Choosing quantity over quality: syntax guides interpretive preferences for novel superlatives

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Abstract

Acquiring the correct meanings of number words (e.g., *seven*, *forty-two*) is challenging, as such words fail to describe salient properties of individuals or objects in their environment, referring rather to properties of *sets* of such objects or individuals. Understanding how children succeed in this task requires a precise understanding not only of the kinds of data children have available to them, but also of the character of the biases and expectations that they bring to the learning task. Previous research has revealed a critical role for language itself in how children acquire number word meanings, however attempts to pinpoint precisely the strong linguistic cues has proved challenging. We propose a novel "syntactic bootstrapping" hypothesis in which categorizing a novel word as a determiner leads to quantity-based interpretations. The results of a word learning task with 4 year olds indicates that this hypothesis is on the right track.

Keywords: Number, quantity, language acquisition, learning, determiners, adjectives, quantifiers, syntax.

Words for quantities

While it is uncontroversial that young children necessarily make use linguistic and extralinguistic information when they set about learning the meaning of novel words, the idea that some pairing of "situation and sound" is *sufficient* has been repeatedly questioned (e.g., Landau & Gleitman 1985, Waxman & Lidz 2006). An especially difficult problem for any view that posits a simple mapping from a portion of experience to the meaning of a novel word has been the acquisition of number words (e.g., *five*, *sixty-seven*). This is particularly challenging as numbers refer to properties of *sets* of objects rather than to properties of any object in particular (Frege 1893; Bloom & Wynn, 1997). Understanding how number words are learned must be informed not only by a precise understanding of the kinds of data children have available to them, but also of the character of the biases and expectations they bring to the learning task.

In this paper, we consider the question of how children decide that a novel word describes numerosity and not some other salient property. To take a simplified example of the problem, consider the novel word *gleeb* in (1).

(1)   The gleeb cows are by the barn.

The novel word *gleeb* appearing in an adjectival position may describe any number of properties relevant to the cows, for instance their color (e.g., they may be *blue*), texture (e.g., especially *soft*), size (e.g., for cows, quite *big*), or even their number (e.g., approximately *many*, or exactly *seven*). Under what circumstances would a child prefer to assume that number is the intended property? Finding such circumstances would aid researchers in finding the unique biases and expectations children must bring to the task in order to accurately acquire number words.

Research on the acquisition of exact number words suggests that language itself must provide critical support for the child to map new words onto such abstract meanings. Wynn (1992; see also Condry & Spelke 2008) found that children at 2;6, who do not yet understand the relationship between the words in the count list and exact cardinalities, nevertheless understand that the number words describe numerosities. This result is striking, as it takes children another full year to gain the knowledge that which exact quantities are intended (Wynn 1992, Carey 2009). Bloom and Wynn (1997) examined the distribution of the numerals in the CHiLDES database of child-directed speech to determine what syntactic cues might prompt quantity-based interpretations. They proposed that the appearance of an item in the partitive frame (e.g., as *X* in *X of the cows*) was a strong cue to number word meaning. The plausibility of such a view is bolstered by the linguistics literature: partitivity has been said to signal to the semantic role of quantification (Jackendoff 1977).

This proposal was recently investigated by Syrett, Musolino and Gelman (2012). Conducting their own corpus study, they pointed out that a great variety of non-quantity-referring expressions occur in the partitive frame (2), so perhaps we should not expect it to be a strong cue to numerical meanings.

(2)   a. **Amount:** *all, two, seven, most, some*

       b. **Segment:** *back, front, edge, side, top*

       c. **Measure:** *mile, hour, pound, bucket*

Regardless, if the partitive were a strong cue, then a novel word embedded in the partitive should lead children to pick a quantity-based interpretation even when the environment supports both this and an alternative interpretation. That is, in a novel word learning task, the novel word *pim* appearing with

the partitive (as in *pim of the trains*) should be analyzed as referring to the quantity TWO but not the quality RED[1] when both interpretations were supported. Syrett et al found that the partitive predicted quantity-based judgments only in restricted cases,[2] casting doubt on the robustness of a "syntactic bootstrapping" account based on the partitive as a strong cue.

