Logico-semantic Aspects of Children's Knowledge about the Universal Quantifier: New Empirical Evidence

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1. Background

It has been widely assumed that a universal quantifier such as *every* evokes an asymmetry among entailments in its first argument (i.e., the NP) and its second argument (i.e., the VP). In particular, the first argument of *every* is downward entailing (henceforth DE), whereas its second argument is non-downward entailing (non-DE). Entailment-sensitive linguistic phenomena, arising as a consequence of these asymmetric entailments, are evident at various levels of representation. This paper discusses the linguistic representation of sentences with universal quantification and the consequences of asymmetric entailment in universal quantification at the logico-semantic level from an acquisition point of view; specifically, is children's knowledge of the universal quantifier and its asymmetric pattern of entailments, previously examined with respect to <u>within</u>-sentence meanings, also reflected in their computation of logical inferences <u>across</u> universally-quantified sentences? We present a new experimental methodology and results which directly address whether children's knowledge extends to the computation of across-sentence meaning relations involving *every*. We begin our discussion by reviewing the consequences of asymmetric entailment for within-sentential and across-sentential meanings.

1.1. Asymmetric consequences at the level of sentential meanings

First, the asymmetric entailments evoked in the arguments of *every* result in asymmetric licensing conditions for a negative polarity item (NPI, such as *any*). In particular, an NPI is licensed in a DE environment, but not in a non-DE environment. Thus an NPI can appear in the first argument of *every*, but not in its second argument, as is shown in (1) below.

(1) a. [Every child who ate *any* vegetable at lunch] may go out.
b. *Every child ate *any* vegetable at lunch.

A second consequence of asymmetric entailment is that a DE environment allows the disjunction operator *or* to be interpreted as if it were equivalent to the conjunction operator *and* ("conjunctive" interpretation of disjunction, cf. Higginbothom 1991), whereas a non-DE environment does not. Thus the "conjunctive" interpretation of disjunction is allowed in the first argument of *every*, but not in its second argument, as is shown in (2) below.

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(2) a. [Every child who ate a carrot *or* a green pepper at lunch] may go out.
≈ Every child who ate a carrot at lunch <u>and</u> every child who ate a green pepper at lunch may go out.
b. Every child ate a carrot *or* a green pepper at lunch.
*≈ Every child ate a carrot at lunch <u>and</u> every child ate a green pepper at lunch.

The cases above demonstrate the phenomenon of entailment-sensitivity represented at the level of independent sentences; a DE environment but not a non-DE environment licenses the appearance of an NPI and the acceptability the "conjunctive" disjunction.

1.2. Asymmetric consequence at the level of meaning relations across sentences

Finally, and crucially in the present paper, the asymmetry under discussion is observed not only at the level of sentence meanings, as the two cases we have just surveyed above demonstrate, but also at the level of across-sentence meaning relations, as the following cases exemplify.

(3) a. [Every **<u>child</u>**] ate a carrot at lunch. → [Every **<u>blonde child</u>**] ate a carrot at lunch.
b. [Every **<u>blonde child</u>**] ate a carrot at lunch. *→ [Every **<u>child</u>**] ate a carrot at lunch.
(4) a. [Every child] ate a **<u>carrot</u>** at lunch. *→ [Every child] ate a **<u>big carrot</u>** at lunch.
b. [Every child] ate a **<u>big carrot</u>** at lunch. → [Every child] ate a **<u>carrot</u>** at lunch.

Note first that the underlined nominals in each pair of sentences constitute a set-subset relation; *blonde child* is a subset of *child*, and *big carrot* is a subset of *carrot*. Also note that each pair of sentences constitutes a minimal pair with respect to the underlined nominals in the set-subset relation.

In (3), where the minimal pair is based on the related set- and subset-denoting nominals (i.e., *child* and *blonde child*, respectively) in the first argument of *every*, the sentence with a set-denoting nominal (*child*) entails the sentence with a subset-denoting nominal (*blonde child*) (see (3a)), but not vice versa (see (3b)). In particular, "every child ate a carrot" logically implies "every blonde child ate a carrot" (in other words, "every blonde child ate a carrot" is necessarily true whenever "every child ate a carrot" is true) as in (3a), but not vice versa, as in (3b). Thus we see that an inference is from a set-denoting nominal to its subset-denoting nominal (from *set* to *subset*, and hence *downward* entailment).

