

Events in the acquisition of adjunct control

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Previous research on 4-6-year olds' interpretations of adjunct control has observed non-adultlike behavior for sentences like "John called Mary before running to the store." Several studies have aimed to identify a grammatical source of children's errors. We show that children's difficulty with adjunct control derives from an interaction between finding the controller and remembering the order of events. When we eliminate the need to remember event order, children's performance on adjunct control is significantly improved. These results suggest that children's knowledge is adultlike, but they have difficulty deploying that knowledge in contexts with a high memory load. We consider the implications of this difficulty for the acquisition of adjunct control.

1. Introduction

Children's interpretations are sometimes different from adults' interpretations. Sometimes the differences are minor, with no significant disruption in communication; sometimes children's interpretations deviate quite a bit, and impact their understanding in a conversation. Importantly, any differences are generally not random: children's non-adultlike interpretations are a sign of some particular difference between children and adults in generating an interpretation of a sentence. Depending on what that difference is, there are different expectations for children's interpretations in the moment, but also for acquisition.

If adultlike knowledge of the input language is necessary for building a grammatical parse, then a non-adult grammar is likely to result in a non-adultlike interpretation. At the same time, the adult grammar alone is not sufficient for veridical perception of the linguistic input. Generating any given interpretation will involve the deployment of specific grammatical knowledge; in addition, any mechanisms involved in deployment will depend on the type of grammatical knowledge, as well as the context. If these mechanisms are still developing, then non-adultlike interpretations may result from difficulty deploying the adult grammar.

The current study focuses on this later question of deployment, with a case study to ask about the impact of immature parsing mechanisms. For a case where children exhibit non-adultlike behavior even after acquiring the adult grammar, we look at how the specific context can influence children's behavior, particularly in contexts with a high memory load. Finally, we consider the influence of this memory load at different points between parsing the sentence and planning and carrying out a behavioral response.

1.1 Case study: adjunct control

Previous studies on the acquisition of adjunct control have consistently observed non-adultlike behavior for sentences like (1):

- (1) John called Mary before PRO running to the store.

In (1), the silent adjunct subject, notated here as PRO, is bound by the main clause subject *John* but not the object *Mary*, and adults typically only accept a subject control interpretation (that John

ran to the store). Meanwhile, children in previous studies have accepted a much wider range of interpretations.

Children's non-adultlike behavior for adjunct control has generally been attributed to a non-adultlike grammar, with one or more non-adultlike stages before the adult grammar. For example, under the Variable Attachment account (Goodluck, 1981; Hsu, Cairns, & Fiengo, 1985; McDaniel, Cairns, & Hsu, 1991; Cairns, McDaniel, Hsu, & Rapp, 1994; Adler, 2006), children misattach the adjunct to the main clause. Low attachment allows the main clause object to bind PRO (i.e. object control), with high attachment resulting in free reference from the discourse. Object control is still consistent with free reference, however, and under the Nominalization account (Wexler, 1992; Broihier & Wexler, 1995; Goodluck, 2001), all of children's responses were proposed to be generated from the same, single, non-adultlike grammar with a nominal adjunct:

(2) John called Mary before [_{NP} (the) running to the store]

In (2), the agent of *running* is underspecified in the adult grammar, which predicts a free reference pattern of responses.

Children's behavior in previous studies is consistent with both the Variable Attachment account and the Nominalization account. However, the same behavior (free reference) is predicted by both accounts, and no predictions are made by either account about the rate of non-adultlike interpretations. Indeed, variation is observed across studies in the specific patterns of non-adultlike behavior. This is especially problematic if children need evidence from the linguistic input for the adult grammar, where variation is also likely in children's perception of the input, i.e. the linguistic intake (Lidz & Gagliardi, 2015; Omaki & Lidz, 2015). Other sources of non-adultlike behavior are the processes involved in parsing a sentence and producing a response, or *extragrammatical* factors.

1.2 Extragrammatical sources

Extragrammatical factors may be involved in deploying specific grammatical knowledge while parsing the sentence itself, but may also be responsible for linking the sentence to a task context to plan and carry out a behavioral response. Even if children's grammars are adultlike, difficulty with any of these processes may result in non-adultlike behavior. Identifying the specific sources of difficulty therefore has different implications for children's language acquisition, depending on when the difficulty arises.

1.2.1 Deploying grammatical knowledge

Difficulty with deploying grammatical knowledge may be observed in contexts that involve some extra processing load. In these contexts, children tend to have a similar pattern of responses to adults; however, the effects are generally amplified in children – where adults may slow down in a difficult context, children are more likely to give a non-adultlike response altogether (Costa, Grillo, & Lobo, 2012; for a review see Omaki & Lidz, 2015). This suggests that the same mechanisms are involved, although the precise factors that are responsible for the

amplified effects and which undergo development are not as clear, due in part to the indirect process of generating a behavioral response.

