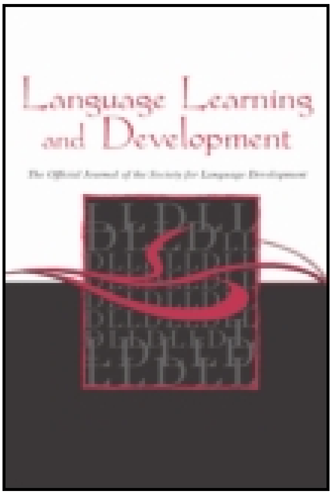

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Is She Patting Katie? Constraints on Pronominal Reference in 30-Month-Olds

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Is She Patting Katie? Constraints on Pronominal Reference in 30-Month-Olds

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In this study we investigate young children's knowledge of syntactic constraints on Noun Phrase reference by testing 30-month-olds' interpretation of two types of transitive sentences. In a preferential looking task, we find that children prefer different interpretations for transitive sentences whose object NP is a name (e.g., *She's patting Katie*) as compared with those whose object NP is a reflexive pronoun (e.g., *She's patting herself*). They map the former onto an other-directed event (one girl patting another) and the latter onto a self-directed event (one girl patting her own head). These preferences are carried by high-vocabulary children in the sample and suggest that 30-month-olds have begun to distinguish among different types of transitive sentences. Children's adult-like interpretations are consistent with adherence to Principles A and C of Binding Theory and suggest that further research using the preferential looking procedure to investigate young children's knowledge of syntactic constraints may be fruitful.

Knowledge of syntax includes an understanding of how words are arranged into constituents and of how the resulting phrase structures are mapped onto meaning. In this paper, we consider young children's knowledge of syntactic constraints on Noun Phrase reference. Such constraints limit the possible mappings of form onto meaning by governing when two Noun Phrases may be understood as referring to the same individual. Because they depend on both the structure of the sentence and the type of Noun Phrase in question, they offer a valuable window on the acquisition of clause structure.

Compare, for instance, sentences (1) and (2), which differ in their clause structures. In (1), the grammar dictates that the pronoun *she* may not refer to Katie, regardless of how salient Katie is in context. In contrast, in (2) coreference is possible.

(1) She went for a walk while Katie called home.

(2) While she went for a walk, Katie called home.

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Despite the fact that the pronoun *she* precedes the name *Katie* in both examples, coreference is available in (2) but not (1). Thus, the constraint that prohibits coreference between the name and the pronoun in (1) must be stated in terms of a particular abstract hierarchical relation between Noun Phrases in the sentence, not in terms of linear order (Langacker, 1969; Lasnik, 1976). The types of Noun Phrase involved are also relevant. Compare (3) and (4).

(3) Katie's helping her.

(4) Katie's helping herself.

Both sentences have the same constituent structure, but the final Noun Phrase is of a different type. In the first sentence, the final pronoun may not refer to Katie, and in the second it must.

Acquiring adult-like competence with grammatical constraints therefore requires both lexical knowledge and a system that makes reference to abstract structural relations (Chien & Wexler, 1990; Lidz, 2007). Acquisition of grammatical constraints is pertinent to two major issues in language acquisition. First, they are often brought up in debates about the learner's contribution to language learning due to claims that an innate representational component is required for learners to acquire a constraint making certain form-meaning pairs impossible (e.g., Crain, 1991). Second, evidence that children have an adult-like version of constraints on Noun Phrase reference is evidence that they represent clause structure hierarchically.

Previous studies of children's adherence to constraints on Noun Phrase reference suggest that children demonstrate knowledge of these constraints consistently from the age of 3 or 4 onward, depending on the particular constraint and method of testing (e.g., Conroy, Takahashi, Lidz, & Phillips, 2009; Kazanina & Phillips, 2001; Lust, Eisele, & Mazuka, 1992; for reviews, see Goodluck, 2007; Lidz, 2007). Younger children have not previously been tested.

This is an important gap to fill. Hierarchical representation is abstract and may be difficult to infer from behavior. Lidz, Waxman, and Freedman (2003) demonstrate that children as young as 18 months of age represent Noun Phrases as having internally nested hierarchical structure, interpreting the pronoun *one* as referring back to an adjective-noun constituent, rather than the noun alone, but similar evidence at the level of the clause is lacking. Evidence that children obey constraints on Noun Phrase reference at an earlier age, and thus that younger children represent sentences as having hierarchical structure would be an important step forward. Furthermore, accounts that any particular constraint is innate make a strong prediction of continuity across development, subject to the potential influence of processing factors. To test this prediction it is necessary to investigate the developmental trajectory of children's knowledge of grammatical constraints and examine what predicts their success. For accounts that constraints are learned, evidence for or against earlier acquisition would place limits on the type and amount of data available to drive learning.