On the other hand, in (4), where the minimal pair is created on the basis of the related set- and subset-denoting nominals in the second argument of *every*, the sentence with a subset-denoting nominal entails the sentence with a set-denoting nominal (see (4b)), but not vice versa (see (4a)). In particular, "every child ate a big carrot" logically implies "every child ate a carrot" (in other words, "every child ate a carrot" is true whenever "every child ate a big carrot" is true) as in (4b), but not vice versa, as in (4a), and thus we get an inference created from a subset-denoting nominal to a set-denoting nominal (from *subset* to *set*, and hence *non-downward* entailment).[1] Thus the entailment pattern determines the direction of inferences between sentences, demonstrating that the asymmetry in entailments is influential at the level of across-sentence meaning relations as well as at the level of sentence-internal linguistic representations.

1.3. Linguistic implementation of universal quantification: every *as a case study*

Before moving on to the specific discussion of *every*, we note that the consequences described thus far are not restricted to the case of the universal quantifier *every*, but are also observed with respect to other types of universal quantifiers, such as *all* and *each* (e.g., Minai 2006). Based on this, we assume that the asymmetry under discussion is due not to the logical nature of the logical word *every* per se, but is due to the logical nature of the universal quantification, although we will not discuss the very nature of universal quantification in detail in the present paper. Hence we focus on the universal quantifier *every* throughout this paper, taking *every* as a representative example of universal quantification.

[1] See Ladusaw (1979, 1980) for a detailed discussion.

To sum up, the asymmetric patterns of entailments created in the two arguments of the universal quantifier *every* consequently determine meanings at various levels, across-sententially as well as sentence-internally.

2. Language Acquisition Issue

From a language acquisition perspective, the asymmetry discussed above raises an interesting issue: whether children are aware of these logico-semantic properties yielded by universal quantification. Given that, as we have noted above, the asymmetry under discussion is a consequence of the logical nature of the universal quantification, studying asymmetric entailment and its consequences allows for direct tests for the linguistic implementation of logical content of the universal quantifier in child semantics.

Many researchers have addressed this issue. Recently, a series of studies has experimentally demonstrated children's adult-like computations of NPI licensing and the "conjunctive" interpretation of disjunction in the first argument of *every* (i.e., a DE environment), but not in the second argument of *every* (i.e., a non-DE environment) (e.g., Crain et al. 1996; Meroni et al. 2000; Gualmini 2004). These studies, supporting the "Full Competence View", have revealed children's knowledge of the asymmetric entailments in sentences containing *every* consequently represented at the sentential-meaning level.[2]

Thus far, most of this research has focused on children's knowledge regarding the universal quantifier in terms of their computation of <u>within</u>-sentential meanings involving *every*, and, on the contrary, far less is known about children's knowledge of *every* with regard to the effects of asymmetric entailment on the inferences created <u>between</u> sentences. There have been some empirical studies which are deeply related to the issue of children's ability to evaluate logical inferences across propositions: Philip and de Villiers (1992) and de Villiers et al. (1998) discussed children's ability to evaluate logical inferences between sentences[3]; there are also studies on children's development of logical reasoning abilities (e.g., Smith 1979). However, none have directly investigated children's knowledge specifically from the standpoint of the linguistic implementation of the universal quantification i.e., the asymmetric entailments and directions of inferences therein. Therefore, it remains to be investigated whether children are able to evaluate the logical inference between *every*-sentences.

This paper thus discusses children's knowledge regarding the universal quantifier *every* with a specific focus on the logical inferences determined by the asymmetric entailments that *every* creates, in order to experimentally examine whether children are aware of the asymmetric consequences represented in the meaning relations across related sentences containing *every*. Directly investigating this would provide a novel step forward in understanding children's semantic representation of universal quantification at the level of meaning relation <u>across sentences</u>, and thus ultimately toward a fuller understanding their logico-semantic competence. More specifically, we will probe whether children can compute inferences involving *every* from set to subset and vice versa appropriately across sentences, which would in turn provide the answer to the question of whether their knowledge about *every* extends to the across-sentence computation of meaning relations, as well as applying at the level of within-sentential meanings.

In what follows, we first describe the methodology we have developed and adopted to assess this new aspect of child semantics, focusing on the design of our new experimental task. We then report the results of an experiment designed to directly examine children's evaluation of meaning relations

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[2] There is another series of studies which alternatively claims that children have a non-adult-like semantic representation of *every*. See Philip (1995), Drozd and Philip (1992), Geurts (2003) and Drozd and van Loosbroek (in press) among others (Gualmini termed this vein of studies the "Partial Competence View" in contrast with the "Full Competence View").

[3] They discussed children's evaluation of logical inferences in terms of entailment patterns, but they did not focus on the asymmetric entailment evoked by *every*. Some potential concerns in their experimental design and materials have been pointed out in Minai (2006), which provides substantial discussion of the methodological issues considered in designing the new experimental method we will describe below in the present paper.

between *every*-sentences.

3. Methodological Issue

Let us now review the relevant linguistic phenomena, i.e., the DE and non-DE environments and their logical consequences involving *every*. The relevant examples are repeated in (5-6) below.