The puzzle raised by Wynn's (1992) original finding remains. Indeed, it appears to raise the question whether it may be necessary to understand how children decide that novel words describe quantities *at all* before we can understand how they learn the meanings of words for *exact* numerosity (see also Barner, Chow & Yang 2009 for discussion). The numerals pattern with a larger class of expressions in natural language called *quantifiers* (i.e., the Amount terms in (2)), which share a similar syntactic distribution. If a child could figure out (as Bloom & Wynn suggested) that a certain bit of syntax corresponded in a stable fashion with the semantics of quantity, they might have a foothold on deciding a novel word referred to numerosity. To get a sense of the problem, consider the sentences in (3a) and (3b) with the novel word *gleebest* against the image in Figure 1.

(3) a. The gleebest cows are by the barn.

 b. Gleebest of the cows are by the barn.

For adults, *gleebest* in (3a) could in principle describe something about the numerosity or some other property of the cows by the barn in contrast to those in the field. Indeed, the meaning one perceives is similar to that conveyed either by the familiar *most* or e.g. *spottiest*. However, if adults were exposed to the novel word in the syntactic context given in (3b), they would *never* suppose it to designate something about the spottiness of the cows by the barn, only their numerosity.

Adults, however, have had a lifetime of language experience. Under what conditions would a child still in the process of mastering their native tongue hypothesize that *gleebest* means MOST as opposed to SPOTTIEST? Would their pattern of preferences be the same if presented with either of the sentences in (3a) or (3b)?

While the evidence for the partitive frame (*...of the cows*) as a strong cue to quantity-based meanings is mixed, we think pairs of sentences like the above suggest that a stronger cue might be whether something occurs to the left of *X*. Of the classes of counterexamples provided by Syrett et al given in (2), we may note that only amount terms can appear without a determiner (*a* or *the*) on the left:

(4) a. Two/most of the cows lowed.

 b. * Back/side of the fridge is blue.

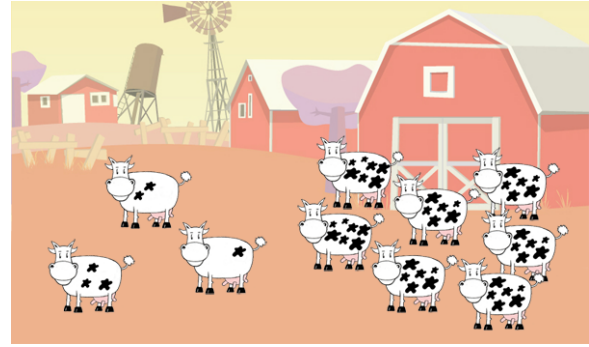 c. * Mile/hour of the race was hard.

Figure 1: **The gleebest cows** are by the barn.

Such data illustrate an important linguistic generalization. Amount terms, or *quantifiers*, can occur in a privileged syntactic position (e.g., Barwise & Cooper 1981): that of determiners, instantiating the category D. Unlike the partitive frame, Ds have a stable syntax-semantics mapping: their interpretation only references quantities, never qualities, of individuals (van Benthem 1989, Gajewski 2002).[3] Observing this pattern leads us to a novel hypothesis: if a child categorizes a novel word as D, she will understand that word to have a quantity- rather than quality-based meaning.

A test of this would be to make both numerosity and spottiness salient, and test children's preferences for interpreting a novel word across syntactic contexts. To construct such a test, we turn to superlatives. As we will see, superlatives (the result of combining a word like *heavy* with the morpheme *-est*) allow for a direct comparison of the hypothesis that syntactic category, and not partitivity, is a strong cue to positing quantity-based meanings.

