LANGUAGE LEARNING AND DEVELOPMENT, *2*(3), 163–194

Children's Early Understanding of Mass–Count Syntax: Individuation, Lexical Content, and the Number Asymmetry Hypothesis

David Barner and Jesse Snedeker
Harvard University

How does mass–count syntax affect word meaning? Many theorists have proposed that count nouns denote individuals, whereas mass nouns do not (Bloom, 1999; Gordon, 1985; Link, 1983), a proposal that is supported by prototypical examples of each (table, water). However, studies of quantity judgments in 4-year-olds and adults demonstrate that some mass nouns (furniture) do denote individuals (Barner & Snedeker, 2005). This is problematic for bootstrapping theories that posit one-to-one syntax-semantics mappings (individual ↔ count; nonindividual ↔ mass; Bloom, 1999), unless mass nouns that denote individuals are late-learned exceptions to mappings. This article investigates this possibility in 3-year-olds and adults using 2 methods: word extension and quantity judgment. Both methods indicate that novel mass nouns can denote individuals in both age groups, and thus fail to support simplified syntax-semantics mappings. Also, differences between word extension and quantity judgment raise the possibility that the tasks measure different underlying knowledge.

How does syntax contribute to the interpretation of individual words? Psychologists, philosophers, and linguists have long been concerned with the question of how syntax and semantics are related, but for developmental psychologists, the question takes on a special significance. Beyond understanding the relation between syntactic structures and their interpretation, there is the additional challenge of figuring out how children discover this relation in acquisition. The mass–count

---

Correspondence should be addressed to David Barner, Laboratory for Developmental Studies, Department of Psychology, Vanserg Hall, Harvard University, 25 Francis Avenue, Room B1, Cambridge, MA 02138. E-mail: barner@fas.harvard.edu

distinction has long been a test case for exploring this question. In English, count nouns (e.g., cat, table) are those words that can appear in both singular and plural forms and can be modified by cardinal numbers (e.g., 1, 2), and quasicardinal determiners such as several, many, these, and those. Mass nouns (e.g., milk, sand) can take none of these determiners, cannot be pluralized, and sometimes are modified by terms such as *little* or *much.* How do children acquiring language discover the meaning of this syntactic distinction and use it to guide the interpretation of new words?

Quine (1960) famously suggested that acquiring mass–count syntax plays a fundamental role in shaping not only word meanings, but also children's understanding of objects. According to Quine, count nouns, but not mass nouns, "possess built in modes, however arbitrary, of dividing their reference" (p. 91). Count nouns denote individuals, whereas mass nouns denote nonindividuals (see also Bloom, 1994, 1999; Gordon, 1985, 1988; Landman, 1991; Link, 1983; Wisniewski, Imai, & Casey, 1996). By defining the boundaries of perceived phenomena, the divided reference of count nouns could provide the inner walls of an "intellectual chimney," up which the developing child could scramble to acquire concepts like "enduring physical object" (for a discussion, see Carey, 1993). In contrast, psychologists such as John Macnamara (1972, 1982; see also Braine, 1992; Schlesinger, 1971) have suggested that categories like "object" and "substance" might form the semantic cores for constructing the grammatical categories "count" and "mass," respectively. Children could initially perform distributional analyses over these semantic categories, and later semantically assimilate nonconforming lexical items (e.g., abstract nouns) on the basis of their distributional profiles. Therefore, like Quine, Macnamara (1982) proposed a theory of bootstrapping to explain the relation between mass–count syntax and semantics. However, although Quine proposed that children use grammar as the walls of their intellectual chimney, Macnamara (1982) suggested that "the child climbs to grammar on a semantic ladder and then kicks the ladder away" (p. 134).

Since the original formulation of these ideas, strong evidence has been brought to bear against each and has led to a shift in how researchers view the relation between syntax and semantics in children's acquisition of the mass–count distinction. There is now substantial evidence that language is not required for acquiring concepts like "enduring physical object," and that prelinguistic infants have rich constraints on how they represent the world and the things that fill it. For example, infants are able to track sets of distinct individuals under occlusion, and they are sensitive to the addition and subtraction of objects from an occluded set (see Carey & Xu, 2001; Feigenson & Carey, 2003; Feigenson, Hauser, & Carey, 2002; Spelke, 1985; Wynn, 1992). In contrast, such representations are not available for tracking portions of noncohesive substances such as sand (see Huntley-Fenner, Carey, & Solimando, 2002).

Children's early knowledge of objects is reflected in how they acquire and interpret new words. Studies of 2-year-olds learning English show that they are sensitive to the object–substance distinction when extending novel words, even before they acquire mass–count syntax (Soja, Carey, & Spelke, 1991). The independence of the object–substance distinction from mass–count syntax is corroborated by the behavior of Japanese 2-year-olds, who distinguish solid objects from nonsolid substances in word extension despite the fact that Japanese lacks count nouns altogether (Imai & Gentner, 1997). These studies, and others like them, indicate that children are biased to extend novel words on the basis of shape when the words name solid objects, but they prefer to extend on the basis of substance when the words name nonsolid stuff (see also Dickinson, 1988; Imai, Gentner, & Uchida, 1994; Landau, Smith, & Jones, 1988; Samuelson & Smith, 1999; Soja, 1992). However, children's early understanding of objects and stuff is almost certainly not the foundation for acquiring mass–count syntax (see Gathercole, 1985; Gordon, 1985, 1988). For example, Gordon (1985) has shown that, when provided with both syntactic and semantic cues in word learning, children ranging in age between 3;5 and 5;5 years old overwhelmingly categorize words on the basis of syntactic context, even when syntactic and semantic cues are in conflict. In fact, when Gordon (1985) provided children with semantic cues in isolation, only older participants (between 4;6 and 6;0) were able to consistently use semantics as a basis for category assignment. In his analysis, Gordon (1985, 1988) suggested that children's early understanding of the mass–count distinction is based on quantification.[1] Pursuing this, Bloom (1999) suggested that children might identify count and mass nouns in the input on the basis of their use to refer to individuals or nonindividuals. In any case where the child construes a referent to be an individual, whether a chair, puddle, sound, or unified group of objects, he or she might also assume that the expression used to name the individual is a count noun phrase. Correspondingly, any noun that names something construed as a nonindividual could be interpreted as a mass noun, yielding the following bidirectional mappings:

(1) a. Individual $\leftrightarrow$ count noun.
    b. Nonindividual $\leftrightarrow$ mass noun.

In support of such mappings, Bloom (1999) noted that infants' early representations of individuals are actually quite abstract (see Lipton & Spelke, 2006; Starkey, Spelke, & Gelman, 1990; Wood & Spelke, 2005; Wynn, 1996) and are encoded by children's language and counting abilities from early in acquisition (Bloom &

[1]Although Gordon's (1985) study demonstrated a clear preference for syntactic cues over basic semantic cues like "object" and "nonsolid substance," it did not empirically establish what semantic interpretation children *do* assign to the mass–count distinction.