For example, retrieving an item from memory is more difficult when another, similar, item is also stored in memory, which may interfere with access to the target item (Similarity-based interference; Gordon, Hendrick, & Johnson, 2001, 2004; Gordon, Hendrick, Johnson, & Lee, 2006; Warren & Gibson, 2002, 2005; for a review see Gordon & Lowder, 2012). In the case of retrieving an antecedent to resolve a dependency, this difficulty is realized as slower reading times and lower accuracy in adults, with parallel effects for children. In general, the dependency will be more difficult to resolve when the grammatical and ungrammatical antecedents are more similar to each other, as defined in terms of matching features like gender, number, person, etc. This *similarity-based interference* is observed with adjunct control (Parker, Lago, & Phillips, 2015), as well as various structures (e.g. relative clauses, anaphora, wh-questions, raising, topicalization)(for reviews see Jäger, Engelmann, & Vasishth, 2017; Van Dyke & Johns, 2012).

In sentences with adjunct control like (1) (repeated below), the syntax identifies a unique antecedent (*John*), but an intervening NP (*Mary*) may cause interference if some features are shared with the grammatical antecedent.

(1) John called Mary before PRO running to the store.

Crucially, the antecedent and intervening NP differ in syntactic position, but they also match in other features like number (singular), animacy (animate), and NP type (name). Children's non-adultlike responses for adjunct control may be explained in part by similarity-based interference, with higher accuracy observed when the intervener is less similar to the grammatical antecedent (Gerard, Lidz, Zuckerman, & Pinto, 2017).

This is consistent with sentences used in previous studies on the acquisition of adjunct control, where the main clause subject and object were generally matched in number and animacy, and sometimes also gender. However, as mentioned above, it does not identify the particular factors which undergo development so that the parser is more resistant to interference. Intuitively, the immature parser will be more susceptible to interference, and processes directly related to parsing the sentence may develop by becoming more efficient in building and storing a representation of the sentence. At the same time, these processes are likely to interact with other extragrammatical factors; in particular, those involved in the specific task.

1.2.2 Task demands

Since the final parse of a sentence cannot be observed directly, a task provides a context for eliciting an explicit behavioral response that maps onto a particular interpretation. For a given task, the sentence is linked to a specific context in order to produce a behavioral response, and this extra step of interpreting the sentence with respect to the task context can help to avoid potential complications with metalinguistic awareness in a more direct task. However, it also introduces more space for error, depending on the demands of the task context. Thus, while children's non-adultlike behavior may result from difficulty deploying grammatical knowledge, it is also possible that parsing mechanisms are influenced by specific task demands, with more interference in a task

with a higher processing load. To tease apart these possibilities (which are not mutually exclusive), it is important to look at task demands in more detail, to identify specific contributing factors and how they may interact with parsing mechanisms.

In previous studies on the acquisition of adjunct control, various different tasks have been used to measure children's interpretations of adjunct PRO. While most studies have used an Act Out Task (Goodluck, 1981; Hsu et al., 1985; McDaniel et al., 1991; Goodluck & Behne, 1992; Cairns et al., 1994; Goodluck, 1998, 2001), a few studies have also used a judgment of reference task (McDaniel et al., 1991; Cairns et al., 1994), or a Truth Value Judgment Task (TVJT; Crain & Thornton, 1998; Broihier & Wexler, 1995; Adler, 2006). Meanwhile, as mentioned above, patterns of non-adultlike behavior have varied across the different studies, suggesting that some aspects of the tasks may have influenced children's responses.

Evidence for this was observed by Gerard, Lidz, Zuckerman, & Pinto (2018, Gerard et al), with a direct comparison between tasks. Using a TVJT based on those used in previous studies with 4-5-year-olds (Broihier & Wexler, 1995; Adler, 2006), Gerard et al reproduced children's non-adultlike behavior, with 40% object control responses and 60% subject control (adult controls gave 95% subject control responses). With a trend for a subject preference, this pattern alone is consistent with the adult grammar and a parser that is susceptible to misretrieval in a context with a high memory load. However, it is also consistent with various non-adultlike grammars. To test these options, Gerard et al identified several factors that may have influenced the demands of the TVJT. Next, with a coloring task which was designed to eliminate several of these factors (Pinto & Zuckerman, 2018), children gave 85% subject control (adultlike) responses. With comparable subject populations for both tasks, Gerard et al concluded that the change in rate of adultlike responses was due to the change in the task. Moreover, the higher rate of adultlike responses in a less demanding task context is predicted by the adult grammar, but no such prediction is made by a free reference grammar, and the reverse prediction is made for a strict object grammar. Therefore, based on the increase in adultlike responses in the less demanding task, Gerard et al argued that children's grammars for adjunct control are adultlike by age 4.

