The role of cardinality in the interpretation of measurement expressions

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Article begins on next page
The role of cardinality in the interpretation of measurement expressions
Abstract

The purpose of this brief article is to investigate four-year-olds’ interpretation of attributive measure phrases (MPs), such as 3-pound, and the role of cardinality in their responses. In two experiments, we demonstrate that four-year-olds appear to recognize that such MPs refer to a property of an individual, such as weight per unit (rather than the weight of an entire collection). Accordingly, they distinguish between attributive and pseudopartitive MPs. However, when the opportunity arises to treat the number word as referring to numerosity, children occasionally succumb to this pressure. We argue that the fundamental aspect of number word meaning that children take the first few years of life to master – that number words denote the cardinality of a set of discrete objects – is the precise aspect they must overcome in order to correctly interpret these expressions. However, the evidence suggests that four-year-olds are well on their way to doing so.

Keywords: semantics, syntax-semantics, measure phrases, number words, cardinality
1. Introduction

The purpose of this brief article is to investigate four-year-olds’ developing understanding of measurement expressions and the role of cardinality in their interpretation. In recent decades, a now well-established line of research has investigated children’s developing understanding of number words, focusing primarily on children’s knowledge of the cardinal principle, which says that the last number in a count sequence carries special significance by indicating the cardinality of a set (Bloom & Wynn, 1997; Briars & Siegler, 1984; Carey, 2004, 2009a, b; Fuson, 1988; Gelman & Gallistel, 1978; Gelman & Meck, 1983; Le Corre & Carey, 2007; Le Corre, et al., 2006; Syrett, Musolino, & Gelman, in press; Wynn, 1990, 1992). To be sure, there is a good reason for this. First, being able to measure out, compare, track, and estimate quantities is a key component of human cognition. Understanding the path of acquisition of the cardinality component of number word meaning is informative about both conceptual and linguistic development and the extent to which they are intertwined. Second, from a linguistic perspective, reference to exact set size represents a core component of number word meaning, differentiating it from other quantificational lexical items with similar distribution (e.g., quantifiers such as some and modifiers such as many, or several). Children must be able to differentiate these lexical items and recognize the relationship between their semantic representations and the syntactic environments in which they appear. Third, knowing how and when children track cardinality is also highly informative about their interpretation of other expressions, such as more and (at) most, which also rely upon cardinality (cf. Hackl, 2009; Halberda et al., 2008, Papafragou & Schwarz, 2005/2006; Pietroski et al., 2009).

However, full mastery of number word meaning entails being able to correctly interpret phrases in which number words appear, which might not necessarily serve to pick out a set of
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objects in the real world with the corresponding numerosity. In fact, recent work in language acquisition has targeted instances in which a number word appearing in an utterance does not necessarily signal the presence of that exact set size in the world (Hurewitz et al., 2006; Noveck, 2001; Musolino, 2004, 2009; Papafragou & Musolino, 2003). However, each of those cases still involves reference to a set of discrete objects, and the research question in those studies concerned whether the grammar is structured in a way as to allow the sentence to be true when the cardinality expressed by the number word is a proper subset of the cardinality corresponding to the relevant set of objects (i.e., whether an ‘at least’ interpretation is available).

Number words can also appear in linguistic environments in which they do not simply appear in prenominal position and do not signal the cardinality of a set. A prime example is Measure Phrases (henceforth, MPs). In a phrase such as 8-pound baby, the number word does not pick out the number of babies (a set of discrete objects in the world, the members of which can be verbally tagged), but rather the total weight of one baby. Thus, interpreting MPs correctly requires knowledge of how number words can measure out quantities, and how the unit of measurement maps onto the dimension being measured (e.g., weight), and yet in order to properly interpret these constructions, children must also be able to suspend their knowledge of how the number word can pick out the cardinality of set in order to attend to the semantic constraints of the linguistic construction in which it appears. The road to becoming fully adult-like in the interpretation of natural language expressions with number words, then, involves navigating through examples that seemingly diverge from the core aspect of number word meaning children strive so hard to master in the first four years. Investigation of this phenomenon in linguistics not only stands at the crossroads of cognitive psychology and linguistics, but also provides insight into children’s early mathematical abilities beyond counting,
and the extent to which children are aware that language places constraints on how we measure out quantities in the world.

