Although the control items also included pictures with Mickey and Dora to more evenly balance the combinations of characters throughout the experiment, other possible categorizations might be made based on e.g. species (human vs. non-human), which would generate a different set of predictions than the predictions for gender: while Dora and Diego mismatch in gender, they match in species, and vice versa for Diego and Mickey. Similarly, the characters could also be categorized based on the fictional worlds that they appear in: Dora and Diego appear in the same world, whereas Mickey appears in a different one.

For both of these alternative categorizations, which categorize Dora and Diego together rather than Mickey and Diego, the opposite prediction would be made with respect to the interference effects. In Experiment 6, lower accuracy was observed in the MATCH condition which categorized Mickey and Diego together, based on gender. These results are therefore not consistent with these alternative categorizations as the

relevant features for similarity-based interference. However, the results themselves do not provide an answer for *why* gender should be a better predictor of interference effects than other features like species or fictional world.

To address this question, the results of Experiment 6 and 7 must be considered in the context of other studies on similarity-based interference in language. In general, effects are observed for features that relevant for *linguistic* computation – i.e. that are realized as grammatical features in a language, even if the feature is not a retrieval cue for every dependency. Furthermore, a different profile is observed for features that encode semantic similarity (like a similarity in species) with no corresponding grammatical features (Lowder & Gordon, 2014; but see Van Dyke & McElree, 2006).

If interference effects in language arise as a result of overlap in *grammatical* features, however, the results of Experiments 6 and 7 raise some additional questions about the particular source of the effects.

First, in both the MISMATCH condition in Experiment 6 (36) and the MATCH condition in Experiment 7 (50), target and intervener overlapped in number (and NP type and animacy) but not in gender.

(36) Dora$_{\text{FEMALE/SG}}$ washed Diego$_{\text{MALE/SG}}$ before PRO eating the red apple.

(50) The girl$_{\text{FEMALE/SG}}$ washed the boy$_{\text{MALE/SG}}$ before PRO eating the red apple.

However, the accuracy for the MISMATCH condition in Experiment 6 (36) was 10% higher than for the MATCH condition in Experiment 7 (50).

Additionally, there was essentially no difference between the MISMATCH condition in Experiment 7 – where the target and intervener mismatched in gender and

number (*the girl*$_{FEMALE/SG}$ *washed the boys*$_{MALE/PL}$…) – and the MISMATCH condition in Experiment 6, with overlapping number (*Dora*$_{FEMALE/SG}$ *washed Diego*$_{MALE/SG}$…).

One source of the lower accuracy in Experiment 6 may be the differences between the two experiment designs, or differences in subject populations. At the same time, it is also worth considering how the differences between the gender and number features might give rise to different levels of interference, as well as the differences between the NP types used in the different experiments (i.e. the names used in Experiment 6 compared to the full NPs used in Experiment 7).

For example, nouns in English are always specified for number (either by the presence or absence of number agreement), and verbs are sometimes marked for number agreement. With some exceptions like "group," the grammatical number marking on a noun agrees with its notional number. That is, *the girl* is grammatically singular and triggers singular agreement on a verb, and also refers to a single girl; similarly, *the girls* is grammatically plural and triggers plural agreement, and also refers to multiple girls. Meanwhile, words like "group" are exceptions, because they may be interpreted as singular or plural, depending on the context (Eberhard, 1999; Humphreys & Bock, 2005; Eberhard et al., 2005; Bock, Nicol, & Cutting, 1999). This type of exception highlights the difference between the conceptual number of the referent (i.e. whether the NP refers to one or two girls) and the form of the referent (whether the NP is grammatically singular or plural). For number in English, these two properties usually align with each other.

From the design in Experiment 7 alone, it is not possible to distinguish between interference due to the storing two forms with the same grammatical number vs.

interference due to representing two referents in memory with the same notional number. Distinguishing between these two possibilities can have implications for the variation in interference effects across languages, with wide variation in the extent to which different languages require explicit number agreement. For example, English has a much more impoverished system of number agreement than many other languages, which has been argued to influence English speaker's interpretation of notional number, compared to speakers of languages with richer inflectional morphology (Vigliocco, Butterworth, & Garrett, 1996; Vigliocco, Butterworth, & Semenza, 1995; Vigliocco, Hartsuiker, Jarema, & Kolk, 1996). This would predict that interference effects for number in any given language depend on the number inflection in that language. However, other studies have found that English speakers exhibit increased sensitivity to notional number depending on its salience in a given context (Eberhard, 1999; Humphreys & Bock, 2005; Eberhard et al., 2005; Bock et al., 1999). This suggests instead that the presence of number marking in the form might have less of an influence on the conceptual representation, and that interference effects are more dependent on the similarity between referents, rather than forms.

Conceptual gender, unlike number, is only available for a few items (e.g. *man*, *woman*) but languages vary widely on the extent to which they make use of grammatical gender – from languages like Turkish and Mandarin Chinese, with no spoken gender marking, to languages like Spanish and German with grammatical gender on all nouns but no gender agreement on the verb, to languages like Hebrew and Russian, which also have verbal agreement for gender. In English, only pronouns and reflexives are grammatically marked for gender, and gender is not marked for

agreement on the verb. As such, the overlap in gender in Experiment 6 was an overlap in conceptual rather than in grammatical gender (since *Dora*, *Diego,* and *Mickey* do not bear grammatical gender marking). This contrasts with the overlap in Experiment 7, which was grammatical as well as conceptual. The finding that children exhibited interference effects for gender as well as number supports an account where both effects are due to similarity in conceptual representations, rather than (or in addition to) form (Vigliocco & Franck, 1999, 2001); however, this does not account for the difference in accuracy between (36) and (50). Furthermore, since English does make use of gender agreement in pronouns and reflexives, the influence of gender marking is not entirely clear without a similar test in a language without any gender marking (e.g. Turkish).

Finally, one factor that might have contributed to the difference in accuracy between (36) and (50) is the different NP types of the target and intervener: names in (36), and full NPs in (50). Since reading times for the NPs alone were not reliably reported in previous studies on similarity-based interference in adults, the role of NP type in Experiments 6 and 7 is not apparent. These questions will be pursued in future research.

Chapter 6: Adjunct control in the input

The experiments in the previous chapters showed that children's knowledge of adjunct control is adultlike by age four, and that their non-adultlike behavior may be attributed to task demands, and to similarity-based interference from the intervening object. In the present chapter, I discuss how children might acquire the adult grammar by the time they turn four, and what assumptions must be satisfied for learning to succeed.

6.1 Assumptions about learning in previous studies

In the adult grammar, the interpretation of PRO is determined by (a) the attachment height of the adjunct, and (b) the rule that PRO is bound by the closest c-commanding NP. A grammar with the correct attachment height but without the c-command rule will not place any restriction on the interpretation of PRO. Meanwhile, different non-adultlike interpretations are predicted for a grammar which has the c-command rule but the wrong attachment site, depending on the specific attachment site. Strict object control is predicted if the adjunct is attached too low, while discourse control with no syntactic restriction is the result if the adjunct is attached too high.

Several studies have proposed that children's errors arise from a grammar with the wrong attachment of the adjunct to the main clause (Goodluck, 1981; Hsu et al., 1985; McDaniel & Cairns, 1990; McDaniel et al., 1991; Cairns et al., 1994; Adler, 2006). These studies operate under the assumption that the c-command rule is a feature of children's grammars from the outset, and does not need to be learned from the linguistic input. However, there has been less in depth discussion of which conditions

must be satisfied for a transition to occur from a grammar with non-adultlike attachment height to the adult grammar.

First, children must have the memory resources to process the main clause and the adjunct clause. Next, they must know enough about the relation between both clauses to correctly attach the adjunct to the main clause. Under the Variable Attachment account, it is the incomplete knowledge of this relation that has been proposed as the source of children's non-adultlike behavior (McDaniel et al., 1991), which is determined by the lexical and semantic properties of the complementizers. Consequently, it is only by learning these properties that children come to attach the adjunct correctly to the main clause. Incomplete knowledge of the lexical and semantic properties, meanwhile, may be available initially, allowing children to understand some aspects of the complementizers (i.e. the temporal relations in *before* and *after*), but not attachment height. If children develop complete knowledge by encountering the complementizers in the linguistic input, then this type of account predicts that complementizers should occur in the input at detectable frequencies, but it is not spelled out how encountering a single instance would provide the particular information needed to determine the correct attachment height. Furthermore, none of the studies that give an attachment height account have included an analysis of the input to determine whether this information is available to children at the relevant ages.

Meanwhile, the researchers who have proposed that children's non-adultlike-behavior is due to a non-adultlike rule for PRO, rather than to attachment height have taken different approaches in explaining how children's grammars become adultlike. Under the Agent Control account as proposed by (Goodluck & Behne, 1992; Goodluck,

1998), children attach the adjunct correctly, but allow a free interpretation of PRO that is sensitive to the context of the experiment. As a result, it is suggested that children are more likely to select an agent antecedent in contexts with a higher proportion of passive sentences (Goodluck & Behne, 1992). In these contexts, children are predicted to exhibit adultlike behavior for sentences with an active main clause, but non-adultlike behavior with a passive main clause. Under this account, children must learn that PRO is *obligatorily* controlled by the main clause subject, with no variation by the context. No further discussion is included regarding what information in the linguistic input would allow children to learn this rule. However, if learning is specific to the interpretation of adjunct PRO, then its success hinges minimally on the availability of adjunct control in the input, and on children's ability to distinguish adjunct PRO from other referential elements with different interpretations. Additional factors that may influence the viability of this learning account are discussed in the following sections.

Finally, Wexler's Nominalization account (Wexler, 1992; Broihier & Wexler, 1995) explains children's non-adultlike behavior based on maturation of features in the adult grammar. Under the Nominalization account, PRO is biologically scheduled to mature. Once PRO matures, it is immediately interpreted correctly in complement clauses. However, an additional step is needed for adjuncts, which require a temporal operator to correctly represent the adjunct as a full clause, rather than a nominal expression. Once the temporal operator has matured, non-finite adjunct clauses are correctly attached to the main clause, with PRO as the subject. One advantage of this type of maturational account is that no specific input is needed for children to acquire the adult grammar of adjunct control. In cases where the input does not contain enough

information about the structure in question, maturation therefore offers another means of converging on the adult grammar.

In support of a maturational account for adjunct control, Broihier and Wexler (1995) conducted a corpus study using transcripts from CHILDES (MacWhinney, 2000), a database containing transcripts of speech from parents and children in naturalistic settings. In all of the available CHILDES transcripts in English, they identified only 21 instances of adjunct control, with 18 instances from utterances by adults and 3 by children. This was hypothesized not to be enough to infer a strict subject requirement on PRO.

