If Everybody Knows, then Every Child Knows

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1. Introduction

Here's a recipe for one kind of argument from the poverty of the stimulus. To start, present an array of linguistic facts to be explained. Begin with a basic observation about form and/or meaning in some language (or, even better, an observation that crosses linguistic borders). Then show how similar forms and/or meanings crop up in other linguistic phenomena. Next, explain how one could account for the array of facts using domain-general learning mechanisms – such as distributional learning algorithms, 'cut and paste' operations or analogy. Follow this by introducing other phenomena that resist explanation on a learning-theoretic account. Make it clear that domain-general learning mechanisms would leave the learner short of the target language or would cause the learner to overshoot, resulting in 'generalizations' that are not characteristic of the natural language(s) under consideration. The next step in the recipe is to show how the entire array of linguistic phenomena can be explained using 'abstract' principles of Universal Grammar. These principles are not likely to be 'learned' because, as just witnessed, the kinds of mechanisms that are offered by learning-theoretic approaches to language development would direct learners away from the target, rather than towards it. This raises the alternative to learning, i.e., innate specification. From that point onward, the proof is in the pudding – the argument should contain an empirical demonstration that children never form the kinds of mistaken generalizations that are anticipated by learning-theoretic accounts of language acquisition. Instead, the argument should be supported by a demonstration that children form the correct generalizations, despite the apparent complexity of the phenomena, and in the absence of supporting evidence in the input. QED.

There are several side issues, such as the availability of negative evidence or some substitute for it, but let us ignore such issues, and follow the recipe from the poverty of the stimulus we just sketched. Our specific argument takes, as principles of Universal Grammar, the syntactic property of c-command and the semantic property of downward entailment. We begin with the basic observation in (1).

(1) a. Every <u>dog</u> in the neighborhood was overweight.
    b. Every <u>poodle</u> in the neighborhood was overweight.

Notice that in any circumstance in which (1a) is true, so is (1b). The difference between these sentences is that an expression referring to a set, 'dog', in the first argument of *every* in (1a) is replaced by an expression denoting a subset of that set, 'poodle', in (1b). This shows that the linguistic expression *every* is downward entailing on its first argument (the NP). The defining property of downward entailing expressions is that they license inferences from a set to its subsets, as with the first argument position of *every*.

The same pattern of inference carries over to (2) (i.e., the inference from 'dog' to 'poodle'). To form (2), we have simply 'cut and pasted' the sentences in (1) such that they are preceded by *Our butcher knew…* .

(2) a. Our butcher knew every dog in the neighborhood was overweight.
b. Our butcher knew every poodle in the neighborhood was overweight.

In (3), the pattern of inference is the same. Here, we have substituted *who* for *our butcher*, and added *I just told you*. Again, *every* is downward entailing on its first argument.

(3) a. I just told you who knew every dog in the neighborhood was overweight.
b. I just told you who knew every poodle in the neighborhood was overweight.

In (4), the meaning changes somewhat. The expressions in (1) have been decomposed, such that *dog/poodle in the neighborhood* appears inside a relative clause (*who knew every dog …)* and *was overweight* is now a VP predicated of *some butcher*; so it is some butcher who is overweight, and not every dog or poodle. But, again, the pattern of inference is the same, showing that the universal quantifier *every* is downward entailing environment on its first argument.

(4) a. Some butcher who knew every dog in the neighborhood was overweight.
b. Some butcher who knew every poodle in the neighborhood was overweight.

Based on the examples so far, it appears that 'cut and paste' operations preserve entailment relations for constructions containing *every* NP, in the sense that downward entailing inferences are *always* licensed. However, (5) shows that this is not so. Here, *some* has simply been replaced by *no*. As a consequence, *…every dog…* no longer entails *…every poodle…* . To see this, we simply need to identify a circumstance in which (5a) is true but (5b) is false; in this circumstance, none of the butchers who knew every dog were overweight, but some of the butchers who knew every poodle were overweight. Since such a circumstance is clearly possible, the first argument of *every* is not downward entailing in (5).