Combining a word with a quality-based meaning like *heavy* with the morpheme *-est* allows the formation of expressions like *the heaviest animals*, with a meaning like THE ANIMALS THAT ARE HEAVIER THAN ANY OTHERS. Similarly, combining *many* with *-est*[4] gives *the most animals*, with a meaning like THE ANIMALS THAT ARE MORE NUMEROUS THAN ANY OTHERS. Importantly for our purposes, both of these types of superlatives surface in the position of an adjective (5a) (where *the* instantiates the syntactic category D), but only the quantity-based superlative *most* can appear bare on its left, instantiating D (contrast (5b) with (5c):

(5) a. The heaviest/most animals are happy.

 b. Most of the animals are happy.

 c. * Heaviest of the animals are happy.

[1] We follow custom in using italics for linguistic expressions and small caps as shorthand for their meanings.

[2] Only when it was used at test; when the partitive was used during training but not at test, children were at chance at picking the quantity interpretation.

[3] As a simple rule to determine which word in a string is D, take *X* in *X of the cows* to be D unless *the* precedes *X*. Since *the* cannot appear without an element to its right before *of* (cp. **the of the cows*), it instantiates D whenever it is present. In *the most cows*, *the* instantiates D, but *most* instantiates D in *most of the cows*.

[4] It is widely assumed that *most* is the superlative of *many*, following Bresnan 1973; cf. Bobaljik 2007 who argues *most* is *more+est*.
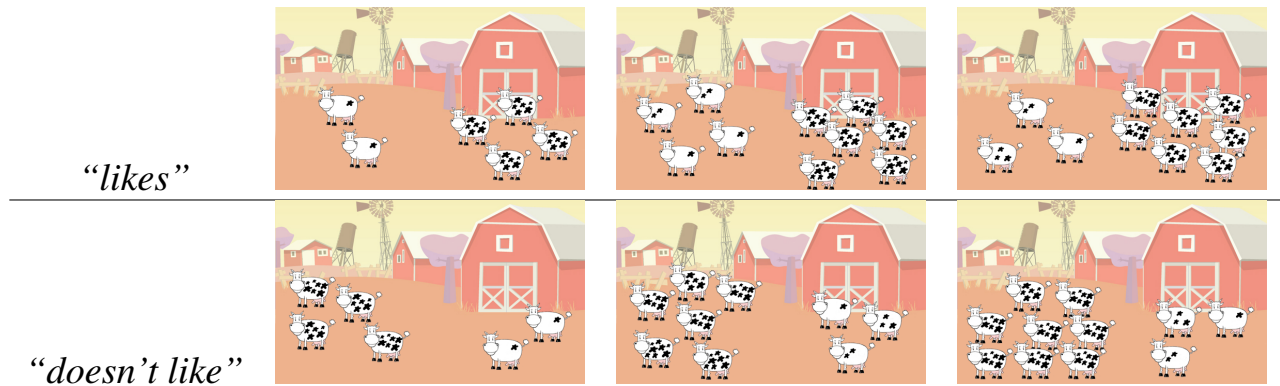
Figure 2: **Ambiguous training cards.**

This restriction can't be conceptual: where we understand the sentence in (5b) to mean MORE THAN HALF OF THE ANIMALS BY NUMBER ARE HAPPY, by analogy we might have expected (5c) to mean MORE THAN HALF OF THE ANIMALS BY WEIGHT ARE HAPPY. To see what this would mean, consider a situation in which the only animals are a cow C, a lamb L, and a rabbit R. It is clear that (5b) is true if any two of the animals are happy. But (5c) requires more information: if C weighs 700kg, L weighs 35kg, and R weighs 8kg, we would know (5c) is true **only if C is happy**. Individuals and their particular properties matter for quality-based superlatives, where only set cardinality matters for *most*. While it is clear that no conceptual necessity rules out a determiner-like meaning for a quality-based adjective, why it is excluded remains a mystery.[5]

Lastly, regardless of whether they have quantity- or quality-based meanings, superlatives can appear in the partitive frame:

(6) a. * The spotty of the cows were by the barn.

b. * The many of the cows were by the barn.

c. The spottiest of the cows were by the barn.

d. The most of the cows were by the barn.

In the next section, we put our hypothesis that syntactic category cues category meanings to the test in a novel word learning task. At the same time, we contrast this hypothesis with that suggesting partitivity as a strong cue.