While 21 instances may seem intuitively like too low a number at first blush, no information was provided about the number of utterances, words, or transcripts that were searched to produce these 21 instances. In the remaining sections of this chapter, I reconsider the possibility that children learn the restriction on adjunct PRO from the linguistic input. Based on an updated dataset from CHILDES, I show that immediately dismissing the input as a viable source is not necessarily warranted, and that further research is needed before making definitive conclusions.

6.2 Adjunct control in CHILDES

Since Broihier and Wexler's (1995) analysis of adjunct control in the input, the number of transcripts available in CHILDES has grown considerably, allowing for a more exhaustive analysis of adjunct control in the input. The corpus analysis in the present chapter includes data from all of the transcripts in CHILDES in North American English which had been parsed with the MOR grammar for English as of April 2014.

This dataset includes nearly 11 million words in total, and 2.8 million utterances. The dataset included speech from caretakers and from children of various ages between infancy and adolescence; speech from caretakers accounted for just under two thirds of the utterances. This corresponds to roughly 2 years of child directed speech.[5] Speech from children and caretakers will be considered in the corpus analysis.

6.2.1 Learning from the size principle

In addition to the raw number of utterances with adjunct control, there are several factors that play a role in determining which conclusions are available, given the data. The initial assumptions in spelling out these considerations are most similar to those made by Goodluck and Behne (1992), who suggested that children correctly attach the adjunct to the main clause, but start out with a grammar that allows a free interpretation of PRO. Converging on the adult grammar, then, depends on restricting the interpretation of PRO to the main clause subject. This type of non-adultlike grammar, which allows a superset of the interpretations allowed in the adult grammar, is tricky to account for: while a transition from a subset to a superset grammar can be easily accounted for based on positive evidence for the superset grammar that is incompatible with the subset grammar, the types of evidence needed to retreat from a superset grammar to a subset grammar are not as clear (Berwick, 1985; Gold, 1967; Baker, 1979; Manzini & Wexler, 1987; Pinker, 2013; Heinz & Riggle, 2011).

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[5] Akhtar, Callanan, Pullum, and Scholz (2004) estimate, based on data from (Hart & Risley, 1995), that children hear a *minimum* of 2.5 million sentences in 3 years. While the configuration of these sentences is not necessarily consistent over time, this allows for a rough estimate for the utterances in CHILDES, which occur in transcripts recorded with children generally between 1 and 6 years of age.

Since Gold's (1967) proposal, different systems have been considered to handle this type of transition. For example, the Subset Principle (Berwick, 1985) allows for learning from positive evidence if there is a specific acquisition procedure that always chooses a subset grammar when the evidence is consistent with multiple grammars. Meanwhile, under the *size principle*, smaller hypotheses are considered to be more likely than larger hypotheses (which generate a superset of the data generated by a smaller hypothesis), and exponentially more likely as more data that is observed that is compatible with both hypotheses (Tenenbaum, 1999; Tenenbaum & Griffiths, 2001; Xu & Tenenbaum, 2007). In the current analysis, I consider what kind of evidence might be available to children that would motivate them to move from a less restrictive grammar to a more restrictive one. For example, if children are able to keep track of the instances of adjunct control and the antecedent of PRO, then they may infer based on the size principle that the interpretation of the antecedent is syntactically restricted.

A crucial assumption of the size principle is that the data are randomly sampled from the true hypothesis. Applied to the acquisition of adjunct control, the assumption is that observed instances of adjunct control are randomly sampled from the hypothesis that generates the full set of interpretations for sentences with adjunct control. Based on these assumptions, it might be possible for children to converge on the adult grammar and draw the correct inference about the antecedent of adjunct PRO; crucially, this relies on the relative size of the hypothesis about the adult grammar compared to hypotheses about non-adultlike grammars, and on the amount of noise in the data.

> A learner who uses the size principle to make inferences about the antecedents of PRO is predicted to favor a stricter restriction on the

smaller hypothesis) over one which allows a wider range of hypothesis), provided that the observed data is compatible with both & Lidz, 2009; Regier & Gahl, 2004). Of the non-adultlike grammars proposed for adjunct control, some allow a free interpretation of PRO and high attachment), some allow an internal, but not an external (optional low attachment), and some allow only an object control (obligatory low attachment). Of these, all but the strict object grammar of the interpretations allowed by the adult (strict object control) relations are represented in

Figure 17, with a rough correspondence between the area of the circles and the range of interpretations generated.

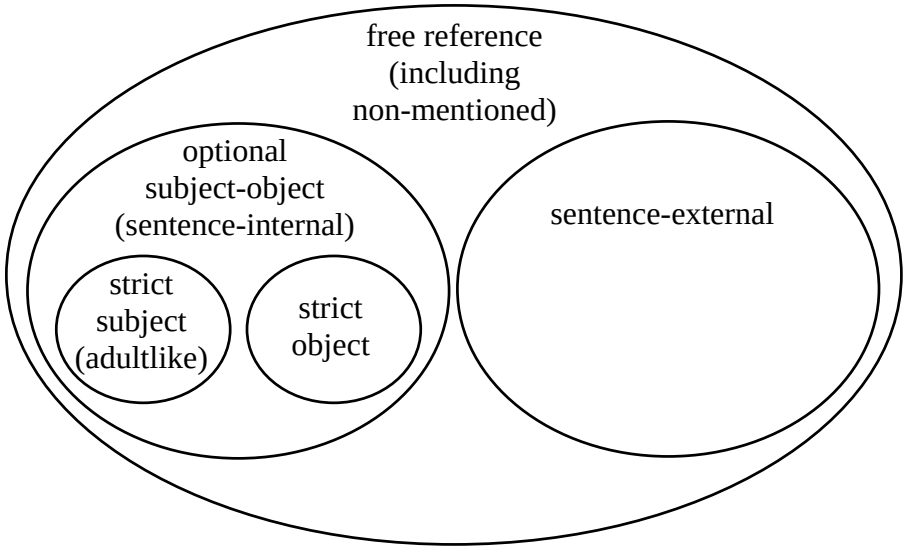


Figure 17: Overlap in data generated by different hypotheses about the antecedent of adjunct PRO. The areas correspond roughly to the relative range of data accounted for by each hypothesis (e.g. the interpretations generated by grammar with obligatory object control is a proper subset of the interpretations generated by an optional subject-object grammar).

If (a) *all* hypotheses for other grammars that can generate the same observed interpretations are larger than the hypothesis for a grammar with strict subject control, and (b) the instances of adjunct control that children do encounter are consistent with the adult grammar, then the probability assigned by a strict subject hypothesis will be exponentially greater than the other available hypotheses as the number of consistent examples increases (Xu & Tenenbaum, 2007). While (a) can be taken for granted, so long as the assumptions are correct about relative sizes of the hypotheses considered by the learner, (b) can only be evaluated by determining what information is available to a learner in the linguistic input. In the following section, I consider what factors might influence a learner's inferences from this information.

6.2.2 Learning from the context

In order for children to assign the highest probability to the hypothesis that the grammar restricts the interpretation of PRO to the main clause subject, they must observe enough instances of adjunct control with the subject as the antecedent of PRO. The number of instances that must be observed depends on the expected probability of observing a subject interpretation, compared to the actual proportion observed. For a grammar that generates all possible interpretations, the probability of observing a subject interpretation will be lower than in the adult grammar, which only generates subject interpretations. If only subject interpretations are observed in the input – consistent with the adult grammar – a learner with a grammar that generates a larger set of interpretations should note this "suspicious coincidence," and restrict their grammar accordingly (Pearl & Lidz, 2009).

However, it is not necessarily sufficient for these instances to be present in the input; they must also be present in the intake (Omaki & Lidz, 2015; Gagliardi & Lidz, 2014). That is, the data that is present in the input is not necessarily represented veridically by a learner, since the learner's representation of the input is filtered through the parsing procedures and other extralinguistic systems. If non-adultlike aspects of these systems influence how the data in the input is represented, then this data – i.e. the data in the intake, may differ from the data in the input. Because the data that the learner uses to update their hypothesis comes from the intake, rather than the input, it is therefore important to consider how the systems that the input is filtered through may influence the representations in the intake.

For children whose grammar does not restrict the interpretation of adjunct PRO, the only way to resolve the antecedent of PRO is to retrieve an antecedent from the discourse. Therefore, the discourse context must provide enough information for children to identify the correct antecedent, independent of the syntax. Otherwise, while the input may not include any ungrammatical uses of adjunct control, an unclear discourse context might introduce an ungrammatical use into the intake, if a child guesses incorrectly about the antecedent of PRO.

With a grammar that places no syntactic restriction on the interpretation of adjunct PRO, there are two different types of contexts that may be consulted when retrieving an antecedent. First, of the sentence-internal NPs, one may be a more plausible antecedent of PRO based on the content of the adjunct clause, as in (18) (a test sentence from Adler's (2006) study on the acquisition of adjunct control) and (52) (from the CHILDES Cornell corpus, PRO added to the transcription)

(18) Donald Duck went to the bank after PRO buying a truck.

(52) You got the other sock without PRO being asked to do that. (mom0282.cha)

In both (18) and (52), the adjunct verb selects for an animate subject. With only one animate NP in each main clause (*Donald Duck* in (18), and pronoun *you* to refer to the child in the conversation in (52)), there is only one plausible sentence-internal antecedent. This does not eliminate the possibility that the context will also include a plausible sentence-external antecedent (as in the test sentences used by Adler (2006)); however, as observed by Goodluck (1987), in both contexts with a truly ambiguous overt pronoun and in sentences with adjunct control, children exhibit the same strong preference for a sentence-internal antecedent over sentence-external antecedent. This suggests that even in contexts with a plausible sentence-external antecedent, children will still be biased towards a sentence internal interpretation, and will be unlikely to retrieve the sentence-external referent as the antecedent of PRO.

In sum, for sentences like (18) and (52), the combination of knowledge about a plausible subject for the adjunct verb and a bias for a sentence-internal antecedent will lead children to retrieve the correct antecedent of PRO, independent of the grammar. Furthermore, the sentence-internal bias also leads children to the correct interpretation of sentences with only one NP in the main clause, as in (53) and (54), from the CHILDES Hall corpus:

(53) You can play without PRO screaming. (sat.cha, 4;6)

(54) Babies don't talk while PRO eating. (ref.cha 4;6-5;0)

In both (53) and (54), there is only one sentence-internal NP, raising little confusion about the antecedent of PRO.