In this article, we ask when children begin to correctly interpret such expressions of measurement, and what factors account for the instances when their interpretations differ from those of adults. Here we focus on one factor in particular – cardinality – by manipulating the count-mass status of the target items. We further narrowed our focus to attributive MPs, such as 8-pound $X$. In such cases, the number word is prenominal and prosodically prominent, but does not necessarily serve to pick out a set of discrete objects with an exact cardinality. Moreover, the real-world referent is expressed by the second noun ($X$), rather than the one immediately following the number word. Such cases would thus appear to present a special challenge to the language learner. In two sets of experiments, we demonstrate that while four-year-olds exhibit a developing command of the syntax-semantics mapping of attributive MPs, their performance in experimental tasks tapping into this knowledge is mitigated by their tendency to interpret the number word in the MP as referring to cardinality of a contextually-relevant set of objects.

2. Semantic background

Measure phrases (MPs) such as those in (1) are constructed from a combination of a number word or a weak quantifier and a word expressing a unit of measurement. This MP then combines with a noun to form a measurement expression (Jackendoff, 1977; Klooster, 1972; Schwarzschild, 2006).

(1) a. They are the proud parents of an 8-pound baby.
   b. I ordered a 2-shot espresso.
   c. They drank several bottles of water.

There are two kinds of MPs: attributive MPs and pseudopartitive MPs. The difference is
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While these MPs are minimally different on the surface (i.e., the presence or absence of the number marking on the MP head *pound(s)* and the word *of*), they differ fundamentally in how they measure out amounts. Attributive MPs express a property of individuals (e.g., weight per unit), while pseudopartitive MPs express a property of the whole (e.g., the weight of the entire quantity). Thus, in (2), (a) entails that each strawberry weighs three pounds, whereas (b) entails that the entire collection of strawberries weighs three pounds. We highlight this difference in Experiment 1. Formally, this difference is captured by saying that pseudopartitive MPs are monotonic on (i.e., track) the part-whole relation, while attributive MPs are non-monotonic (Barwise & Cooper, 1981; Ladusaw, 1982; Link, 1983; Schwarzschild, 2006). This difference in measuring out quantities has consequences when subtraction is performed on the quantity. Taking away a subset from a larger set of strawberries changes the overall weight of the collection, but it does not change their weight per unit. We take advantage of this difference in Experiment 2.

3. Previous research on MPs in child language

Recent investigations of four-year-olds’ interpretation of attributive MPs by Syrett & Schwarzschild (2009) and Syrett (2010) have produced somewhat mixed results concerning children’s knowledge of these expressions. In a forced-choice task in which children were given a choice between one card with two cups on it, and two cards with five cups on each, children were more likely than chance to select the individual card with two cups when asked to find the *two-cup card* and to select the set of two cards that each had five cups when asked to find the *two*...
cup-cards (a NN compound with similar surface-level features). Moreover, children correctly appealed to the number of cups on the card to justify their response to the attributive MP, and to the number of cards for the NN compound. While these results are promising in that they appear to indicate that children assigned the correct syntactic constituency to these phrases, the number word still referred to a set of discrete entities in the discourse context (e.g., the set of cups on the card). Thus, it remains an open question whether four-year-olds can correctly interpret attributives that do not rely upon cardinality of a set. That is, do they recognize that the attributive refers to a property of an individual in the absence of a set of objects to count?

In a second experiment using the visual world paradigm, which explicitly contrasted attributive and pseudopartitive MP interpretations (2-cup cards v. 2 cups of cards), four-year-olds selected the correct referent for the pseudopartitive more often than chance, but were at chance with the attributive. Once again, however, the question of the role of cardinality arises. It is possible that upon hearing the number word and the MP head, children were drawn to the set of two cups. In the ‘pseudopartitive’ condition, where this choice was the correct one, children retained this selection upon hearing the plural marking (and perhaps of). However, children in the ‘attributive’ condition may have found it difficult to overcome this initial selection and turn their attention to the 2-cup cards afterwards. Their chance-level performance may then have been a reflection of an inability to completely overcome an error based on incremental processing of the instructions, rather than a lack of understanding of the attributive MP.

The combined set of results from these two experiments thus leads us to ask to what extent four-year-olds can correctly interpret attributive (and pseudopartitive) MPs, and how they will perform when the number in the MP does not make reference to the cardinality of a set. The two experiments presented below were designed to answer these questions. In the first
experiment, we follow up on previous experimental results to further probe children’s knowledge of attributive MPs by avoiding a forced-choice scenario that pits the cardinality of the MP head against cardinality of the second noun, and by manipulating the count-mass status of the target items. In the second experiment, we investigate what children (and adults) know about how attributive and pseudopartitive MPs differ in their ability to track the part-whole relation (i.e., monotonicity). This difference has – to our knowledge – gone uninvestigated until now.