It is important to note at this stage that observations about children's interpretations of a small set of sentences are necessarily compatible with many characterizations of the knowledge that gives rise to these interpretations. Previous research on children's adherence to Principle C, the principle of grammar widely held to constrain binding in (1), has typically tested children's interpretations of sets of sentence structures such as those shown in (5) and (6) (Crain & McKee, 1985; Eisele & Lust, 1996; Kazanina & Phillips, 2001), which permits the elimination of a particular alternative hypothesis: that children use a constraint based on linear order, rather than an adult-like, structure-based constraint.

(5) He ate the hamburger when Smurf was on the fence.

(6) When he stole the chickens, the lion was in the box.

In this paper we test 30-month-olds' interpretation of a single sentence for each constraint of interest, which will necessarily be compatible with many characterizations of the knowledge that gives rise to these interpretations. Consequently, we proceed cautiously in this paper, providing evidence only that children correctly interpret such sentences. Nonetheless, we frame the paper in terms of the Binding Principles, as this allows us to use a precise theoretical vocabulary for characterizing the potential cognitive source of children's behavior. As it is, this study represents a crucial first step toward determining whether children under 3 adhere to the Binding Principles in their mature form, as do older children and adults.

THE BINDING PRINCIPLES

The Binding Principles are a series of constraints governing referential dependencies in language (Chomsky, 1981). These principles define the structural configurations over which such dependencies can and cannot be computed and the locality domains in which these configurations are relevant. Principle A governs the distribution of reflexive pronouns and reciprocals. Principle B governs the distribution of nonreflexive pronouns. Principle C governs the distribution of "R-expressions," a category comprising all other Noun Phrases, including names, definite descriptions, and quantificational expressions. The Binding Principles restrict the permissible form-meaning pairs in language by limiting the reference possibilities within a particular type of sentence. A formal statement of the Binding Principles (from Chomsky & Lasnik, 1993) and the requisite technical terms are given in (7)–(11). Because Principles A and C have been the most robust in previous studies of children's knowledge, we focus on those.

(7) Principle A: An anaphor must be bound in a local domain.[1]

(8) Principle B: A pronoun must not be bound in a local domain.

(9) Principle C: An R-expression must not be bound.

(10) X binds Y iff

a. X c-commands Y AND
b. X is coindexed[2] with Y.

(11) X c-commands Y iff

a. The first branching node dominating X also dominates Y.
b. X does not dominate Y.

[1]The precise definition of "local domain" has been the subject of debate since Chomsky (1973) and is immaterial for the purposes of this paper. As a rough approximation we take local domain to refer to the minimal clause containing the anaphor or pronoun.

[2]Coindexation is a syntactic device for indicating reference. If two NPs are coindexed in the syntax, then they are interpreted as identical in the semantics.

For our purposes, the effect of these definitions is that Principle C prohibits coreference between a name and a c-commanding pronoun, and Principle A requires that a reflexive have a coreferential, c-commanding Noun Phrase within the minimal clause containing it. Consider the following sentences:

(12) She's patting the dough.

(13) She's patting Katie.

(14) She's patting herself.

In (12) there is no reflexive pronoun, nor a relevant R-expression in the c-command domain of the pronoun, and so neither Principle A nor C constrain the interpretation. Consequently, *she* can refer to any female in the discourse model, including Katie. In (13), an R-expression, the name *Katie* is in the c-command domain of the pronoun *she*, and so these expressions must be disjoint in reference. The effect of Principle C is that *she* may not refer to Katie. Similarly, in (14) the reflexive pronoun *herself* appears in the local c-command domain of the pronoun *she*. Because Principle A requires that a reflexive be bound in the local domain, this means *she* and *herself* must be coreferential.

Thus, a grammar unconstrained by the Binding Principles would allow (15a) and (15b) as potential meanings for both (13) and (14), while a grammar constrained by Principle C would allow only (15a) as an interpretation of (13), and a grammar constrained by Principle A would allow only (15b) as an interpretation of (14).

(15) a. She_i's patting Katie_j. DISJOINT REFERENCE (SHE $\neq$ KATIE)

b. She_i's patting Katie_i. COREFERENCE (SHE $=$ KATIE)

Several early studies showed that children as young as 3 and 4 years old reliably demonstrate knowledge of Principle C, consistently refusing to assign coreferential interpretations to sentences governed by the constraint (e.g., Crain & McKee, 1985; Eisele & Lust, 1996; Kazanina & Phillips, 2001; Lust & Clifford, 1986; Lust, Loveland, & Kornet, 1980). Other studies show that children abide by Principle A from at least the age of 4, preferring locally bound interpretations of reflexive pronouns (e.g., Chien & Wexler, 1990; McDaniel, Cairns, & Hsu, 1990; McKee, 1992).