(5) a. [Every **child**] ate a carrot at lunch. → [Every **blonde child**] ate a carrot at lunch.
    b. [Every **blonde child**] ate a carrot at lunch. *→ [Every **child**] ate a carrot at lunch.
(6) a. [Every child] ate a **carrot** at lunch. *→ [Every child] ate a **big carrot** at lunch.
    b. [Every child] ate a **big carrot** at lunch. → [Every child] ate a **carrot** at lunch.

Recall that an inference is created from a set-denoting nominal (*child*) to its relating subset-denoting nominal (*blonde child*) in (5), where the relevant position is the first argument of *every* (DE), whereas in (6), an inference is created from a subset-denoting nominal (*big carrot*) to its related set-denoting nominal (*carrot*), where the relevant position is the second argument of *every* (non-DE).

In order to probe this new aspect of children's logico-semantic knowledge, beyond their truth-conditional semantic competence, a challenge we need to surmount is to design an experimental methodology to directly assess children's ability to evaluate the validity of inferences created across propositions, which has never been discussed from a methodological point of view, to the best of my knowledge. To do so, we take advantage of a pragmatic "template" which encodes the direction of entailment explicitly (i.e., set-to-subset pattern or subset-to-set pattern) between two related propositions, while minimizing the extraneous information load in children's computation. We call it the "demand-fulfillment" context, which we will describe in the following.

Let us take the simplest case to demonstrate the basic paradigm of the "demand-fulfillment" context and its relation with the logical inference which holds among the propositions presented in the context. Imagine that Alvin has a Japanese banana. In this context, it is true that Alvin has a Japanese banana, and consequently it is necessarily true that Alvin has a banana. The inferential relation between these two propositions is represented in (7).

(7) Alvin has a **Japanese banana**. → Alvin has a **banana**.

Now consider the situation in which Alvin has a banana, but in which there is no specific information about this banana. In this context, it is true that Alvin has a banana, but it is not necessarily true that Alvin has a Japanese banana; he might have a Taiwanese or Philippine banana. This can be represented as in (8).

(8) Alvin has a **banana**. *→ Alvin has a **Japanese banana**.

Crucially, the example in (7) is a representation of a valid inference created between two propositions, normally licensed from a subset-denoting nominal (*Japanese banana*) to its related set-denoting nominal (*banana*); on the other hand, the reversed pattern, an inference from a set-denoting nominal (*banana*) to its subset-denoting nominal (*Japanese banana*), is not valid, as illustrated in (8).[4]

Keeping this simple schema in mind, suppose now that Alvin wants a banana and he demands that Dave bring one. In response Dave brings him a Japanese banana. Since a Japanese banana is a kind (subset) of banana, Alvin's demand is satisfactorily fulfilled by Dave's bringing a Japanese banana. This is an example of a successful demand-fulfillment event with the two propositions, which can be illustrated as follows.

(9) a. Demand: Dave brings Alvin a **banana**.
    b. Fulfillment: Dave brings Alvin a **Japanese banana**.

[4] Note that the inference pattern we are observing here is the non-DE subset-to-set pattern we have seen previously. The "default" pattern of the inference is the non-DE pattern.

Now let us reverse these propositions. Alvin wants a Japanese banana, and is demanding that Dave bring one. In response Dave brings simply a banana, without specifying whether it is a Japanese one. Since Alvin specified that he wanted a banana which is Japanese, this demand is not logically satisfied unless it turns out that the banana Dave brought is in fact Japanese. This unsatisfactory demand-fulfillment event can be illustrated as in (10) below.

(10) a. Demand: Dave brings Alvin a <u>**Japanese banana**</u>.
b. Fulfillment: Dave brings Alvin a <u>**banana**</u>.

Now consider these demand-fulfillment events from a different point of view, i.e., logical inferences created from demand to fulfillment. Note that these pairs of propositions are related to each other creating minimal pairs with respect to the two nominals in a set-subset relation.

Recall first the case in (9), which demonstrates the satisfactory demand-fulfillment event. In terms of the inferential relation from demand to fulfillment, we see that an invalid inference is created in this direction; "Dave brings Alvin a banana" does not logically imply "Dave brings Alvin a Japanese banana". Now, consider (10), which is the demand-fulfillment failure example. In terms of the inferential relation, a valid inference is created from demand to fulfillment; "Dave brings Alvin a Japanese banana" logically implies "Dave brings Alvin a banana". Thus we see a counter-intuitive correspondence between the satisfaction of demand-fulfillment event and the validity of inference created from demand to fulfillment. That is, <u>when a demand is logically satisfied by a fulfillment, the inference from demand to fulfillment is invalid; when a demand is not logically satisfied by a fulfillment, a valid inference is licensed from demand to fulfillment</u>.