Testing superlatives

In the previous section, we hypothesized that representing a novel word as an instance of the category D was a strong cue to the learner that the word should be assigned a quantity-based meaning. An alternative was presented that suggested presence of the partitive frame alone was a strong cue. We test

these ideas by examining children's preferences when embedding *gleebest* in a variety of syntactic contexts, using a variant of the Picky Puppet task (Waxman & Gelman 1986).

Method

In this task, the experimenter first explains that the game is to sort cards according to whether a puppet likes them or not. The puppet is described as picky, but friendly enough to share the reasons for why he likes what he does. The experimenter explains the puppet's criterion by showing preferred and dispreferred cards along with the sentence: "The puppet said he likes the cards where **target sentence**, but he doesn't like the ones where it's not true that **target sentence**". The target sentence always contained the novel word *gleebest* (see Table 1). The experimenter explains that she doesn't know what *gleebest* means, but was hoping the child could help her figure it out. In the Training phase, the child is shown 6 training cards (Figure 2), the ones the puppet had "already told" the experimenter it liked or didn't like.

Table 1: **Target sentences: "***The puppet likes the cards where* **DP** *are by the barn.***"**

cond	DP	*the*	partitive
ADJ	*the gleebest cows*	✓	×
CON	*the gleebest of the cows*	✓	✓
DET	*gleebest of the cows*	×	✓

While the training cards are perfectly ambiguous (the group by the barn is both the most numerous and the most spotty), the test cards are perfectly *un*ambiguous.[6] The same cards (in counterbalanced order) were presented to each participant. The form of the target sentence was our between-subjects factor, with *gleebest* appearing in adjectival (ADJ), confounded (CON), and determiner (DET) positions, so our conditions feature different combinations of presence/absence of *the* and the partitive, as schematized in Table 1.

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[5]This is especially surprising, given recent proposals in the formal semantics literature that nothing much *semantically* distinguishes *most* from *spottiest* (Hackl 2009). Yet, it is difficult to see how appeal to numerosity would be possible in formulating a *syntactic* constraint to make sense of facts like (5b)-(5c).

[6]For our test cards, the ratio of the numerosities of the cows was inversely proportional to the ratio of the spots of the cows.

