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Semantic Interactions of Quantificational Expressions in Child Language*

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The nature of language acquisition has fueled a debate between the generative approach and the constructivist approach. These approaches disagree about both the quantity and quality of innate linguistic knowledge. The present study compares these two approaches using children’s acquisition of the semantics of quantification. Specifically, we investigate whether children are aware of a semantic property associated with the universal quantifier every, and its non-local interaction with the negative quantifier nobody. Children’s adult-like comprehension of sentences with these two quantificational expressions reveals early mastery of the complex semantic properties of natural languages, and is suggestive of innate linguistic knowledge.

1. Introduction

The universal quantifier every introduces a downward entailing environment in its first argument, i.e., the NP (Ladusaw 1976, Zwarts 1996, among others). Consequently, the first argument of every encompasses the following linguistic phenomena: it creates valid certain inferences between sentences, namely inferences from expressions that refer to a set of things, to ones that refer to a subset of those things, as in (1); it accepts the negative polarity item (NPI) any, as in (2); it licenses ‘conjunctive’ entailments with disjunction, as in (3)\(^1\).

* We would like to express our gratitude to the following people: Paul Pietroski, Rosalind Thornton, Luisa Meroni, Andrea Gualmini, Robert Fiorentino, Lisa Pearl, Anastasia Conroy, Colin Phillips, and especially the staff, children and parents of the Center for Young Children, UMCP.

\(^1\) This interpretation of disjunction is characteristic, more generally, of downward entailing linguistic environments, including the first argument of every. This is a generalization of one of De Morgan’s laws, according to which a disjunction in the scope or negation (or, more generally, any downward entailing expression) is logically equivalent to the conjunction of the two negated premises, as the following truth table illustrates.

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
<th>A ∨ B</th>
<th>¬(A ∨ B)</th>
<th>¬A</th>
<th>¬B</th>
<th>¬A ∧ ¬B</th>
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A number of studies have demonstrated children’s early mastery of some of these semantic properties of the universal quantifier every. For example, children license ‘conjunctive’ entailments for disjunction when it appears in the first argument position of every, but not when it appears in the second argument position (the VP) (Crain et al. 2002; Gualmini in press). On the other hand, it is not obvious whether or not children license valid inferences between sentences with every (Philip and de Villiers 1992; de Villiers et al. 1998).

The present paper focuses on some consequences of the entailments generated within the first argument of the universal quantifier every, starting from the fact that this argument position permits valid downward entailments, i.e., inferences from claims about things to claims about subsets of those things (Experiment I). Once we have established that children know this aspect of natural language quantification, we put this knowledge to use in Experiment II, to see if children know that embedding one downward entailing expression under another reverses the pattern of entailments. Finally, in the third experiment, we aim to rule out a superficial account of children’s linguistic behavior in Experiments I and II, by comparing children’s responses to sentences with every with their responses to corresponding sentences with lots of. Although these expressions are similar in meaning, they differ in their entailments. Experiment III assesses children’s knowledge of the differences in entailments between these expressions.

2. Experiment I

We look first at children’s knowledge of the semantics of the universal quantifier in minimal pairs of sentences, such as (4). For this experiment, we constructed contexts that falsify one member of the pair, but verify the other member. Notice that sentence (4a) entails (4b), but not vice versa. As a consequence, it is possible to construct contexts that falsify (4a), while leaving (4b) intact. The situation depicted in (5) represents one such context.

(4) a. Every dog has a chicken.
   b. Every brown dog has a chicken.
The aim of Experiment I was to establish whether or not children accept sentences like (4b), but reject (4a), when presented in the context depicted in (5). The experiment used the Truth Value Judgment task (Crain and Thornton 1998). Twenty English-speaking children (ages 3;8-5;6; mean 4;10) evaluated the sentences in (4) independently as descriptions of the situation in (5). The experimental hypothesis was that children would consistently accept (4b), but would reject (4a), if their awareness of the semantics of every is adult-like. This is exactly what happened. Children’s rate of acceptance for (4b) was 95% (19/20), and their rate of rejection for (4a) was 100%. With this preliminary finding in hand, we proceeded to examine children’s knowledge of more complicated sentences containing two quantifiers. In the next experiment, the entailment patterns in the test sentences of Experiment I are reversed, due to the presence of a second quantificational expression.