Crucially, putting the minimal-paired propositions in the demand-fulfillment event thus explicitly reflects the validity of inferences created between demand and fulfillment in whether the demand is satisfied by the fulfillment. Keeping this in mind, we now turn to the inferential and demand-fulfillment behavior of pairs of propositions involving the universal quantifier *every*.

3.1. Case I: DE pattern in the first argument of every

Let us start with the first argument of *every*, which is a DE environment licensing an inference from set to subset. Suppose that Mary owns a set of pens, a few red pens and blue pens, but she is not carrying them with her at the moment; now she demands that John bring them all to her. John is a forgetful man and somehow he ends up bringing the red pens but not the blue pens. In this situation, Mary's demand was not satisfied by John's bringing red pens.

Now consider this unsatisfactory demand-fulfillment event from the point of view of logical inference. These two propositions are related to each other in that they constitute a minimal pair with respect to the alternate two nominals in set-subset relation, as (11) shows.

(11) a. Demand: John brings Mary [every <u>**pen**</u>]
b. Fulfillment: John brings Mary [every <u>**red pen**</u>]

Crucially, notice that an inference is validly created from (11a) with a set-denoting nominal *pen* to (11b) with a subset-denoting nominal *red pen*, under the DE environment yielded by *every* in its first argument position. Hence, the valid DE inference licensed in the first argument of *every* is reflected in the unsatisfactory demand-fulfillment event.

Now, reverse the demand and fulfillment. Mary owns a set of pens, a few red pens and blue pens, but she is not carrying them with her at the moment; now she demands that John bring every red one to her. Forgetful John ends up bringing all the pens, without remembering the color Mary specified in her request. In this situation, Mary's demand is logically satisfied, even though John brings a redundant (sub)set of pens Mary really did not request.

Consider this satisfactory demand-fulfillment event, which involves the two propositions related to each other creating a minimal pair with respect to the set-subset nominals, *pen* and *red pen*, as concerns logical inference.

(12) a. Demand: John brings Mary [every **<u>red pen</u>**]
b. Fulfillment: John brings Mary [every **<u>pen</u>**]

Notice importantly that an invalid inference is created from (12a) with a subset-denoting nominal *red pen* to (12b) with a set-denoting nominal *pen* under the DE environment yielded by *every* in its first argument position. Hence, the invalid DE inference in the first argument of *every* is reflected in the satisfactory demand-fulfillment event. The following table summarizes the paradigm we have seen thus far.

Table 1: Demand-Fulfillment Context and Inference I

		Inference	Demand satisfaction
Demand	John brings Mary [every **<u>pen</u>**]	Valid DE pattern (set-to-subset)	Unsatisfactory
Fulfillment	John brings Mary [every **<u>red pen</u>**]		
Demand	John brings Mary [every **<u>red pen</u>**]	Invalid DE pattern (set-to-subset)	Satisfactory
Fulfillment	John brings Mary [every **<u>pen</u>**]		

3.2. Case II: Non-DE pattern in the second argument of every

Now let us move on to the case of the propositions which constitute minimal pairs with respect to the nominals in the set-subset relation in the second argument of *every*. First consider the situation in which there are three boys, John, Bill and Tom, and Mary wants each of them to bring her a pen, without specifying the color. Each boy ends up bringing a red pen.

(13) a. Demand: [Every boy] brings Mary a **<u>pen</u>**.
b. Fulfillment: [Every boy] brings Mary a **<u>red pen</u>**.

This demand-fulfillment event is a success since Mary should be happy with the pens each boy brought whose color happens to be red. Note that the inference from (13a) to (13b) is invalid, since "every boy brings Mary a pen" does not logically imply "every boy brings Mary a red pen".

Now reverse the demand and fulfillment in (13). Mary wants each boy to bring her a red pen. The hasty boys each brought a pen, but somehow the color of the pens they brought is not known, e.g., they each put the pen in a closed box.

(14) a. Demand: [Every boy] brings Mary a **<u>red pen</u>**.
b. Fulfillment: [Every boy] brings Mary a **<u>pen</u>**.

In this case, Mary's demand is not logically satisfied unless the pens in the boys' boxes turn out to be red. Note that the inference created from the demand in (14a) to the fulfillment in (14b) is now valid, since "every boy brings Mary a red pen" logically implies "every boy brings Mary a pen". Therefore, we see the mirror-image pattern to the one we have observed regarding the case of the first argument of *every*, as schematized in Table 2.

