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Journal

Proceedings of the Annual Meeting of the Cognitive Science Society, 26(26)

ISSN

1069-7977

Authors

Barner, David
Snedeker, Jesse

Publication Date

2004

Peer reviewed

Mapping individuation to mass-count syntax in language acquisition

David Barner (barner@fas.harvard.edu)

Department of Psychology, William James Hall, 33 Kirkland Street
Cambridge, MA 02138 USA

Jesse Snedeker (snedeker@wjh.harvard.edu)

Department of Psychology, William James Hall, 33 Kirkland Street
Cambridge, MA 02138 USA

Abstract

Various theories propose that count nouns are distinguished from mass nouns by their specification of individuation. We present evidence that, while 3-year-old children acquiring language extend words differentially on the basis of mass-count syntax, they quantify over individuals for both novel mass and count nouns. We suggest that children may begin acquisition with an underspecified representation of mass noun semantics, permitting quantification over both individuals and continuous quantities. Also, children may rely on ontologically based biases to guide quantification.

Introduction

In English, the specification of number sends a ripple through the language, determining a word's status as mass or count, licensing the use of plural morphology, and selecting among measure terms such as *many* and *much*. Children begin to show signs of such knowledge early in language acquisition, with plural production and comprehension emerging as early as 2 years of age (Brown, 1973; Cazden, 1968; Ferenz & Prasada, 2002; Gordon, 1988), sensitivity to the mass-count distinction evidenced by around 2;6 years (see Soja, 1992), and the use of measure terms like *more* and *less* emerging between 2;6 and 3 years of age (Donaldson & Balfour, 1968; Gathercole, 1985; Palermo, 1973).

The mass-count distinction provides a particularly interesting case of number specification, because it entrains important consequences for both the syntax and semantics of noun phrases. For example, count terms like *cat* can take the plural morpheme (e.g., *cats*) follow cardinal numbers (e.g., *one cat*, *two cats*, *three cats*), and be modified by quantifiers like *these*, *those*, *few* and *many* (e.g., *many cats*). Mass terms, on the other hand, can occur in none of these environments and can be distinguished by their use with terms like *much* and *little* (e.g., *I don't eat much porridge*). According to most accounts, this distributional difference corresponds to a semantic distinction whereby count nouns quantify over individuals and mass nouns quantify over non-individuals (e.g., Bloom, 1994, 1999; Gordon, 1985; Link, 1998; Quine, 1960; Wisniewski, Casey, & Imai, 1996). For example, Bloom proposed that children might begin acquisition with bidirectional mappings between

syntax and semantics, as in (1), resulting in a categorical effect of number specification in noun phrases:

- (1) a. count noun ↔ individual
b. mass noun ↔ non-individual

However, such mappings may not provide the full story of what children know about the mass-count distinction. As noted by Barner and Snedeker (2004), mass syntax may not have a strong interpretation like count syntax, but may be semantically unspecified and allow reference to either individuals or non-individuals. In their study, Barner and Snedeker observed that 4-year-old children and adults interpreted many mass and count nouns in the way predicted by the mappings in (1). For example, participants judged three tiny shoes to be *more shoes* than one giant shoe and one giant portion of butter to be *more butter* than three tiny portions. However, they also based judgments on number for “object-mass” terms like *furniture*, *jewelry*, *mail*, and *clothing*, which children begin to produce by around 4 years of age. In each case, participants judged six tiny objects to be more than two giant ones. Thus, count syntax led to quantification on the basis of number, while mass syntax quantified over both continuous quantities and certain individual objects.¹ As a result, it was concluded that object-mass terms like *furniture* must allow quantification over individuals due to a lexical specification of number, which is normally found in count syntax. Expressions that house this feature quantify over individuals, while those that do not assume a default interpretation of quantifying over a continuous extent (see Borer, 2004, for a similar proposal). This view is schematized in (2):

- (2) a. count syntax → individual
b. mass syntax ↔ no number specification

If the dimension of measurement of mass terms is specified in part by lexical semantics as these results suggest, children may need some amount of experience with

¹ But not all objects. Terms that can be used as either mass or count (e.g., *string/s*, *chocolate/s*, *paper/s*, *stone/s*) quantified by number as count nouns and by continuous extent as mass nouns.

particular mass terms before using them to specify a measuring dimension. This raises the question of what mass syntax contributes to the early interpretation of noun phrases, and whether children's interpretation of mass nouns differs from that of adults at any stage of development. For example, before acquiring exceptions like *mail* and *furniture*, do children respect mappings as in (1), or is mass syntax semantically unspecified throughout development?