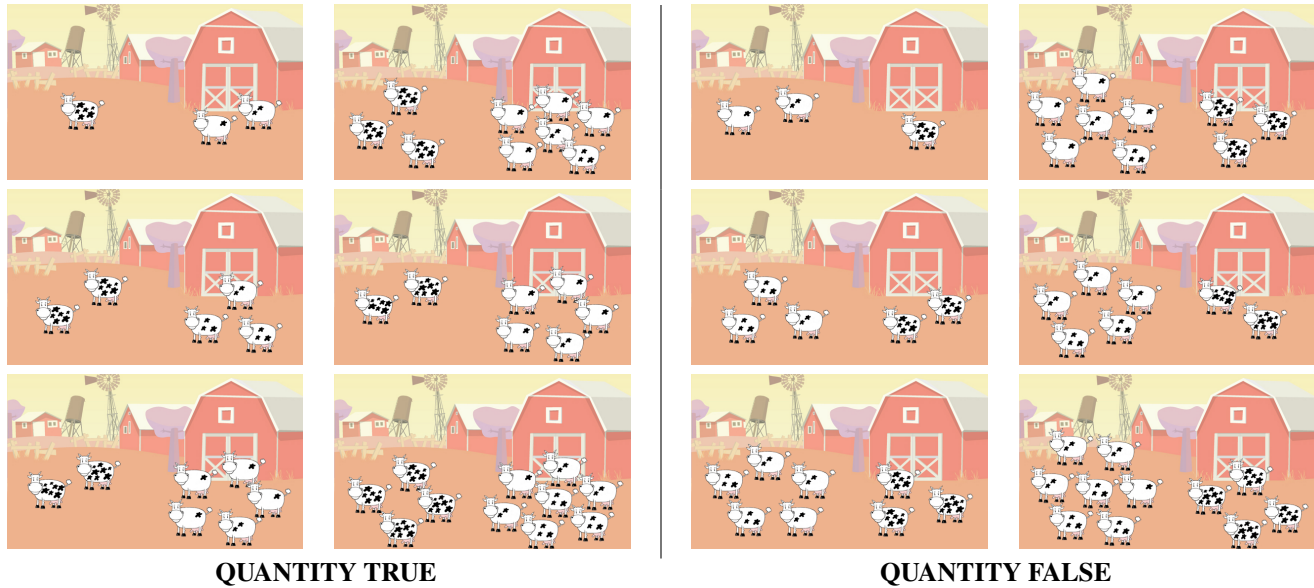QUANTITY TRUE   QUANTITY FALSE

Figure 3: **Unambiguous test cards.**

At the beginning of the Test phase, the experimenter handed each test card to the child with the question "Do you think he likes this one?". The child was to place each card below a green circle with a checkmark on it if the puppet likes it, and below a red circle with a black X if he doesn't like it. At the end of the experiment, the child was probed as to what s/he thought *gleebest* meant, and responses were recorded.

We hypothesized that categorizing a novel word as D restricts a child's hypothesis about the word's meaning to a quantity-based interpretation. Another proposal was that the presence of the partitive frame itself was a strong cue to such interpretations. Thus the relevant hypotheses are schematized in Table 2 according to whether they predict a greater-than-chance quantity-based response (indicated by +).

Table 2: **Predicted neutral (−) versus increased quantity-based responses (+).**

Hypothesis	ADJ	CON	DET
Category as strong cue	−	−	+
Partitive as a strong cue	−	+	+
No bootstrapping	−	−	−

36 children participated (range 4;0-5;2, mean 4;7), recruited from families in the University of Maryland area. Each child was given a small gift for participating. Four additional children were tested and subsequently excluded—2 due to experimenter error, 1 due to presenting with a strong "yes" bias (i.e., the participant indicated the puppet "liked" 11/12 of the test cards), and 1 due to a strong "no"-bias (i.e., they said the puppet "didn't like" 12/12 of the test cards). We measured the percentage of cards sorted consistent with a quantity-based interpretation.

Results

Across our three conditions, responses were significantly different from chance (sign tests: ADJ $p < 0.0001$, CON $p < 0.05$, DET $p < 0.0001$). These differences were in different directions, however. Children sorted cards consistent with a quantity-based interpretation in DET 72% of the time, compared to 29% in ADJ and 40% in CON. In addition, DET was significantly different from both ADJ (t-test, $p < 0.0001$) and CON (t-test, $p < 0.0001$). These results are presented graphically in Figure 4.

It is noteworthy that these results are not simply an averaging effect: 8 out of 12 of the children in DET sorted at least 9 out of 12 test cards consistent with a quantity-based interpretation, while only 2 out of 12 children did so in ADJ and 3 out of 12 in AMB.
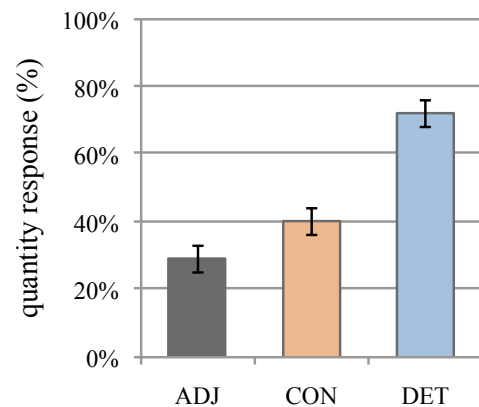

Figure 4: **Percent quantity responses by condition.**

As there were no differences between our conditions except for the syntactic context in which *gleebest* occurred, these results support the idea that syntax cues children into quantity-based meanings, with syntactic category playing a strong role. Partitivity, on the other hand, is a fairly weak cue: while there was a slight effect (CON had slightly higher quantity-based responses than ADJ, $p < 0.05$), in neither of these conditions did children sort cards consistent with a quantity-based interpretation, in fact both conditions displayed *lower* than chance sorting of cards consistent with that interpretation. A table summarizing the predicted versus actual results is given in Table 3.