These conclusions raise important questions about the role of extragrammatical factors in children's language acquisition. If children's responses are affected by the task, the task demands will affect some of the steps involved in linking the sentence to the task context to generate a response. The demands may also spill over, though, to affect the mechanisms involved in parsing the sentence initially. This has implications for how children's perception of the linguistic input may be affected in demanding contexts (e.g. more interference in a more demanding context). For example, if antecedent retrieval is influenced in contexts with high task demands for sentences with adjunct control, then the question arises of how these demands affect other types of dependencies where an antecedent must be retrieved. Any effect on children's interpretations in the linguistic input will depend on the specific source of the task demands, however, which may be more or less prevalent in the input. Therefore, the next step following the task effects observed by Gerard et al is to tease apart the specific demands of the two different tasks, to identify the source of the increase in adultlike responses.

In the following sections, we first discuss the TVJT and coloring tasks used by Gerard et al and potential task demands. With different types of behavioral responses as well as different task contexts, there are various aspects of the tasks that may have contributed to the effect. Next, we present an experiment controlling for some of these differences in order to focus on a particular contrast – namely, whether the order of different events was relevant to the task context. Although event order has been relevant in the tasks in previous studies, it is not necessary for an adjunct control task, which should identify children’s interpretations of adjunct PRO. Children’s responses were more adultlike in the study by Gerard et al when event order was not relevant to the task context, and we observe the same result after controlling for other factors. We conclude with a discussion of timing and implications for parsing and acquisition.

2. Tasks

The tasks used by Gerard et al were a TVJT based on previous studies on the acquisition of adjunct control (Broihier & Wexler, 1995; Adler, 2006) and a coloring task, where children gave a response by coloring a black and white picture (Pinto & Zuckerman, 2018). Designed to investigate task effects in general, there were various differences between the two tasks – most obviously, in being two different types of task – but also in the relevant contrast to distinguish between the subject control and object control responses. Importantly, for both tasks, children needed to retrieve an antecedent for PRO in order to select a response, where children’s interpretations could then be inferred from their responses. Behavioral responses may be more or less reliable, though, depending on how many steps there are between the initial interpretation and the observable response. These steps are discussed in the following sections on the TVJT and the coloring task.

2.1 Truth Value Judgment Task

The TVJT used by Gerard et al included short stories to set up contexts which made both a subject control and object control interpretation available. Test sentences either made the subject interpretation true and the object interpretation false (*subject-true* condition) or the subject interpretation false and the object interpretation true (*object-true* condition), manipulated within-subjects. An example story is presented in (3a), with events described by the test sentence in bold (adapted from Gerard et al):

- (3) a. 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.
- b. subject-true: Dora tagged Diego before getting a jacket.
object-true: Dora tagged Diego after getting a jacket.

For the test sentences in (3b), the adultlike (subject control) interpretation is that Dora got a jacket, while the non-adultlike (object control) interpretation is that Diego got a jacket. Children were prompted to judge whether these sentences were true or false (by correcting a puppet), and to give justifications for their judgments.

To give a true/false answer, children first needed to disambiguate the event in the adjunct clause by retrieving the antecedent of PRO. This determined the specific events in the story to compare to the events in the sentence. Coming up with a truth value then involved comparing the *order* of the events in the sentence to the order of the relevant events in the story, and keeping this comparison in mind in order to give a justification (which generally aligned with the true/false answers).

Importantly, the true/false answers about the order of events in the test sentence were the dependent measure for children's interpretations of adjunct PRO. Children's interpretations could be inferred from their true/false answers (with each answer corresponding to only one interpretation), and their justifications confirmed that the judgments were indeed based on event order. At the same time, the link from the antecedent of PRO to the true/false answer involves several complex steps. If children's responses were influenced by the extra steps, then a task with fewer steps is predicted to find more adultlike behavior. This prediction was tested by Gerard et al using a different task with different type of behavioral response. As predicted, they observed a much more adultlike pattern overall.

2.2 Coloring Book

In the Coloring Book task, children are presented with a black and white picture on a touchscreen that can be colored in different ways to reflect different interpretations of a test sentence (Pinto & Zuckerman, 2018). It was designed to address complications with the pragmatics of a task context and the availability of alternative interpretations. Although these concerns can be often be controlled for by modifying the original task, the coloring book task can offer an alternative in more challenging contexts, as well as some practical advantages (see Gerard et al and Pinto and Zuckerman (2018) for discussions).