Keleman, 1995; Giralt & Bloom, 2000; Nelson, Hampson, & Shaw, 1993; Soja, 1992; Wynn, 1990).

However, following Quine (1960), Bloom's (1999) syntax-semantics mappings also predict that all nouns used in count syntax should denote individuals and that all nouns used in mass syntax should denote nonindividuals, both in children and adults. The problem with this, as some linguists have observed, is that many mass nouns appear to denote individuals (Chierchia, 1998; Gillon, 1992, 1999). Mass nouns like furniture, jewelry, clothing, ammunition, and waterfowl appear to denote discrete individuals; arguably, they do not differ from plural count nouns in their interpretation.

To explain such apparent counterexamples, Quine (1960) and others (Bloom, 1994; Wisniewski et al., 1996) have argued that different linguistic terms can apply to the same stuff in the world with different results for interpretation. For Quine, expressions like "shoe," "pair of shoes," and "footwear" all apply to the same "scattered stuff"; however, only the first two divide their reference—"the contrast is in the words, and not in the stuff they name" (p. 91). In the words of Wisniewski et al., speakers "conceptualize the referents of count nouns as distinct, countable, individuated things and those of mass nouns as non-distinct, uncountable, unindividuated things" (p. 271).

An important question is how to evaluate when a discrete physical object is being conceptualized as a nonindividual for linguistic purposes. In a recent investigation of mass–count semantics (Barner & Snedeker, 2005), we offered a test of linguistic construal for mass–count syntax. Based on the arguments of Quine (1960), we reasoned that if words denote individuals then this semantic property should be reflected in how the words quantify (see also McCawley, 1975). For example, the expression "more apples" means "more individual things," whereas "more butter" means more homogeneous stuff. Whenever nouns encode a referent as an individual, this should be reflected by its interpretation when used with natural language quantifiers: Words that individuate should lead to judgments of amount that are based on number.

Following this logic, we asked English-speaking 4-year-olds and adults to perform quantity judgments for familiar mass and count nouns. For example, participants judged six tiny shoes to be more shoes than two giant shoes, and two giant portions of butter to be more butter than six tiny portions, suggesting that participants individuated for the count nouns but not for the mass nouns (see also Gathercole, 1985). However, participants also based almost all judgments on number (rather than volume) for mass nouns like furniture and mail (e.g., judging 3 tiny parcels and 3 tiny letters to be more mail than a giant parcel and a giant letter). These results cannot be explained by a failure to use mass–count syntax to guide quantification. When asked to perform quantity judgments for words that can be used in either mass or count syntax (e.g., string, stone), children and adults judged according to number when terms were presented in count syntax, but by mass or volume when they were presented in mass syntax. Because words used in mass syntax can denote either individuals (e.g., furniture) or nonindividuals (e.g., string), we concluded that mass syntax does not force an unindividuated construal, and that instead only count syntax specifies a rigid interpretation for nouns. We proposed that the mass–count distinction is inherently asymmetric: Mass nouns are not an overt category but are simply those nouns that lack count features in the syntax. Whereas count syntax specifies quantification over individuals, mass syntax simply fails to specify a dimension of quantification or measurement. This "number asymmetry hypothesis" can be schematized as the following:

(2) a. Count syntax → individuals.
    b. Mass syntax → unspecified.

The quantity judgment data indicate that 4-year-old children and adults have an asymmetric interpretation of mass–count syntax; therefore, for them, mass syntax does not force an unindividuated construal. However, the results leave open the possibility that children begin acquisition with a qualitatively different analysis, which might allow them to bootstrap their way into mass–count syntax. For example, children might assume that all nouns used in mass syntax denote nonindividuals until receiving explicit evidence to the contrary when they acquire mass nouns like *furniture.* Further, children might assign special interpretations to exceptional mass nouns, but otherwise treat mass syntax as specifying an unindividuated interpretation. Given these possibilities, it seems preferable to evaluate children's interpretation of mass syntax in the context of novel words for which they could have no preassigned exceptional interpretation, and to test them before they have acquired mass nouns like *furniture* or *mail,* which might cause a fundamental reorganization of mass–count semantic representations.

Several studies have investigated younger children's interpretation of mass–count syntax using novel words. These results suggest that although young children show some difference in how they extend words used in mass and count syntax, mass syntax may permit reference to individuals early in acquisition. For example, Soja (1992) reported that when children aged 2;6 were taught names for novel objects, they extended these words by shape 90% of the time when presented in count syntax and 76% of the time when presented in mass syntax. Similarly, Subrahmanyam, Landau, and Gelman (1999) found that 3-year-old children accepted the extension of novel count nouns by shape 90% of the time compared to 86% for mass nouns. More important, this shape bias for mass nouns did not increase with age, but fell to 44% in older children, and stabilized at 30% in adults. Therefore, studies of early word extension suggest that mass syntax allows reference to individuals (as indicated by extension according to shape). Consistent with this, Samuelson and Smith (1999) provide evidence from adult ratings of words drawn from the MacArthur Communicative Development Inventory (Fenson et al., 1993). Whereas adults in their study classified 70% of count nouns as names for solid things, only 35% of mass nouns were classified as names for nonsolid substances, indicating "asymmetric relations between mass syntax and non-solidity" (p. 30).

However, studies that examine the relation between mass–count syntax and stimulus dimensions like shape and solidity are perhaps not a fair test of the bootstrapping hypothesis or a valid assessment of how mass–count syntax is more generally interpreted. As noted above, mass–count semantics is best characterized not by reference to particular classes of objects and stuff in the world but, rather, by quantification. For familiar nouns, the dissociation is clear enough. First, although all count nouns quantify over countable individuals, a large number of count nouns (most conspicuously, abstract ones) cannot be classified according to shape, solidity, or material. Although abstract count nouns are relatively infrequent in child speech, they are very common in adult speech. Second, when shape does matter for count nouns, substance is almost always implicated too (e.g., practically all natural kinds are defined by both their shape and the material that forms them, although many artifact kinds place some minimal requirements on substance, such as rigidity). Finally, in many cases where nouns can be classified according to shape or material, these dimensions do not predict quantification, as shown by the minimal pairs in Table 1.

Therefore, rather than testing the interpretation of mass–count syntax, word extension may offer a better test of children and adults' knowledge about typical mass and count nouns. Children may form associations between syntactic frames and types of lexical content (e.g., solidity, shape) without a prior analysis of the semantic interpretation of mass–count syntax. Therefore, mass–count quantification could be based on knowledge that is distinct from that which subserves word extension; or, alternatively, quantification could provide a logical background of individuation that is required for an analysis of shape because shape is, after all, a property of individual things.