Table 2: Demand Fulfillment and Inference II

		Inference	Demand satisfaction
Demand	[Every boy] brings Mary a **pen**	Invalid non-DE pattern (set-to-subset)	Satisfactory
Fulfillment	[Every boy] brings Mary a **red pen**		
Demand	[Every boy] brings Mary a **red pen**	Valid non-DE pattern (set-to-subset)	Unsatisfactory
Fulfillment	[Every boy] brings Mary a **pen**		

To sum up, the demand-fulfillment contexts as presented above explicitly demonstrate the patterns of inference (crucially determined by the direction of entailment) by whether or not the demand is logically satisfied by the fulfillment, which we can take advantage of in designing an experiment to test children's judgment of logical inferences from universally-quantified sentences; we describe this experiment and its results in the following sections.

4. A New Methodology: "Demand-Fulfillment" Task

On the basis of the paradigm described above, we designed a new experimental task featuring demand-fulfillment events represented in short skits involving two characters, i.e., the controlling demander (the mean Genie) and the forgetful fulfiller (Grover). The simplified outline of the skits is listed below.

(15) a. Introduction:
Genie puts a spell on a character. The laptop computer, called "Genie's magic screen" in the story, shows the transformation of the character, via animated pictures.

b. Demand Presentation:
Genie verbally describes the demand. The object(s) he requests is(are) presented visually on "Genie's magic screen".

c. Grover's Search:
Grover leaves for a while to look for what Genie requests, and comes back with a box.

d. Fulfillment Evaluation I: "Before-Open-the-Box" Evaluation
Grover verbally describes what is inside the box to the child, crucially without showing it, and asks the child whether he did something good enough to make Genie happy.

e. Fulfillment Evaluation II: "After-Open-the-Box" Evaluation
After the child answers, Grover lets the child open the box and see what is inside.

f. Final Outcome:
If Grover satisfied the genie, then the spell was removed. If Grover failed to satisfy the genie, the child was asked to help Grover correct his mistake so that the character is freed.

The Introduction (15a) provides not only the lead-in information about the entire skit but also a felicitous reason for Genie to make a demand, by means of putting some character under his spell. On the basis of the event performed in (15a), Genie felicitously makes a request as in (15b). Grover's search in (15c) is not visually presented in order to not give any information about the specific item(s) selected during the demand-fulfilling process. The steps (15d) and (15e) are the evaluation stages, in which the child provides responses to be collected as data; "Before-Open-the-Box" Evaluation as in (15d), and "After-Open-the-Box" Evaluation as in (15e). Importantly, at the "Before-Box" Evaluation, what Grover brought is not visually shown, but is first verbally described by Grover. The "Before-Box" Evaluation thus requires that the child deductively evaluate whether the fulfilling outcome, which is linguistically encoded (but not visually shown), logically satisfies the demand. The "After-Box" Evaluation phase was included in order to provide a second stage for the child to evaluate the demand-fulfillment event again with the specific objects(s) brought by Grover and to confirm their judgment. This two-stage evaluation procedure is to avoid the possibility in which the child evaluates the demand-fulfillment by simply matching what is requested and what is brought by means of the visual comparison, rather than deductively evaluating the outcome. Finally, the Final Outcome of the entire skit was presented at in (15f), simply in order to satisfy the child's curiosity about what happens in the end.

5. Experiment

5.1. Design

Utilizing the "Demand-fulfillment Task", we tested two experimental conditions: "*Satisfactory Condition*" in which the demand is logically satisfied by the fulfillment (i.e., the demand does not logically entail the fulfillment, see (16)); "*Unsatisfactory Condition*" in which the demand is not logically satisfied by the fulfillment (i.e., the demand does logically entail the fulfillment, see (17)).

We developed three types of stimuli to be provided both in the "Satisfactory" Condition and the "Unsatisfactory" Condition. The stimulus items are listed below. The stimuli can be categorized into the following three types. The first type of tokens are *Control Items* shown in (16a) and (17a), which do not contain the universal quantifier *every*; this type served as a control to test set-/subset-denotation inferences without *every*, in comparison with the target items involving *every*. "*First-Argument" Items*, listed in (16b) and (17b), are the items showing the relevant inferences with respect to the first argument of *every*. *"Second-Argument" Items*, in (16c) and (17c), are the items showing the relevant inference s with respect to the second argument of *every*.

(16) "Satisfactory" Condition
a. Control Item
Demand: "Bring me a **car**."
Fulfillment: "I brought you a **red car**."
b. "First-Argument" Item
Demand: "Bring me [every **gold coin**]."
Fulfillment: "I brought you [every **coin**]."
c. "Second-Argument" Item
Demand: "[Every one of you] brings me a **cat**."
Fulfillment: "[Every one of us] brought you a **white cat**."

(17) "Unsatisfactory" Condition
a. Control Item
Demand: "Bring me a **blue train**."
Fulfillment: "I brought you a **train**."
b. "First-Argument" Item
Demand: "Bring me [every **dog**]."
Fulfillment: "I brought you [every **white dog**]."
c. "Second-Argument" Item
Demand: "[Every one of you] brings me a **green noodle**."
Fulfillment: "[Every one of us] brought you a **noodle**."