In the coloring task used by Gerard et al for adjunct control, children could color in one of two items, with one item representing a subject control interpretation and the other representing an object control interpretation. In each trial children saw two black and white pictures (Figure 1) with the characters from the test sentence (4) (both adapted from Gerard et al):

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

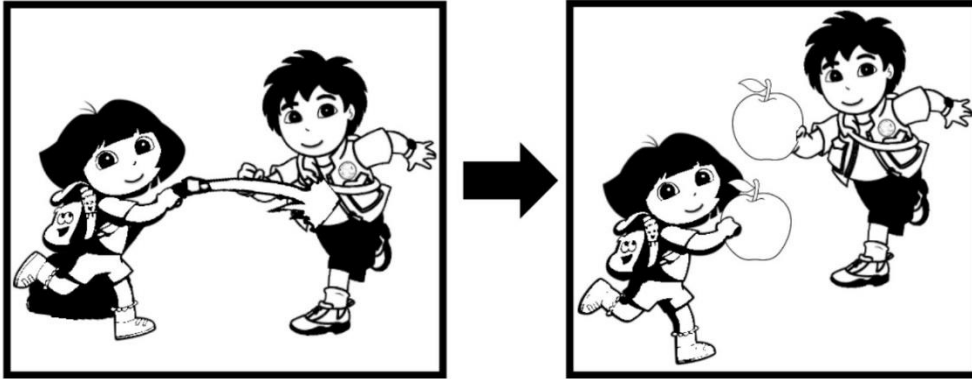


Figure 1: Example item for the coloring book task, to go with (4)

One picture showed the characters from the test sentence performing the action in the main clause (*Dora washed Diego*), and the other picture showed both characters performing the action from the adjunct clause (*eating the apple*). Following a preamble to introduce the items and actions, the test sentence served as a prompt to color in one of the items. In (4), the adultlike, subject control interpretation is that Dora ate the red apple; the subject control response would therefore be to color Dora's apple red. Meanwhile, the object control response would be color Diego's apple red (the task was programmed so that only these two items could be colored).

Compared to the TVJT, the coloring task involves fewer, less complex steps in between parsing the sentence and producing a behavioral response: after retrieving an antecedent for PRO and identifying the correct item to color, children needed to store that item in memory, select the correct color from an array of colors below the pictures, retrieve the item from memory, and color it in. These steps more directly represent children's interpretations of adjunct PRO, and this difference was reflected in children's more adultlike pattern of responses.

2.3 Differences

The study by Gerard et al demonstrated that children's responses can be influenced by the demands of the specific task. With several differences between the TVJT and the coloring task, though, there are various factors that may have influenced children's behavior, and the experiments were not designed to identify a specific source. Although the tasks themselves differed in the type of behavioral response, there were also differences in the task context, with the type of contrast between the subject control and object control interpretations.

For the TVJT, children needed to compare the order of the events in the main clause and adjunct clause with events in the story context. Depending on how children resolved the antecedent of PRO, the events would be in the correct or incorrect order; that is, the events in the main clause and adjunct clause would stand in the correct relation or the incorrect relation. This contrast involves much more information than the contrast in the coloring task, which depends on the color (a property) in the object of the adjunct clause. In the coloring task, children needed to retrieve the antecedent of PRO from the main clause to identify which item to apply the property to, but the relevant contrast involved no relations between events, for the test sentence or the task context.

If the specific type of contrast affected children's responses, then the same effect should be still be observed after controlling for other factors, including the response type. In the next section, we present an experiment to test this prediction. By adapting the task context from the coloring task into a TVJT and repeating the original TVJT design, we observe the same increase in adultlike responses, even with the same response type. This suggests that children's responses may be influenced by the particular type of contrast. The implications of this influence are discussed in the final section.

3. Experiment

In this section we ask about the role of an event order contrast in children's responses for sentences with adjunct control. We compare children's behavior in a task where event order is relevant and a task where event order is not relevant. This difference was also present in the tasks from the study by Gerard et al; however, these tasks also differed in response type, making it unclear how much each factor influenced children's responses. Here, we focus specifically on the influence of needing to compare event orders.

To manipulate the event order contrast directly, we control for the different response types by using the same type of task – a TVJT – for the task with an event order contrast (repeating the design used in Gerard et al) and for the task without an event order contrast (a TVJT version of the coloring task, described below).¹

3.1 Participants

Participants for the TVJT with an event order contrast were 32 children (13 males) ages 4;0-5;6 ($M=4;9$). An additional 22 children were excluded from the sample for answering too many control sentences incorrectly (13), inattention (5), or failure to complete the training portion (4). For the TVJT without an event order contrast, another 32 participants were recruited from the same general area and with similar demographics (15 males), ages 4;0-5;2 ($M = 4;6$). An additional 22 children were excluded from this sample for answering too many control sentences incorrectly (21) or inattention (1). Both groups were recruited through the University of Maryland Infant and Child Studies Database or participated at their local preschools.