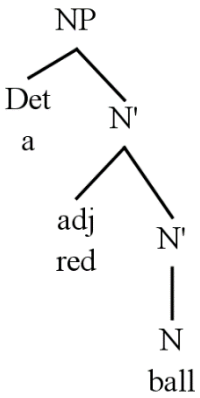
> Adultlike interpretations are predicted both for sentences like (18) and (52) (with multiple NPs in the main clause, but only one plausible antecedent) and for sentences like (53) and (54) (with only one NP in the main clause at all), independent of the grammar. However, since both types of sentences are compatible with the adult grammar *and* with the superset grammars that allow a wider range of interpretations (in Figure 17), the size principle assigns the highest probability to the adult grammar, i.e., the smallest subset grammar. This suggests that even the instances that don't require the adult grammar to access the correct interpretation would be informative for a learner, because of the assumptions of the size principle.

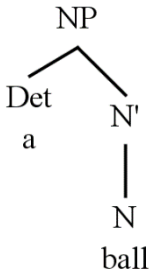
Meanwhile, this kind of data has been shown to be less informative for other structures; in particular, for the acquisition of anaphoric "one" (Pearl & Lidz, 2009):

(55) a. Jack wants a red ball. Lily doesn't have *one* for him.

b. a. Jack wants a ball. Lily doesn't have *one* for him.

In (55a), *one* is anaphoric to *red ball*, while in (55b), *one* is anaphoric to *ball*. In both cases, *one* is anaphoric to a constituent of the category N':

(56) a. 

b. 

In (55b), however, *ball* is ambiguous between N' and N. Since only one interpretation is available for *one* in this context (*ball*), the adult grammar that

specifies that *one* is anaphoric to N' is not necessary for accessing the correct interpretation. These instances are analogous to the sentences with adjunct control with only one plausible antecedent for PRO, in that neither requires the adult grammar for determining the correct interpretation. However, unlike the instances with adjunct control, for which the size principle does favor the adult grammar, Pearl & Lidz (2009) showed that the size principle favors a *non*-adult grammar for instances like (55b) – in particular a grammar that treats anaphoric *one* as N rather than N'. Consequently, Pearl & Lidz (2009) concluded that the instances with only one plausible interpretation for anaphoric *one* must be not be included in the data that is used by the learner to converge on the adult grammar.

This restriction on the data that the learner can use for anaphoric *one* raises questions about how the analogous data should be treated for adjunct control, for which the adult grammar is not needed to access the correct interpretation (e.g. for the sentences in (18), (52), (53), and (54)). While the size principle does favor the adult grammar for the sentences with adjunct control, a model which includes all of the data for adjunct control but excludes some of the data for anaphoric *one* only raises additional questions about how a learner would know which data to attend to for which phenomenon. More realistically, a learner would be expected to (a) use all of the data in the input distribution for any given phenomenon, which would require an alternative explanation for how children could converge on the adult grammar for anaphoric *one*, or (b) adopt the same strategy for adjunct control as for anaphoric *one*, and attend only data that provide the opportunity to observe the adultlike interpretation selected over a non-adultlike one. For example, in sentences like (55a), the antecedent of *one* is the N'

constituent *red ball*. Repeatedly observing instances like this where the N' constituent is selected over N (*ball*) serves as the "suspicious coincidence" that supports the adult grammar (Pearl & Lidz, 2009; Akhtar, Callanan, Pullum, & Scholz, 2004); crucially, these contrast with (55b), where the only possible interpretation does not distinguish between N and N'.

Similarly, the corresponding data for adjunct control must consist of instances where multiple plausible antecedents are available, so that a learner can repeatedly observe the grammatical antecedent selected over other plausible antecedents. However, before a learner has converged on the adult grammar, additional information is needed to select the correct antecedent. If children have a grammar that does not restrict their interpretation of adjunct PRO, then this information must come from the discourse context. The more informative the discourse context is about the antecedent of PRO, the less likely the intake is to contain instances of adjunct control that are inconsistent with the adult grammar. Meanwhile, with instances that are underinformative about the antecedent of PRO, non-adultlike interpretations of the input are more likely to arise, making it more difficult for the learner to converge on the adult grammar.

For example, the context in the following exchange between a parent (P) and a three-year-old child (C) does not clearly support a single interpretation of adjunct PRO (from the CHILDES Providence corpus):

(57) a. C: [child hugs doll] Hug for Oscar.

b. P: A hug for Oscar?

c. C: Yeah.

d. P: Don't take it off.

e. P: I'll give you a hug, I can give you a hug without PRO taking that off. (wil39.cha 3;1)

In (57e) the main clause contains two NPs, *I* (the mother) as the subject, and *you* (the child) as the object. The subject control interpretation is plausible; however, in the previous utterance, (57d), the adjunct verb in (57e) (*taking*) is used as an imperative (*take*) with the child intended as the subject. This context could instead support an interpretation with the child as the subject of *taking* in (57e) – an object control interpretation, which is inconsistent with the adult grammar.

Furthermore, other contexts may unambiguously support an ungrammatical interpretation of adjunct PRO. For example, the following utterance has a clear subject control interpretation without a context (from CHILDES Suppes corpus):

(58) P: I thought we could give her some tea before PRO going to bed from this pretty little tea pot. (nina53.cha 3;2)

In (58), the subject of the embedded clause (where the adjunct attaches) is *we*, which is plausible antecedent of PRO in the context of the sentence by itself. However, a different interpretation is supported when the preceding discourse is included, in which the mother and the child are playing with a doll:

(59) P: Now we're gonna give her some breakfast.

C: No she's gonna go to bed.

P: She's gonna go to bed?

C: Uhhuh [= yes].

P: Maybe she would like something to eat before PRO going to bed.

P: Where's the other wash cloth?

P: I thought we could give her some tea before PRO going to bed from this pretty little tea pot.

From the discourse in (59), it becomes clear that the indirect object in (58) (*her*, referring to the doll), as the topic of the discourse, was the actual intended antecedent of PRO. Additionally, another instance of adjunct control is observed just two utterances prior to the instance in (58), with the exact same referent as the antecedent of PRO (*she*, referring to the doll), but in the subject position of the main clause. Therefore, for this discourse context alone, the smallest hypothesis that is consistent with both instances of adjunct control is the sentence-internal hypothesis. In considering the instances of adjunct control in the input, it will be important to note what proportion of the data require closer attention to the discourse, and are more likely to result in an interpretation that is inconsistent with the adult grammar.

6.2.3 Instances of adjunct control

To identify the instances of adjunct control within the 2.8 million utterances mentioned above, I used the search criterion described by Broihier and Wexler (1995). This search included all utterances containing the string “before” followed by “ing” in

the same utterance (with any number of intervening characters), “after” followed by “ing,” and “while” followed by “ing.” In addition to these searches, I also conducted searches for “without” followed by “ing,” “instead” followed by “ing,” and “for” followed by “ing.” The motivation for this additional search was drawn in part from Adler's (2006) prediction that children should show more adultlike behavior for adjuncts that can only appear in a non-finite frame (e.g. *without, instead of,* and *for*) than for adjuncts that can appear in both finite and non-finite frames (e.g. *before, after,* and *while*). If this difference is also reflected in the input distribution, then this may be another source of children’s pattern of behavior, independent of the non-adultlike grammar proposed by Adler (2006). A search was also conducted for “despite” followed by “ing,” but none of the four instances of “despite” in CHILDES involved adjunct control.

While these search terms identified many instances of adjunct control, they were also sensitive to utterances containing sequences without adjunct control like “before something was the matter” and “what happens after spring?” To filter out these utterances, the output of the searches was coded by hand for whether the utterance contained an instance of adjunct control. Also included in the coding schema were which NP was the antecedent of PRO, and how many plausible or implausible referents were also available in the sentence context. The raw numbers from these searches are presented in Table 13, by complementizer.

Complementizer	Example	Counts
after	I think you should take a shower tonight after running.	52
before	I want a story before going to sleep.	33
while	It curls back its trunk while feeding.	27
without	I'm just holding a cup without making it crack.	207
instead of	You eat it instead of giving it to the doggie.	181
for	Can you scold Jennifer for stepping on the truck?	360
	Total	860

Table 13: Instances of non-finite adjuncts in transcripts from CHILDES in North American English, over roughly 2 years of input.

Immediately apparent from Table 13 is that even for *after, before,* and *while,* there are more instances of adjunct control in the corpus than in the analysis by Broihier and Wexler (1995). Furthermore, the complementizers that were not included in the previous search (*without, instead of,* and *for*) occur at a much higher frequency than those included in the original search. Finally, the type of adjunct that occurs at the highest frequency is the one with the complementizer *for,* which is exceptional in that it does not follow the rule of subject control that is observed for the other non-finite adjuncts:[6]

(60) John$_1$ bumped Mary$_2$ for PRO$_{*1/2}$ tripping on the sidewalk.

(61) John$_1$ was bumped by Mary$_2$ for PRO$_{1/*2}$ tripping on the sidewalk.

While the complementizers discussed so far select for a non-finite complement with a subject control interpretation, the antecedent in the same non-finite frame with *for* varies by the voice of the clause (i.e. active vs. passive). Therefore, in addition to learning the strict subject requirement for the complementizers that require subject

[6] The search for instances of *for* also returned instances of purpose clauses, as in "Mommies are not for hitting." These were not included in the analysis.

control, a learner must also distinguish between the complementizers that require a strict subject interpretation on the one hand, and *for* on the other.

The exception of *for* raises the question of whether children would take a by-complementizer or a by-frame approach in learning from the instances of adjunct control in the input. With a by-complementizer approach, the strict subject rule would be learned for each complementizer individually, without drawing generalizations between complementizers. By treating each complementizer separately, there is very little risk of drawing the wrong conclusion as a result of generalizing the pattern from *for* to the other complementizers as well. However, for a learner to settle on the rule in the adult grammar – that subject control is observed for non-finite adjuncts *in general*, rather than for adjunct clauses headed by specific complementizers – this strategy requires the additional realization that the same source is responsible for the distribution of antecedents for all of the complementizers, other than ones observed for *for*.

Alternatively, with a by-frame approach, children might treat all instances of non-finite adjuncts as a single category, and determine the probability of a subject interpretation based on the distribution for all non-finite adjuncts, collapsed across the different complementizers. In this case, the learner would need to realize that adjuncts with *for* as the complementizer do not have the same strict subject restriction as other complementizers, and should therefore be categorized separately.