3. Semantic Interactions

Experiment I demonstrated that, in the first argument of the universal quantifier every, children licensed valid entailments from sentences with set-denoting expressions to ones with subset-denoting expressions, such as (6). We assume that if children judge a sentence with a set-denoting expression dog to be true, then they should also judge a sentence that differs from the first sentence in having a subset-denoting expression collie, to be true. While Experiment I did not test this directly, it showed that children could judge (6b) to be true, but (6a) to be false, reflecting their knowledge of the entailment relation among these two sentences. This will also serve as our metric in the second experiment.

(6)  a. [Every dog in town] has been vaccinated.
    b. [Every collie in town] has been vaccinated.

Consider the examples in (7), in which the examples from (6) are now preceded by the fragment no vet who treated. This fragment provides a 'negative' (downward entailing) environment for the NPs in (6): every dog in town and every collie in town. (Ludlow 2002)

(7)  a. [No vet who treated [every dog in town]] has been vaccinated.
    b. [No vet who treated [every collie in town]] has been vaccinated.

In (7), the every N phrases from (6) are now embedded in the first argument of the quantifier no. Since both arguments of the quantifier no are downward entailing, the every N phrases (every dog/every collie) in (6) reside within the scope of a downward entailing operator in (7). As a result, the sentences in (7)
no longer permit the inference from *every dog* to *every collie*. In fact, the entailment pattern is now reversed; (7b) entails (7a): *no vet who treated every collie in town has been vaccinated* entails *no vet who treated every dog in town has been vaccinated*, but not vice versa. Therefore, sentence (7a) could be a true description of a situation in which (7b) was false. In other words, the inference pattern that is licensed is from a subset-denoting expression (*collie*) to a set-denoting expression (*dog*), but the reverse inference no longer holds. That is, the pattern of inference is no longer downward; in fact, it is upward.

From an acquisition perspective, the reversal in truth conditions for sentences like those in (6) and (7) is worth investigating. For children to correctly compute the meanings of sentences like these, they would need to know to reverse the truth conditions that would be assigned to the expression *every N* if it were not in the scope of another downward entailing expression. Therefore, this phenomenon provides an interesting testing ground to examine children’s awareness of the semantic interactions between two quantifiers. To our knowledge, no one has studied children’s awareness of the reversal in the entailment pattern of a downward entailing operator such as *every N* in the scope of another downward entailing expression.

The outcome of this investigation is directly relevant to the claims of two approaches to language acquisition: the *generative approach* and the *constructivist approach*. The former claims that children come equipped with considerable linguistic knowledge (e.g., Chomsky 1981; Pinker 1984; Crain 1991; Crain and Pietroski 2001), whereas the latter approach emphasizes the influence of experience, and the gradualness of language acquisition (e.g., Tomasello 1995, 2000, 2003; Goldberg 2003).

Let us spell out these alternative approaches to children’s developing linguistic competence in slightly more detail. The generative approach assumes that an innately specified language faculty guides the process of language acquisition. Consequently, children are expected to project beyond their linguistic experience, often in ways that the input does not even suggest. Innate linguistic properties are seen to be operative at a considerable depth of abstraction, tying together apparently diverse linguistic phenomena, as illustrated in (1)-(3) for the first argument position of *every*. Children are expected to ‘cognize’ these apparently diverse phenomena from the earliest stages of language development (e.g., Chomsky 1981).

By contrast, the constructivist approach contends that language acquisition is usage-based, such that the course of acquisition largely depends on the specific input children are exposed to. According to this approach, children are initially conservative learners, with the earliest stages of language acquisition being devoted to learning the basic constructions attested in the input. Before age 3, young children build a stock of such basic/simple constructions, without symbolically marking differences in the functional roles of each construction. Later, the constructions children have amassed are functionally categorized as ‘words’, ‘NPs’, ‘VPs’, ‘Transitives’, ‘Questions’ and so on, “on the basis of their general skills of categorization (Tomasello 1995: 151)”. Children eventually combine the basic form/function units using ‘cut and paste’ operations to form more abstract/complex constructions, including novel utterances (Tomasello 1995, 2000, 2003).
Let us consider how each of these approaches would envision the acquisition of the entailments of complex sentences with quantificational NPs such as *every N* and *no N*. The generativist approach predicts that children will have no difficulty interpreting even complicated sentences with multiple quantifiers. Children are expected to compute the meanings of such sentences in an adult-like way, accessing the logic beneath the surface strings of words. Despite the non-local linguistic dependency between the phrases *no N* and *every N* in sentences like (7), children should be able to figure out that the normal behavior of the quantification NP *every N* is reversed in such sentences, because this phrase is c-commanded by another downward entailing expression *no N*.