4. Experiment 1: Truth Value Judgment Task

4.1. Participants

16 children (8 boys, 8 girls) between the age of 3;6 and 5;3 (mean: 4;3) participated. Only one child was above five years of age, and three between age 3;6 and 4. There was no correlation between age and responses. Data from one additional child was excluded, due to a ‘yes’ bias across test and filler items. Children were randomly assigned to one of two experimental orders, balancing for age and gender. Children in both experiments were recruited from area preschools and tested in a quiet room on the premises. All children were normally developing, native speakers of American English.

4.2. Materials and Procedure

The procedure was a Truth Value Judgment Task (TVJT) (Crain & McKee, 1985). One experimenter told the child a series of stories, using supporting images presented on Powerpoint slides, while a second experimenter played the role of a rabbit puppet, who watched the stories alongside the child. At the end of each story, the puppet said what she thought happened in the story, and the child’s job was to say whether she was right or wrong. When the puppet was right, she got to nibble a cookie; when she was wrong, she gulped some milk. Children were occasionally invited to supply justifications for acceptances or rejections, given the premise that
the puppet was learning, and justifications for both types of answers were helpful. Children happily played along.

In an example scenario, Dora is at a farmer’s market purchasing strawberries. One farmer is selling huge strawberries (each one weighing 3 pounds), but doesn’t have many of them. Another farmer is selling small strawberries and has a lot of them (all together, weighing 3 pounds). Dora needs to decide which strawberries to buy. She thinks about it, and eventually chooses the large quantity of small strawberries. After the story, the puppet explains that Dora was deciding which strawberries to buy, and that she bought the 3-pound strawberries. The puppet’s utterance for test items always stood in contradiction with the choice favored in the experimental scenario. Thus, the puppet always used the attributive (e.g., 3-pound strawberries), but the character in the story never made the choice corresponding to this description (e.g., she bought the 3 pounds of strawberries instead). (Because a purchase of the 3-pound strawberries would entail that Dora had also purchased 3 pounds of strawberries, we avoided this potential confound by only running a condition in which the character purchased the set corresponding to the pseudopartitive, and the puppet delivered an utterance with the attributive.)

There were two ‘count’ items (3-pound strawberries/3 pounds of strawberries, 2-ton bricks/2 tons of bricks) and two ‘mass’ items (4-foot ribbon/4 feet of ribbon, 3-foot rope/3 feet of rope). For example, a character entered a craft store in search of some ribbon for an art project and chose the spool with a lot of very narrow ribbon (4 feet of ribbon) rather than the spool with a little bit of very wide (4-foot) ribbon. In this experiment and the next, the mass items (ribbon, rope) remained wrapped or coiled, and the experimenter verbally and visually highlighted the difference in width. There were two orders: one in which the two count items appeared before the two mass items (‘count, mass’), and another in which this order was reversed (‘mass, count’).
We predicted that if children recognized that an attributive (the MP used by the puppet) describes a property of the individual, they would reject the puppet’s statement, since the character in the scenario had chosen the object(s) that did not reflect this interpretation (i.e., not the large, 3-pound strawberries or the wide, 4-foot ribbon). In both orders, test items were pseudorandomized with four filler items involving a similar forced-choice discourse context, which were designed to elicit both ‘yes’ and ‘no’ responses within the session. The fillers involved descriptors similar to the attributive MPs (e.g., red/green cars, polka dot/ladybug boots) or of constructions similar to the pseudopartitive (e.g., plate of sandwiches/vegetables, glass of pink/yellow lemonade). Performance with the filler items was at or near ceiling for all children.

4.3. Results
Recall that the correct response is rejection of the puppet’s utterance. Responses to the test items were therefore coded as percentage of ‘no’ responses, and are presented in Table 1. In presenting the results, we distinguished between the two experimental orders (‘count, mass’ and ‘mass, count’). We also noticed that there were four children (two in each order) who accepted the puppet’s response for all test items, but who did not display a ‘yes’ bias for the experimental session, since they correctly rejected filler items. These children did not, however, provide justifications for their ‘yes’ answers that would be additionally informative about their response pattern. We therefore included their data in the analysis, but we also present the data without their responses (in parentheses). Note that no child ever commented on the oddness of strawberries weighing 3 pounds or of bricks weighing 2 tons.