Many of these studies used the truth-value judgment task (TVJT). This method allows researchers to explore the properties of children's grammars by testing children's acceptance of specific sentence-meaning pairs. In the task, children watch a short story acted out in front of them using small toys and then judge a potentially ambiguous description of the story uttered by a puppet to be true or false. Stories are designed to make the two potential meanings for the test sentence salient and to make one meaning true and the other false. Children's judgments of the puppet's description reveal whether they believe the true sentence-meaning pair to be acceptable. From these judgments, researchers can infer which interpretations children disallow, and thus make inferences about their grammars.

The TVJT represents a particularly powerful way to test children's knowledge of constraints. Children have a general bias to assume that their interlocutors are speaking truthfully and therefore tend to answer "yes" to experimenter's questions when a sentence can be interpreted as true (Crain & Thornton, 1998). Thus, consistent refusals to accept the puppet's description of the event in the TVJT are strong evidence that their grammar disallows a particular sentence-meaning pair.

For instance, Crain and McKee (1985) tested 3- and 4-year-olds on sentences like (5) and (6). They found that children correctly rejected the coreferential interpretation of (5), answering "no" 88% of the time. In contrast, children correctly and reliably accepted the coreferential interpretation of (6), saying "yes" 73% of the time. This suggests that children obey a mature, structure-based version of the constraint, not one based on linear order. This finding has been further supported in studies by Lust and Clifford (1986), Eisele and Lust (1996), Guasti and Chierchia (1999/2000), Kazanina and Phillips (2001), and Leddon and Lidz (2005), among others.

Children's demonstration of mature knowledge of grammatical constraints in these studies is impressive, but in light of more recent research, children's mastery of these constraints at this age is perhaps unsurprising. After all, preschoolers already have large vocabularies, regularly form complex sentences, and show knowledge of other related constraints (for a review, see Goodluck, 2007; Lidz, 2007). To probe the developmental profile of this constraint, it is necessary to test younger children's interpretations of similar sentences.

In fact, evidence from the word-learning literature suggests that children as young as 19 months are already interpreting sentences of the necessary complexity (Yuan, Fisher, & Snedeker, 2012). In a preferential looking task, 19-month-olds looked longer at a video showing an event with two participant-roles (one man pushing another so that he bends forward) when they hear a transitive sentence, such as (16), than when they hear an intransitive sentence, such as (17).

(16) He's gorping him.

(17) He's gorping.

The preferential looking task is based on the finding that infants and toddlers look longer at a visual stimulus that matches audio they hear than at one that does not (Hirsh-Pasek & Golinkoff, 1996; Spelke, 1979).[3] Thus, children's preference for the two-participant video over a one-participant video (one man making arm-circles) suggests that they prefer an interpretation in which each Noun Phrase in the sentence is assigned a separate participant-role.

This is an important point on the developmental trajectory we are discussing: by 19 months toddlers have begun to assign interpretations to sentences with more than one NP, the context in which constraints governing intrasentential patterns of reference become relevant. However, knowing that toddlers prefer a two-participant interpretation over a one-participant interpretation in these studies tells us little about young children's syntactic representations or constraints on interpretation that depend on such representations. In fact, toddlers' use of the number of Noun Phrases in the sentence to help them determine transitivity has typically been described as a simple, innate heuristic that assigns each Noun Phrase in the sentence an argument role, present and helpful even before children can assign a hierarchical structure to the sentence (e.g., Fisher, 2002; Yuan et al., 2012). What developmental trajectory takes children from these earliest forms of sentence interpretation to adult-like competence with the complex grammatical constraints that govern Noun Phrase reference?

[3]Looking time is a measure whose interpretation varies across paradigms (Aslin, 2007; Johnson, Slemmer, & Amso, 2004; Rose, Gottfried, Melloy-Carminar, & Bridger, 1982; Wagner & Sakovits, 1986) but in intermodal matching experiments such as the one reported here, looking time is a reliable indicator of the participant's perception of the match between visual and auditory stimuli.

THE PRESENT STUDY

The current study investigates whether 30-month-old children prefer different interpretations for different types of transitive sentences. To do this, we use a preferential looking task. This task makes fewer demands on children's working memory and language processing abilities than truth-value judgment and act-out tasks do, and the word-learning literature has shown it to be useful in testing very young children's interpretations of sentences of similar complexity.

Recall that there are two potential interpretations of transitive sentences containing two Noun Phrases: one in which the two Noun Phrases have disjoint reference and one in which they are coreferential. Because these two potential meanings correspond to different events, we can use the preferential looking task to determine which event 30-month-olds understand the sentences in (13) and (14) to describe. In the current study, we present these two events to children as videos, each showing the same two women, and paired with a sentence of interest. In one video a single character is both the agent and the patient of the action depicted (self-directed), and in the other different characters fill the agent and patient roles (other-directed).