The predictions of the constructivist approach are less clear. Children would presumably encounter quantificational expressions like *every N* more often in positive sentences, like (8a) and (8b), than in negative sentence like (8c). If so, children could be tempted to conclude that it is valid to replace set-denoting expressions like *every dog* by subset-denoting expressions like *every collie*. As (8b) shows, even when the phrase *every N* appears late in the string of words, the inference often remains valid. The problem children confront is in dealing with sentences like (8c). For adults, the inference in (8a) and (8b) is from the set-denoting expression *every dog* to the subset-denoting expression *every collie*. In (8c), it is the reverse, due to the presence of the determiner *no*. We conjecture that the constructivist approach would predict that children would generate a similar pattern of inference for all three types of sentences, based on frequency of occurrence, since ‘positive’ examples like (8a) and (8b) predominate in the input. If so, children should make errors in interpreting sentences like (8c), where the inference related to *every N* is reversed because of the presence of *no N* in the preceding position.

(8)  

a. Every *dog* chased a cat ⇒ Every *collie* chased a cat  
b. A cat chased every *dog* ⇒ A cat chased every *collie*  
c. No cat chased every *dog* *⇒* No cat chased every *collie*

To make matters even worse for learners who lack assistance from Universal Grammar, the reversal in entailment patterns for quantificational NPs like *every N* is triggered only if the two downward entailing quantificational expressions are in a specific structural relation, such that one downward entailing expression c-commands the other. Consider the following examples.

(9)  

[No vet who treated [every *dog* in town]] was vaccinated.  

*⇒ [No vet who treated [every *collie* in town]] was vaccinated.

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2 In fact, Minai’s (2004) input analysis demonstrated that the percentage of the utterances of *every N* appearing in downward entailing environments, such as negative environments, is considerably lower than that of *every N* in non-downward entailing environments, such as positive environments. Hence, the input children are exposed to would not provide the concrete ground for them to learn the fact that the entailment pattern in *every N* is determined depending on the context in which it appears.
(10)  [[A vet [with no experience]] treated [every dog in town]].
     ⇒ [[A vet [with no experience]] treated [every collie in town]].

In (9), the downward entailing expression no vet c-commands the other downward entailing expression every dog. Consequently, it is not valid to replace every dog with the subset-denoting expression every collie. However, in the absence of the c-command relation, as in (10), the inference from the set-denoting expression every dog to subset-denoting expression every collie is valid. If, as Goldberg claims that “constructionist theories do not derive one construction from another, as is commonly done in mainstream generative theory” (Goldberg 2003: 221), then the underlying structural representations that are needed to distinguish the truth conditions of sentences like (9) and (10) would not be readily available to children. According to the usage-based model, children would be required to learn the patterns of linguistic behavior for quantificational expressions like no vet and every collie independently, without having immediate access to the reversal in entailments that is triggered when the first expression c-commands the second. This should not be a problem for children according to the generative approach, since children are presumed to come to the task of language acquisition armed with knowledge about the consequences of downward entailments and about structural notions such as c-command.

Summarizing so far, the two approaches to language acquisition seem to make different predictions about children’s knowledge of the semantic interactions between two downward entailing quantifiers. The generative approach anticipates that children will manifest early mastery, based on their innate knowledge of downward entailment as well as knowledge of the (non-local) structural dependencies between constituents, including quantificational expressions. On the constructivist approach in contrast, the development of the linguistic competence to interpret sentences with multiple quantificational expressions would take considerable time, depending on the frequency with which such constructions were encountered. To compare these two approaches, we conducted a further experiment designed to examine children’s interpretation of sentences containing two quantificational NPs, every N and nobody.3

4. Experiment II

Experiment II was designed to investigate children’s awareness of the reversal in the entailment pattern of the first argument of every when this quantifier is in the scope of nobody. This experiment utilized the Truth Value Judgment task, based on the observation that the inference patterns we have described are

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3 Gualmini and Crain (2002) demonstrated children’s knowledge that the partitive expression none of the Ns creates a downward entailing environment in both its first and its second argument. Given that nobody has a similar semantics to none of the Ns, we assumed that children would know that nobody is downward entailing in both its first and its second arguments, as well as that every is downward entailing in its first argument. The present study extends this line of research to examine the interaction between nobody and every in children’s grammars.
reflected in the truth conditions that are assigned to minimal pairs of sentences. The experimental sessions were carried out by two experimenters, one who acted out the story, and the other who operated a puppet that watches the story along with the subject.