Adult controls ($n = 6$) who participated in the TVJT adapted from the coloring book task consistently gave subject control answers, and their answers are not included in further analyses. The adults were enrolled in an introductory Linguistics course and the University of Maryland, and received course credit for their participation. These adults did not also participate in the original TVJT, although the adult controls in the study by Gerard et al with the same design were largely consistent in giving subject control responses.

This study was approved by the Institutional Review Board at the University of Maryland, College Park, with written informed consent collected from all parents of child participants.

¹ Note that it would also be possible to compare the two tasks directly, while controlling for the event order contrast (with the coloring task from Gerard et al and a TVJT version of the coloring task). This contrast would not be informative about the influence of event order, however, and more importantly, would not identify any specific components of the task that might influence children's responses.

3.2 Design and procedure: with event order

For the TVJT with an event order contrast, we repeated the design described in §2.1 from Gerard et al. Test sentences each followed a short story like in (3a), and were either in the *subject-true* condition or the *object-true* condition (within-subjects) as in (3b), repeated below as (5):

- (5) a. subject-true: Dora tagged Diego before getting a jacket.
b. object-true: Dora tagged Diego after getting a jacket.

In (5a), the adultlike (subject control) interpretation is that Dora got a jacket, which makes the sentence true. However, the sentence is false with an object control interpretation (that Diego got a jacket), *because* this describes the reverse order of events in the story (with the reverse truth values in (5b)). Thus, in order to correctly judge the sentences, children needed to be able to retrieve an antecedent of PRO *and* judge whether the events described in the test sentence were stated in the correct order. Children were also prompted to briefly summarize the main events in the story right before the test sentence was delivered, and to give justifications for their true/false answers. To help with these, images of the main events from the story remained visible from the end of the story until the beginning of the next trial.

A training session ensured that children could correctly judge simple sentences with *before* and *after*, and children who did not do so despite corrective feedback did not proceed to the testing portion. Control trials were also interspersed with the test trials to confirm that children could judge minimally different sentences whose truth value did depend on the order of events, but which did not involve antecedent retrieval:

- (6) Dora hugged Diego before/after the plane landed.
(where Diego has arrived on a plane to meet Dora)

Training and control sentences involved temporal relations, but contained no features of syntactic control. In total, children saw six training items with and without visuals, four test items as in (5), and three control items as in (6). Children were included in the analysis if they answered zero or one control question incorrectly, but were excluded if they answered more than one control question incorrectly. Stories were presented with PowerPoint on a touchscreen PC, with sessions lasting from 20-25 minutes.

3.3 Design and procedure: without event order

In the coloring task used by Gerard et al, the test sentences functioned as instructions for which item to color in in a black and white picture. The end result following the coloring action was that, of the two possible items to color, one of the items was filled in (e.g. one of the apples in Figure 1, while the other apple was not colored). This coloring action therefore *created* a contrast between the two items, which reflected how the antecedent of PRO had been resolved.

To adapt this task into a TVJT, the pictures were modified so that the two items were already filled in with different colors; that is, so that a contrast was already present between the two items. The test sentences (in (7)), which had the same structure as in the coloring task and mentioned one of the colors, could then be judged as true or false depending on the antecedent of

PRO. For example, the apples in Figure 1 were filled in so that Dora’s apple was orange, and Diego’s apple was blue (unconventional colors were used to avoid judgments based on real-world biases, with different colors for different items). The test sentences were then modified to create a version for each condition:

- (7) a. subject-true: Dora washed Diego before PRO eating the orange apple.
- b. object-true: Dora washed Diego before PRO eating the blue apple.

For the sentences in (7), the adultlike (subject control) interpretation is that Dora ate the apple. This makes the sentence true in (7a), because Dora’s apple was orange in the picture. The truth value depends on the interpretation of PRO however: the object control interpretation is that Diego ate the apple, which makes (7a) false because Diego’s apple was blue in the picture (with the reverse truth values in (7b)).

In order to judge the test sentences, children needed to compare the color in the test sentence to the color in the picture. This meant retrieving the antecedent of PRO from the main clause to identify whose apple should have the color mentioned in the test sentence, and judging whether this matched the color of that character’s apple in the picture. Additionally, to confirm that both the subject interpretation and the object interpretation were available (and to prevent children from developing a strategy of focusing on just one part of the sentence), we included control sentences with a finite adjunct and an overt pronoun subject:

- (8) a. Dora washed Diego before she ate the orange apple (subject antecedent, true)
- b. Dora washed Diego before she ate the blue apple (subject antecedent, false)
- (9) a. Dora washed Diego before he ate the blue apple (object antecedent, true)
- b. Dora washed Diego before he ate the orange apple (object antecedent, false)

Control items were interspersed with test items, and were balanced for the number and order of subject and object pronoun antecedents. Truth values were set dynamically, based on the participant’s previous answer, to avoid answer biases; e.g. if a participant had just previously answered “true”, then for the following control item the false version of the sentence would be delivered (and vice versa). As in the other TVJT, children were prompted to give justifications for their true/false answers.