While watching these videos, children hear a sentence of one of two types: Name or Reflexive. In both cases the verbs are transitive and there are two Noun Phrases present in the sentence. Thus, a grammar unconstrained by the Binding Principles should permit either interpretation for either sentence. In a grammar constrained by the Binding Principles, however, each sentence will get a different interpretation: Principle C prohibits the coreferential (self-directed) interpretation of Name sentences, and Principle A prohibits a disjoint (other-directed) interpretation of Reflexive sentences. If 30-month-olds differentiate between the two types of transitive sentences, assigning them different interpretations, we should see it in their looking patterns.

An anonymous reviewer correctly points out that the strongest inference that can be drawn from preferential looking-time data is that the child prefers one interpretation of the stimulus. If a child looks longer at one video or image than the other, we cannot conclude that the child would under no circumstances accept the less-preferred option as a possible match. Consequently, inferences from children's behavior to their grammatical knowledge and their knowledge of constraints prohibiting certain interpretations in particular are somewhat delicate. In this case, however, explicit tasks that permit stronger inferences are too demanding for young children and may even be subject to the same concern (see Conroy et al., 2009; Viau, Lidz, & Musolino, 2010). Therefore, in order to begin characterizing younger children's knowledge, we rely on a paradigm that will reveal their preferred interpretations.

METHOD

Participants

Thirty-two children (19 boys, 13 girls) ranging in age from 28;14 to 33;1 (mean 30;6) were included in the final sample. All participants were recruited from the College Park, Maryland, area and were exposed to English more than 80% of the time. Parents filled out a MacArthur Communicative Development Inventory: Words and Sentences questionnaire (Fenson et al., 1994). Mean productive MCDI vocabulary was 446 words (range: 76–675 of 680 possible). An additional two children were excluded from the sample for refusal to sit through the experiment (1) and for incomplete MCDI (1).

Materials

To determine what interpretations 30-month-olds preferentially assign to different types of two-NP transitive sentences, in critical trials we simultaneously presented children with two event video clips and a sentence of interest. The two events corresponded to two potential two-role interpretations of transitive sentences: a self-directed and an other-directed action. Critical sentences were of two types, Name and Reflexive, shown in (18) and (19). Note that both types include two Noun Phrases; it is only the type of the second Noun Phrase that differs.

(18) She's washing Katie. NAME

(19) She's washing herself. REFLEXIVE

Adults, who are familiar with the function of reflexive pronouns and have mastered Principles A and C, will map (18) onto the other-directed event, and (19) onto the self-directed event. Do children do the same, or do they rely primarily on the number of Noun Phrases in the sentence when assigning meaning?

If we find a different pattern of responses in the Name and Reflexive trials, we can conclude that 30-month-olds have begun to differentiate between different types of two-NP transitive sentences, and assign them different sorts of two-role meanings. Furthermore, if we see differences for each sentence type between a neutral baseline period and the test period in which the critical sentence is presented, we can conclude that 30-month-olds are beginning to understand the rules involved in determining Noun Phrase reference for both NP types in this configuration.

Eight critical trials were embedded in a 5.5-minute video. The video began with an introduction to the two characters and included six short "face checks" interspersed throughout. The introduction consisted of a series of centrally presented video clips showing the two characters individually, accompanied by audio naming the character shown. This served to familiarize participants with the characters and to teach them the characters' names. Note that though hearing and learning the names may help children to process the subsequent sentences, the nature of the test sentences and event videos made knowing the character's names unnecessary. The face checks presented participants with side-by-side images of the two characters, accompanied by audio directing them to find one character or the other. The critical trials are the final component of the video. The eight critical trials each showed a different continuous two-participant action (fanning, spinning, washing, drying, patting, covering, squeezing and painting). A schematic of a video order is shown in Table 1.

Each of the eight critical trials was made up of three phases: familiarization, salience and test. These are shown graphically in Table 2. During the familiarization phase, the two events, self-directed and other-directed, were shown sequentially, accompanied by audio that directs participants' attention to the action being shown, as in (20).

(20) It looks like someone's getting patted!

We chose to use a passive sentence with an indefinite subject because it introduces the relevant verb while being non-specific as to the identity of the participants in the event and applying equally to both the other-directed and the self-directed actions. This allows participants to hear the verb that will be used in the test sentence and to see each of the event-videos before being presented with them at test. It is not necessary that participants fully understand the passive construction, only that they hear the verb and see both videos.