To date, no studies have investigated the relation between word extension and quantity judgment. Furthermore, studies of quantity judgment in young children

TABLE 1
Dissociation Between Word Extension and Quantity Judgment

	Quantify by Number	*Quantify by Nonnumber*
Distinguished by shape	table/chair	spaghetti/macaroni
	car/truck	rain/snow
	dog/cat	wheat/(whole wheat) flour
Distinguished by substance	chocolate chips/butterscotch chips	toothpaste/mustard
	gold medals/silver medals	coffee/tea
	leather boots/rubber boots	salt/pepper

have not resolved what they know about mass–count syntax. Many such studies simply have not addressed the question, focusing instead on the age at which children are able to distinguish "more" from "less" (Donaldson & Balfour, 1968; Palermo, 1973). Those studies that have tested mass–count quantity judgments in younger children have done so only with familiar items and with unclear results (e.g., Gathercole, 1985).[2] Therefore, little is known about children's early representation of mass–count quantification and whether they might begin acquisition with syntax-semantics mappings of the type proposed by Bloom (1999) and Gordon (1985).

To evaluate children's early interpretation of mass–count syntax and to investigate the relation between lexical content and mass–count quantification, the present study tested 3-year-olds and adults using both word extension and quantity judgment tasks. Because young 3-year-olds show little evidence of understanding mass terms like *furniture, jewelry,* and so forth,[3] they may provide us with a glimpse of syntax-semantics mappings prior to the acquisition of such words. We tested participants with novel nouns and referents to separate the effects of syntax from knowledge of specific lexical items. This allowed us to explore the stimulus properties that might impact the interpretation of novel nouns (e.g., shape, solidity, complexity) because such properties are known to affect word extension (e.g., Imai & Gentner, 1997; Soja et al., 1991). Stimulus properties were manipulated to approximate the physical differences between the referents of mass nouns that quantify by mass or volume (e.g., stone) and the more complex referents of mass nouns that quantify by number (e.g., jewelry). If children begin acquisition with an unindividuated interpretation of mass syntax, then they should fail to base quantity judgments on number for novel nouns used in mass syntax, regardless of the nature of their referents. However, if children do not begin acquisition with an unindividuated interpretation of mass syntax, then they should base judgments on number for nouns used in mass syntax whenever their referents are construed as objects.

---

[2]Gathercole (1985) tested quantity judgments for familiar words in children as young as 2;6, but found little difference in mass and count judgments in children as old as 5. This is surprising because Barner and Snedeker (2005) found a reliable effect of syntax in 4-year-olds for similar items. Differences in populations cannot likely explain this discrepancy because Gathercole found that children's performance only grew worse with age, with the biggest mass–count differences present in the youngest children.

[3]Although Gordon's (1985) study suggests that young children know something about the distributional profiles of object-mass nouns, it does not establish what they know about the meanings of these words. Our own informal analysis of 37 corpora from the CHILDES database (MacWhinney, 2000) indicated that children begin using object-mass nouns between ages 3;5 and 5;0, on average. Average ages of first use for terms were as follows: furniture (3;8), jewelry (4;5), clothing (4;4), mail (3;5), and silverware (5;0). The average age of first use for all object-mass terms combined was 3;10 (n = 52). Given this relatively late onset in production, it is unlikely that children understand nouns like *furniture* at 2;0, despite being sensitive to their grammatical subcategorization.

EXPERIMENT 1

The first experiment examined adults' and 3-year-olds' interpretation of mass and count syntax for novel words that named solid objects and nonsolid substances. The primary question was whether 3-year-olds have mappings between syntax and semantics that prohibit mass nouns from denoting individuals. Because young 3-year-olds understand few if any object-mass terms, we might expect them to have preserved one-to-one mappings between syntax and semantics, if any such mappings ever exist during acquisition. A secondary question was whether the interpretation of mass–count syntax is mediated by properties of specific referents and whether any such mediation is more pronounced for mass syntax relative to count syntax. In our previous study, children based judgments on mass or volume for mass nouns that denoted simple objects like *stone* and nonsolid substances like *mustard,* but on number for complex objects like *furniture* and *jewelry* (Barner & Snedeker, 2005). However, count nouns always quantified by number. Based on these results, we might expect the interpretation of words used in mass syntax, but not those used in count syntax, to shift according to the solidity and complexity of particular referents. Finally, we were interested in how mass–count quantification is related to word extension, whether the two tests tap the same underlying representations, and whether they are equally good tests of mass–count competence. Previous studies of word extension have found clear differences in how children and adults extend names for nonsolid stuff and simple and complex novel objects (e.g., Imai & Gentner, 1997; Soja et al., 1991). Therefore, by testing children with both quantity judgment and word extension using the same range of referents, we were able to compare effects of stimulus type for each test.

Method

Participants. Participants were 48 native English speakers recruited from the Harvard University (Cambridge, MA) campus and 48 children (25 boys, 23 girls; age 3;0–3;6; $M = 3;3$) who were learning English as a first language. Children were recruited at local childcare centers and via a database created from mailed invitations and follow-up phone calls. Four children were excluded from analyses due to failure to respond.

Stimuli and procedure. Each testing session comprised four trials. In each trial, the participant was introduced to a novel object or portion of nonsolid stuff that was named with a novel term four times using either unambiguous mass syntax or unambiguous count syntax. These exemplars were called the "standard items." For example, participants were shown a standard item and told, "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?"[4] Mass–count syntax was manipulated between-subject. One third of the participants were shown simple objects, one third were shown complex objects, and the final third were shown portions of nonsolid stuff. Simple and complex items were selected from a set of stimuli that had been rated for complexity by adults (see Li, Dunham, & Carey, 2005).[5] Simple items had complexity items ranging from 1.75 to 3.19 out of 7 ($M = 2.31$), and complex items had complexity ratings ranging from 4.20 to 6.20 ($M = 5.18$). Standard items and the alternatives used in the word extension and quantity judgment tasks are depicted by drawings in Appendix A (for simple solid objects) and Appendix B (for complex solid objects).

The standard nonsolids were matched to the simple objects in complexity and had roughly the same shape (given their nonsolid nature, it was impossible to provide an exact match). The standards and alternatives were as follows: (a) a half egg shape made of red media mixer gel (*same shape:* purple sparkly paint half egg; *same substance:* red media mixer gel in a cross shape), (b) an arrow shape made from green butter (*same shape:* an arrow made from brown oatmeal; *same substance:* green butter in a pitchfork shape), (c) a kidney bean shape made from brown hair gel (*same shape:* pink oatmeal in a kidney bean shape; *same substance:* brown hair gel in a pitchfork shape), and (d) a round shape made from orange paint (*same shape:* pink marshmallow paste in a round shape; *same substance:* a thin orange line). The names for these objects and portions, always presented with either mass or count syntax, were *fem, tannin, tulver,* and *dak,* respectively (repeated within each set).