(5) a. No butcher who knew every dog in the neighborhood was overweight
b. No butcher who knew every poodle in the neighborhood was overweight

This example exposes the limitations of a class of domain-general learning mechanisms. The problem inherent in such mechanisms is that they rely on local regularities. For example, connectionist (parallel distributed processing) networks extract information and make corresponding changes in the "connection between one unit and another on the basis of information that is locally available to the connection" (Rumelhart and McClelland 1986: 214). As we saw, however, the reliance on 'local' information can be misleading. More often than not, the local interpretation of expressions of the form e*very A* licenses downward entailing inferences, such that if *Every A is B* is true, then *Every A' is B* is also true, where $A' \subseteq A$. However, such inferences are occasionally blocked, as in (5) (The example is adapted from Ludlow 2002, p. 139). In fact, the pattern of entailments is reversed in (5). The reason is that *every dog* appears in the scope of (i.e., is c-commanded by) another downward entailing expression, the Determiner Phrase *no butcher*. As a consequence, the 'lower' quantificational expression is now upward entailing: sentence (5b) entails (5a), rather than the reverse. The reversal of entailment relations is controlled by two linguistic properties: (a) sentence structure (c-command) and (b) the semantic property of downward entailment: when a downward entailing expression occurs in the scope of another downward entailing expression, then the 'lower' expression becomes upward entailing.

These observations are difficult to reconcile on many approaches to language acquisition, especially ones that invokes general cognitive mechanisms to explain language learning. One such approach is the constructivist (constructionist) view advocated by Tomasello (2000) and Goldberg (2003). Here are representative quotes:

> "As they attempt to comprehend and reproduce the utterances produced by mature speakers – along with the argument constituents of those utterances – they come to discern certain patterns of language use (including patterns of token and type frequency), and these patterns lead them to construct a number of different kinds of (at first very local) linguistic categories and schemas." (Tomasello 2000: 73)

> "Constructions are understood to be learned on the basis of the input and general cognitive mechanisms…" (Goldberg 2003: 219)

As we observed in (1)-(5), the interpretation of phrases like *every dog* cannot be accurately rendered as "very local" schemas, based on the recurring patterns used by mature speakers, and which are then combined by 'cut and paste' ("pastiche") operations into larger constructions. The interpretation of such phrases depends on the presence or absence of other downward entailing expressions, and on the structural relations between them. To the extent that these properties are not discernible from the input available to language learners, they are good candidates for innate specification, as part of the initial state of the biological blueprint for language acquisition, Universal Grammar. It is worth asking, then, if young children know the linguistic properties manifested in examples like (5); i.e., the structural notion of c-command, and the semantic property of downward entailment.

2. Previous Research

In collaboration with Andrea Gualmini, we have conducted a series of investigations of children's knowledge of the syntax and semantics of downward entailing expressions, using the Truth Value Judgment task (for extensive discussion, see Crain and Pietroski 2000, Gualmini 2003). The research project has primarily focused on the interpretation of the disjunction operator *or* in English. The interpretation of disjunction is a useful diagnostic for assessing children's knowledge of downward entailment, because sentences with *or* are open to a wider range of interpretations in 'positive' linguistic environments, as compared to sentences in which *or* appears in the scope of a downward entailing expression. When disjunction appears in the scope of a downward entailing expression, the validity of each of the disjuncts can be inferred in a way that closely resembles one of de Morgan's laws: $\neg [A \vee B] \Rightarrow [\neg A \wedge \neg B]$. Following Higginbotham (1991), we refer to this as the 'conjunctive' interpretation of disjunction.

In one study, we investigated the interpretation of disjunction in sentences like (6) and (7) (Crain, Gardner, Gualmini and Rabbin 2002).

(6) The girl who stayed up late will <u>not</u> get a dime <u>or</u> a jewel.

(7) The girl who <u>didn't</u> go to sleep will get a dime <u>or</u> a jewel.