The total number of ‘no’ answers across all test items approaches significance from chance for the ‘count, mass’ order (binomial probability, \( p = .13 \)) and is significant with the two ‘yes’ children excluded (\( p = .02 \)). It is not, however, significant in the ‘mass, count’ order across
all test items, both with and without the two ‘yes’ children (p=.34, p=.84). When we look at the ‘count’ items and the ‘mass’ items within each of the two orders, we see that for children in the ‘count, mass’ order, there is not a significant difference between these two item types (McNemar’s, p=.1, two-tailed), but the difference is marginally significant for the ‘mass, count’ children (McNemar’s, p=.06, two-tailed). As a consequence, the difference between the ‘count, mass’ and ‘mass, count’ orders is not significant for the ‘count’ items (Mann-Whitney, U_A = 33.5, p = .44), but it approaches significance for the ‘mass’ items (Mann-Whitney, U_A = 46.5, p = .06) and is significant with the four ‘yes’ children excluded (Mann-Whitney, U_A = 6.5, p = .04). Thus, children in the ‘count, mass’ order were more likely to say ‘no’ overall, and children in the ‘mass, count’ order were more likely to say ‘no’ for the count items.

Table 1: results of Experiment 1: mean percentage of ‘no’ responses (the correct answer) for all children and all items, and for the two orders of children and the two types of items

<table>
<thead>
<tr>
<th></th>
<th>‘count’ items only</th>
<th>‘mass’ items only</th>
<th>all items</th>
</tr>
</thead>
<tbody>
<tr>
<td>all children (excluding four ‘yes’)</td>
<td>59.1 (79.3)</td>
<td>44.0 (57.9)</td>
<td>51.6 (68.6)</td>
</tr>
<tr>
<td>‘count, mass’ order (excluding two)</td>
<td>61.1 (78.6)</td>
<td>66.7 (85.7)</td>
<td>63.9 (82.1)</td>
</tr>
<tr>
<td>‘mass, count’ order (excluding two)</td>
<td>57.1 (80.0)</td>
<td>21.4 (30.0)</td>
<td>39.3 (55.0)</td>
</tr>
</tbody>
</table>

Upon encountering such results, we wondered why children in the ‘mass, count’ order would exhibit such a low rate of rejection for (i.e., accept) the ‘mass’ items (the items they encountered first). Here, we think cardinality plays an important role in that the children in the opposite order were somehow aided by the initial count items to home in on the relevant dimension and property of the individual highlighted in the stories – a task made easier when applying the property to each individual in a set. However, also note that when we consider the attributive MP as applied to the mass items, the children’s acceptances for the mass items do not
appear to be entirely unreasonable. Although we specifically highlighted a difference in width between the two objects, it is in theory possible for the attributive MP to refer to either the length or the width of the object. That is, *4-foot ribbon* could be ribbon that is four feet wide or four feet long. While we cannot be sure that children were tapping into this interpretation when responding, the possibility remains that this interpretation was somehow available to them, leading them to accept the puppet’s utterance. This makes children’s rejection of the ‘count’ items that much more striking: they seemed to know that these MP referred to a property of the individual members of the set, and not the quantity as a whole.

4.4. Discussion

With the exception of children’s responses to the ‘mass’ items in the ‘mass, count’ condition, children were generally inclined to reject the puppet’s utterance. The experimental results therefore demonstrate that preschoolers are able to interpret attributive MPs as referring to a property of the individuals and not a property of the entire group. They are therefore aware that this expression measures out something like weight per unit, and not weight of the overall quantity, and that the number word in the MP does not necessarily pick out the cardinality of a set. An open question is whether this difference carries over to scenarios probing monotonicity on the part-whole relation, and to what extent cardinality could play a role in this aspect of their interpretation. We explore these questions in Experiment 2.

5. Experiment 2: Subtraction Vignettes

5.1. Participants

20 children (8 boys, 12 girls) between the age of 4;0 and 4;11 (mean: 4;7) participated. This time, we also included 24 adults controls for two purposes: first, to verify the difference in monotonicity between the two MPs, and second, to provide an adult baseline for the potentially
more challenging mathematical computation allowed in this task. Participants were randomly assigned to one of two between-subject experimental conditions, and within these two conditions to one of two experimental orders, depending on the kind of test items (as before).