Following the naming of each standard item, participants were asked two questions, the order of which was varied between-subject (see Figure 1). First, in the word extension task (see Soja et al., 1991), participants were shown two additional items (1 that 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, 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 (for a similar procedure, see Gathercole, 1985). The standard items had a greater overall mass and volume than the three miniature objects, but they were otherwise identical in shape and substance. Specifically, the ratio in volume between single stan-

[4]More important, mass nouns were presented in syntactic frames that were unambiguously mass to prevent their possible interpretation as irregular plurals (e.g., "This is some nice fem, isn't it?").

[5]In their study, participants were given the following instructions: For the first part, you are to rate the complexity of the shape of the item displayed in front of you. Focus on the overall shape and outline of the three-dimensional item while ignoring the internal texture of the item. A complex-shaped item is one that has a complicated outline defined by multiple points and sides, whereas a simple-shaped item has a relatively simple outline with few points and sides. For example, a five-point star is more complex in shape than a triangle; 1 (*low complexity*), 4 (*medium complexity*), to 7 (*high complexity*).

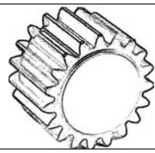
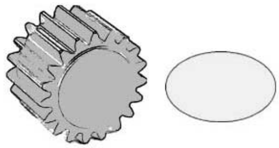
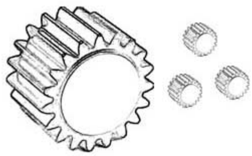
Study phase	Stimulus	Instructions
Training (standard object)		Look, this is some fem! or, Look, this is a fem
Word extension task		Show me some fem. or, Show me a fem?
Quantity judgment task		Who has more fem? or, Who has more fems?

FIGURE 1 An example of a naming trial, word extension trial, and quantity judgment trial (see Appendixes A and B for stimulus details).

dard objects and the sum of their corresponding miniatures ranged from 4:1 to 9:1 and averaged 5.66:1 (see Appendixes A and B for details). For nonsolid substances, it was impossible to accurately measure the ratio of continuous amount between the standard objects and the three small objects used for quantity judgment. However, stimuli were based on simple solid object shapes and, when viewed from above, had roughly the same shape and size (although they had less height when viewed from the side). Therefore, the nonsolid stimuli had similar ratios to the simple solid stimuli.

The side on which the standard or miniatures were shown was systematically varied. Participants were told, for example, "Farmer Brown has some fem/a fem and Captain Blue has some fem/some fems too. Who has more fem/fems?" Participants were encouraged to point to indicate their response when they could not recall the relevant character's name.

Results

Word extension (adults). For the word extension task, we calculated the percentage of trials in which the participant extended a word on the basis of shape. Data were submitted to an analysis of variance (ANOVA) with three between-subject variables: syntax (mass vs. count), referent type (simple solid vs. complex solid vs. nonsolid), and task order (word extension first vs. quantity judgment

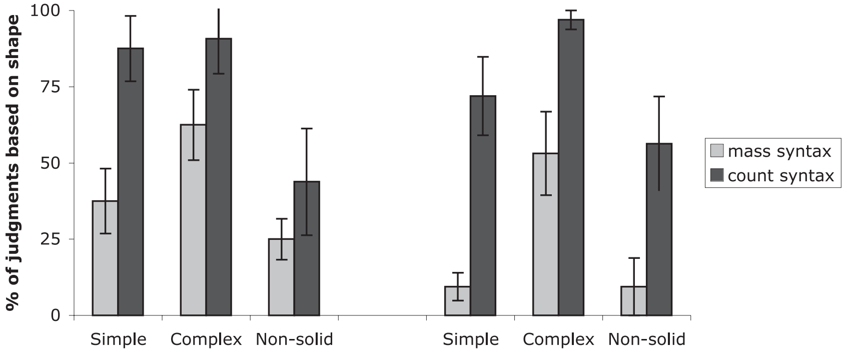


FIGURE 2 Word extension by 3-year-old children and adults for items used in mass and count syntax for simple objects, complex objects, and nonsolid substances.

first). Parallel ANOVAs were conducted for the quantity judgment data (below) and for the children's data.

Adults used mass–count syntax to guide word extension, extending items used in count syntax by shape 75% of the time, compared to 24% for items used in mass syntax, $F(1, 36) = 35.59$, $p < .001$. They also showed a significant difference in their extension based on referent type, extending names by shape 40.6% of the time for simple objects, 75% of the time for complex objects, and 32.8% of the time for nonsolid substances, $F(2, 36) = 8.4$, $p < .001$ (see Figure 2). There was no interaction between syntax and referent type, nor any main effects or interactions involving order.[6]

Quantity judgment (adults). For the quantity judgment task, we calculated the percentage of trials in which the participant chose the array with the greater number of objects, indicating that they were basing quantification on number rather than on mass or volume. Adults used mass–count syntax to guide quantity judgment, basing judgments on number 91.7% of the time for items used in count syntax, compared to 13.5% for items used in mass syntax, $F(1, 36) = 141.81$, $p < .001$. They also showed a significant effect of referent type, basing quantity judg-

[6]For adults and children, all items were extended more by shape when used in count syntax versus mass syntax (4 out of 4 items for each of the 3 referent types for both groups). For adults, quantity judgments were based more on number when used in count syntax versus mass syntax in all items (4 out of 4 items for each of the 3 referent types). For children, this was also true for all nonsolid items (4 out of 4), whereas for both simple and complex solids, three out of four items had slightly more judgments based on number for count syntax, and one item showed no difference (*tulver* for the simple solids, and *tannin* for the complex solids).

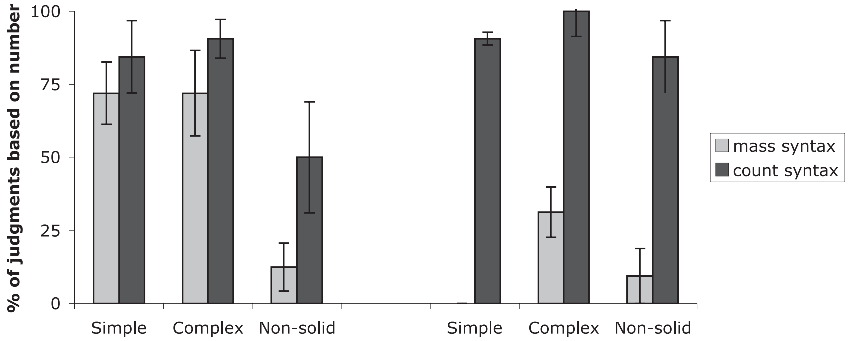


FIGURE 3 Quantity judgment by 3-year-old children and adults for items used in mass and count syntax for simple and complex objects.

ments on number 45.3% of the time for simple objects, 65.6% of the time for complex objects, and 46.9% of the time for nonsolid substances, $F(1, 36) = 3.96$, $p < .05$ (see Figure 3). There was no main effect of order or interactions of any kind.