A training session ensured that children could judge sentences with colors correctly. In total, children saw five training items, four test items as in (7), four control items with a pronoun subject antecedent as in (8), and four control items with a pronoun object antecedent as in (9). Children who responded incorrectly to more than one control item with a subject pronoun antecedent or to more than one item with an object pronoun antecedent were excluded from the analysis. That is, children could answer up to two control items incorrectly (one of (8) and one of (9)) and still be included in the analysis. The pictures were presented with PowerPoint on a touchscreen PC, with sessions lasting around 15 minutes.

3.4 Predictions

In contrast with the TVJT with event order, where the judgment is whether two different sets of events are in the same order, the adapted TVJT involves judging whether two colors match.

If comparing events in particular imposes a substantial cost, independent of the type of response in a given task, then a more adultlike pattern should be observed for the adapted TVJT that is based on the contrast in color. Meanwhile, these differences will be less noticeable if other factors were more responsible for the effect observed by Gerard et al, particularly any differences in the process of generating a response in the task (e.g. differences in the demands associated with evaluating the truth of a sentence in the TVJT, compared to indicating an interpretation in the coloring task).

3.5 Justifications

In addition to the true/false responses, children gave justifications for their answers, usually with little prompting. Children’s explanations were transcribed and coded for whether their justification made it clear who they had interpreted as the antecedent of PRO, and if not, whether their justification was relevant to the task context. Clear justifications were coded as *clear*, and for which character had been interpreted as PRO (Dora or Diego). Unclear justifications either as *unclear*, but still relevant to the task context, or *irrelevant*, if the child forgot their answer or was unable to give a justification (Syrett & Lidz, 2011).

Task		Code		
		Clear	Unclear	Irrelevant
Task	TVJT with event order	110 (54 Diego, 56 Dora)	11	7
	Coloring TVJT	104 (48 Diego, 56 Dora)	18	5

Table 1. Breakdown of justifications by clear, unclear, and irrelevant

Children’s justifications were not different from each other across the two tasks, and the responses patterned similarly whether or not the unclear responses are included.

3.6 Results and discussion

Results are presented in Figure 2. To analyze these results, we used R (R Core Team, 2015) and lme4 (Bates, Maechler, Bolker, & Walker, 2015) to perform a mixed-effects logistic regression, with Task and Context as fixed effects, and subjects and items as random effects. The model revealed a main effect of Context ($\beta = 2.82, Z = 5.43, p < .001$), a significant interaction between Context and Task ($\beta = -1.58, Z = -2.49, p = .01$), with no effect of Task ($\beta = 0.72, Z = 1.41, p = 0.16$).

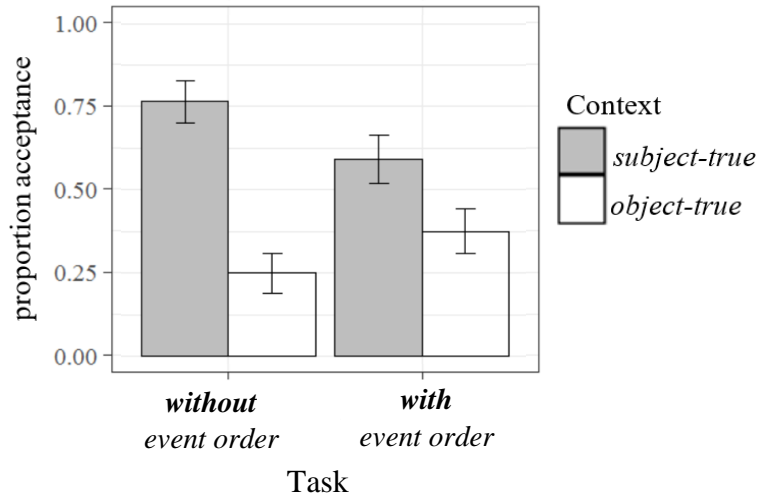


Figure 2: Effects of task context and specific type of contrast – depending on order of events (with event order) compared to a contrast in color (without event order) – on sentence acceptance

The main effect of Context reflects that children accepted more *subject-true* responses than *object-true* responses, in the direction of the expected adult pattern. This was true for both tasks (without event order ($t(31) = 6.5, p < .001$); with event order ($t(31) = 1.79, p = .009$)). Meanwhile, the interaction is due to the greater effect of context for the coloring task without an event order context. Although children did accept more *subject-true* sentences and reject more *object-true* sentences in the task with event order – that is, the responses predicted for the adult (subject control) grammar – they still gave many object control responses, with a near identical response pattern to the one observed by Gerard et al. This replicates the trend in the direction of a subject preference for the task with an event order contrast, with a different sample of children.