Two sources of evidence regarding this question suggest conflicting conclusions. First, studies of word extension indicate that children are biased to map novel count terms to physical objects and mass terms to non-solid substances. In a study by Soja (1992), English children aged 2;6 extended novel words on the basis of shape for solid objects 90% of the time when presented with count syntax, but only 76% of the time with mass syntax. For non-solid substances, children extended novel words on the basis of substance 91% of the time when presented with mass syntax, and 51% of the time when given count syntax (see also Soja, Carey, & Spelke, 1991, and Imai & Gentner, 1997). Thus, children in her study shifted their extension of novel terms according to their use in mass or count syntax.

However, results from Gathercole (1985) suggest that young children may not distinguish the referential consequences of mass and count syntax. In her study, Gathercole found that children aged between 2;6 and 5;6 quantified mostly by number for both count nouns and mass nouns. In fact, even children as old as 5;6 failed to reliably quantify by continuous extent for mass nouns, unlike the 4-year-olds in Barner and Snedeker (2004), who quantified by continuous extent for both solid and non-solid stimuli named with mass syntax (e.g., *some string*; *some mustard*). These differences are difficult to interpret, since only Gathercole tested both mass and count terms within subjects, and because stimuli used in the studies were common household objects and may have varied in familiarity and lexico-semantic properties.

In any case, the results from Gathercole's study are difficult to reconcile with those from Soja's study of word extension, and thus it remains unclear how children represent the semantics of the mass-count distinction early in acquisition. Also unclear is how the different types of knowledge used in each task are related in young children's linguistic representations. While for adults it seems necessary that word extension should predict quantification (e.g., only words that refer to discrete things quantify over individuals) such links between content and quantification may not yet be established in the minds of 2 or 3-year-olds.

No previous study has explicitly tested the quantification of mass-count syntax for novel terms (i.e. where prior lexical knowledge does not play a role). As a result, previous studies have also not examined the relationship between quantification judgments and word extension for the same objects and substances. However, both of these measures are needed in order to properly assess children's early interpretation of mass-count syntax, before lexical

exceptions such as object-mass terms (e.g., *mail*, *silverware*) arise. For this reason, the present study assessed children's and adult's interpretation of novel mass and count terms in both word extension and quantity judgment paradigms.

Also, it remains an open question how object-mass terms come to quantify over individuals, and what the precise nature of lexical information is that distinguishes mass nouns like *mail* from mass nouns like *string*. Various researchers have suggested that factors such as complexity of structure, occurrence of multiple individuals in spatio-temporal contiguity (Wisniewski, Casey, & Imai, 1997), and shared function (Prasada, 1999) might characterize object-mass terms. The present study examined this question via the manipulation of stimulus complexity and solidity in each of the testing paradigms.

Experiment 1

The first experiment examined three main questions. First, does mass syntax have a strong interpretation early in acquisition, as measured by both word extension and quantity judgment? To examine this question, participants were tested with both methods for the same novel objects, with either mass or count syntax. Second, using this method we explored how the word extension and quantity judgment tasks are related, and whether they make use of the same underlying logical resources. Third and finally, we explored whether an object's relative complexity predicts quantification over individuals when used in mass syntax. What lexical properties, if any, might characterize object-mass nouns like *mail* and *furniture*? This question was tested by varying the shapes and substances of novel referents in the word extension and quantity judgment tasks, to include simple and complex solid objects.

Method

Subjects

Participants were 24 Harvard undergraduates and 32 children ranging in age from 3;0 to 3;6 (mean = 3;3).