The experiment (a Truth Value Judgment task) was designed to see if children know that negation must c-command the disjunction operator *or* in order to license the conjunctive interpretation. For adults, the conjunctive interpretation is required in (6), so it can be paraphrased as: the girl who stayed up late will not get a dime, <u>and</u> she will not get a jewel. This interpretation is not imposed when negation precedes, but does not c-command, disjunction. Sentence (7) illustrates. In (7), the meaning afforded to adults is consistent with a range of truth conditions, including ones in which the girl who didn't go to sleep gets a dime (but not a jewel), or she gets a jewel (but not a dime), or she gets both a dime and a jewel. In the experiment, (6) and (7) were presented to (different groups of) children.

The experiment used what we have dubbed the 'prediction' mode of the Truth Value Judgment task. The predictions are made at a certain point in each story by a puppet, Merlin the Magician, who speculates about what will happen next in the story. In the story preceding Merlin's prediction, both girls had lost a tooth, and were waiting for the Tooth Fairy to come. One girl decided to stay up late to see what the Tooth Fairy looks like. The story continues following Merlin's prediction. The Tooth Fairy gives a jewel, but not a dime, to the girl who stayed up late. Then children are reminded of Merlin's prediction, and are asked whether he accurately described "what really happened." The experimental hypothesis was that children would reject (6) as an accurate description of the story, but would accept (7). This was indeed the pattern of children's responses. This indicates that children distinguished between the truth conditions associated with *or* in the two sentences. In particular, children knew that (6) requires both disjuncts to be true (the girl should not receive a jewel <u>and</u> she should not receive a dime), whereas (7) only requires one of the disjuncts to be true (the girl should receive one of the two objects, possibly both).

In a follow-up study, Gualmini and Crain (to appear) demonstrated that children are not influenced by the number of words intervening between negation and disjunction in deciding when to impose the conjunctive interpretation of disjunction. In half of the test sentences, negation c-commanded disjunction, and the two logical words were separated by several words. In the remaining test sentences, negation was closer to disjunction, but did not c-command it. Example sentences are provided in (8) and (9).

(8) Winnie the Pooh will <u>not</u> let Eeyore eat the cookie <u>or</u> the cake.

(9) Winnie the Pooh will give the troll he can<u>not</u> lift the honey <u>or</u> the donut.

The pattern of responses by children was the same as in the study by Crain et al. (2002). Children imposed the conjunctive interpretation of disjunction in sentences like (8), where negation c-commands disjunction, but not in ones like (9), where negation is close to disjunction, but does not c-command it.

Another series of experimental investigations of children's interpretation of disjunction in sentences containing the universal quantifier *every* was conducted by Gualmini Meroni and Crain (2003a, b). As noted earlier, in sentences of the form *Every A is B*, the universal quantifier *every* is downward entailing on its first argument, *A,* but not on its second argument, *B* (see, e.g., Partee, ter Meulen and Wall 1990.) Consequently, when the disjunction operator *or* appears in the second argument, as in (10), the conjunctive reading of disjunction is not enforced. By contrast, the conjunctive reading is required when *or* appears in its first argument, as illustrated in (11).

(10) Every child picked a tiger or a dinosaur.
*⇒ Every child picked a tiger <u>and</u> every child picked a dinosaur.

(11) Every lady who bought an egg <u>or</u> a banana got a basket.
⇒ Every lady who bought an egg got a basket <u>and</u> every lady who bought a banana got a basket.