For both approaches, distinguishing the strict subject complementizers from *for* depends on how much noise is present in the input, which would introduce non-adultlike interpretations into the intake distribution. For example, generalizing across

complementizers in the by-complementizer approach depends on observing similar (high) proportions of subject antecedents for the complementizers that require a strict subject interpretation. However, the amount of noise in the input can affect how similar these proportions are in the intake, and might prevent the correct generalization across complementizers if a strict subject requirement is not observed for each one. Similarly, categorizing *for* differently from the remaining complementizers in the by-frame approach depends on observing a different enough proportion of subject interpretations for *for* adjuncts from the proportion of subject interpretations observed for the remaining adjuncts (discussed further in §6.3.2.1). The amount of noise in the input can therefore affect how different the distribution for *for* adjuncts is perceived to be from the remaining adjuncts, as well as how much similarity is perceived between the remaining adjuncts, in order to motivate a separate category for the *for* adjuncts.

As discussed above, based on the parallels between the data for adjunct control and the data for anaphoric *one*, the type of utterance that a learner should most closely attend to is the type with multiple plausible referents in the sentence context. At the same time, for these instances a learner with a grammar that does not restrict the interpretation of PRO can rely only on the discourse context to resolve the antecedent of PRO, especially when both referents are sentence-internal. The frequencies of these types of instances are listed in Table 14.

On average, just 12% of the instances of adjunct control include more than one plausible antecedent (Table 14). This number is most reliable if children have a preference for a sentence-internal antecedent and are able to use plausibility information in resolving the antecedent of adjunct PRO. However, these considerations

are further dependent on whether each context provides enough information for the learner to retrieve the correct antecedent, and on the amount of noise that can be tolerated by the learner in converging on the adult grammar for each complementizer individually or the set of non-finite complementizers as a category. In the following section, I discuss some further constraints on these parameters.

Complementizer	Raw total	Raw >1 plausible referent	% >1 plausible referent
after	52	3	6%
before	33	3	9%
while	27	0	0%
without	207	22	11%
instead of	181	27	15%
for	360	44	12%
Totals	860	99	12% (average)

Table 14: Number of utterances with more than one plausible referent of PRO adjunct PRO, by complementizer, over roughly 2 years of input.

6.2.4 Additional considerations: prerequisite knowledge and timing

In discussing the information available in the linguistic input, it is important to consider what kind of grammatical knowledge must already be in place for a learner to make use of this information (Sutton, 2015). Furthermore, the result from Chapter 4 that children show adultlike behavior for adjunct control by age four places an upper bound on the time by which the learning process must be complete. At the very least, the types of grammatical knowledge that must be in place for a learner to compute the probabilities involved in the size principle for adjunct control include knowledge of binding relations between a main clause and an adjunct clause, and knowledge of finite vs. non-finite tense distinctions.

A number of studies on children's knowledge of binding relations have found that even very young three-year-olds can make accurate judgments about binding relations between a main clause and an adjunct clause. For example, in the sentences in (62) and (63) (adapted from Kazanina & Phillips (2001)), three-year-old children correctly accept a coreferential interpretation when there is no Principle C violation, but reject a coreferential interpretation that is blocked by Principle C (Crain & McKee, 1985; McKee, 1992).

(62) Pooh$_1$ ate the apple while he$_{1/2}$ was reading a book.

(63) He$_{*1/2}$ ate the apple while Pooh$_1$ was reading a book.

Similar performance has also been observed in three-year-olds for binding relations between a main clause and an adjunct clause for Principle A, with a full NP or name in one clause, and a reflexive in another (McKee, 1992). We can be confident, then, that children are able to compute binding relations between a main clause and an adjunct clause by age three, if not younger.

Next, a learner must be able to distinguish non-finite adjuncts from finite adjuncts, in order to exclude finite adjuncts from the relevant probability distributions over non-finite adjuncts. This distinction is crucial, because while all of the non-finite adjuncts require a subject control interpretation (except for those with *for*), finite adjuncts require an overt subject, and thus do not place any restriction on the interpretation of the subject:

(64) Bill$_1$ called yesterday. John$_2$ bumped Joe$_3$ after he$_{1/2/3/4}$ tripped on the sidewalk.

In contrast to adjunct PRO, the subject of a finite adjunct can grammatically corefer with any sentence-internal NP (barring contexts that would result in a Principle C violation, as in (63)), or sentence-external NP. As these interpretations are all realized in the linguistic input for finite adjuncts (Table 15), ignoring this distinction would result in the wrong conclusion about adjunct PRO.

		coreference with		
	Total	main clause subject (*John* in (64))	other internal referent (*Joe* in (64))	external referent (*Bill* in (64))
after	465	268	37	160
before	803	426	90	287
while	314	104	33	177

Table 15: Frequencies of finite adjunct subjects by subject referent, in transcripts from CHILDES in North American English (coded by hand), over roughly 2 years of input.

In studies comparing children's understanding of finite and non-finite clauses in similar contexts, four-year-olds distinguished between finite and non-finite complement clauses (Syrett & Lidz, 2011; Harrigan, 2015), and children demonstrate an understanding of tense in main clauses at much younger ages (Guilfoyle, 1984; Marcus et al., 1992). Additionally, finite and non-finite adjuncts differ by an even more salient cue: while finite adjuncts have an overt subject, the subject in non-finite adjuncts is not pronounced. As this distinction is surely detectable for three-year-olds, the *latest* age at which children are likely to have acquired all of the grammatical features to begin tracking the antecedents in non-finite adjuncts can be set at three years of age. In all likelihood, these features are available even earlier, although due to constraints on working memory capacity, children's ability to track referential dependencies between

a main clause and an adjunct clause with any reliable consistency may be highly limited before age two.

From the upper limit of four years from the experiments in Chapter 4, and the lower limit based on when the relevant grammatical features in non-finite adjuncts are available for tracking the antecedent of adjunct PRO, we can estimate that a learner has between one and two years to converge on the adult grammar of adjunct control. This estimate matches up roughly with the 2 years estimated for the CHILDES data, although a computational model will be needed to further evaluate exactly what conclusions are available, given the data.

6.3 Alternative learning accounts

6.3.1 Previous accounts

Most studies on the acquisition of adjunct control have assumed that the strict subject rule is already specified in children's grammars, and have proposed that their grammars are non-adultlike due to misattachment of the adjunct to the main clause (Goodluck, 1981; Hsu et al., 1985; McDaniel & Cairns, 1990; McDaniel et al., 1991; Cairns et al., 1994; Adler, 2006), or to an inability to represent PRO before it becomes available via maturation (Wexler, 1992). The maturation account is difficult to evaluate empirically, however, because it makes the same predictions as other accounts with the highest proportion of non-adultlike behavior predicted in the youngest children, and more adultlike behavior in older children. This pattern is consistent with maturation, but also with several other types of accounts.

In contrast, the learning story from the studies that have proposed variable attachment must be considered for all accounts, to a given degree. This is because in order to correctly attach the adjunct to the main clause, children must somehow learn the correct attachment site for the complementizers in their language, under any account of language acquisition. Under the Nominalization account, the Agent account, and the input account discussed above in §6.2, this step is essentially taken for granted, without any consequences for children's interpretation of adjunct control; for the Variable Attachment account, it is the source of children's non-adultlike behavior.

Under McDaniel et al.'s (1991) Variable Attachment account, children's limited processing resources lead them to represent attachment incorrectly in their grammar, with the adjunct attached too high. This analysis is later abandoned in favor of the adult grammar (with optional intermediate stages involving other non-adultlike structures). Importantly, children discard their initial high attachment analysis for each complementizer based on its lexical and semantic properties.[7] An advantage of this account is that it does not depend on the availability of non-finite adjuncts alone, since the complementizers may also be encountered in other syntactic frames (e.g. finite adjuncts) at higher frequencies, but with the same attachment height. However, McDaniel et al.'s (1991) account is less specific about the specific lexical properties of the complementizers that determine attachment height, and how those properties could be learned by encountering the complementizers in the input.

[7] See also Adler's (2006) misattachment account, which proposes that children converge on the adult grammar upon encountering evidence that distinguishes adjuncts from conjoined clauses.

6.3.2 Proposed account

The experiments in this dissertation showed that children's interpretations of adjunct control are highly dependent on the particular context. For all of the experiments, a sentence-internal ungrammatical antecedent was also available. The corpus analysis presented in §6.2 revealed that approximately 12% of the utterances in the input have this form, which would require (minimumally) either (a) the adult grammar or (b) additional support from the discourse context to guarantee an adultlike interpretation. Additionally, the studies by Adler (2006) and Broihier and Wexler (1995) showed that even with only one plausible sentence-internal antecedent (as in (18) and (52)), children will still sometimes access an ungrammatical, sentence-external interpretation of adjunct PRO. Finally, as demonstrated by the discourse contexts in (57) and (59), the adultlike interpretation is not always supported by surrounding discourse in the input.

Based on these considerations, a statistical learning mechanism that uses information about the antecedents in the input will face problems in inferring a syntactic restriction on adjunct PRO, once the high probability of non-adultlike interpretations are taken into account. These problems are further magnified by any individual differences in both the availability of adjunct control in the input, and in the sensitivity to the discourse context when retrieving an antecedent. If children do not acquire the adult grammar of adjunct control by tracking the antecedents of PRO in the input, the focus on which properties to learn shifts back to the attachment height of the

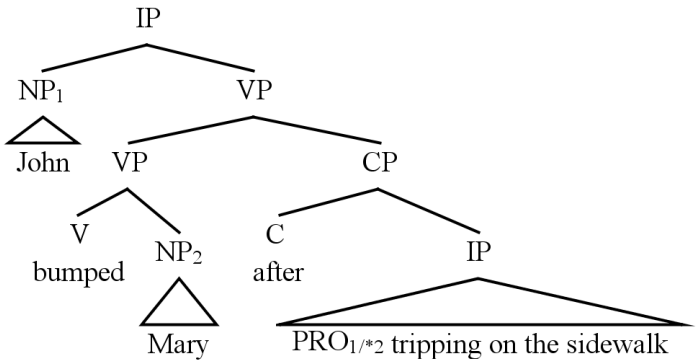
adjunct and the c-command rule (PRO is controlled by the closest c-commanding NP of the next highest clause).