TABLE 1
Schematic of a Video

Items	*Length*	*Sample Audio*
Character Introduction	58 s	Hey look! There's Anna! She's waving! Wow! There's Katie! She's waving too!
Face Check 1	6 s	Where's Katie? Do you see Katie?
Face Check 2	6 s	Where's Anna? Do you see Anna?
Trial 1	27 s	She's drying Anna!
Face Check 3	6.5 s	Find Anna! Do you see Anna?
Face Check 4	6.5 s	Find Katie! Do you see Katie?
Trial 2	27 s	She's patting Katie!
Trial 3	27 s	She's painting herself!
Trial 4	27 s	She's fanning Anna!
Face Check 5	6 s	Where's Katie? Do you see Katie?
Trial 5	27 s	She's spinning herself!
Trial 6	27 s	She's washing Katie!
Trial 7	27 s	She's squeezing herself!
Face Check 6	6 s	Anna's waving! Do you see Anna waving?
Trial 8	27 s	She's covering herself!

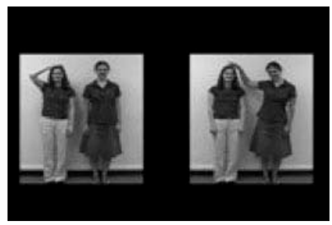
During the salience and test phases, the self-directed and other-directed events appeared simultaneously, one on each side of the screen. The salience phase lasts three seconds, during which neutral audio simply drew participants' attention to the screen. This allowed us to determine participants' baseline preference for the events. The test phase was nine seconds long, during which participants heard the test sentence three times. If children show a preference for one event over the other as a result of their interpretation of the sentence, we expect it to surface within this nine-second period.

All visual stimuli were recordings of live actors performing the continuous two-participant actions named by the verbs. Audio was recorded by a native speaker of American English using child-directed speech intonation. Tokens of each utterance were selected for clarity and consistency of speaking rate and then synchronized with the video. Audio always began 600ms after the corresponding video. The three instances of the test sentence were synchronized by their offsets, which occurred 4.5, 7.5, and 10.5 seconds after the appearance of the side-by-side event videos.

Design

This resulted in a 2 (trial type) x 2 (window) design, with proportion of time spent looking to the other-directed action as the dependent measure. Both trial type and window were within-participant factors: children heard 4 Name trials and 4 Reflexive trials each, in pseudorandom order, and each critical trial included a salience and a test window. (See Table 1 for a schematic of a video sequence.) Eight such sequences were created by crossing order (critical trials in the order shown in Table 1 or the reverse), trial type (Name or Reflexive sentence) and the first video shown in familiarization (other- or self-directed). Thus, across participants, each verb occurred equally in the first or second half of the video, appeared equally in the two sentence types, and

TABLE 2
Trial Layout

Phase	*Time*	*Audio*	*Video*
Familiarization	6 s	Hey look! It's Anna and Katie! It looks like someone's getting patted!	
	6 s	Wow! There they are again! It looks like someone's getting patted again!	
Salience	3 s	Hey look! Now they're different!	
Test (Name trial)	9 s	She's patting Katie! Do you see the one where she's patting Katie? Find the one where she's patting Katie!	

was preceded equally often by both potential orders for the events during familiarization. Within participants, in addition to the critical trial type, first familiarization video and match side were evenly distributed across trials: in each video sequence there were equal numbers other- and self-directed actions as the first event in familiarization, and the event an adult would choose as a match appeared equally on the right and the left.

Procedure

Children and their parents were greeted and shown to the laboratory playroom, where parents filled out the consent form and MCDI while children played freely. When the forms were complete and participants were acclimated to the laboratory surroundings, one parent and the child were shown to the adjacent testing room. The testing room was 8.5x10.3 feet, sound-attenuated and had plain white walls.

Children were seated in a highchair centered in front of a 51-inch plasma television at a distance of six feet. Parents were seated behind the child's highchair, out of the child's field of vision and out of physical contact with the child. Parents were asked not to talk to their child or direct their child's attention during the experiment. Overhead lights were dimmed so that most of the light in the room came from the television. A camera mounted directly over the television captured the participant's eye movements for subsequent coding.

Researchers controlled stimulus presentation from the adjacent control room. Researchers could control the position and zoom of the camera in order to keep the child's eyes in sight throughout the experiment, even if the child moved. This, however, was almost never necessary. Visual stimuli appeared on a 3.5x1.7-foot area of the screen.

The video-feed from the camera, with the addition of a picture-in-picture window of the video being shown to the child, was recorded to a lab computer using QuickTime. This was subsequently coded frame-by-frame (30 frames per second) for looks to the left, right or neither, using SuperCoder (Hollich, 2005). Coders were blind to condition, and could not hear the audio.

RESULTS

Figure 1 shows the average proportion of time spent looking to the other-directed action. This was calculated for each participant by dividing the number of video frames (30 frames/second) in which the child was looking to the other-directed event by the number of frames in which the child was looking to either event. During the salience window, children did not look preferentially at either event. During the test window, however, children looked longer at the other-directed event during Name trials than during Reflexive trials.