Procedures and Stimuli

Each testing session comprised four trials. In each trial the participant was introduced to a novel object and heard the object named with a novel term at least four times using either unambiguous mass syntax or unambiguous count syntax on all four trials. Half of the participants were shown four simple objects and half were shown four complex objects, all of which we will call "standard" objects. The four simple standard objects were: (1) a half egg shape made of red sculpy; (2) a kidney bean shape made from painted-green das; (3) a cork shape made from black Crayola-Magic; (4) an arrow shape made from terracotta. The four complex standard objects were: (1) a gear made from orange playdo; (2) a brass t-shaped plumbing fixture; (3) a suede texture-painted reamer; (4) a clay milk pump stand. The names for these objects, always presented with either mass or count syntax (between subjects), were *fem*, *tannin*, *dak*, and *tulver*. Thus, for each trial, the

experimenter introduced the novel object by saying, for example “Oh look, this is some/a fem. Have you ever seen any fem(s) before? Do you think you have some fem(s) at home? That is some/a nice fem isn’t it”.


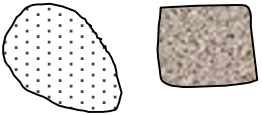

	Stimulus	Instructions
Training		Look, this is some fem! or, Look, this is a fem
Word Extension Task		Can you point at the fem?
Quantity Judgment Task		Who has more fem? or, Who has more fems?

Figure 1. An example of a training trial, word extension trial and quantity judgment trial (shaded oval represents a red sculpy half-egg, white oval represents a styrofoam shape alternative, and shaded square represents a red sculpy substance alternative; small ovals represent mini half-eggs).

Following the naming of each object, participants were asked two questions, the order of which was varied systematically (see Figure 1). First, in the word extension task (see Soja, Carey, & Spelke, 1991), participants were shown two additional objects, one which matched the standard in shape, the other in substance, and were asked to choose which of the two the novel word named: “Show me some/a fem”. Second, in the quantity judgment task (see Barner & Snedeker, 2004), participants were shown two characters (Farmer Brown and Captain Blue), one who was shown with the standard object and the other who was shown with three miniature versions of the object. The standard objects had a greater overall mass and volume than the three miniature objects, but were otherwise identical in shape and substance. The side on which the standard or miniatures were shown was varied systematically. Participants were told, “Farmer Brown has some/a fem(s) and Captain Blue has some/a fem(s) too. Who do you think has more fem(s)?” For both tasks, participants pointed to indicate their response. Procedures were identical for adults and children.

Results and Discussion

Word extension trials

Responses for the word extension task were coded in terms of how many times (out of four) each participant extended a word on the basis of shape.

For adults, two main results were obtained (see Figure 2). First, adults used mass-count syntax to guide word extension, extending count terms by shape 3.5 times on average (87.5% overall), compared to only 1.08 times on average (27% overall) for mass syntax, $F(1, 16) = 31.1, p <$

.001. Second, adults also showed a main effect of stimulus type, extending novel words for complex objects 2.83 times on average (71.8%), compared to 1.75 times on average (43.8% overall) for simple objects, $F(1, 16) = 6.3, p < .05$. There were no interactions.

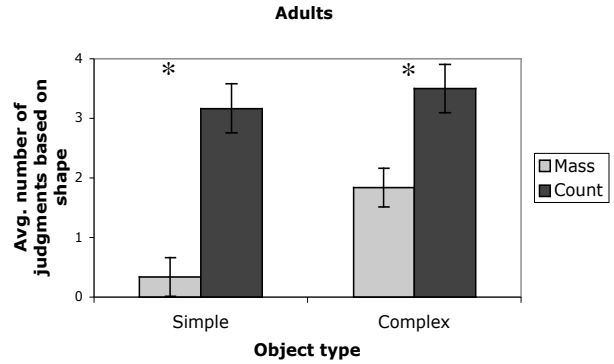


Figure 2. Word extension by adults for novel mass and count nouns.

These results indicate that adults use syntax to guide word extension, but that extension is also influenced to a large extent by the relative complexity of stimuli. Thus, mass-count syntax does not appear to be the sole factor determining word extension behavior for adults. More general properties of referents appear to play a role.

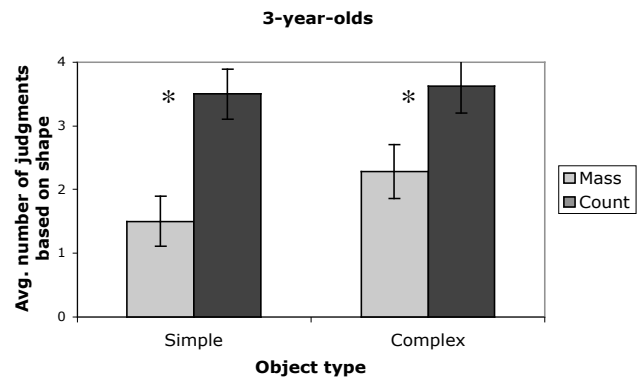


Figure 3. Word extension by 3-year-old children for novel mass and count nouns.