Two experiments were devised to assess children's knowledge of the asymmetry in the interpretation of disjunction in the two arguments of the universal quantifier. In one experiment, children were presented with sentences like (10). In the corresponding story, one of the children had picked a tiger, one child had picked a dinosaur and one had picked both. If child subjects know that the second argument of *every* is not downward entailing, they should accept the target sentence in (10) as a description of this context. However, if children do not know the entailment properties of the second argument of *every*, they could reject it. In a second experiment, children were presented with sentences like (11) in a context in which only ladies who bought eggs received a basket. If children know that the first argument of *every* is downward entailing, they should reject (11) in this context. However, if children do not know the entailment properties of the first argument of *every,* they could accept it. The finding was that children consistently accessed the conjunctive interpretation of disjunction for sentences like (11), but almost never for sentences like (10). In short, children clearly distinguished between the first and second argument of the universal quantifier *every*, as anticipated by the theory of Universal Grammar. This pattern of behavior by children is difficult to reconcile on models of acquisition based solely on domain general cognitive mechanisms, such as analogy or 'cut and paste,' because the same logical operator, *or*, generates different patterns of entailment depending on which argument position of *every* is involved.

3. Experiments on Downward Entailment

The present study takes a different tack in assessing children's comprehension of sentences with the universal quantifier. First, recall that the universal quantifier does not enforce downward entailing inferences for expressions that appear in its second argument. So, (12a) can be true and (12b) false, in the same situation. On the other hand, if (12b) is true, then (12a) must also be true. In fact, the universal quantifier *every* and the existential quantifier *some* make equivalent contributions to the interpretation of linguistic material located in the VP, as shown in (13).

(12) a. Every boy caught a <u>koala bear</u>.
b. Every boy caught a <u>brown koala bear</u>.

(13) a. Some boy caught a <u>koala bear</u>.
b. Some boy caught a <u>brown koala bear</u>.

However, a different pattern of inferences emerges if we 'cut' the set denoting expressions *koala bear* and *brown koala bear* from (12), and 'paste' these expressions into the first argument of the universal quantifier. The result is (14). Now, the entailment pattern is reversed. If (14a) is true in a situation, then (14b) must also be true, but the inverse does not hold.

(14) a. Every <u>koala bear</u> caught a bug.
b. Every <u>brown koala bear</u> caught a bug.

Another 'cut and paste' operation is performed in (15). We have cut the Determiner Phrase *every koala bear* from (14a), and pasted it into (15a), such that it is now c-commanded by another downward entailing expression, *nobody*.

(15) a. Nobody fed every <u>koala bear</u>.
b. Nobody fed every <u>brown koala bear</u>.

For adults, the pattern of entailments for the phrases headed by the universal quantifier are reversed in (14) and (15). The first argument of the universal quantifier *every* in (15a) is no longer downward entailing, so (15b) does not follow from (15a). Instead, (15b) entails (15a). That is, the first argument of *every* is now upward entailing. The remainder of this section describes three experiments designed to test children's interpretation of sentences like (12), (14) and (15).

All three experiments employed the Truth Value Judgment task. This experimental technique allows one to investigate whether a specific interpretation of a target sentence is licensed by the child's grammar (Crain and McKee 1985; Crain and Thornton 1998). Two experimenters usually participate in a Truth Value Judgment task. One experimenter acts out short stories in front of the child, using props and toys. The story constitutes the context against which the child evaluates a target sentence. The target sentences are produced by a puppet which is manipulated by a second experimenter. The acceptance of the target sentence is interpreted as indicating that the child's grammar licenses an interpretation that makes the sentence true in the context under consideration. By contrast, the rejection of a target sentence is interpreted as suggesting that the child's grammar does not license any interpretation that makes the sentence true in the context.

3.1 Experiment I

The first experiment was designed to investigate children's knowledge of the entailment properties of the first argument of the universal quantifier *every*. Twenty children participated in the experiment. They ranged in age from 3;8 to 5;11, with a mean age of 4;10. The study used a Latin Square design. Each child heard two sentences similar to (14a) and two sentences similar to (14b). For half of the children, any given test sentence contained the set denoting expression (e.g., *troll*); for the other half of the children, the corresponding sentence contained the subset expression (e.g., *purple troll*). There were also four fillers trials; two were designed to evoke positive responses, and two were designed to evoke negative responses. We illustrate a typical trial in (16).