The expected responses for the items in the "Satisfactory" Condition are "Yes" Responses, in which the child accepts Grover's fulfillment as a satisfactory fulfillment of the demand by Genie. On the other hand, the expected responses for the items in the "Unsatisfactory" Condition are Non-"Yes" Responses, where the child will point out the inadequacy of Grover's fulfillment instead of accepting it as a suitable response to Genie's request. Table 3 below illustrates the entire experimental design schematically.

Table 3: Summary of Experimental Design

Condition (Expected Response)	Item Type	Proposition 1: Demanded Outcome (D)	Proposition 2: Fulfilling Outcome (F)	Inference (D) → (F)
Satisfactory Condition (“Yes” Reponses)	Control (16a)	Grover brings Genie a **car**	Grover brings Genie a **red car**	Invalid
	First-Arg. (16b)	Grover brings Genie [every **gold coin**]	Grover brings Genie [every **coin**]	
	Second-Arg. (16c)	[Every one] brings Genie me a **cat**	[Every one] brings Genie a **white cat**	
Unsatisfactory Condition (Non-“Yes” Responses)	Control (17a)	Grover brings Genie a **blue train**	Grover brings Genie a **train**	Valid
	First-Arg. (17b)	Grover brings Genie [every **dog**]	Grover brings Genie [every **brown dog**]	
	Second-Arg. (17c)	[Every one] brings Genie a **green noodle**	[Every one] brings Genie a **noodle**	

5.2. Procedure: “Demand-fulfillment” Task

Below in Figures 1 and 2, we demonstrate sample trials showing the “First-Argument” Item in each condition, illustrating the outline of the actual skit performances, in order to show the experimental procedure. Two experimenters performed Genie’s and Grover’s role respectively.

Figure 1: Sample Trial of “Satisfactory” Condition (“First-Argument” Item)