The children also used mass-count syntax to guide word extension (see Figure 3). They extended novel count terms by shape 3.56 times on average (89% overall), compared to 2 times on average (50% overall) for novel mass nouns, $F(1, 24) = 16.9, p < .001$. However, children showed no main effect of stimulus type, and no significant interactions.

Quantity judgment trials

Responses for the quantity judgment task were coded in terms of how many times (out of four) each participant chose the array with the greater number of objects. For adults, two main results were obtained (see Figure 4). First, as was the case with word extension, adults used mass-count

syntax to guide quantity judgment, using count terms to quantify by number 3.75 times on average (93.8% overall), compared to .67 times on average (16.8%) for mass nouns, $F(1, 16) = 85.6, p < .001$. Second, adults quantified by number 2.67 times on average (66.8% overall) for complex items, which was significantly more than the 1.75 times on average (43.8%) for simple items, $F(1, 16) = 7.6, p < .05$. This difference appeared to be due in part to adult's interpretation of mass syntax. While adults quantified by number for some mass nouns that named complex objects, they never did so for mass nouns that named simple objects. This is interesting, since it suggests that for adults object complexity may be sufficient to permit individuation using mass syntax (i.e. the use of object-mass terms).

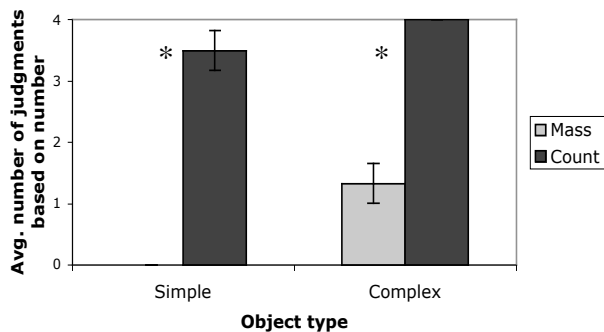


Figure 4. Quantity judgment by adults for novel mass and count nouns.

In contrast to adults, children quantified mostly by number for both simple and complex objects, for both mass and count syntax (see Figure 5). As a result, children showed no significant effect of syntax, $F(1, 24) = 2.2, p > .1$, nor of stimulus type, $F(1, 24) = .09, p > .8$.

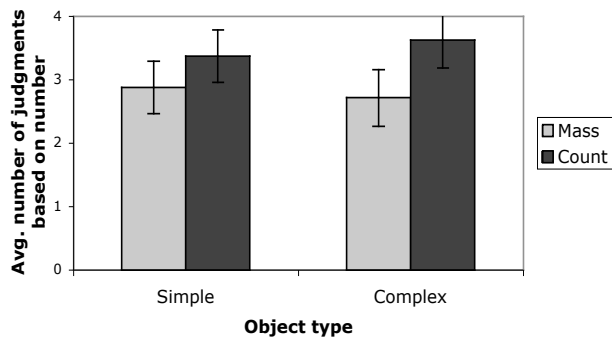


Figure 5. Quantity judgment by 3-year-old children for novel mass and count nouns.

The results of Experiment 1 indicate that while both children and adults used mass-count syntax to guide word extension, only adults appeared to use this information to guide quantity judgment. This suggests that word extension and quantity judgment may tap discrete logical resources. Among the possible explanations for this are: (1) an

incomplete understanding of mass-count syntax, (2) a problem interpreting the term “more”, or (3) a bias to quantify by number for discrete physical objects. These possibilities are examined in Experiment 2.