A greater difference is observed for the coloring TVJT without event order, as reflected by the interaction. Although children’s responses were still not completely adultlike – in both conditions, there were still some object control responses – importantly, there were *more* subject control responses than in the task with event order. That is, children accepted more *subject-true* responses and fewer *object-true* responses, with no expected differences in the children’s grammars, or other major factors.

These results are consistent with the hypothesis that some aspect of needing to compare different event orders had an impact on children’s responses. For both TVJTs, there is likely to be some cost associated with comparing the test sentence to the task context – indeed, in both task conditions, children gave some object control responses. Importantly, it is the difference between the two TVJTs which demonstrates the extra effect on children’s responses, depending on the type of information involved in making the comparison. In the final sections, we consider the type of information in the context of the specific steps in generating a response, and implications for parsing and acquisition.

4. General discussion

In this paper we asked about how specific extragrammatical factors can interact with children's linguistic knowledge. We compared children's behavior for sentences with adjunct control on two TVJT tasks, which differed in the type of contrast between the adultlike and non-adultlike interpretations. In one task, the contrast involved event order, where one interpretation made the order in the sentence match with the order in the context, while the other interpretation resulted in the reverse (incorrect) order. In the other task, the contrast involved colors, where one interpretation made the color in the sentence match with the corresponding color in the context, while the other interpretation resulted in a mismatch. Children's behavior was more adultlike when the judgement involved a contrast in color compared to event order, suggesting that the type of information that is relevant for the contrast can influence the process of generating a response. In the following sections, we discuss the influence of the context at different times while generating a response, as well as some issues for acquisition.

4.1 The effect of each context on...

As discussed in §1.2 above, a task introduces a specific context for a test sentence, with a behavioral response as an indirect measure of the sentence interpretation. Different responses map onto different interpretations; however, as we observed, the context can also influence children's responses, making this mapping less reliable with more interference from the context. To generate a behavioral response, children need to parse the test sentence and link the sentence to the context, and then produce a behavioral response based on that link. Depending on what is involved in each of these steps, there are various points where the context may have an influence. Here we discuss several of these, starting from the response itself and working back to PRO.

4.1.1 ...the task response

The task response is the behavioral measure to link back to children's interpretations, and is unique for each type of task. The current study used two TVJTs in order to control for the type of task – and therefore the type of behavioral response. For giving a true/false response, there are no obvious steps that should be influenced by storing events, in particular, as opposed to other costly information. However, with various steps involved in planning and producing the response itself, it is possible that any extra cost of keeping track of events may have interfered with these steps, compared to the lower cost of the coloring TVJT.

Similarly, tasks in previous studies on the acquisition of adjunct control have also involved keeping track of event order; for example, in the act out task, children could only act out one clause at a time, meaning that they needed to identify the first clause to act out and hold the second clause in memory, and then finally retrieve the second clause to act out. At the same time, there are various points where event order may also influence children's interaction with the sentence itself. In the following sections, we return to the adjunct control sentence to discuss these points and the influence of the context on parsing.

4.1.2 ...parsing the full sentence (main clause and adjunct clause)

Depending on the specific contrast, children's interpretations as a whole may have been influenced by some aspect of the contrast. For example, in the context with an event order contrast, even before parsing the test sentence, children would have already had some representation of the events in the story, which would end up to be in the same or reverse order as the events in the sentence. Children therefore needed to encode the order of events in the test sentence as distinct from the order of events in the story, in order to compare them. Thus, any interference from the story event order already stored in memory may have influenced either the encoding or storage of the events in the story. This in turn would affect the comparison itself between the sentence and the context, if the events in the sentence were influenced in memory by the events in the story.

Meanwhile, the context with the color contrast was unlikely to affect the full sentence in a way that would negatively affect children's responses, because the content of the main clause was not relevant in the context, by design. In fact, children may have learned based on the irrelevance of the main clause picture exactly which information to focus on. Children's justifications are consistent with this learning strategy, as they generally only mentioned whether the color in the sentence was correct. This suggests that they had learned to link the sentence to just the relevant portion of the context, based on which character had been interpreted as the antecedent of PRO.²

4.1.3 ...parsing the main clause (specifically)

Children's accuracy is shown to vary depending on the similarity between the grammatical antecedent and another NP in the main clause (Gerard et al., 2017; although this similarity was not manipulated in the present study). Drawing from the speculation about parsing the full sentence in §4.1.2, the encoding and storage of elements from the main clause would be influenced by the events from the story that would already be stored in memory. This explanation leaves out a key feature of interference accounts, though: while interference between similar NPs is expected, and interference between event representations is not too far of a leap, it is not clear where interference between NPs and events fits in.