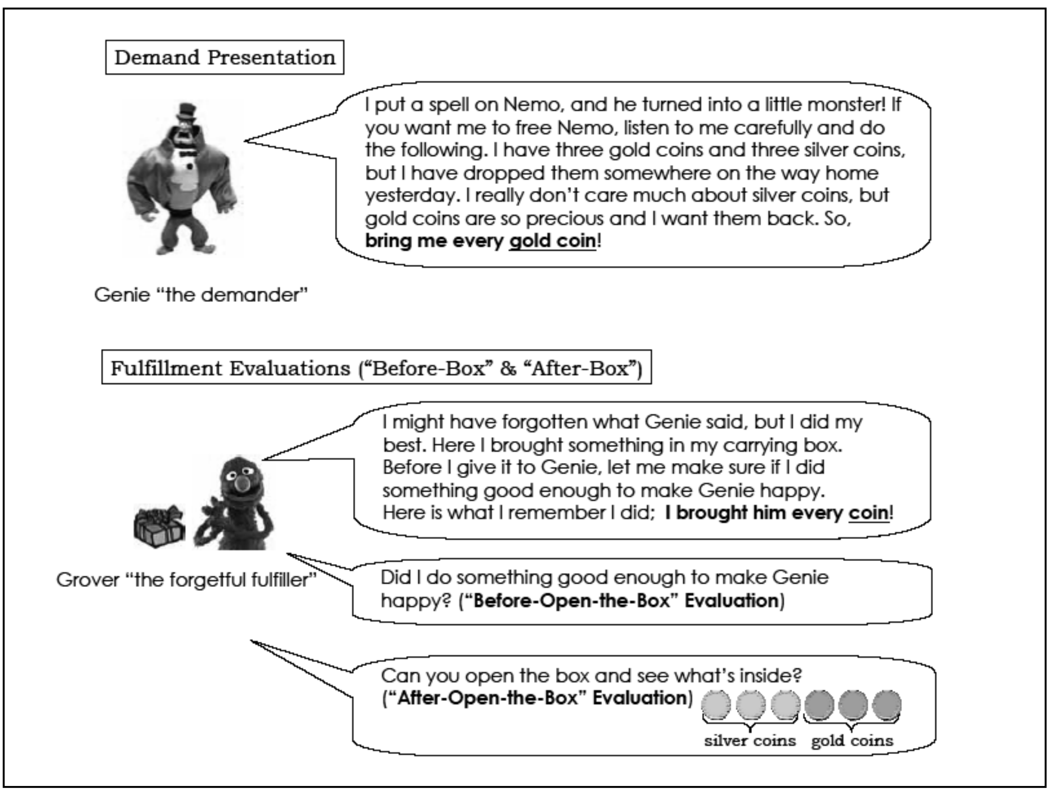
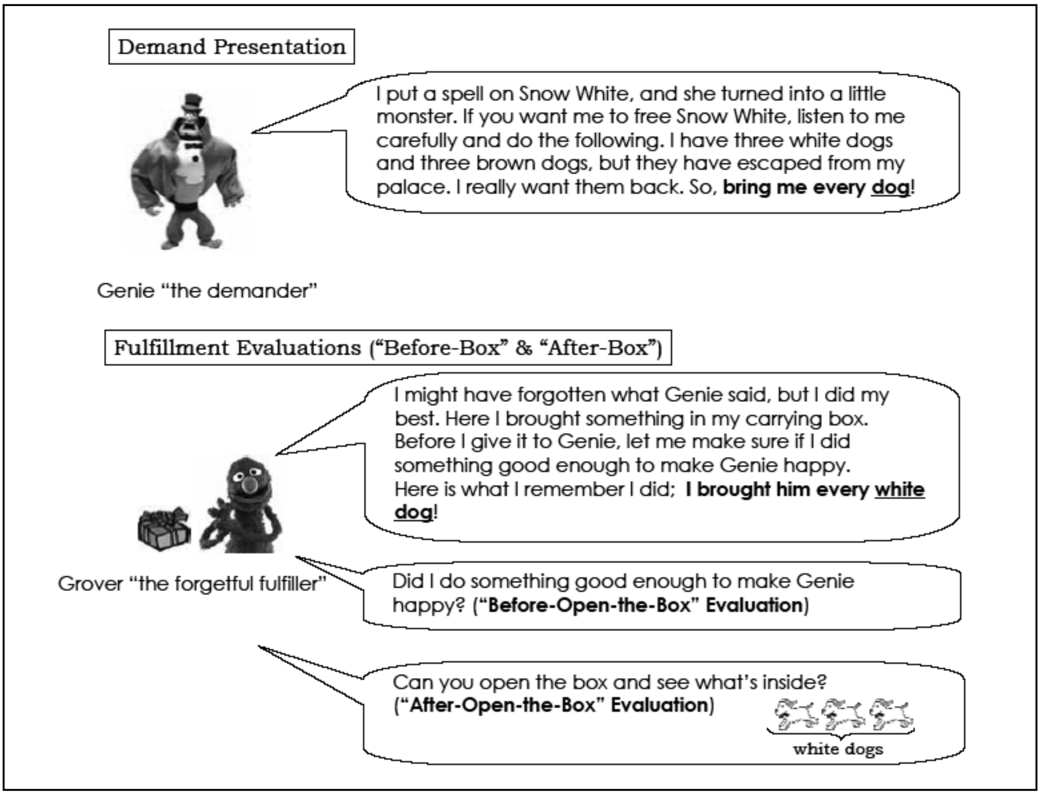


Figure 2: Sample Trial of “Unsatisfactory” Condition (“First-Argument” Item)



5.3. Subjects

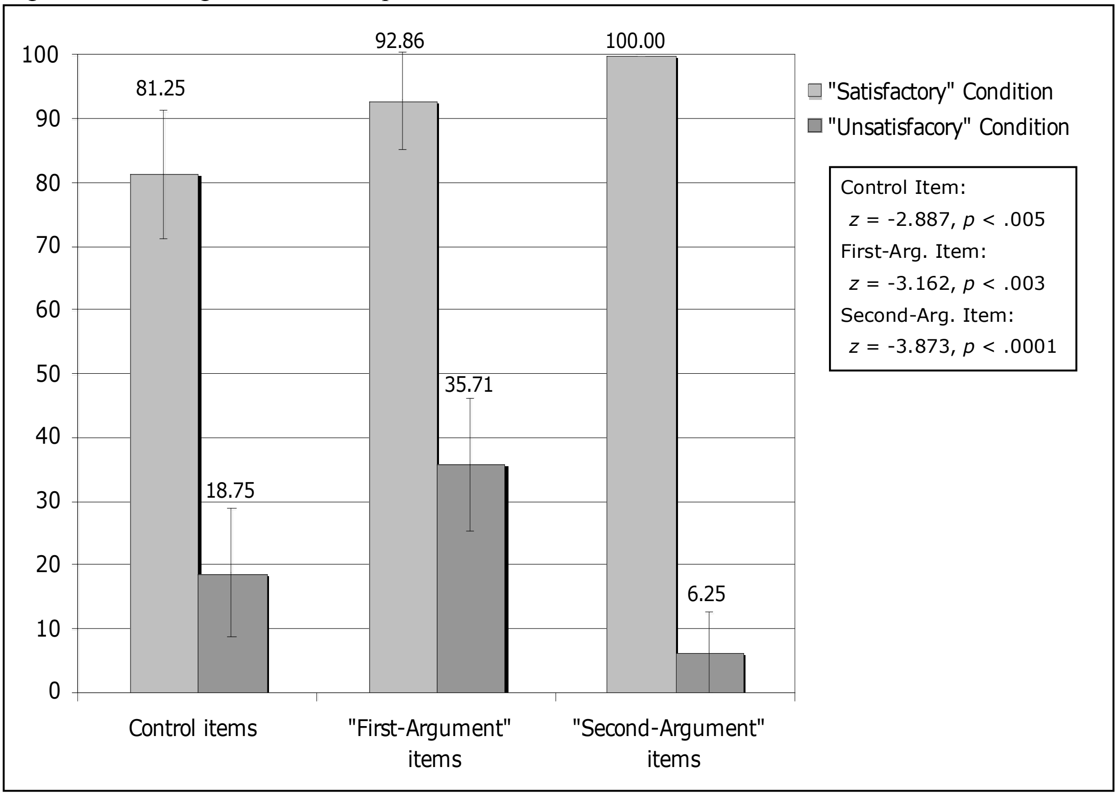
Sixteen English speaking children, whose mean age was 4;10, participated in the experiment. The children were recruited at the Center for Young Children at University of Maryland, College Park, with parental permission to participate in our experiment.