(16) This is a story about Tigger, who invited five trolls to a party. Three trolls have yellow hair and two trolls have purple hair. Tigger says: "Hi friends! I have prepared a lot of food for you. I have baked three regular potato chips and one extra spicy potato chip. I also baked two cookies and one donut. Help yourselves!" The trolls consider their choices. All the trolls think about eating the donut, but they decide it would not be good for them. Then they look at the spicy potato chip and decide that it could be too spicy. In the end, the three purple trolls each take one regular potato chip. The two yellow trolls each decide to take a cookie.

At the conclusion of the story, the puppet offered his description of the story. For this trial, half the children heard (17), and half heard (18).

(17) Every <u>troll</u> has a potato chip.

(18) Every <u>purple troll</u> has a potato chip.

The experimental hypothesis was that children would reject sentences like (17), but would accept ones like (18). This is exactly what happened. Children rejected sentences like (17) 90% of the time, but accepted sentences like (18) on every trial.

The findings show that children as young as 3;8 know that sentences like (17) and (18) receive different truth-values in the same context. In particular, the same context can falsify sentences of the form *Every A is B*, but verify ones of the form *Every A' is B*, where A' $\subseteq$ A. Two follow-up experiments investigated whether or not children persisted in using the same pattern of judgments in the second argument of the universal quantifier (Experiment II), and in sentences in which *every A* occurs in the scope of a downward entailing operator (Experiment III).

3.2 Experiment II

Experiment I investigated children's interpretation of sentences with different noun phrases in the first argument of the universal quantifier *every*. The second experiment investigated whether or not the same pattern of judgment about truth or falsity would be observed in the second argument of *every*. The same twenty children participated in both experiments. In Experiment II, each child heard two sentences similar to (12a) and two sentences similar to (12b) in different contexts, in a Latin Square design. The four target trials were interspersed with an equal number of filler trials to balance the number of children's 'Yes' and 'No' responses. Here is a typical trial:

(19) This is a story about five smurfs who go to a fair. They want to play a game being operated by Mickey Mouse. In this game, there is a big swimming pool in which some animals are swimming. There are four blue bugs, three small ones and one very big one. In addition there is a red bug, a green bug and a frog. The idea of the game is to catch one of the animals, to win a prize. Mickey Mouse tells the smurfs that if they catch the big blue bug, they will get a bigger prize. At first the smurfs try to catch the frog, but the frog is very quick, and jumps away. Then three smurfs each catch a small blue bug. The remaining smurfs first attempt to catch the big blue bug, but they give up. One of them catches a red bug and one catches a green bug.

At this point, one group of children was asked to evaluate (20) and the second group was asked to evaluate (21).

(20) Every smurf caught a <u>bug</u>.

(21) Every smurf caught a <u>blue bug.</u>

The null hypothesis was that children would extend the pattern of judgments witnessed for the first argument of the universal quantifier *every* (see Experiment I) to the sentences in (20) and (21). By contrast, the experimental hypothesis was that children would not be influenced by the entailment pattern of the first argument of the universal quantifier *every*. Thus, the experimental hypothesis was that children would accept (20) but reject (21). The results were consistent with the experimental hypothesis. Children accepted sentences like (20) 95% of the time, but they rejected ones like (21) on every trial. The findings show that children do not apply the same entailment patterns in the first and second argument of the universal quantifier *every*.

3.3 Experiment III

We now consider whether or not the pattern of entailment witnessed in Experiment I persists when phrases like *every A* occur in the scope of a second downward entailing expression, as in (22).

(22) a. Nobody fed every koala bear.
b. Nobody fed every brown koala bear.

Twenty-two children participated in the experiment. The children ranged in age from 4;5 to 6;8, with a mean age of 4;11. Each child heard two sentences similar to (22a) and two similar to (22b). Each child was also presented with an equal number of fillers to balance the number of affirmative and negative responses. A typical trial is presented below.