6.3.2.1 Attachment height

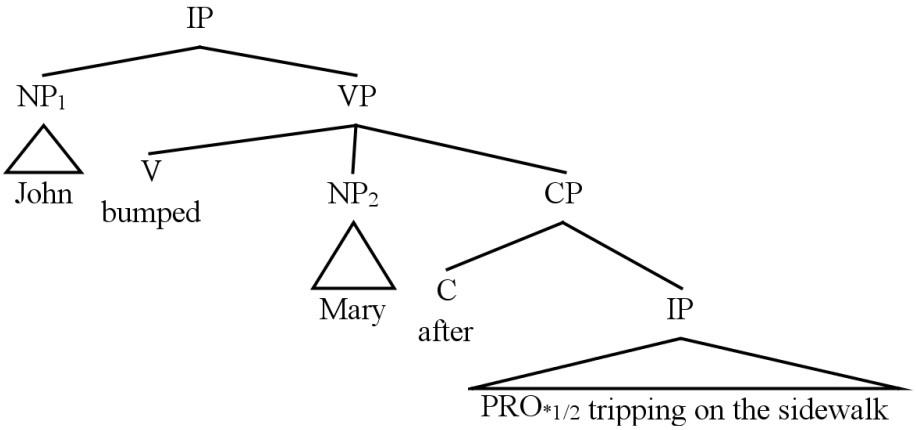
Other than the Nominalization analysis, which involves a maturation account and therefore does not make testable predictions about learning from the input, the primary proposal has been that children take a *by-complementizer* approach (as discussed in §6.2.3) based on specific properties of the complementizers themselves. The one exception to this is Adler's (2006) proposal, a *by-frame* approach, which depends on the availability of specific evidence from the input to infer that non-finite adjuncts differ from conjoined clauses (and should thus be attached at a different site). The proposed evidence for this distinction is not supported with a corpus analysis, however, and consists of complex constructions that are unlikely to occur at any detectable frequencies in the input. At the same time, Adler's (2006) proposal has the advantages described in §6.2.3 for a by-frame approach. The current proposal therefore expands on this by-frame approach, with a few key modifications.

First, I assume that complementizers that occur with a full (finite or non-finite) complement clause are attached at the VP level (as in (11), repeated below) by default, with evidence needed from the input for low-attaching adjuncts with a c-commanding object (as in (26), repeated below). A learner is tasked, then, with distinguishing clausal complements from adjuncts. These are differentiated on various features; furthermore, verbs that subcategorize for clausal complements are relatively frequent in the linguistic input (Harrigan, 2015).

(11)



(26)



The primary exception to high attachment that occurs in the same context as the high attaching adjuncts is the instances of adjunct control with the complementizer *for*, which can have a subject control *or* an object control interpretation, as discussed in §6.2.3:

(60) John$_1$ bumped Mary$_2$ for PRO$_{*1/2}$ tripping on the sidewalk.

(61) John$_1$ was bumped by Mary$_2$ for PRO$_{1/*2}$ tripping on the sidewalk.

While *for* is exceptional in that it exhibits a different pattern of interpretation compared to the other complementizers included in the present corpus analysis, it does not present

a problem for the proposed account, since the *for* adjuncts occur at a much higher frequency than the other types of non-finite adjuncts (Table 13). Additionally, out of the 360 instances of non-finite adjuncts with *for*, 266 of them (74%) occurred in the frame "*thank you for ___ ing*," as in (65), from the CHILDES Providence corpus:

(65) Thank you$_1$ for PRO$_1$ helping me.

(wil07_2.cha 1;8)

In the vast majority of these "thank you" instances, there was no explicit subject, and so for these instances alone, a strategy could be available of retrieving the only plausible NP in the main clause as the antecedent of PRO. However, out of the remaining instances, many included multiple plausible antecedents in the main clause with the same use of *for* as in (65), which would not be compatible with this kind of plausibility strategy (from the CHILDES Providence corpus):

(66) I'm$_1$ very proud of you$_2$ for PRO$_2$ making a good decision.

(ale47.cha 3;3)

Between the instances with *for* in the "*thank you for ___ ing*" frame and the additional instances with an object interpretation of PRO, there should be enough evidence in the input that *for* adjuncts are an exception, and can attach low. Importantly, evidence must also be available that *for* adjuncts do not *only* attach low, since a subject interpretation is *also* available. Of the instances not in the "*thank you for ___ ing*" frame, 30 had an object interpretation of PRO (as in (66), 50 had a subject interpretation (67a), and 5 had an external interpretation (67b):

(67) a. Your sister$_1$ just got in trouble for PRO$_1$ doing that.

(vio52.cha 3;9, from the CHILDES Providence corpus)

b. I thought it was getting stickers for PRO$_1$ pulling up your$_1$ pants!

(mat40.cha 4;1, from the CHILDES Weist corpus)

In sum, the data available in the linguistic input about the exceptionality for *for* is likely to be sufficient to distinguish *for* from the consistently high-attaching adjuncts; however, a computational model would be needed to confirm this prediction.

One potential complication for an account with default high attachment may be presented by depictives, which may attach high or low, depending on whether they modify the subject or the object, respectively (adapted from Williams (1980)):

(68) John$_1$ ate the meat$_2$ nude$_1$.

(69) John$_1$ ate the meat$_2$ raw$_2$.

As demonstrated by (68) and (69), depictives occur in the same linear position when they modify the main clause subject (as in (68)) as when they modify the main clause object (as in (69)). However, similar analyses have been proposed as for control constructions in terms of their subjects (a null PRO), and the c-command rule that determines the antecedent (Williams, 1980; Bowers, 2001). If children attach the adjunct high by default, with sufficient evidence needed for low attaching adjuncts, then further research is needed to confirm the availability of low attaching depictives in the linguistic input. Alternatively, if depictives do not occur at sufficient frequencies in the input, then acquisition will be expected to be significantly delayed; otherwise, a

more fine-grained account is needed to explain how children learn attachment height for clausal adjuncts, with a separate account for depictives.

6.3.2.2 Control by the closest c-commanding NP

Most of the studies on the acquisition of adjunct control have assumed that control by the closest c-commanding NP is a principle of Universal Grammar (UG), with no role of the input in the acquisition of this rule (but see Goodluck & Behne, 1992). Crosslinguistically, this rule is highly consistent, and if it were not a principle of UG, inferring the c-command rule from the input would necessarily involve keeping track of antecedents in the input.

In previous studies that investigated the acquisition of control in complement clauses as well as adjunct clauses, children have consistently exhibited adultlike behavior for complement control (as in (14b), repeated below) before adjunct control (Cairns et al., 1994; Hsu et al., 1985; McDaniel et al., 1991).

(14) b. $Bill_1$ told $John_2$ $PRO_{*1/2}$ to leave.

Since the corpus analysis in the present chapter did not include data for instances of complement control, it is not currently possible to evaluate whether enough information is available in the input for children to infer the control rule from complement control. However, it is not immediately obvious that a learner would draw a meaningful connection (at least with respect to the c-command rule) between complement control and adjunct control, which would depend on assigning the same analysis to PRO in (14b) as to PRO in sentences with adjunct control. Although the same notation is used in many leading theories of control, as outlined in Chapter 1, there are several

differences between the contexts that PRO occurs in for complement control that contrast with adjunct PRO. These differences cast doubt on the possibility of a learner applying a rule for complement control to the relevant contexts for adjunct control, based solely on the distributions in the linguistic input.

Because of the crosslinguistic prominence of the c-command rule in explaining control relations, as well as the questionably reliable alternative of tracking the antecedents of PRO in the input, the current proposal maintains the assumptions made in most previous studies, that the c-command rule is a principle of UG.

If the default setting for non-finite adjuncts is the correct attachment height, and the c-command rule is already part of UG, then what do children have to learn, and why do they exhibit non-adultlike behavior? As discussed in the previous section, children must distinguish adjuncts and the complementizers that select them from other types of clauses – in particular, from complement clauses that are selected by the verb, as well as conjoined clauses. As information about verb subcategorization and conjoined clauses is relatively frequent in the linguistic input, the main sources of children's nonadultlike behavior are the ones discussed in Chapters 2, 4, and 5 in this dissertation, which addressed how different extragrammatical factors can influence children's interpretations, independent of the grammar.

6.4 General discussion

In the present chapter, I reviewed previous accounts of how children acquire the adult grammar of adjunct control, and discussed the requirements for learning the strict subject restriction on adjunct PRO from the distribution of non-finite adjuncts in

the input. There were two main yet-to-be-determined factors that prevent a conclusion from being drawn about whether the subject restriction can indeed be learned.

First, with 12% of the instances of adjunct control containing multiple plausible antecedents, it is unclear how often a learner might retrieve the wrong antecedent for adjunct PRO, depending on the discourse context. Next, the size principle may allow a learner to converge on the correct (strict subject) grammar for adjunct control, but success is dependent on the amount of noise in the intake. If too many instances are present in the intake with a non-subject interpretation of PRO, then a learner may not converge on the correct grammar. Finally, these parameters are constrained by the age at which children have the grammatical knowledge and parsing abilities required for linking adjunct PRO to an antecedent, and by the age at which children demonstrate adultlike behavior for adjunct control, indicating that they have already acquired the adult grammar.

The results presented in this dissertation provide evidence that children's interpretations of adjunct control are highly variable depending on the processing demands of the task, and are more error prone in contexts with a grammatically inaccessible NP that shares features with the grammatical antecedent (Chapter 5). The implications of these results are not entirely clear if learning the adult grammar of adjunct control requires only the acquisition of semantic and lexical knowledge of the complementizers, as proposed under the Variable Attachment account (McDaniel et al., 1991). However, they bear directly on the learning account considered in §6.2, in which children track the statistics for adjunct control based on their antecedents. This is because these results suggest that children's more limited processing resources will

serve as an additional source of noise in the intake, on top of any uncertainty introduced by the discourse context. The more noise is introduced into the intake, the more information is needed to provide a clear enough signal for children to draw the correct conclusions from the input.

The experiments presented in this dissertation demonstrated how children's interpretations may be non-adultlike much of the time, even with the adult grammar, and that adultlike behavior is consistent only in contexts with a much more simplified task. This suggests that in real-world contexts, many of the instances of adjunct control will be interpreted incorrectly. As a result, the information available in the input will be consistent with the non-adultlike grammars in Figure 16, rather than the adult grammar. Children's susceptibility to non-adultlike interpretations therefore places a major hurdle in the path of a statistical learning mechanism that depends on having a clear signal of the intended interpretation.

Chapter 7: Conclusion

In this dissertation, I explored how children's non-adultlike behavior can inform a model of language acquisition and language processing, using children's errors for adjunct control as a case study. First, I provided evidence that grammatical analyses cannot fully account for children's errors, and I suggested that extragrammatical factors must be considered in explaining children's behavior. To support this, I showed that children's behavior was influenced by task effects, and by similarity-based interference. Finally, I discussed the assumptions needed in considering the role of the linguistic input. In this conclusion, I will summarize the key findings of the dissertation, and discuss some remaining questions to be considered in future research.

7.1 Key findings

The first goal in this dissertation was to spell out the predictions of previous grammatical accounts, and to test these predictions without the methodological concerns that might have influenced children's behavior in previous studies. In Experiment 1, we reproduced 4-5 year old children's non-adultlike behavior for sentences with adjunct control, establishing a baseline for comparison with the following experiments.