5.4. Results

The data was evaluated based on the percentage of “Yes” Responses in each condition. In the “Satisfactory” Condition, children overall demonstrated a high rate of “Yes” Responses. In evaluating the satisfactory demand-fulfillment in the Control Items (in which the inference pattern from the demand to the fulfillment is an invalid non-DE pattern, i.e., “set-to-subset” pattern), the percentage of the “Yes” Responses was 81% (13/16). In evaluating the satisfactory demand-fulfillment in the “First-Argument” items (in which the inference pattern from the demand to the fulfillment is an invalid DE pattern, i.e., “subset-to-set” pattern), the percentage of the “Yes” Responses was 92% (12/13). In evaluating the satisfactory demand-fulfillments in the “Second-Argument” items (in which the inference pattern from the demand to the fulfillment is an invalid non-DE pattern, i.e., “set-to-subset” pattern), the percentage of the “Yes” Responses was 100% (16/16). On the other hand, the ratio of the “Yes” Responses was significantly lower in the “Unsatisfactory” Condition. In evaluating the unsatisfactory demand-fulfillment in the Control Items (in which the inference pattern from the demand to the fulfillment is a valid non-DE pattern, i.e., “subset-to-set” pattern), the percentage of the “Yes” Responses was 19% (3/16). In evaluating the unsatisfactory demand-fulfillments in the “First-Argument” items (in which the inference pattern from the demand to the fulfillment is a valid DE pattern, i.e., “set-to-subset” pattern), the percentage of the “Yes” Responses was 15% (2/13). In evaluating the unsatisfactory demand-fulfillments in the “Second-Argument” items (in which the inference pattern from the demand to the fulfillment was a valid non-DE pattern, i.e., “subset-to-set” pattern), the percentage of the “Yes” Responses was 6.25% (1/16). These numbers show that children correctly accepted the satisfactory, and correctly did not accept the unsatisfactory demand-fulfillments.

A Wilcoxon Signed-Rank test was conducted to examine whether the number of "Yes" Responses observed in the "Satisfactory" Condition was significantly higher than the number observed in the "Unsatisfactory" Condition. More specifically, a "Yes" Response was scored as 1, and a Non-"Yes" Response was scored as 0. Then the sum of the total scores in each condition was compared in terms of whether the total score for the "Satisfactory" Condition was significantly higher than the one for the "Unsatisfactory" Condition with respect to each type of items across subjects. According to the test, the total scores for the "Satisfactory Condition" were significantly higher than those for the "Unsatisfactory" Condition with respect to each type of item: z = -2.887, p < 0.005 for the Control Items; z = -3.162, p < 0.003 for the "First-Argument" items; z = -3.873, p < 0.001 for the "Second-Argument" items. Figure 3 below illustrates the results and the statistical analysis.

Figure 3: Percentages of "Yes" Responses



6. Discussion

As is shown in the above pattern of results, this experiment revealed children's sensitivity to the validity of logical inferences between two propositions, which were reflected in the demand-fulfillment contexts regarding whether the demand is logically satisfied by the fulfillment. The findings thus provide a new piece of empirical evidence in favor of children's adult-like semantic competence in computing across-propositional meaning relations (which are determined by the pattern of entailment) involving *every*, demonstrating that children's knowledge regarding the semantic properties of *every* extends to the computation of across-propositional meaning relations, together with the computation of the truth-conditional meanings of *every*-sentences presented independently.

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