Experiment 2

The results of Experiment 1 are consistent with the idea that the interpretation of mass syntax is unspecified from early in acquisition, and allows quantification over individuals or non-individuals. However, the results are also consistent with several other possibilities, including a response bias to quantify by number regardless of syntax, or an interpretation of “more” as quantifying only by number. To rule out these possibilities, we tested participants with non-solid substances. If responses in Experiment 1 were due to either a response bias or a strong interpretation of “more”, then responding on the basis of number should persist for both mass and count nouns. However, a change in children’s quantification for only mass syntax would represent evidence that children modulate judgments based on mass-count information, but allow quantification over individuals when referents are construed as such. This, in turn, would support the claim that mass syntax, but not count syntax, has an unspecified interpretation regarding individuation.

Method

Subjects

Participants were 16 Harvard undergraduates and 23 children ranging in age from 3;0 to 3;6 (mean = 3;3).

Procedures and Stimuli

Procedures for Experiment 2 were identical to those used in Experiment 1. However, solid stimuli were replaced with non-solid substances. The standard substances were: red media mixer, green butter, orange paint, and brown hair gel.

Results and Discussion

Results suggest that only the adults used mass-count syntax to guide word extension (see Figure 6). Adults extended count nouns by shape 2.57 times on average (64% overall) and mass nouns 0.5 times on average (13% overall), a difference that was marginally significant, $F(1, 12) = 4.8, p < .06$. Children extended count nouns by shape 1.82 times on average (46% overall) and mass nouns 1.42 times on average (36% overall), which was not significant.

However, both the 3-year-olds and adults appeared to use mass-count syntax to guide quantity judgment (see Figure 7). Adults based judgments on number 3.83 times on average for count syntax (96% overall) and 0.5 times on average for mass syntax (13% overall). This difference was significant, $F(1, 12) = 40, p < .001$. Children based judgments on number 1.82 times on average for count syntax (46% overall) and 0.5 times on average for mass syntax (13% overall), a difference that was marginally significant, $F(1, 23) = 4.1, p < .06$. There was also a large effect of task order, $F(1, 23) = 11.7, p < .05$, that reflected a much greater distinction of mass-count syntax when

quantity judgment was tested after word extension. Children who were given the tasks in this order quantified by number 2.67 times on average for count syntax (compared to .8 times in the alternative order) and 0 times on average for mass syntax (compared to 1 time on average in the alternative order).

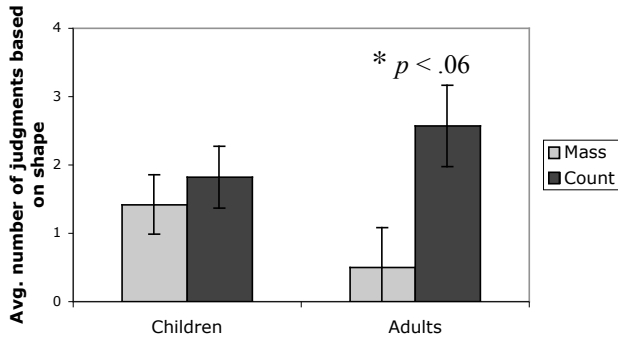


Figure 6. Word extension by 3-year-olds and adults for mass and count nouns that label non-solid substances.

A review of the word extension data revealed a similar trend, where performance on word extension more closely resembled adult performance when it followed quantity judgment, suggesting an overall effect of accumulated input on mass-count sensitivity over the course of the experiment.

Overall, results suggest that children have more than one interpretation for the word “more”, but that its meaning is shifted primarily by the ontological category of referents, rather than mass-count syntax.

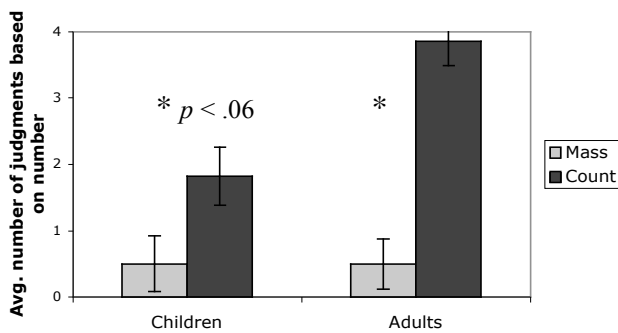


Figure 7. Quantity judgment by 3-year-olds and adults for mass and count nouns that label non-solid substances.