Data analysis was conducted using empirical logit mixed effects models, fit in R (R Core Team, 2013) with the *lmer()* function of the *lme4* library (Bates, Maechler, & Bolker, 2013). The dependent measure in the models was the empirical logit transform of the proportion of time spent

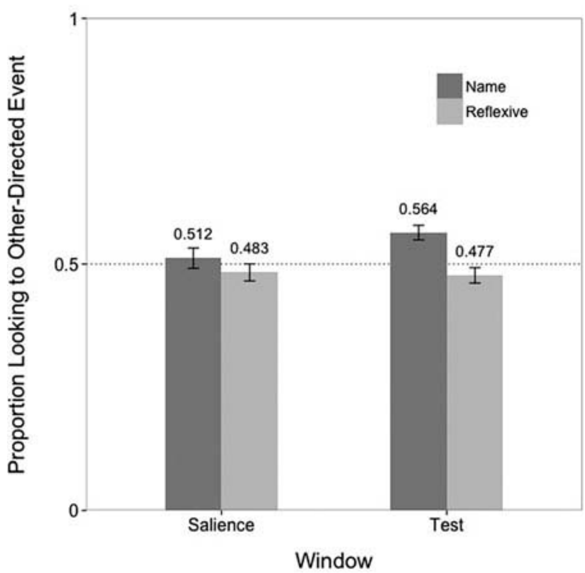


FIGURE 1 Average looking time to other-directed event, as a proportion of looks to either event.

looking to the other-directed action out of time spent looking to either action. In a preliminary analysis, predictor variables were the fixed effects of participant age and MCDI score, in addition to the crucial fixed effects of window (salience or test) and trial type (Name or Reflexive), and all interactions. Both window and trial type were coded with mean-centered variables.

By comparing the full preliminary model to models that dropped age or vocabulary and the associated interactions (see Appendix), we were able to test whether those factors contributed to model fit. Model comparison revealed that including participant age and its interactions did not significantly improve fit ($\chi^2(8) = 12.28$, p = .139; further details in appendix), and age was therefore dropped from subsequent analyses. Vocabulary score and its interactions, however, did improve model fit ($\chi^2(8) = 24.61$, p = .0018), and were retained.

Analysis followed the procedure outlined by Barr, Levy, Scheepers, and Tily (2013). Because the model with the maximal random effects structure resulted in rather severe nonconvergence issues, we used the recommended forward best path algorithm ($\alpha = .2$) to determine which random slopes to include in our model. The resulting model included the random intercepts for participants and items and retained only the by-item random slopes of window and the window-vocabulary interaction. The model syntax can be found in the Appendix.

Parameter estimates are shown in Table 3. There was a marginal main effect of vocabulary, and there were significant interactions of trial type and window and of trial type, window, and vocabulary. To better understand these effects, we offer two displays of our data. Figure 2 shows each child's performance (raw proportion looks to the other-directed event in the test window) as a function of MCDI-vocabulary and trial type. The LOESS (locally weighted scatterplot smoothing; Cleveland & Devlin, 1988) curves represent an estimate of the effect of increasing vocabulary size on looking times. Figure 3 shows average looking time to the other-directed action in each window and trial type for two vocabulary groups, created by splitting children around the median MCDI score of 504.5 words. Both the model fit and the graphs make it plain that there are different patterns of response within our sample: Children with higher vocabularies showed a greater influence of sentence type, looking longer at the other-directed video in Name trials, and longer at the self-directed video in Reflexive trials. Children toward the low-vocabulary end of the scale show smaller differences between trial types.

Minimally, this suggests that higher-vocabulary 30-month-olds have begun to distinguish between the two types of transitive sentences tested and preferentially assign them different two-role meanings. The fact that only higher-vocabulary children appear to differentiate between the two sentence types is a difficult pattern to interpret. We return to the vocabulary effect in the discussion.

DISCUSSION

The aim of the present study was to investigate 30-month-olds' interpretation of two different types of transitive sentences, in hopes of better characterizing young children's knowledge of constraints on Noun Phrase reference. We found that children's looking behavior differed depending on the sentence structure. Overall, children looked longer to the other-directed event when they heard Name sentences than when they heard Reflexive sentences (Figure 1). This suggests that they differentiate between these two types of two-participant-role actions, and that they have begun to determine which types of sentences may make reference to each. Furthermore,

TABLE 3
Estimates for Empirical Logit Mixed Effects Model of Looking Time, with Vocabulary Score as a Between-Participants Factor (N = 507, AIC = 1737, BIC = 1822, Log Likelihood = -848.6)