As in Experiment I, the two target sentences in each pair were independently presented in the same context, as illustrated in (11).

\[(11)\]
\[
\begin{align*}
\text{a.} & \quad \text{Nobody fed every koala bear.} \\
\text{b.} & \quad \text{Nobody fed every big koala bear.}
\end{align*}
\]

The test sentences such as (11) were presented as the puppet’s description of the story that has been acted out. Each sentence in (11) was presented in virtually the same story, as illustrated in (12).

\[(12)\]
\[
\text{This is a story about a zoo. There are three zoo-keepers: Eeyore, Tigger and Pooh, and they each have a cage of koala bear to take care of. In each cage, there are five koala bears: a few small ones and a few big ones. It’s dinner time, and they each prepare a bunch of pizzas for their koala bears. Eeyore starts feeding the small koala bears, but he soon realizes that he doesn’t have enough pizzas to feed the big koala bears. Then it’s Tigger’s turn. He says: “I will do better than you.” He starts feeding the small koala bears, and he manages to give a pizza to both of the small koala bears in his cage and to one of the big ones, before running out of pizzas. Finally, it’s Pooh’s turn. He says: “I know why you didn’t make it! You have to start by feeding the big koala bears!” So he gives a pizza to each of the big koala bears in his cage, but he also runs out of pizzas, so the two small koala bears in his cage do not get fed.}
\]

The outcome of the story in (12), i.e., the experimental context against which the subject evaluated the target sentences as in (11), is depicted in Figure 1.

**Figure 1: Experimental Context**

\[
\begin{array}{|c|c|c|}
\hline
\text{Eeyore} & \text{Tigger} & \text{Pooh} \\
\hline
\text{=} & \text{=} & \text{=} \\
\text{small koala bear} & \text{big koala bear} & \text{was fed} \\
\hline
\end{array}
\]

The crucial observation is that, in such a context, sentence (11a) is true, because none of the characters could feed all the koala bears in his domain; but sentence (11b) is false, because one of the characters (Pooh) was able feed all the big koala bears in his domain, though no one could feed all of his koala bears. Hence, the inference from (11b) to (11a) is valid, but not the reverse pattern. If children are aware of this, they should accept sentences such as (11a), but reject those such as (11b).
Each child was presented with four test sentences like those in (11), and an equal number of fillers, to balance the number of affirmative and negative responses by each child. Twenty-two children participated in this experiment. The children were tested individually, and ranged in age from 4;5 to 6;8, with a mean age of 4;11. The results are summarized in Table 1.

Table 1: Rates of correct responses

<table>
<thead>
<tr>
<th></th>
<th>“True” Condition</th>
<th>“False” Condition</th>
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<tbody>
<tr>
<td>Accuracy</td>
<td>89% (39/44) of acceptance</td>
<td>81% (34/42) of rejection</td>
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</table>

As shown in Table 1, children accepted the sentences like (11a) and rejected those like (11b), when presented in virtually the same context. Thus Experiment II revealed that children are sensitive to the reversed entailment pattern in the first argument of every in the scope of another downward entailing quantifier, nobody. This suggests, moreover, that children are aware of the c-command relation between every and nobody, and that they were able to use this relation to determine the truth conditions of the test sentences. These findings would resist explanation under the constructivist approach, but can be readily accommodated by the generative approach.

5. Experiment III

Despite the results from Experiment II, there still may remain doubts regarding whether children compute the meaning of the sentences based on the local interpretation of each quantifier, or whether they compute the meanings of the sentences based on the logical interaction of these quantifiers. To address this question, we designed a control experiment using another quantificational NP, lots of N, in place of every N. The quantifier lots of is similar in meaning to every, since sentences with either expression will both be true in a wide range of similar circumstances. However, the patterns of inference generated by the two expressions are diametrically opposed. Therefore, if children use the surface similarity among quantifier meanings to make generalizations about entailments, they will make false generalizations in making judgments regarding sentences in which lots of has replaced every. On the other hand, if children access the semantic property that distinguishes these expressions (downward entailment versus non-downward entailment), then they will be sensitive to the opposing truth conditions that are assigned to sentences with lots of.

The substitution of lots of for every raises a few additional issues that merit discussion. In particular, lots of, which is semantically similar to many, may introduce other factors that could interfere with children’s interpretation. According to the conventional analyses of quantifiers (Milsark 1976; Barwise and Cooper 1981), many is a weak quantifier, while the universal quantifier every is a strong quantifier. This distinction is intuitively clear, since the meaning of many/lots of introduces a sense of context dependence, whereas the

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4 One of the subjects answered “I don’t know” in two trials in the “False” Condition. We excluded these responses from the analysis.
meaning of *every* does not. The meaning of *every* is not context dependent in this sense, once the domain of quantification has been established. In addition, as Partee (1989) pointed out, the interpretation of *many* evokes an ambiguity between *cardinal reading* and *proportional reading*.