Table 3: **Predicted neutral (+) versus increased quantity response (+): prediction met (✓) versus not (×).**

Hypothesis	ADJ		CON		DET	
Category as strong cue	−	✓	−	✓	+	✓
Partitive as strong cue	−	✓	+	×	+	✓
No bootstrapping	−	✓	−	✓	−	×

Of the three hypotheses sketched, only syntactic category as a strong cue captures the results we found.

Discussion

Our results show that a syntactic bootstrapping hypothesis for acquiring novel superlatives is supported. An additional hypothesis, that the presence of the partitive frame is a strong cue to quantity-meanings, was not supported. These results are important for a number of reasons. As observed in the introduction, choosing number as the relevant property from a set of available properties is potentially challenging for children. Our results highlight the role of the child's syntactic representations in narrowing her hypotheses about what matters when she tries to determine the meaning of a novel word, in particular the role of the syntactic category D as a strong cue to quantity-based meanings.

A different but related question that this work raises is the strength of the bias towards quality-based meanings in ADJ and CON. Given that children had no problem deciding that *gleebest* referred to numerosity in DET, we cannot assume some inability to reason about number. One might speculate that the bias is due to the child's distribution of known adjective (or superlative) meanings: since many more words in this category refer to object properties than set properties, the prior distribution of meanings biases her towards the former, absent syntactic cues to the contrary. Future work with younger children could examine the degree to which this bias emerges as a function of the size of their lexicons. The line of thought just outlined predicts that that the youngest children would show less of a bias in this direction.

Acknowledgments

References

Barner, D., Chow, K., & Yang, S.-J. (2009). Finding one's meaning: A test of the relation between quantifiers and integers in language development. *Cognitive Psychology*, *58*, 195-219.

Barwise, J., & Cooper, R. (1981). Generalized quantifiers and natural language. *Linguistics and Philosophy*, *4*, 159–219.

Benthem, J. van. (1989). Logical constants across types. *Notre Dame Journal of Formal Logic*, *3*.

Bloom, P., & Wynn, K. (1997). Linguistic cues in the acquisition of number words. *Journal of Child Language*, *24*, 511-533.

Bobaljik, J. D. (2007). *On comparative suppletion.* (University of Connecticut, m.s.)

Bresnan, J. (1973). Syntax of the comparative clause construction in English. *Linguistic Inquiry*, *4*(3), 275–343.

Carey, S. (2009). Where our number concepts come from. *Journal of Philosophy*, *106*(4), 220-254.

Condry, K. F., & Spelke, E. S. (2008). The development of language and abstract concepts: The case of natural number. *Journal of Experimental Psychology*, *137*, 22-38.

Frege, G. (1893[1967]). *Grundgesetze der arithmetik, begriffsschriftlich abgeleitet (the basic laws of arithmetic)* (English translation in M. Furth (trans.) ed.). University of California: Berkeley.

Gajewski, J. (2002). L-analycity in natural language. *Unpublished manuscript: MIT*.

Hackl, M. (2009). On the grammar and processing of proportional quantifers: *most* versus *more than half. Natural Language Semantics*, *17*, 63-98.

Jackendoff, R. (1977). *X' syntax*. Cambridge, Massachusetts: MIT Press.

Landau, B., & Gleitman, L. (1985). *Language and experience: Evidence from the blind child*. Cambridge, Massachusetts: Harvard University Press.

Syrett, K., Musolino, J., & Gelman, R. (2012). How can syntax support number word acquisition. *Language Learning and Development*, *8*(146-176).

Waxman, S., & Gelman, S. (1986). Preschoolers' use of superordinate relations in classification and language. *Cognitive Development*, *1*, 139-156.

Waxman, S., & Lidz, J. (2006). Early word learning. In D. Kuhn & R. Siegler (Eds.), (6th edition ed., Vol. 2, p. 299-335). Hoboken NJ: Wiley.

Wynn, K. (1992). Children's acquisition of the number words and the counting system. *Cognitive Psychology*, *24*, 220-251.