(23) This is a story about a zoo. There are three zoo-keepers and they have to feed 15 koala bears. The koala bears are divided in three different cages. The three zoo-keepers are Eeyore, Tigger and Winnie the Pooh. Each zoo-keeper has to feed the five koala bears, in one of the cages. In Eeyore's cage, there are three small koala bears and two big ones. Tigger and Winnie the Pooh must each feed three big koala bears and two small koala bears. Eeyore has a bunch of pizzas and he 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 Winnie the 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 two groups of children were asked to evaluate (24) and (25). The relevant observation is this: Winnie the Pooh has managed to feed all the big koala bears in his cage, but no zoo-keeper has managed to feed all of the koala bears in his cage.

(24) Nobody could feed every koala bear.

(25) Nobody could feed every big koala bear.

Sentence (24) is true, since every zoo-keeper ran out of pizzas before feeding all of the koala bears in his own cage. However, (25) is false, because Winnie the Pooh managed to feed all of the big koala bears in his cage, although the small koala bears in the cage were not fed.

As in Experiment II, the experimental hypothesis was that children would not be thrown off by the entailment pattern of the first argument of the universal quantifier, and would evaluate the sentences in (24) and (25) relative to the context in (23). The results are consistent with the experimental hypothesis. Children accepted sentences like (25) on 89% of the trials, but they rejected ones like (24) 81% of the time. As in Experiment II, we conclude that children do not 'cut and paste' the entailment pattern from the first argument of the universal quantifier *every* into downward entailing environments such as in (22).

4. Conclusion

Beginning with Inhelder and Piaget (1964), research on children's understanding of the universal quantifier *every* has uncovered systematic non-adult behavior. As an example, young children often reject (20) as a description of a picture in which every boy is riding an elephant, if there is an 'extra' elephant, i.e., one not ridden by a boy.

(26) Every boy is riding an elephant.

Recently, linguistic accounts have been proposed to explain the pattern of children's behavior. Common to these accounts is the assumption that children fail to distinguish between the first and second arguments of the universal quantifier in the way adults do. Here is the way Philip (1995) and Drozd and van Loosbroek (1998) put it:

> "All that matters for semantic interpretation of the universal quantifier in such a representation is that this quantifier have scope over the entire sentence: its original position in surface structure is completely irrelevant." (Philip 1995)

> "… under this condition, children fail to register the presuppositional force of the quantifier, and subsequently lose the functional distinction between the quantifier's restriction and nuclear scope, when they come to the task of evaluating the universally quantified sentence in context." (Drozd and van Loosbroek 1998)

These accounts of children's non-adult interpretations of sentences containing *every* are challenged by the findings of the research we have presented in this paper. Taken together, the results of the three experiments we reported show that children's knowledge of the universal quantifier *every* runs deeper than anticipated by these accounts. Children clearly distinguish between the first and second arguments of the universal quantifier. In particular, children are sensitive to the semantic property of downward entailment, which distinguishes between the first argument and the second argument of the universal quantifier *every* in adult languages.

The findings therefore add credence to the conclusions reached by Crain et al. (1996), who suggested that children's non-adult responses only emerge in experimental tasks that fail to satisfy the felicity conditions associated with judgments of truth. The debate that has ensued has mainly focused on features of experimental design, in particular on the salience of the objects denoted by the referential expressions appearing in the two argument of the universal quantifier. To address this issue, 'extra' objects were made highly salient in the experimental contexts of the studies reported here, to evoke non–adult responses if these were permitted in child grammars. In Experiment I the extra object was a spicy potato chip and, in Experiment II, it was a big blue bug. In both cases, the experimenter tried to draw children's attention to these objects to make sure they were highly salient. Despite this, these 'extra' objects did not influence children's responses, presumably because the contexts in these experiments were constructed to satisfy the felicity conditions of the task, as prescribed by Crain et al. (1996). As a final comment, we wish to note that the findings illustrate abstract syntactic and semantic phenomena that children have mastered at a young age, in the absence of decisive evidence in the input. Therefore, the data support the Continuity Assumption, according to which children have access to the same linguistic principles that govern adult languages (Pinker 1984; Crain 1991).

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