One solution is to appeal to domain general processes entirely, with a quantitative difference in the "processing resources" needed for NPs vs events. This fails to capture the generalization that these categories are specific to language, however, and assumes that any interference between them is due to general processing.

Based on the relevant information in the different conditions, the effect of context on the main clause might be captured as a difference in sheer amount of information encoded – while the events in both clauses and the order between them is relevant for the event order contrast, for the color contrast, the content of the main clause is not relevant other than the subject and object

² We are confident that children were not ignoring the main clause completely, however, since children needed to retrieve the main clause subject to identify an item for the test sentences. In addition, they needed to retrieve the main clause object for the control trials, and could not be certain of which of these they would need to retrieve until the start of the (finite or non-finite) adjunct clause.

characters. Further implications of this difference are discussed in the following section on the influence of the different contexts on retrieving an antecedent for PRO.

4.1.4 ...adjunct PRO

For the task with event order, children needed to encode the content of the main clause and adjunct clause as individual events, as well as the order of the events with respect to each other. The cue to retrieve the antecedent of PRO was the non-finite adjunct verb (since PRO is silent), but this same verb was also the beginning of the adjunct clause (following the complementizer), which must be ordered with respect to the main clause. Since the complementizer has already occurred at this point, the ordering of the main clause would already be available. However, the adjunct clause is ambiguous between two different events in the context until an antecedent is retrieved for PRO, so retrieval must happen first, before the correct event can be ordered with the main clause.

Depending on which mechanisms are involved in building this ordered representation of the events, there may be a bottleneck with multiple retrievals and encodings in a short span. This procedure contrasts with the coloring TVJT in two important ways: first, since the order between the main and adjunct clauses in the coloring TVJT is not relevant for the true/false response, this relation need not be represented as deeply, as long as the adjunct is correctly attached, syntactically. Second, as mentioned above, other than the characters in the subject and object positions, encoding exact details about the event in the main clause would not be necessary.

These contrasts avoid several of the contributing factors to the bottleneck in the TVJT with event orders: If the complementizer is taken as a cue for high attachment, then no further relation needs to be computed between the two clauses. The adjunct verb then serves as a cue to retrieve an antecedent for PRO; this operation picks out the relevant item in the context to contrast with the color later in the sentence. Thus, the cue to retrieve the antecedent of PRO occurs at the same point for both tasks, but competes more with other operations in the TVJT with event order. This may increase the chance of misretrieval in the TVJT with event order, compared to the coloring TVJT.

4.2 Issues for acquisition

Based on the difference that we observed between the two tasks, the children who participated in the current study seem to have acquired the adult grammar of adjunct control (these results are also consistent with a subject preference grammar, but this would be problematic for observing evidence for the adult grammar). Nevertheless, they still gave object control responses some of the time, even in the coloring task with lower task demands. This is problematic for acquiring the adult grammar in the first place, because it means that the antecedent of PRO is not likely to be a reliable source of evidence for the adult grammar. Children must therefore use a different form of evidence for acquiring the adult grammar, which raises several new questions.

First, if children cannot use the elements of a dependency to acquire the restrictions on that dependency, how do they know what can be used as evidence? If this is a problem for adjunct control, then it is likely to be relevant for other dependencies as well. This point brings up the

question of overall frequency. Although structures with adjunct control are not frequent in the input, they are not absent (Gerard, 2016). However, if children do not use these instances to learn the adjunct control dependency, then the frequency does not contribute to the acquisition problem. If this is true for adjunct control, though, then it is also likely for other types of dependencies, particularly where children access non-adultlike interpretations that would provide evidence for a non-adult grammar.

Next, if children's behavior can still be non-adultlike at age four, what develops so that their responses are eventually adultlike? With some possibilities outlined above of how the specific task might interact with children's sentence processing, there are various aspects of the deployment system that may become more efficient or faster with development. The current study is not designed to tease these options apart, but they will be investigated in future research.

Finally, a prediction is made based on the present results for dependencies which *are* acquired from the input that the elements of the dependency will not appear in separate clauses with a relation like temporal ordering.

4.3 Conclusion

In this paper we investigated the source of children's non-adultlike behavior for adjunct control, as a case study on the interaction between different types of extragrammatical factors. Controlling for the specific task, we compared children's behavior on two TVJTs. Children's responses were not as adultlike when they had to make a judgment about the order of events in the task context, in addition to retrieving an antecedent for adjunct PRO. However, their responses were more accurate when the task involved a contrast that did not depend on event order. This demonstrates that having to compare event orders can affect children's responses, although future research will look more closely at the specific aspects of generating a response.

5. References

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