To test the proposal that children's grammars treat sentences with adjunct control as ambiguous, in Experiment 2 we compared children's behavior for adjunct control to truly ambiguous sentences involving discourse anaphora. Despite their errors for sentences with adjunct control, children nevertheless showed a contrasting pattern

of behavior for the ambiguous sentences. While children showed a preference for the adultlike interpretation for sentences with adjunct control, they exhibited no preference for the ambiguous sentences, demonstrating that their interpretation of adjunct PRO is not discourse-driven.

Next, we addressed the proposal that children's interpretations of adjunct PRO are driven by an agent strategy. As described by Goodluck (Goodluck & Behne, 1992; Goodluck, 1998), this interpretive strategy predicts adultlike performance for sentences with an active main clause, where the same referent is picked out by both the agent and the subject, but non-adultlike performance with a passive main clause. Furthermore, the proportion of agent interpretations was proposed to be dependent on the context, with more agent interpretations predicted in contexts with a high proportion of passive sentences. Using similar stories to those in Experiments 1 and 2, but with contexts supporting the use of a passive main clause, we observed the same pattern of behavior for children and adults. Although children again made more errors than adults, their behavior patterned in the opposite direction of the pattern predicted by an agent strategy. Since all of the test and control sentences had a passive main clause, the results of Experiment 3 showed that children do not use an agent strategy for interpreting adjunct PRO, even in contexts with a high proportion of passive sentences.

The final grammatical account addressed in this dissertation was the Variable Attachment hypothesis. For the low attachment grammar, which was proposed to account for children's object control interpretations, different binding relations are predicted between the main clause and an adjunct than for the adult grammar. One such relation involves a pronoun in the object position in the main clause and an R-

expression in an adjunct. Co-reference is permitted in the adult grammar between the pronoun and the R-expression, because the adjunct is attached such that the pronoun does *not* c-command the R-expression. In contrast, coreference is ruled out by Principle C for the low attachment grammar, because the main clause object *does* c-command the R-expression.

We found in Experiment 4 that with a context that allowed both a sentence-external interpretation (available with both grammars) and a sentence-internal interpretation of the pronoun (available only with the adult grammar), children's interpretations patterned with adults', both in their responses to the truth of the test sentences, and in the types of justifications provided. The parallel behavior for children and adults provides evidence that children have access to the adult structure, although as discussed in §3.4.6, the design in Experiment 4 did not rule out the hypothesis that children never access a low attachment structure. While their justifications were consistent with those predicted for the adult grammar, the overall rate of justifications in Experiment was much lower than in Experiments 1-4, leaving open the possibility that a low attachment structure might have been accessed on trials where no clear justification was given. Nevertheless, children's acceptance of both sentence-external and sentence-internal interpretations is consistent with the predictions of an adult grammar, with further support from the parallel pattern of behavior observed in adults.

In all three of the experiments that tested the predictions of grammatical accounts (Experiments 2-4), children's behavior patterned with adults', in contrast with the behavior predicted by the non-adult grammars. The second goal of this dissertation,

then, was to determine the role of extragrammatical factors in predicting children's behavior (Experiments 5-7).

First, we spelled out the ways that task-specific factors in the Truth Value Judgement Tasks used to investigate children's interpretations of adjunct control may have influenced children's behavior. By reducing the number of steps needed to produce a response, we observed significantly higher accuracy in 4-5 year olds. Furthermore, unlike in the TVJT experiments, accuracy was strongly correlated with age, with above chance accuracy observed for older 3-year-olds but not for younger 3-year-olds. Consistent with Experiments 1-4, these results support the conclusion that children's grammars are adultlike by age 4, and suggest that their behavior in previous studies was influenced by task-specific processing factors.

Finally, we reviewed previous research on similarity-based interference in adults, and argued that the results observed for children in similar contexts are not inconsistent with these models. With the same type of manipulation for sentences with adjunct control, we observed the pattern of behavior predicted by a similarity-based interference account, with lower accuracy when the target and intervener matched in features than when they mismatched, for both number and gender.

Although previous studies have observed interference effects for gender and number for other constructions, these constructions included explicit retrieval cues for gender or number (e.g. reflexive anaphors, pronouns, or relative clauses with explicit agreement marking on the verb). Interference effects in these studies have been attributed to retrieval interference, that is, interference due to partial match between retrieval cues and a grammatically inaccessible intervener.

Meanwhile, gender and number are not explicitly marked for agreement on the verb in a non-finite adjunct, suggesting that the interference effects for adjunct control should be compared instead with other contexts where interference effects are observed without explicit retrieval cues. For example, interference effects are observed for NP type and animacy, in children and in adults. However, the source of these effects, as well as the differences between children and adults, is not well understood. These issues will be considered in the following section, along with other remaining questions in the dissertation.

7.2 Open questions

The experiments presented in this dissertation examined children's interpretations of adjunct control, with a more general goal of investigating how the factors that influence children's interpretations of adjunct control might interact with their interpretations in other contexts, and how these factors affect the information that children access in the linguistic input. In drawing more general conclusions from the results, a number of questions remain about the source of the observed effects, especially when it comes to the manipulations addressing extragrammatical factors.

7.2.1 Why were children more accurate with the coloring task than with the TVJT?

The introduction in Chapter 4 outlined several aspects of the TVJTs that have been used to investigate children's interpretations of adjunct control that might have introduced task effects for those studies in particular. For example, all of the TVJTs that have looked at adjunct control have used temporal ordering to distinguish between true and false contexts. Comparing the order of two events in order to determine a truth

value may have increased the difficulty associated with the task. At the same time, children were able to provide clear justifications for their true/false judgments the vast majority of the time. This suggests that any difficulty associated with comparing the order of events did not prevent children from selecting an antecedent to adjunct PRO, at least for the trials for which clear justifications were provided. However, it does not rule out the possibility that this difficulty interfered with children's ability to deploy the relevant grammatical constraint when retrieving an antecedent. If so, this would predict that the same high accuracy in the coloring task should also be observed for a TVJT with a contrast other than temporal ordering to determine the truth value of the test sentences.

Observing higher accuracy in a TVJT with a different contrast than temporal ordering would provide support for the difficulty associated with evaluating the order of events as one source of children's non-adultlike behavior. However, it would not speak to the question of *how* evaluating the temporal ordering of events should interfere with children's ability to retrieve the correct antecedent of adjunct PRO. If making this comparison interferes with sentence processing abilities in general, then children should exhibit lower accuracy for all tasks that involve this contrast. Additionally, if children's ability to compare the relevant events was affected by the pragmatic context of the stories, then children might exhibit higher accuracy with the same contrast, but with a modified context to highlight different aspects of the stories (e.g., by making the relevance of temporal ordering more salient in the stories).

In addition to the temporal ordering contrast, the TVJT also differs from the coloring task in the type of response elicited. In the TVJT, children give a true/false

judgment and (ideally) a justification for their judgment, while in the coloring task children color in one item in a picture sequence after selecting a color from an array below the sequence. Although coloring is an activity that children have more experience with compared to judging the truth value of a sentence, the TVJT has been used to show adultlike behavior in children in the same age range for many other types of structures. Children's lower accuracy for the TVJT therefore should not necessarily be attributed to a general inability to judge the truth value of a test sentence. A more likely source of children's errors has to do with their sensitivity to pragmatic subtleties in the TVJT. In contrast, there is little to no pragmatic context involved in the coloring task, which translates to fewer opportunities in the coloring task for children's interpretations to be influenced by the context. Therefore, as observed for numerous other types of structures, children should exhibit higher accuracy for sentences with adjunct control in a TVJT which sets up the right pragmatic context. From the studies conducted so far, however, it is not clear exactly how this context should differ from the ones used for the TVJTs presented in this dissertation.

7.2.2 What are the mechanisms responsible for the interference effects, and how do they differ between children and adults?

The introduction in Chapter 5 outlined two potential sources for similarity-based interference effects in the absence of matching retrieval cues. One possibility is that interference occurs when a target and intervener are maintained in memory. If storing items with overlapping features causes the representations of these items to become degraded, then more difficulty is predicted at retrieval than with non-

overlapping features. Accounting for the accuracy differences in children will then involve a more detailed model of how the items become degraded (e.g. feature overwriting (Nairne, 1988, 1990)), and determining whether children's lower accuracy results from the representations becoming even more degraded in memory compared to adults, or from more difficulty retrieving degraded representations (or both).

Another potential source of interference is the initial encoding of an item that overlaps in features with some representation that is already stored in memory. A matching item will be encoded as less distinct than a mismatching item. Furthermore, encoding a matching item may be more likely to interfere with the representation of the item already stored in memory, resulting in the displacement of mismatching features and causing the matching items to be represented as even less distinct in memory. Children's differences in accuracy, then, may be related to their ability to encode items in general, causing all items to be encoded as less distinct in memory compared to encoding in adults, and resulting in even less distinct representations in memory for matching items.

Finally, the status of gender marking vs. number marking in English raises questions about the type of interference effects observed in the experiments presented in this dissertation, and how these results relate to the effects observed for NP type and animacy. If the presence of agreement in a language overall influences how these features are represented in memory even in cases where agreement is not realized overtly, then different effects are predicted, depending on what aspect of the representation is responsible for interference. For example, if interference occurs for gender in languages with no linguistic realization of gender marking, then this would

suggest that interference results from storing representations of similar referents, rather than similarity between the forms of the items in the test sentence. Meanwhile, the effects of interference observed for NP type, which is not marked for agreement, suggest that at least some aspects of an item's form can cause similarity-based interference. Whether these are the same types of interference effects as those for features that correspond to conceptual differences between referents therefore remains an open question.

7.2.3 How and when do children acquire the adult grammar of adjunct control?

The experiments in Chapter 4 showed that children's grammars for adjunct control are adultlike by age 4, but the pattern of behavior for 3-year-olds did not clearly differentiate between a non-adultlike grammar that does not restrict the interpretation of PRO to the adjunct subject, and an inability to deploy the restriction in the adult grammar due to extragrammatical factors. Furthermore, if 3-year-olds have an adult grammar, but task-specific factors associated with the coloring task interfere with the deployment their grammar, it is not obvious how the coloring task should be designed to tease these two hypotheses apart.