5.2. Materials and Procedure

Participants were presented with seven short vignettes (four test and three filler items) involving subtraction of a quantity. Images capturing key components of the plot accompanied each vignette and were presented on slides on the computer screen. The stories were recounted aloud by the experimenter to child participants. Adults read the stories from text on the slides.

In each vignette, the participant was shown an amount of some object on the screen, which was described with either an attributive (e.g., 3-pound strawberries, 4-inch ribbon) or a pseudopartitive MP (e.g., 3 pounds of strawberries, 4 feet of ribbon), depending on the condition. In the ‘attributive’ condition, it was pointed out that each member of the set in the count condition or the relevant mass item had the property expressed by the MP. (In the ‘mass’ condition, the participant’s attention was directed toward the relevant dimension referred to by the MP.) In the ‘pseudopartitive’ condition, it was pointed out that the entire quantity had the property expressed by the MP. Two of the vignettes involved a set of discrete ‘count’ items (strawberries, bricks), while two involved a ‘mass’ item (ribbon, rope). We note that no child appeared to have any difficulty with the irregular plural (feet) in the pseudopartitive condition, and some produced this form correctly in their justifications. The filler items were of the same structure and involved the highly frequent prenominal adjectives red, delicious, and dirty and were balanced to ensure both “yes” and “no” responses during the test session.

In each scenario, a quantity was removed, leaving some of the objects or mass item remaining on the screen. (When the quantity was removed, it was clear that it had either been
taken away completely, because it had been eaten – for example, in the case of the strawberries – or used for some other purpose and was no longer available to the person who originally had it – for example, in the case of the ribbon. Whenever children indicated that they thought the object was still available, because it was still visible on screen, the experimenter clarified to say that it was with the person who took it and no longer available to her. Children went along with this.

Following each vignette, the participant was asked about the difference of the subtraction operation (i.e., what remained after the subtraction was performed), as in (3).

(3) Do I still have…

a. 3-pound strawberries/4-inch ribbon? ‘attributive’ condition
b. 3 pounds of strawberries/4 feet of ribbon? ‘pseudopartitive’ condition

The correct response in the ‘attributive’ condition is ‘yes’, since some quantity with the original property remains – that is, there are still individuals with the property associated with the attributive MP. The correct response in the ‘pseudopartitive’ condition is ‘no’, since the total amount is decreased, and the MP is monotonic on the part-whole relation. Given previous findings that preschoolers are successful with similar subtraction problems involving cardinality (see Baroody, et al., 2009; Hughes, 1981; Starkey & Gelman, 1982; Zur & Gelman, 2004), we predicted that the only variability in children’s responses would arise from participants’ interpretation of measurement expressions, and their ability to deploy this knowledge in the experimental task (not their inability to interpret the question linked to the subtraction operation).

5.3. Results

Child and adult responses to the test items are presented in Table 2. This time, the dependent measure is the percentage of ‘yes’ answers, since this is predicted to differ categorically based on the MP in the target question: participants should be inclined to respond ‘yes’ in the ‘attributive’
condition and ‘no’ in the ‘pseudopartitive’ condition.

Table 2: results of Experiment 2: mean percentage of ‘yes’ answers

<table>
<thead>
<tr>
<th></th>
<th>‘attributive’ condition</th>
<th>‘pseudopartitive’ condition</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>‘count’</td>
<td>‘mass’</td>
</tr>
<tr>
<td></td>
<td>items</td>
<td>items</td>
</tr>
<tr>
<td>adults</td>
<td>100</td>
<td>91.7</td>
</tr>
<tr>
<td>children</td>
<td></td>
<td></td>
</tr>
<tr>
<td>‘count, mass’ order</td>
<td>50.0</td>
<td>80.0</td>
</tr>
<tr>
<td>‘mass, count’ order</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(a) N=3 in each condition</td>
<td>16.7</td>
<td>0</td>
</tr>
<tr>
<td>(b) N=2 in each condition</td>
<td>100</td>
<td>100</td>
</tr>
</tbody>
</table>

We turn first to the responses from the adults (presented in the topmost row). In these results, we see a clear difference between the ‘attributive’ and ‘pseudopartitive’ conditions, with adults responding affirmatively in the ‘attributive’ condition, but negatively in the ‘pseudopartitive’ condition (Mann-Whitney, $U_A = 0$, $p < .0001$). Such results not only provide us with a baseline, but also support theoretical claims about a difference between the two MPs concerning whether or not they are monotonic on the part-whole relation.