Given these potential confounds, special attention was paid toward eliminating the extra burden on children’s interpretive processes due to the difference between strong and weak quantifiers. To this end, we attempted to create plausible contexts for them to compute the meaning of *lots of* in the intended way. Our pilot data regarding how many objects children accept as referring to *lots of* X’s, i.e., how many objects they accept as providing the minimal cardinality for *lots of*, shows that at least five of the X’s in the experimental workspace is required to license the use of *lots of* X’s for children. As for the proportional reading, we observed that children accepted a two-thirds proportion of the objects as constituting *lots of* them.

Experiment III employed the same design as Experiment II, again utilizing the Truth Value Judgment task. The test sentences in each minimal pair were presented in virtually the same contexts, which were of the same structure as those in Experiment II. Sample test sentences are shown in (13); each sentence was presented in the end of the story as illustrated in (14).

(13) a. Nobody could catch *lots of* aliens.

   b. Nobody could catch *lots of* blue aliens.

(14) This is a story about three children from the Rugrats cartoon: Chucky, Tommy and Lil. They came to a theme park, and decided to play the “alien catching game”. Each of them has his/her own playing field where there are 13 aliens: 6 blue aliens and 7 red aliens. Using a catching tool, each of them took a turn. First, Chucky tried. He could only catch four aliens: two blue ones and two red ones. Second, Tommy tried. He, too, could only catch four aliens: two blue ones and two red ones. Finally, it was Lil’s turn. Before starting, she thought of a good idea: to make the catching tool bigger, in order to catch more aliens. With this brilliant idea, she did a great job; she caught 9 aliens including all seven of the red aliens, even though she could only catch two of the blue aliens.

The outcome of this story is depicted in Figure 2.

**Figure 2: Experimental Context**

![Figure 2: Experimental Context](image)

= red alien;  = blue alien;  = was caught
Despite the similarity in meaning among *lots of* and *every*, the sentences in (13) validate the opposite inference pattern than the sentences tested in Experiment II, as in (11). That is, the inference from (13a) to (13b) is licensed from a set-referring expression (*aliens*) to its subset-referring counterparts (*blue aliens*). As a consequence, the pattern of truth value assignment in each sentence is also reversed. The sentence in (13a) is false, since one of the characters, Lil, caught lots of aliens. On the other hand, sentence (13b) is true, because none of the characters was able to catch lots of blue aliens, though Lil had caught lots of aliens. (Recall that in the sentences in (11), (11a) which contained a set-denoting noun is true, whereas (11b) containing its subset-denoting counterpart is false, due to the opposite pattern of inference created between them.)

Each child encountered four test sentences, and an equal number of fillers, to balance the number of affirmative and negative responses. Twenty-two children participated in the experiment. The children were tested individually, and ranged in age from 3;11 to 6;3, with a mean age of 5;0. The results are summarized in Table 2.

**Table 2: Rates of correct responses**

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<tr>
<td>Accuracy</td>
<td>86% (38/44) of acceptance</td>
<td>95% (42/44) of rejection</td>
</tr>
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</table>

As Table 2 shows, children consistently produced adult-like responses to sentences containing *lots of* in place of *every*; they accepted the sentences like (13b) and rejected those like (13a), presented in the same context. This demonstrates children’s awareness of the opposing pattern of entailment for *lots of*, and its consequences for generating the truth conditions of the target sentences. Thus, Experiment III showed that children were not led off course in language development by the similarity in meaning between *lots of* and *every*, and that they computed the meanings of the sentences based on the logical interactions of the quantifiers which go beyond the surface strings of the words. Taken together, our experimental findings suggest that children accessed the ‘deep’ semantic properties of the two quantifiers, and computed their structurally-mediated relations.

**6. Conclusion**

The present paper reports the findings of three experiments designed to investigate children’s awareness of the entailments manifested by the universal quantifier *every*. In particular, the experimental findings revealed children’s adult-like knowledge of the complex semantics of the universal quantifier. Not only do children know that the first argument of *every* is downward entailing, but they also know that the pattern of entailment is reversed when *every* appears in the scope of a downward entailing operator, *nobody*, which non-locally commands *every*. Finally, children base their responses on the logical properties of *every*, and not on its superficial meaning, since they distinguish sentences with *every* from those with *lots of*. These findings resist explanation on a usage-based language learning model such as the constructivist approach, and provide
additional empirical support for the UG-based generative approach to language acquisition.

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