Word extension (children). Like the adults, the 3-year-olds used mass–count syntax to guide word extension, extending words used in count syntax by shape 74% of the time, compared to 44.8% for items used in mass syntax, $F(1, 36) = 9.72$, $p < .005$. Children also resembled adults by showing a significant difference in their extension based on referent type, extending names by shape 65.6% of the time for simple objects, 78.1% of the time for complex objects, and 34.4% of the time for nonsolid substances, $F(2, 36) = 7.74$, $p < .005$ (see Figure 2). There was no main effect of order and no interactions of any kind.

Quantity judgment (children). Children used mass–count syntax to guide quantity judgment, basing judgments on number 75% of the time for items used in count syntax and 53.1% of the time for items in mass syntax, $F(1, 36) = 5.29$, $p < .05$. They also showed a large effect of referent type, basing 79.7% of quantity judgments on number for simple objects, 81.2% for complex objects, and 31.3% for nonsolid substances, $F(2, 36) = 11.76$, $p < .05$ (Figure 3). There was no effect of order and no interactions of any kind.

Developmental course. Above, we found that both word extension and quantity judgment are sensitive to mass–count syntax and referent type in both adults and children. Here, we explore how the responses to these tasks change over development by comparing adults and children for each task.

Word extension (children and adults combined). Word extension data for children and adults were submitted to an ANOVA with three between-subject variables: syntax (mass vs. count), referent type (simple solid vs. complex solid vs. nonsolid), and age (children vs. adults). When considered together, children and adults showed strong effects of both syntax, $F(1, 72) = 38.42$, $p < .001$; and referent type, $F(1, 72) = 14.74$, $p < .001$. However, there was no effect of age or significant interactions of any kind. Therefore, for word extension, we found no evidence of any difference between 3-year-old children and adults.

Quantity judgment (children and adults combined). Quantity judgment data for children and adults were also submitted to an ANOVA with three between-subject variables: syntax (mass vs. count), referent type (simple solid vs. complex solid vs. nonsolid), and age (children vs. adults). When children and adults were considered together on quantity judgment, there were both strong effects of syntax, $F(1, 72) = 74.32$, $p < .001$, and referent type, $F(1, 72) = 12.23$, $p < .001$. However, in contrast to the word extension task, there was a marginal effect of age, $F(1, 72) = 3.90$, $p = .053$, reflecting a greater tendency on the part of children to base judgments on number. Also, there was a significant interaction between and age and referent type, $F(2, 72) = 6.32$, $p < .005$, and age and syntax, $F(1, 72) = 23.52$, $p < .001$. There were no interactions between referent type and syntax or between age, referent type, and syntax.

To understand this interaction of age and referent type in the main ANOVA, we performed two additional subanalyses. First, we compared children's and adults' quantity judgments for complex objects and nonsolid substances. Because these were the two referent types that differed most in terms of quantity judgment, comparing them allowed us to estimate the overall magnitude of the effect of referent type. Children based quantity judgments on number 81.3% of the time for complex objects and 31.3% of the time for nonsolid substances. Adults based judgments on number 65.6% of the time for complex objects and 46.9% of the time for nonsolid substances. The interaction between age and referent type persisted in this subset of conditions, confirming that referent type affected children's quantity judgments more than adults', $F(1, 48) = 4.08$, $p < .05$.

Second, we explored whether the interaction between age and referent type reflected a difference in how children and adults treated simple solid objects. The interaction between age and referent type persisted for simple solid and nonsolid substance items, $F(1, 48) = 4.06$, $p < .01$, but not for the simple and complex solid items, $F(1, 48) = 3.56$, $p > .1$. Adults' quantity judgments did not differ significantly for simple solids and complex objects, $t(30) = 1.27$, $p > .2$, or for simple objects and nonsolid substances, $t(30) = 0.09$, $p > .9$. Children's quantity judgments did not differ for simple and complex solids, $t(30) = 0.30$, $p > .7$, although, they based judgments on number significantly less for nonsolids than for simple solid objects, $t(30) = 3.5$, $p < .01$ (see Figure 3).

To understand the interaction between age and syntax, we looked separately at mass and count trials. For count syntax, adults based more quantity judgments on number (91.7%) than children (71.4%), resulting in a marginal effect of age, $F(1, 36) = 3.84$, $p = .058$, and no interaction between age and referent type, $F(1, 36) = 1.10$, $p > .3$. However, for mass syntax, children based significantly more quantity judgments on number (46.4%) compared to adults (13.7%), resulting in a robust effect of age, $F(1, 36) = 25.19$, $p < .001$. Also, for mass syntax, there was a large interaction between age and referent type, $F(1, 36) = 6.92$, $p < .005$. This was attributable to a significant difference between children and adults for mass nouns that named simple solids (75% vs. 0%), $t(14) = 7.94$, $p < .001$, mass nouns that named complex solids (71.9% vs. 31.3%), $t(14) = 2.37$, $p < .05$, but not for those that named nonsolid substances (12.5% vs. 9.4%), $t(14) = .25$, $p > .8$. Therefore, when words were presented in mass syntax, children were both less likely than adults to base quantity judgments on mass or volume and more likely to be swayed by the nature of the referent. In contrast, when the novel word was presented in count syntax, the difference between adults and children was smaller, and the effects of referent type were similar for both ages.

Comparison of word extension and quantity judgment. The analyses presented thus far suggest interesting differences between word extension and quantity judgment. In the case of word extension, there were no significant differences between children and adults, although several important developmental differences were found for quantity judgment. For quantity judgment, we found a moderate effect of age, interactions of age with syntax, and age with referent type. These interactions indicate a greater effect of mass–count syntax for adults relative to children and a greater sensitivity to referent types in children, especially for nouns used in mass syntax.

To directly assess the relation between word extension and quantity judgment, we performed several additional analyses. First, to determine whether the tests differed in their sensitivity to mass–count syntax and referent type, we treated task as an independent variable and compared the percentage of shape responses for word extension to the percentage of number responses for quantity judgment for all trials types. For adults, we found a significant interaction between syntax and task, indicating that mass–count syntax had a larger effect on quantity judgment than on word extension, $F(1, 36) = 10.04$, $p < .005$. However, no such difference was found for children, $F(1, 36) = .24$, $p > .6$. Therefore, quantity judgment was more sensitive to mass–count syntax than word extension for adults only.