The overall difference between the ‘attributive’ and ‘pseudopartitive’ conditions for the children approaches overall significance (Mann-Whitney, $U_A = 30$, $p = .07$). However, as in Experiment 1, we noted a contrast in responses between the ‘count, mass’ and ‘mass, count’ orders. Like the adults, children in the ‘count, mass’ were more likely to say ‘yes’ in the ‘attributive’ condition, and ‘no’ in the ‘pseudopartitive’ condition (Mann-Whitney, $U_A = 2.5$, $p = .02$). Some children in the ‘mass, count’ order, however, consistently said ‘yes’ and others who
consistently said ‘no’. Recall that what counts as adult-like performance for each of the conditions varies, so that the ‘yes’ children patterned more like their counterparts in the ‘attributive’ condition, whereas the ‘no’ children patterned more like their counterparts in the ‘pseudopartitive’ condition. In light of the lack of uniformity within this order and the different interpretation across conditions, it is therefore not necessarily the case that the ‘mass, count’ order induced a particular response pattern. Regardless of the reason for this pattern, we thought that averaging over these responses for this order would have been misleading, and so presented results for these two subgroups separately.

Given the variability among children’s responses, we looked to their justifications to complement their overall response patterns and shed light on their behavior in this task. Upon further examination, it appeared to be the case that while children often interpreted the MP correctly and responded in a way that reflected this knowledge as in (4), they were also influenced by a tendency to treat the number word as an indicator of cardinality and seemed to interpret the question as asking about the total number of objects left over, as in (5).

(4)  *Do I still have 3-pound strawberries?*

a.  [child nodded head yes] Because they’re the kind … Because they’re 3-pound strawberries.  
    (age 4;8)

b.  [child nodded head yes] There’s two more left. (Experimenter asks, “How much do you think each weighs?”) Three pounds.  
    (age 4;10)

*Do I still have 3-foot rope?*

c.  Yes, because he only took some to make his swing.  
    (age 4;10)

Experimenter: What do I have left?

Child: Some 3-foot rope.
(5) Do I still have 3-pound strawberries?

a. No. Those are just two. (age 4;1)

b. Do I still have 3-pound strawberries?

No, just two. [child held up two fingers.] … Two strawberries (age 4;5)

Note, however, that even with this tension between the interpretation of the MP and the default interpretation of number words more generally, we are left with a clear difference between the ‘attributive’ and ‘pseudopartitive’ conditions, which approached overall significance and was significant for the count items. This difference between the conditions that emerged must be due to children’s recognition that the two MPs measure out quantities differently—a difference encoded in the syntax-semantics mapping. Thus, in this group of preschoolers, we are witnessing a point in development in which they are sorting out the correct interpretation of number words, given the linguistic environment in which they appear and the discourse context in which they are used.

5.4. Discussion

In this experiment, as predicted by the semantics, adults correctly distinguished between attributive MPs, which measure out a property of individuals (e.g., weight per unit), and pseudopartitive MPs, which measure out a property of an entire quantity (e.g., overall weight). This distinction was evidenced in their response patterns, as they responded ‘yes’ to subtraction vignettes and questions with an attributive MP and ‘no’ to those with a pseudopartitive MP. Children, too, appeared to be sensitive to this distinction, as the difference in response patterns between the two conditions indicated.

At the same time, however, their success rate appeared to have been diminished by a proclivity to interpret the number word as a marker of the cardinality of the set of objects on the
screen. This explains both the drop in ‘yes’ responses by children in the ‘count, mass’ order of the ‘attributive’ condition to the ‘count’ items, as well as the categorically ‘no’ responses from some children in the ‘mass, count’ order of this condition. It also explains an occasional non-adult-like justification for an otherwise correct ‘no’ response in the ‘pseudopartitive’ condition. Thus, while the overall pattern supports children’s knowledge that the attributive and pseudopartitive MPs have a different semantics, it is incumbent upon us to explain why children were led astray.