Depending on what type of linguistic input is required for children to acquire the adult grammar, there are different interpretations available for the pattern of behavior observed in 3-year-olds. If children learn the restriction on adjunct PRO by tracking which antecedents occur in the input, then the wider variation between 3-year-olds could be attributed to variation in children's experience with adjunct control. Children who had not observed enough instances of adjunct would then be predicted to

exhibit chance behavior, while children who had encountered enough data to make the correct inference would be the ones who were adultlike. This type of account does not make explicit predictions about individual differences related to sentence processing abilities. At the same time, it does not rule out the possibility that some of the variation between children might be due to extragrammatical factors, in addition to experience with adjunct control in the input.

Another possibility outlined in Chapter 6 is that the control rule (PRO is bound by the closest c-commanding NP of the next highest clause) is universal, and children's knowledge of adjunct control depends on learning about adjunct attachment height, either by distinguishing adjunct clauses from other types of clauses (§6.3.2.1), or by learning the specific lexical and semantic properties of the complementizers (McDaniel et al., 1991). If this is the only aspect of adjunct control that children need to learn, then no additional machinery is needed to account for how children acquire the adult grammar. However, an account in which children learn the adult grammar by learning the lexical features of the complementizers has the same limitations as the antecedent tracking account when it comes to explaining the pattern of behavior for 3-year-olds in Experiment 5b. Under the Variable Attachment account, children have mostly learned the correct attachment for complements by age 4, with up to a year or more after that needed to learn the correct attachment height for adjuncts. The adultlike pattern of behavior observed for 4-year-olds with the coloring task provides evidence against this particular timeline of acquisition, but it may not be unreasonable to consider a similar account for the 3-year-olds. If children learn the relevant lexical properties between the ages of 3 and 4, then the same type of variation in the input described for the antecedent

tracking account may also explain the variation observed for the 3-year-olds in Experiment 5b: as some children will have encountered more instances of the relevant complementizers than others, those with enough experience will exhibit adultlike behavior, with higher proportions of adultlike behavior with age (as a predictor of experience). Alternatively, if the relevant properties to learn depend on distinguishing adjunct clauses from argument clauses, then these are likely to be available at an earlier age than the lexical properties proposed by McDaniel et al. (1991) to be the source of development.

7.2.4 Are there crosslinguistic differences in the acquisition of adjunct control?

With all of the research to date on children's acquisition of adjunct control conducted only on children learning English as their first language, the question arises of whether there are different trajectories for the acquisition of adjunct control in different languages. One factor that might influence children's acquisition is the availability of argument dropping in discourse-licensed contexts. While English allows arguments to be dropped in a few select contexts (e.g. Diary drop contexts, as in 'Saw a good film yesterday'), this type of argument omission is limited to main clauses (Haegeman, 2000, 1997, 1990; Haegeman & Ihsane, 2001; Scott, 2010; but see Haegeman & Ihsane, 1999). Meanwhile, most other languages allow arguments to be dropped in a wider range of contexts, including the subject position of a main clause:

(70) Italian (adapted from Haegeman (2000)):

(Io) Parlo italiano.

(I) speak-1SG Italian.

'I speak Italian'

(71) Brazilian Portuguese (adapted from Holmberg, Nayudu, & Sheehan (2009)):

A: Você viu o fogo?

you saw the fire

'Did you see the fire?'

B: Vi.

saw

'Yes'

(72) Mandarin Chinese (adapted from Huang (1984)):

A: Zhangsan kanjian Lisi le ma?

Zhangsan see Lisi ASPECT Q

'Did Zhangsan see Lisi?

B: Ø kanjian Ø le.

Ø saw Ø ASPECT

'[He] saw [him].'

Additionally, many languages allow arguments to be dropped in finite embedded clauses, which can result in null discourse anaphora in similar contexts as adjunct PRO (Sundaresan, 2014):

(73) Italian (adapted from Haegeman (2000)):

Gianni canta quando Ø è felice.

Gianni sings when Ø be-3SG happy.

'Gianni sings when he is happy.'

(74) Brazilian (BP) and European Portuguese (EP) (adapted from Nunes (2014)):

O João$_1$ sempre cumprimenta a Maria$_2$ quando Ø entra na sala

the João$_1$ always greets the Maria$_2$ when Ø enters in-the room.

'João always greets Maria when $\left\{\begin{matrix}\text{EP: he/she}\\ \text{BP: he}\end{matrix}\right\}$ enters the room.'

(75) Mandarin Chinese (adapted from Wu (1992))

Zhangsan zoule yihou Ø jiu mei huilai guo

Zhangsan leave after Ø then not come-back ever

'After Zhangsan left, he has never returned.'

While discourse anaphora in embedded contexts in English are realized overtly, languages that are less restrictive with respect to argument dropping will have fewer explicit cues to distinguish between null elements that are syntactically bound and those that involve a discourse dependency. One possibility is that children learning these languages will need more experience to distinguish PRO as an element of a syntactic dependency from other null elements that receive an interpretation from the discourse. However, another possibility is that children learning a language that involves more experience with different types of null elements will be more sensitive to the variation between discourse and syntactic dependencies involving a null element compared to children learning languages like English, which have less variation of this sort.

Another source of crosslinguistic variation is in the interpretation of adjunct PRO itself, which is usually restricted to the main clause subject but has some exceptions. For example, adjunct control in European and Brazilian Portuguese generally patterns like English, with obligatory subject control in non-finite clauses:

(76) O João$_1$ cumprimentou a Maria$_2$ depois de PRO$_{1/*2}$ entrar na sala
the João$_1$ greeted the Maria$_2$ after of PRO$_{1/*2}$ enter in-the room.
'João greeted Maria after entering the room.'
(adapted from (Nunes, 2014))

However, in contexts when the matrix object undergoes wh-movement, both EP and BP allow subject *or* object control (Nunes, 2014):

(77) Que mulher$_2$ é que o João$_1$ cumprimentou t$_2$ depois de PRO$_{\mathbf{1/2}}$ entrar na sala?
which woman$_2$ is that the João$_1$ greeted after of PRO$_{\mathbf{1/2}}$ enter in-the room?
'Which woman did João greet after entering the room?'
(adapted from Nunes (2014))

Furthermore, while BP and EP allow wh-phrases to remain *in situ*, it is only with wh-*movement* that the object control interpretation is available, as the object control interpretation is not available when the wh-phrase is left *in situ*:

(78) Que homem$_1$ cumprimentou que mulher$_2$ depois de PRO$_{1/*2}$ entrar na sala?
which man$_1$ greeted which woman$_1$ after of PRO$_{1/*2}$ enter in-the room?
'Which man greeted which woman after entering the room?'
(adapted from Nunes (2014))

This difference between English and Portuguese is accounted for formally in terms of the features on the wh-phrase in English compared to Portuguese. It is not clear how this distinction should be available to the learner, however – of the 860 instances of adjunct control from the corpus analysis in the previous chapter, 12 also contained a wh-moved object from the main clause. In none of these instances was the moved wh-word a plausible antecedent of PRO, and 7 of them had a form as in (79) (from the CHILDES Hall corpus), with *do* as the verb in the main clause:

(79) P: What did you do instead of going up to the loft then? (rob.cha 4;6-5;0)

It is an open question, then, how children would learn this type of distinction, and when children learning Portuguese as their first language would be sensitive to it.

7.2.5 For what other structures do children exhibit interference effects, and does this interference influence their acquisition?

An important implication of the interference effects observed for adjunct control in Chapter 5 is that, if these effects are indeed due to processes involved in encoding and storing elements in linguistics dependencies, then similar effects should also be observed for other types of linguistic dependencies that involve the same processes. Meanwhile, although feature match has been manipulated in a number of structures in studies with children (Table 11), there is a lot of variation across studies, and in some cases effects are observed for older children (i.e. 7 years and older) but not for younger children (Adani et al., 2010; Adani, 2011). In many of these contexts, however, children exhibited chance performance across the board, suggesting that the absence of any observed interference effects have also been related to the context of

the task. The recent development of the coloring task (Pinto & Zuckerman, 2015), may therefore present an opportunity to revisit these structures in a more simplified context.

Furthermore, depending on what type of linguistic information is needed to acquire different types of dependencies, interference effects are predicted to influence how these dependencies are represented in the linguistic intake (as opposed to the input). Crucially, if similarity-based interference causes children to retrieve the wrong antecedent some proportion of the time, then this will directly affect the amount of noise in the *intake*, and may cause children to draw the wrong conclusions about their language, even with little noise in the *input*. If a significant proportion if the input is interpreted incorrectly due to similarity-based interference, then this will place much greater restrictions on what kinds of accounts are available for explaining children's non-adultlike behavior. That is, any account that relies on children acquiring the adult grammar for a linguistic dependency by observing the relevant structure in the input must also consider how likely children would be to draw the wrong conclusions, due to noise in the *intake*. If similarity-based interference influences children's interpretations in a high proportion of contexts (for example, as observed in Experiments 1, 3, 6, and 7), then distributional learning accounts of linguistic dependencies may face a significant challenge in accounting for this noise.

7.3 Conclusion

The research presented in this dissertation has investigated children's acquisition of adjunct control, using children's non-adultlike behavior to compare the predictions of different grammatical and processing accounts. While children's

grammars appear to be adultlike by age 4, we saw that their errors persist depending on task-specific processing factors, as well as the feature overlap between the grammatically accessible antecedent and a grammatically inaccessible intervener. While instances of adjunct control do occur in the linguistic input, children's susceptibility to errors in the contexts demonstrated in this dissertation raises doubts about the utility of the input distribution for learning the adult grammar of adjunct control. Furthermore, as interference type effects are also observed in a number of other structures, both in children (realized as differences in accuracy) and in adults (as differences in reading times), these effects may account for children's difficulties on a much more general scale, and point to a continuous developmental trajectory as children's processing mechanisms become more resistant to interference.