Second, we performed a concordance analysis to determine how the two tasks were related on a trial-by-trial basis (i.e., how often word extension by shape co-occurred with quantity judgment based on number, and word extension by substance co-occurred with quantity judgment based on volume). For adults, 80% of trials showed a correspondence between the tasks, which was highly significant,

$\chi^2(1, N = 192) = 80.08$, $p < .001$. Of the remaining 20% of trials, 58% were cases where adults extended by substance and based judgment on number (12% of trials overall), and 42% were cases where they extended by shape but based judgment on volume (8% of trials overall). As might be expected by the above interaction between syntax and task, in those cases where the tasks did not correspond (20% of trials overall), quantity judgment was consistent and word extension was inconsistent with syntax in most cases (84% of trials). In other words, when the tasks did not correspond, it was due to a divergence of word extension from syntax.

For children, 59% of trials showed a correspondence between quantity judgment and word extension, resulting in only a marginal relation between the tasks, $\chi^2(1, N = 192) = 3.34$, $p > .06$. Of the remaining 41% of trials, 56% (23% of trials overall) were cases where children extended by substance but based quantity judgments on number, and 44% (18% of trials overall) were cases where they extended by shape but based quantity judgment on volume. Unlike in adults, neither task was more consistent with mass–count syntax (quantity judgment matched syntax on 46% of trials, whereas word extension matched on 54%). Therefore, word extension and quantity judgment were only moderately related in children, and neither matched syntax more consistently than the other, indicating that 3-year-olds have not yet attained adult-like knowledge of mass–count quantification.

Discussion

Experiment 1 revealed three main findings. First, for both children and adults, word extension was influenced by both mass–count syntax and referent type, with no differences between the two age groups. Second, both groups used mass–count syntax for quantity judgment, but with differences between groups. Children's quantity judgments were more influenced by referent type than those of adults, particularly for items used in mass syntax. Adults, in turn, were more influenced by syntax. Third, a comparison of the word extension and quantity judgment tasks indicated (a) that the two tasks are strongly correlated in adults but correspond only about 60% of the time for children, and (b) mass–count syntax had a larger effect on quantity judgment than on word extension in adults but not in children.

These results support the following conclusions: First, although mass–count syntax and individuation are clearly related, there was no indication that mass syntax forces an unindividuated construal of objects. Children extended a large proportion of items used in mass syntax by shape and based many of their quantity judgments for these items on number. The adults' word extension resembled that of children, and they also based quantity judgments on number for one third of mass usages that named complex objects. Second, the relatively greater sensitivity of the quantity judgment task to mass–count syntax in adults (relative to word extension) suggests that the two tasks draw on distinct representations. Third, given the greater sensitivity of quantity judgment in adults, and the fact that quantity judgment and word extension were only marginally related in children, we conclude that word extension may not be as valid an assessment of children's developing understanding of mass–count interpretation relative to quantity judgment. Consistent with this, we found no developmental difference between children and adults for word extension but a significant difference between the groups for quantity judgment, indicating that the latter task is sensitive to developmental changes that the former is not.

EXPERIMENT 2

Experiment 1 indicated that, for children, mass syntax does not force an unindividuated construal. Instead, their interpretation of mass syntax varies depending on referent type. For both simple and complex solid objects, children based quantity judgments on number when items were presented in mass syntax. In contrast, adults based quantity judgments relatively more on volume when names for simple and complex objects were presented in mass syntax; thus, they were less sensitive to referent type than children. This difference between children and adults is subject to three possible interpretations. First, children may be unable to detect that the single object in each quantity judgment set comprised more overall stuff than the array of three small things, or may have been unaware that mass or volume is a possible dimension for comparison. There are several reasons that this is unlikely. First, although the size ratios between the three small and one large object varied considerably (from 4:1 to 9:1) the patterns of responses for these items did not systematically differ (see footnote 6). Second, children's behavior with nonsolid substances showed no evidence of a number bias, despite the fact that the ratio between continuous amounts for these items is no greater than ratios used for the simple solids.

A second alternative is that children are able to perceive differences in continuous amount, but that their performance on the quantity judgment task is subject to a number bias akin to the spatiotemporal bias found in studies of counting in 3- to 6-year-old children (see Shippley & Shepperson, 1990; Wagner & Carey, 2003). In these studies, children are biased to include discrete physical objects in their counts of things even when these objects are only partial instances of the kind to be counted (e.g., half forks). On analogy to this counting bias, children in our study may have overridden their assumptions about what counts as "some blicket" and based judgments on number when confronted with discrete physical objects. Importantly, this second alternative makes the prediction that children should show a number bias not only for novel nouns but also for nouns that name familiar things since Shippley and Shepperson (1990) found a number bias for both novel and familiar terms in their study (see also Wagner & Carey, 2003).

Our own interpretation for the difference between children and adults is that it reflects children's initial assumption about how nouns quantify: Names for discrete physical objects individuate and, thus, quantify by number. Names for nonsolid substances do not individuate and, thus, quantify by mass or volume. Mass syntax, being semantically unspecified with regards to individuation, does nothing to alter this interpretation. Children's initial assumption may not be a hard rule, but simply a starting point from which lexical learning can depart. According to this hypothesis, we might expect that children who base quantity judgments on number for novel mass nouns that name solids will nonetheless base judgments on mass or volume for familiar mass nouns that name solid or cohesive things (i.e., lexical learning may play a role in shifting interpretations of words as they become known to children).

Experiment 2 examined whether children exhibit a number bias for familiar words. To do this, we tested 3-year-olds' quantity judgments for mass–count flexible words that are known to show effects of syntax in older children (Barner & Snedeker, 2005). If children have a spatiotemporally based number bias that overrides the role of kind information in quantity judgments, then this bias should apply to both familiar and novel nouns. However, if children assume that novel names for objects quantify by number and modify their interpretations as they become familiar with words, then we might expect no such bias to be found for familiar items.

Method

Participants. Participants were 24 children (12 of each gender; aged 3;0 to 3;6, M = 3;4) learning English as a first language, recruited as in Experiment 1. One child was excluded due to failure to respond.