Given the prevalence of the counting routine in child-directed speech, which places emphasis on a link between numbers and set size, and children’s ‘exact’, cardinality-based interpretation of number words across experimental tasks (cf. Fuson, 1988; Gelman & Meck, 1993; Hurewitz et al., 2006; Papafragou & Musolino, 2003, a.o. for discussion), it is perhaps not so surprising that similar behavior would manifest itself in this task. Moreover, it is by now well attested that preschoolers are aware that when a subset of items is removed from a larger set, a number word that was applied to the original set (e.g., six) no longer applies to the new, smaller set (cf. Condry & Spelke, 2008; Lipton & Spelke, 2006; Sarnecka & Gelman, 2004). These results have been used to argue that children in these tasks are aware that such numbers refer to an exact numerosity. It is therefore possible that children in the current experiment recruited what they know about the cardinality meaning of number words and their application of these words to a set of objects, and were drawn to focus on set size when rendering their response. That is, they expected that the mathematical operation performed on the set of objects would result in a new number word being applied to the set, overlooking the linguistic environment in which that number word had appeared. Note that if this were the only strategy at work, however, we would have seen ‘no’ responses across the board. Given that we did not, we must conclude
that children’s responses reflected a difference between the semantic representation of the MPs.

6. Conclusions

The goal of this brief article was twofold. First, we aimed to investigate young children’s interpretation of measurement expressions – specifically their interpretation of attributive MPs, which force them to move beyond a cardinality-driven interpretation of number words. Second, we sought to follow up on previous research suggesting that four-year-olds may be unduly influenced by the cardinality component of number word meaning when interpreting these expressions. Accordingly, we sought to minimize the role of set size in the interpretation of the target numerical expressions by using units of measurement that mapped onto continuous dimensions, while manipulating the count/mass status of the post-MP noun.

In the first experiment, we showed that children trend toward an adult-like interpretation of expressions such as 3-pound strawberries, recognizing that they refer to a property of individuals, and not an entire collection. In the second experiment, children also demonstrated knowledge that attributive and pseudopartitive MPs measure out quantities differently, but also appeared to be drawn towards interpreting the number word in the MP as an indicator of cardinality when possible, ostensibly reinterpreting the MP as a simple numeral and occasionally allowing the cardinality of the set of objects remaining on the screen to seep back into the MP expression itself. It thus appears that four-year-olds are on the cusp of fully interpreting these expressions correctly, but are torn between the different senses of number word meaning that are called upon in different linguistic environments, given the context.

Of course, given the extent to which number words appear in count routines, arithmetic operations, and labels for set size, the finding that children are inclined to rely on the cardinality aspect of number word meaning in the interpretation of phrases containing them may not be
entirely unexpected. But another way to interpret these results is to say that in light of the fact that the scales are tipped heavily in cardinality’s favor, it is impressive to discover that at four years of age, many children recognize that an MP can be used to pick out the kind of object based on an individual property of that object such as how much the object weighs or how wide it is. The challenge for future research is to determine the conditions under which children’s performance with measurement expressions can be improved (perhaps where visibly accessible objects cannot be counted), and what children at this age know about the semantic aspects of number word meaning above and beyond cardinality.

References


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Example of ‘count’ vignette

This summer I wanted to make a dessert with some juicy strawberries. So I went to the farmer’s market, where they have nice, fresh fruit.

(A)

Attributive version

Some of the strawberries were enormous. They each weighed 3 pounds! Since I love strawberries, I couldn’t resist, so I bought some. Do you see these? These are my 3-pound strawberries. They each weigh 3 pounds.

Pseudopartitive version

Since I love strawberries, I couldn’t resist, so I bought 3 pounds of strawberries. Look, that’s 3 pounds of strawberries – all of that together is 3 pounds of strawberries.

(B)

Now what if a little mouse comes along and nibbles up some of my strawberries, but I still have these [point to 2 on bottom of screen] left?

Do I still have 3-pound strawberries/3 pounds of strawberries?
Example of ‘mass’ vignette

Last week, I went to the craft store, because I wanted to get some materials for an art project. While I was there, I noticed they had some beautiful ribbon. In fact, they had some green ribbon that I thought it would be perfect for an art project.

(A)

**Attributive version**

Do you see? This ribbon is 4 inches wide. That’s 4-inch ribbon.

(B)

**Pseudopartitive version**

They didn’t have very much left, but I got all they had and that was 4 feet of ribbon. Do you see all of that ribbon? That’s 4 feet of ribbon.

(B)

Now, what if a little girl comes along and she takes some of my ribbon to make a bow for her dress, but I still have this [point to spool of green ribbon] left?

*Do I still have 4-inch ribbon/4 feet of ribbon?*