General Discussion

Experiment 1 revealed two main results. First, for the word extension task, both children and adults used mass-count syntax to guide their judgments, extending count terms on the basis of shape and mass terms on the basis of substance. This replicates results found for English-speaking 2.5 year olds (see Soja, 1992). Second, for solid objects, adults used mass-count syntax to guide quantity judgment and used mass nouns to quantify over individuals only for complex objects. Children, however, interpreted both novel mass and

count terms as quantifying by number regardless of referent type, suggesting a lack of strong quantificational interpretation for mass syntax.

Results from Experiment 2 indicated that children could use mass-count syntax to guide quantification for non-solid substances. Across conditions, children’s interpretation of mass syntax appeared more affected by referent type than the interpretation of count syntax. The number bias found in Experiment 1 disappeared mainly for mass nouns when referents were changed from discrete physical objects to non-solid substances.

Table 1

Summary of results for Experiments 1 and 2
(✓ = effect of syntax; ✗ = no effect of syntax)

	Solids		Non-solids	
	W.E. ¹	Q.J. ²	W.E.	Q.J.
3-year olds	✓	✗	✗	✓
Adults	✓	✓	✓	✓

¹ Word extension

² Quantity judgment

These results (summarized in Table 1) have three important consequences. First, children appear to employ distinct mechanisms for performing quantity judgments and word extensions. The main source of this difference, and of the difference between children and adults in this study, was children’s treatment of simple solid objects. While both adults and children quantified by number for mass nouns that referred to complex objects, only children quantified by number for mass nouns that referred to simple objects and that were extended by substance. Interestingly, these results appear to be consistent with observations that young children are biased to enumerate spatio-temporally defined individuals when counting segmented objects (e.g., counting a fork cut in half as two forks; see Shippley & Shepperson, 1990; Wagner & Carey, 2003). In these tasks, children are unable to use criteria of individuation for specific words, despite being able to correctly extend them. By analogy, when performing quantity judgments, children seem to ignore criteria of individuation for newly learned words and instead employ the more primitive criteria of the “object” sortal (Xu, 1997). Children appear to base quantification on spatio-temporal individuals whenever arrays are composed of physical objects, and only later in acquisition use specific sortal information to guide judgments.

It should be noted that although a spatio-temporal bias may account for the content of individuals that children quantified (i.e. rather than specific sortal knowledge) it cannot explain the failure of mass syntax to determine the dimension of measurement. Our evidence suggests that 3-year-olds are only beginning to understand the effect of mass-count syntax on quantification, and that they do not have strong syntax-semantics mappings of the type proposed by Bloom (1999). Thus, this study provides further evidence children never use one-to-one mappings

between syntax and semantics of the type proposed by Bloom (1999). Instead, it seems that only count syntax is ever truly specified for a uniform interpretation (Barner & Snedeker, 2004).

Given children's difficulty using syntax to guide quantity judgment, how do they succeed with word extension? Minimally, the task requires an ability to distinguish mass and count distributional frames and to determine a novel word's criteria of application, or content. One possibility is that these two types of knowledge are sufficient for solving word extension, and may operate somewhat independently of actual mass-count semantics. For example, children may observe that a novel term like *blicket* has been used in the same syntax as a word like *plastic*, for which shape is an irrelevant dimension, and therefore extend the word on the basis of substance. Novel word extensions may be made on the basis of correlations between mass-count syntax and previous extensions, and may be the product of simple mappings between content and syntax, bypassing noun phrase quantification altogether.

Based on this, our results suggest an ability to use mass-count syntax to guide word extension by 2;6 (e.g., Soja, 1992) may not reflect mature knowledge of mass-count semantics. Even by 3;6, children are only beginning to understand the full effect of mass-count syntax on quantification, which arguably defines the distinction. Early in acquisition, children may approximate adult behavior conditions by exploiting correlations between content and distributional frames, and by employing ontologically based biases for interpreting quantifiers like "more". Sometime between 3;6 and 4, children appear to recognize that count syntax specifies number as a dimension for comparison, and that in this way it differs from mass syntax (Barner & Snedeker, 2004). Mass nouns continue to be interpreted based on lexical properties, as shown by adults in this study, and never specify a uniform dimension for measurement.

Acknowledgements

We would like to thank Susan Carey and Peggy Li for their helpful comments on previous versions of this paper. This work was funded in part by a grant from the National Science Foundation to the second author (IIS-0218852, schaward 5710001440).

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