Procedures and stimuli. Children were given a quantity judgment task that tested knowledge of nouns that can be used with both mass and count syntax. These items have been shown to produce significant effects of mass–count syntax on quantity judgment in older children (Barner & Snedeker, 2005). As in the previous experiments, participants were shown two characters and asked to choose which of the two had more (quantity; e.g., "Who has more string/s?"). One character always had a single large object, whereas the other character had three small objects of the same kind. Again, the three objects had a smaller combined volume and surface area than the large object. Ratios (reported in Figure 4 for individual items) averaged 3.75:1 and, thus, were smaller on average than those in Experiment 1, where the average was 5.66:1. Four mass–count flexible terms were tested: *string, chocolate, paper,* and *stone.* According to norms provided by the MacArthur Communicative Development Inventory (Dale & Fenson, 1996), by 30 months of age, *paper* is used by 97.1% of children, *stone* by 51.4%, and *chocolate* by 88.6%. Data

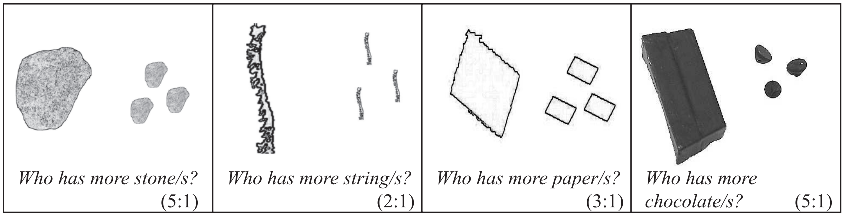


FIGURE 4 Drawings of stimuli from Experiment 2 (*stone/s, string/s, paper/s, chocolate/s*).

for *string* are not available. This suggests that at least three of the four target words are familiar to most children by 36 months, the age of our sample. Mass–count syntax was manipulated between participants, and each word was presented three times in an unambiguous syntactic frame. Images depicting three of these stimuli are shown in Figure 4.

Results

Children used syntax to guide their quantity judgments (Figure 5). Children based judgments on number more often when nouns were used in count syntax compared to when they were used in mass syntax (77.1% vs. 43.8%), $t(22) = 2.26$, $p < .03$, one tailed.[7] To determine whether there was a difference between familiar words and names for novel solid objects, we compared familiar words from Experiment 2 with words that named simple solid objects in Experiment 1 and found no significant interaction between syntax (Mass × Count) and familiarity (Novel Simple Solid Items × Familiar Items), $F(1, 36) = 1.00$, $p > .3$. Because there was no reliable difference between novel and familiar words, the precise role of word familiarity in children's developing knowledge of mass–count quantification remains uncertain and must be explored in future studies.

Discussion

Results from Experiment 2 indicate that 3-year-olds showed a difference in their interpretation of mass and count syntax for familiar nouns. This provides further evidence that 3-year-olds perceive differences in continuous amounts at the ratios presented here and in Experiment 1. Also, they indicate that children do not have a number bias for familiar mass nouns, in contrast to the bias found in children's counting (Shippley & Shepperson, 1990). Finally, the presence of an effect of

[7]All items ($n = 4$) had more quantity judgments based on number when used in count syntax versus mass syntax.

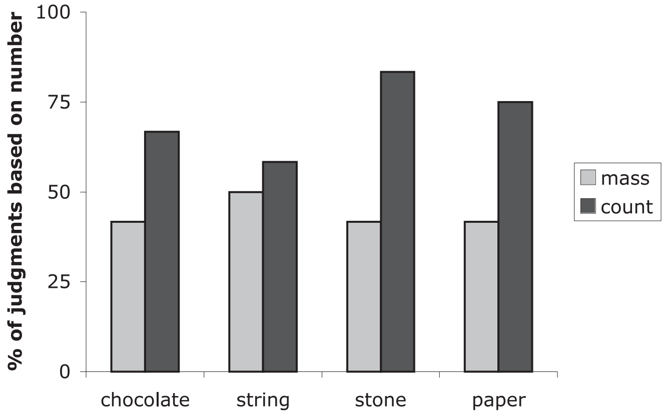


FIGURE 5 Quantity judgments by 3-year-old children for mass–count flexible familiar nouns.

mass–count syntax here, but not for the simple solid objects of Experiment 1, suggests that familiarity (i.e., lexical learning) might play a role in shifting quantity judgments for mass nouns over time. However, because we found no reliable interaction between the two conditions, this remains open to further investigation.

GENERAL DISCUSSION

The results from this study fail to support the idea that children begin acquisition with an unindividuated interpretation of mass syntax (e.g., Bloom, 1999). Instead, when nouns were used in mass syntax, 3-year-olds extended them by shape (rather than substance) about one half of the time, and they based quantity judgments on number (rather than volume) most of the time for the denoted objects. Apparently, the use of novel words in mass syntax did not cause children to construe the referents of those words as nonindividuals. The results also indicate that word extension and quantity judgment are more highly correlated for adults than for children, and that quantity judgment is more sensitive to mass–count syntax than word extension in adults, but not in children. This greater sensitivity of quantity judgment to mass–count syntax supports the widespread theoretical claim that mass–count syntax is best characterized by quantification. As noted by Gordon (1985), the mass–count distinction is not based on reference to objects and substances, but rather on how nouns in each category quantify: Count nouns quantify over individuals, while mass nouns can quantify by volume, number, and other dimensions of measurement (see Barner & Snedeker, 2005).

Below, we discuss these results in light of existing accounts of the mass–count distinction and its acquisition. We also discuss how word extension and quantity judgment are related and why children and adults differ only on the quantity judgment task. Finally, we conclude with a sketch of how children might begin mass–count acquisition.

The Interpretation of Mass–Count Syntax in Adults

Since Quine's (1960) discussion of the mass–count distinction, the dominant view in linguistics and psychology has been that count and mass syntax have distinct effects on interpretation such that only count nouns can denote individuals (Bloom, 1994, 1999; Gordon, 1985, 1988; Landman, 1991; Link, 1983; Papafragou, in press; Wisniewski et al., 1996). However, as noted by Gillon (1999), very little evidence has been offered for this claim, beyond observing prototypical instances of each category (e.g., count nouns that denote individuals and mass nouns that do not). Similarly, Chierchia (1998) complains that typically, "theories of mass nouns have focused on terms like *rice* and *water*" and that this has "led to the idea that the denotation of mass nouns is somehow qualitatively distinct from that of count ones" (p. 68). Following the arguments of Gillon (1999) and Chierchia, psychological tests of mass–count interpretation provide evidence that some familiar mass nouns (e.g., furniture, jewelry) do indeed denote individuals (Barner & Snedeker, 2005). Experiment 1 extends this observation to novel words. Although adults' count noun quantity judgments were based on number for all three referent types, their mass noun judgments were based on volume for simple objects and nonsolid substances, but on number about one third of the time for mass nouns that denoted complex objects.