	Model Summary			*Model Comparison*		
	β	*SE*	*t*	χ^2	*df*	*p*
Fixed Effects						
Intercept	0.29	0.14	1.99	3.44	1	0.064
Window	−0.16	0.35	−0.46	0.23	1	0.635
Sentence Type	0.07	0.28	0.24	0.05	1	0.821
Vocabulary	−0.0005	0.0003	−1.55	2.85	1	0.092
Window × Sentence Type	−1.64	0.57	−2.88	8.12	1	0.004*
Window × Vocabulary	0.0007	0.0008	0.91	1.64	1	0.2
Sentence Type × Vocabulary	0.0005	0.0006	0.83	0.73	1	0.393
Window × Sentence Type × Vocabulary	0.004	0.001	3.68	13.32	1	<.001*

	s^2	*Correlations*		
Random Effects				
Subject				
Intercept	2.6968e-08			
Item				
Intercept	6.1843e-03			
Window	3.2923e-01	−0.136		
WindowSalience × Vocabulary	1.1460e-06	0.456	0.820	
WindowTest × Vocabulary	1.6983e-07	−0.333	−0.889	−0.991

higher-vocabulary children show distinct differences in both conditions: an increase in looking to the other-directed action in the Name condition, and a decrease in the Reflexive condition (Figure 3). This suggests that each of these sentence types is making a contribution to the effect.

Because we only tested two sentence types in this study, we are unable to determine whether 30-month-olds are sensitive to the specific structural criterion for Principle C's application or the locality restrictions on the appearance of reflexive pronouns. Just as there were numerous theoretical antecedents to Principle C during the development of binding theory in the 1960s and 1970s that were eventually shown to provide inadequate descriptions of the facts (e.g., Chomsky, 1980; Dougherty, 1969; Lakoff, 1969; Langacker, 1969), there are many competing hypotheses that are equally consistent with children's preference for one interpretation of a particular sentence structure. Some reasonably straightforward alternatives are shown in (21):

(21) Children obey a constraint prohibiting a pronoun from coreferring with . . .

a. any Noun Phrase in the same sentence
b. any Noun Phrase that it precedes
c. any Noun Phrase in the minimal clause containing it
d. any Noun Phrase that it precedes in the minimal clause containing it
e. any Noun Phrase that it c-commands in the minimal clause containing it

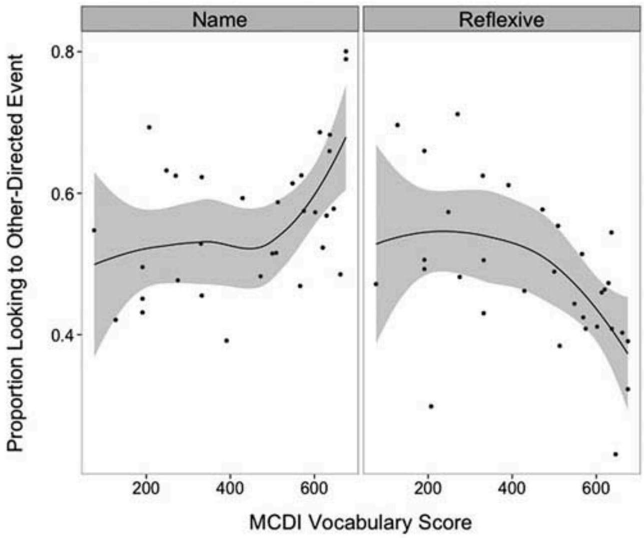


FIGURE 2 Proportion looks to other-directed event in the test phase for each sentence type, as a function of MCDI vocabulary. LOESS curves represent the effect of vocabulary on looking time. Shaded area represents a 95% confidence interval.

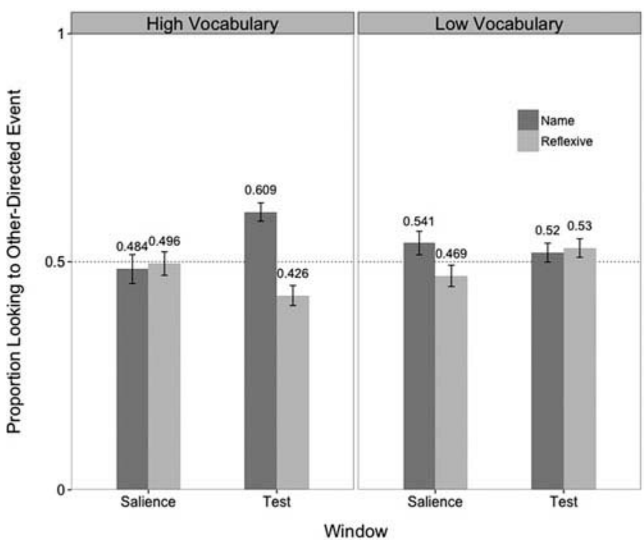


FIGURE 3 Average looking to other-directed video. High and low vocabulary groups were created for the purposes of data display by splitting participants around the median MCDI score of 504.5 words. All analyses used raw vocabulary score, not a binary measure.