Appendix A: R code used for analyses

```
library(lme4)
library(lmtest)
```

Experiments 1-4

```
#Define the model with context and age as fixed effects
and subject and item as random effects
model_no_interaction <- glmer(acceptance ~ context + age
          + (1|subject) + (1|item), family="binomial",
          data=dataset)

#Define the model with context, age, and the interaction
as fixed effects and subject and item as random effects
model_all_predictors <- glmer(acceptance ~ context + age
     + context:age + (1|subject) + (1|item),
     family="binomial", data=dataset)

#likelihood ratio test
lrtest(model_no_interaction,model_all_predictors)
```

```
#summaries of the models
summary(model_no_interaction)
summary(model_all_predictors)
```

Experiments 5a and 5b

```
#Define the null models with only subject and item as
random effects
null_task_model <- glmer(correct ~ (1|subject) +
          (1|item), family="binomial", data=task_data_5a)
null_age_model <- glmer(correct ~ (1|subject) + (1|item),
          family="binomial", data=age_data_5b)

#Define the model with task as the fixed effect and
subject and item as random effects
full_task_model <- glmer(correct ~ task + (1|subject) +
          (1|item), family="binomial", data=
          task_data_5a)

#Define the model with age as the fixed effect and
subject and item as random effects
full_age_model <- glmer(correct ~ age + (1|subject) +
          (1|item), family="binomial", data=age_data_5b)
```

```
#likelihood ratio tests
lrtest(null_task_model,full_task_model)
lrtest(null_age_model,full_age_model)

#summaries of the models
summary(full_task_model)
summary(full_age_model)
```

Experiments 6 and 7

```
#Define the null model with only subject and item as
random effects
null_match_model <- glmer(correct ~ (1|subject) +
          (1|item), family="binomial", data=dataset)

#Define the model with feature match as the fixed effect
and subject and item as random effects
feature_match_model <- glmer(correct ~ if_match +
          (1|subject) + (1|item), family="binomial",
          data=dataset)
```

```
#Define the model with feature match and participant's
gender as fixed effects and subject and item as random
effects
match_with_gender_model <- glmer(correct ~ if_match +
          participant_gender + (1|subject) + (1|item),
          family="binomial", data=dataset)


#likelihood ratio tests
lrtest(null_match_model,feature_match_model)
lrtest(feature_match_model,match_with_gender_model)


#summary of the model
summary(feature_match_model)
```

Appendix B: Test items used for Experiments 1 and 2

Experiment 1 characters: Dora and Diego

Experiment 2 characters: Mickey and Diego

1. Dora and Diego are going outside to play in the snow but neither of them has a jacket. Diego wants to get a jacket and asks Dora if she wants one too, but Dora doesn't because she thinks she won't be cold if they play tag. Diego gets a jacket anyway, and tries to hide from Dora behind a snowman. Dora sees Diego hide, so she tags him and he falls down in the snow. Dora realizes that she's cold now too, and asks Diego if he's cold since he's covered in snow. Diego says he's not since he already had a jacket on, so Dora gets a jacket too so she won't be cold anymore either.

   Experiment 1: Dora tagged Diego before/after getting a jacket

   Experiment 2: Mickey tagged Diego before/after he got a jacket

2. Dora and Diego are going swimming, but Diego can't find his swimsuit. Diego decides to jump into the pool with his clothes on but then he finds his swimsuit at the bottom of the pool. So, he puts on his swimsuit, but this time when he jumps in the pool he splashes Dora. Then, Dora decides to put on her swimsuit so she won't have to wear her wet clothes anymore

   Experiment 1: Diego splashed Dora before/after putting on a swimsuit

   Experiment 2: Diego splashed Mickey before/after he put on a swimsuit

3. Dora and Diego are going hiking. Diego trips on a rock and scrapes his knee, so Dora gives him a bandaid, and Diego puts a bandaid on his knee. Diego still doesn't feel better, though so he asks Dora to carry him until he can walk on his knee again. So Dora carries Diego, and they continue on their hike. Eventually, Dora gets a blister from carrying Diego, so she stops carrying him so she can put a bandaid on her blister.

   Experiment 1: Dora carried Diego before/after putting on a bandaid

   Experiment 2: Mickey carried Diego before/after he put on a bandaid

4. Dora and Diego are sneaking downstairs to eat cookies from the cookie jar. Dora is too afraid that she'll make too much noise, so Diego sneaks across the floor and eats a cookie. Dora is still too afraid to get a cookie, so she asks Diego to bring her the whole cookie jar so she can eat a bunch of cookies. Diego tiptoes over with the cookie jar but bumps into Dora and drops the cookie jar and the cookies on the floor. There's one more cookie left, though, so Dora eats the last cookie.

   Experiment 1: Diego bumped Dora before/after eating a cookie

   Experiment 2: Diego bumped Mickey before/after he ate a cookie

Appendix C: Test items used for Experiment 3

1. Dora and Diego are chasing butterflies in the park. Diego tries to catch an orange butterfly but it's too fast for him and he misses. Then, Dora catches a pink butterfly. Diego is still running after the orange butterfly but he isn't looking where he's going and he smashes into Dora and breaks her butterfly net. Diego apologizes, and Dora points out a slower blue butterfly for him to catch. So Diego runs after the blue butterfly and catches it instead.
   Test sentence: Dora got smashed by Diego before/after catching a butterfly

2. Dora and Diego are painting pictures. Dora finishes her painting and decides to go get a turkey sandwich. On her way back, she accidentally bumps into Diego, and he gets paint on himself and on Dora's sandwich. Diego realizes that he's hungry now too, so he gets a peanut butter and jelly sandwich.
   Test sentence: Diego got bumped by Dora before/after getting a sandwich

3. Dora and Diego are going trick or treating on Halloween. Dora is dressed as a cat, and Diego is dressed as a bee. Dora gets hungry and decides to eat some of their Halloween candy. She offers some to Diego, but when he reaches for it, he accidentally stings her with the stinger on his costume. So, Dora decides to throw some candy to Diego instead so he doesn't sting her again, and then Diego eats

some candy too.

Test sentence: Dora got stung by Diego before/after eating some candy

4. Dora and Diego are cutting out some shapes. Dora cuts out a star and Diego cuts out a star. Then Diego drops his scissors on the floor and they break, so Diego asks to borrow Dora's scissors so he can cut out a star too. Dora hands her scissors to Diego, but she points them the wrong way and cuts Diego's hand! So Diego has to be really careful while he's cutting out his star.

   Test sentence: Diego got cut by Dora before/after making a star

Appendix D: Test items used for Experiment 4

1. Dora, Diego and Boots are going to pick apples. Dora gets bored, but she doesn't want to leave yet. So, she picks an apple for Diego. He is very happy that Dora picked him an apple, but he doesn't have anywhere to put it because he lost his basket! So Diego asks Dora to help him find his basket. Dora finds Diego's basket behind the bushes, but suddenly Boots runs up to Dora and asks her to pick him an apple too, since he's too short to reach any of them. So, Dora picks Boots an apple too. Boots shows Diego the apple that Dora picked for him, and Diego shows Boots the apple that Dora picked for him.

   Test sentence: Dora picked him an apple before/after finding Diego's basket.

2. Dora, Diego and Boots are playing tag in the park. Dora is it, but she gets tired and wants to get some water. She asks if anyone else wants water; Diego does, but Boots doesn't, so Dora gets water for herself and Diego. They start playing tag again, and Dora decides to run after Boots. Dora almost tags Boots' tail, but he's too quick for her, and Dora doesn't quite catch him. Then, Boots asks for some water too, since running away from Dora made him thirsty, so Dora gets Boots some water as well. Boots tells Diego how nice Dora was to get him some water, and Diego agrees, mentioning that Dora got him some water too.

   Test sentence: Dora got him some water before almost tagging Boots' tail.

3. Dora and Boots are going to eat breakfast. Boots asks Dora to make him some bacon, so Dora does. Dora wants cereal, but she doesn't have any left, so she eats the rest of Diego's cereal instead. When Diego wakes up, he wants cereal as well, but there's none left because Dora ate it. So Dora makes Diego some bacon instead. Diego complains to Boots that he wanted cereal and got bacon instead, and Boots shows Diego his bacon and says how excited he is to eat it.
   Test sentence: Dora made him some bacon before/after eating Diego's cereal.

4. Dora and Boots are on their way to the park to meet Diego to play soccer. Suddenly, Boots trips on his shoelace and scrapes his elbow, so Dora gives him a bandaid for his elbow. Later, Dora gets too close to Boots when they're walking and she accidentally hits his face with her elbow. She offers Boots another bandaid, but he says he doesn't need one for his face, only for his elbow. When they get to the park, Diego runs up and tries to kick the ball, but he slips in the grass and scrapes his knee. So Dora gets Diego a bandaid as well. Diego tells Boots how nice Dora was to get him a bandaid, and Boots complains that Dora hit him in the face but agrees that Dora is nice since she got him a bandaid too.
   Test sentence: Dora got him a bandaid after hitting Boots' face.

Appendix E: Items used for Experiments 5-7

Experiments 5a and 5b

Test items:

1. Dora fanned Diego after hugging the brown bear
2. Dora washed Diego before eating the red apple
3. Diego lifted Dora after catching the blue fish
4. Diego splashed Dora before flying the green kite

Control items:

1. Dora painted Diego after she/he picked the blue flower
2. Dora buried Diego after she/he kicked the red ball
3. Dora hugged Diego before she/he opened the blue box
4. Dora tagged Diego before she/he read the orange book
5. Diego pushed Dora after he/she drove the green car
6. Diego dried Dora after he/she baked the yellow cake
7. Diego fed Dora before he/she rode the yellow bicycle
8. Diego brushed Dora before he/she petted the brown dog

Experiment 6

Test items (List 1/List 2):

1. Diego brushed Mickey/Dora before petting the brown dog
2. Diego lifted Dora/Mikey after catching the blue fish
3. Mickey/Dora tagged Diego before reading the orange book
4. Dora/Mickey fanned Diego after hugging the brown bear
5. Mickey/Dora painted Diego after picking the blue flower
6. Diego splashed Dora/Dora before flying the green kite
7. Diego dried Mickey/Dora after baking the yellow cake
8. Dora/Mickey washed Diego before eating the red apple

Control items (List 1/List2)

1. Dora hugged Diego before she/he opened the blue box
2. Dora buried Mickey after he/she kicked the red ball
3. Dora patted Diego after he/she painted the yellow lion
4. Mickey poked Dora after he/she threw the brown football
5. Mickey combed Dora before she/he rang the yellow bell
6. Diego pushed Dora after she/he drove the green car
7. Diego fed Dora before she/he rode the red bicycle
8. Dora scrubbed Mickey before he/she built the orange tower

Experiment 7

Test items (Plural list/singular list)

1. The boys/the boy brushed the girl before petting the brown dog
2. The girls/the girl scrubbed the boy before building the orange tower
3. The girl fanned the boys/the boy after hugging the brown bear
4. The boy lifted the girls/the girl after catching the blue fish
5. The boy splashed the girls/the girl before flying the green kite
6. The girls/the girl painted the boy after picking the blue flower
7. The girl washed the boys/boy before eating the red apple
8. The boys/the boy dried the girl after baking the yellow cake

Control items (List 1/List 2)

1. The girl hugged the boy after she/he opened the blue box
2. The girls patted the boy after he/they painted the yellow lion
3. The boy poked the girls after they/he threw the brown football
4. The boy pushed the girl after he/she drove the green car
5. The boy fed the girl before she/he rode the red bicycle
6. The girl tagged the boy before he/she read the orange book
7. The girl buried the boys before she/they kicked the red ball
8. The boys combed the girl before they/she rang the yellow bell

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