Ruling out each of these equally plausible alternatives to Principle C, and similar alternatives to Principle A, as potential accounts of the current data would require substantial further experimentation, which we leave to future research.

Despite the difficulties involved, further investigation of young children's knowledge of these and other constraints on Noun Phrase reference will have much to contribute. Investigating children's knowledge of constraints provides an excellent way to explore their ability to represent and use hierarchical structure during online sentence processing. Furthermore, because of the Binding Principles' role in ruling out particular form-meaning pairs, researchers have argued that they must depend on innate knowledge (e.g., Crain, 1991). A better understanding of the developmental trajectory that constraints on Noun Phrase reference follow is crucial to testing this innateness hypothesis. By bringing the preferential looking procedure to bear on questions of constraint acquisition, we have begun to pave the way for future research clarifying the sources of the preferences children show in the current study, and extending these investigations to even younger children.

Interpreting the vocabulary effect we find requires care. First, no model predicts that vocabulary size should have any direct effect on constraints on pronoun interpretation. Second, MCDI vocabulary score is simply one measure of productive vocabulary among a particular set of participants, as reported by their parents and relative to a particular list of words. Thus, to the extent that vocabulary size tells us anything, it does so indirectly.

There are many reasons that this task may have been too difficult for some children. After all, despite making fewer demands on children than other methods, this is still a difficult task. It involves distinguishing and choosing between two highly similar videos. On each trial, both videos show the same two people, in the same left-right configuration, performing the same action. The sole difference is whether the patient of the event is the actor herself or her partner. As they parse and compare the two event videos, children must also be attending to, parsing and assigning meaning to the test sentence. In order to show sensitivity to the form of the test sentence in their looking times, all of this must be completed well before the end of the test window.

Taking the working assumption that the constraint driving children's interpretations is structural in nature, there are at least two potential reasons that vocabulary might correlate with performance on this task. Vocabulary correlates with both grammatical development (Bates & Goodman, 1997) and increasing processing efficiency (Fernald, Perfors, & Marchman, 2006), both of which are necessary for successful online application of constraints on Noun Phrase reference. Specifically, if grammatical development is not sufficiently advanced, children will fail to rule out the inappropriate interpretation because they fail to consistently and successfully construct the structure of the sentence they are hearing, and have no way to calculate the relationships over which the constraints are defined. Similarly, children might have sufficient grammatical capacity, but lack the processing abilities necessary to access words in the lexicon, assign a syntactic structure to the sentence, assign meaning and map it onto the event videos presented. If children fail to complete these component processes with sufficient speed, they will be unable to comprehend the sentence and match it with the video before the trial ends.

Of course, many alternative explanations exist. Vocabulary effects appear in studies of many aspects of language acquisition and at many different ages (e.g., Borovsky, Ellman, & Fernald, 2012; Scott & Fisher, 2012). This suggests that vocabulary correlates with independent individual differences in both linguistic and nonlinguistic cognition as well.[4] Children who are more

[4]Thanks to Jesse Snedeker for pointing this out in her review.

distractible, or less concerned with what adults want them to do may fail to show clear responses to the test sentences for reasons independent of their actual ability to process the sentence or compute a constraint.

These findings add to the existing literature on the acquisition of grammatical constraints by bringing a new methodological paradigm to bear. We show evidence that 30-month-olds have begun to assign different meanings to different types of two Noun Phrase transitive sentences. This demonstrates that children have already made strides toward refining simple counting-the-nouns biases in the direction of the complex constraints they will eventually master. Furthermore, we open the way for gathering evidence on the nature of the knowledge that gives rise to the interpretations we observe and for outlining the developmental timecourse with much younger children.

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APPENDIX

Preliminary Model

```
prelim <- lmer(emplogit_looks ~ 1 + window*trialtype*age*vocab +
(1|participant) + (1 + window|item))
```

Model comparison for age and interactions

```
noage <- lmer(emplogit_looks ~ 1 + window*trialtype*vocab +
(1|participant) + (1 + window|item))
  anova(noage, prelim)
         Df  AIC     BIC     logLik   Chisq   Chi Df  Pr(>Chisq)
  noage  13  1666.2  1721.1  -820.08
  prelim 21  1669.9  1758.7  -813.94  12.282  8       0.1391
```

Model comparison for vocabulary and interactions

```
novoc <- lmer(emplogit_looks ~ 1 + window*trialtype*age +
(1|participant) + (1 + window|item))
  anova(novoc, prelim)
         Df  AIC     BIC     logLik   Chisq   Chi Df  Pr(>Chisq)
  novoc  13  1678.5  1733.5  -826.25
  prelim 21  1669.9  1758.7  -813.94  24.606  8       0.001812 **
```

Final Model

```
lmer(emplogit_looks ~ 1 + window*trialtype*vocab +
(1|participant) + (1 + window + window:vocab|item))
```