This result supports our suggestion that the measuring dimension of mass syntax is unspecified in adults, and that mass nouns select dimensions of comparison lexically (Barner & Snedeker, 2005). On this view, mass syntax does not specify reference to nonindividuals; rather, it simply fails to specify reference to individuals. The difference is subtle, but important, because only given this characterization can the semantic diversity of mass nouns be explained. Although measurement and comparison of amount is carried out identically for all count nouns (i.e., by evaluating the cardinality of sets), mass nouns do not share a single dimension of measurement. Some mass terms quantify by mass or volume (e.g., stone, mustard), others select abstract dimensions (e.g., wisdom, hope), and others select number (e.g., furniture, silverware).[8] Thus, while we measure quantities of cats,

---

[8]A large number of mass nouns are abstract and pick out highly idiosyncratic dimensions that are unrelated to notions like "stuff" or "substance." A rough indicator of this is provided by the Machine Readable Dictionary (MRC) psycholinguistic database (http://www.psy.uwa.edu.au/mrcdatabase/uwa_mrc.htm), which can be used to generate lists of nouns that have no plural form (and thus many mass nouns). Such a query turns up 325 no-plural nouns with imageability ratings below 500 (on a 700-point scale) and only 137 nouns with ratings over 500. Although a gross measure, this suggests that mass nouns are no more likely to name highly imageable substances or things than they are to name abstract entities.

ideas, votes, pushups, and puddles in terms of number, phenomena such as wealth, mustard, string, furniture, and hope are each measured in radically different fashions. More often than not, mass nouns have *incommensurable* measuring dimensions: They do not permit comparison of amount along a single dimension. Strikingly, when mass nouns are used in count syntax, their semantic incompatibility disappears: While it is unclear how to decide whether I have more string than hope, it is perfectly clear that if I have three strings and one hope, then I must have more strings than hopes.[9]

The Early Interpretation of Mass Syntax

The data for 3-year-olds do not support the idea that children begin acquisition with a special interpretation of mass syntax that precludes object-mass nouns. If this were the case, we would predict a relative increase in quantity judgments based on number for mass nouns through the course of development. Instead, for mass nouns, children based quantity judgments on number far more than adults did, a difference that was driven by a relatively greater attention to referent type for mass nouns. In contrast, children's judgments for count nouns were almost adult-like; both groups generally preferred to base judgments on number, and the children were no more sensitive to referent type than the adults. Combined, these results suggest that for children, mass nouns are subject to effects of referent type, but that count syntax is relatively resilient to item-specific knowledge.

Lexical Content and Mass–Count Quantification

The study of how syntax and semantics are related is made difficult by the fact that both lexical items and syntax play roles in determining the meaning of expressions. Our comparison of quantity judgment and word extension indicated that the two tasks generate different results, particularly in children for whom the tasks diverged on over 40% of trials. We also found that, for adults, quantity judgment is a significantly more reliable test of mass–count syntax than word extension.

These results are consistent with the intuition that word extension is logically dissociable from quantification. The extensions of many concrete nouns are distinguished both by shape and by substance. Some of these nouns quantify over individuals (e.g., dogs, trucks), whereas others do not (e.g., rice, celery). Meanwhile, abstract nouns can quantify over individuals despite the fact that their referents have no shape or substance. In general, the importance of shape and substance in

[9]It is often possible to perform comparisons for incommensurable nouns by appealing to normative values on two discrete dimensions. For example, expressions like, "he has more money than brains," do not provide evidence that money and brains are measured in the same way any more than, "he is richer than he is smart," suggests that all adjectives pick out a single dimension (for a discussion, see Kennedy, 1999). In each case, mappings are required between two distinct dimensions of measurement.

distinguishing word referents varies according to the set of items under comparison, whereas a word's dimension of quantification remains constant.

How then are word extension and quantification related? Why do they correlate as well as they do in adults? Two considerations seem relevant. First, as noted earlier, the ability to perceive something as a discrete unit is logically prior to evaluating shape. A referent must be a *thing* to have a shape in the first place. Therefore, it should be unsurprising that quantification by number is correlated with extension by shape. In fact, our data support this and show that, for adults, the effect of syntax on word extension is completely mediated by quantity judgment, although its effect on quantity judgment is not mediated by word extension. When adults' word extension trials are divided into two sets based on quantity judgment responses (number responses vs. nonnumber responses), there is no effect of mass–count syntax within either subset, suggesting that syntactic effects on word extension are parasitic on effects due to quantity judgment. However, when trials are separated based on word extension responses, effects of mass–count syntax on quantity judgment persist, indicating that quantity judgment is not mediated by word extension.[10] These results are consistent with the idea that extension by shape requires a prior analysis of something as an individual. They also suggest that mass–count quantification may not be acquired on the basis of cues like shape, but instead may emerge from distinct mental representations in acquisition.

If word extension does not reveal the underlying semantics of the mass–count distinction, then why is it sensitive to shifts in syntax? One hypothesis that is consistent with our proposal is that referent properties like solidity, shape, and substance are differentially correlated with mass and count syntax by virtue of their association with known nouns. For example, children might observe that a novel term like *blicket* has been used in the same syntactic context as a word like *plastic* for which shape is an irrelevant dimension and, therefore, extend the word on the basis of substance. Following the suggestion of Samuelson and Smith (1999), children's word extensions could be based on "the regularities among the nouns already known by that child" (p. 13), and could bypass noun phrase quantification altogether. This possibility is supported by the fact that, unlike the case for adults, children's word extension was not mediated by quantity judgment.[11]

---

[10]For quantity judgments based on number, a chi-square analysis found no significant relation between mass–count syntax and word extension; $\chi^2(1, N = 101) = 0.015, p > .9$. Similarly, for quantity judgments not based on number, there was no relation between syntax and word extension: $\chi^2(1, N = 91) = 2.40, p > .1$. There were highly significant relations between syntax and quantity judgment both for trials where word extension was based on shape, $\chi^2(1, N = 95) = 34.12, p < .001$, and for trials where extension was based on substance, $\chi^2(1, N = 97) = 58.02, p < .001$.

[11]For children, there was a significant effect of syntax on word extension for quantity judgments based on number, $\chi^2(1, N = 123) = 11.18, p < .001$, and a marginal effect for those not based on number, $\chi^2(1, N = 69) = 3.74, p = .053$. Meanwhile, there was a significant effect of syntax on quantity judgment for words extended by shape, $\chi^2(1, N = 114) = 5.9, p < .05$, although no effect for words extended by substance, $\chi^2(1, N = 78) = 2.01, p > .15$. Therefore, it seems that only in adults is word extension

Therefore, associations between mass–count syntax and referent properties like shape and solidity might be acquired via a learning mechanism that is distinct from that used to acquire knowledge of mass–count quantification. For example, Samuelson (2002) suggests that although statistical regularities between mass–count syntax, solidity, and shape may teach children to attend to shape when learning names for novel objects, these regularities may be independent of how mass–count syntax is acquired:

> The statistical regularities hypothesis is limited in that it does not say anything about how the child learns the initial set of nominal categories from which they abstract the shape-bias. Rather, the statistical regularities hypothesis concerns how children go from knowing some set of individual nouns to knowing how to learn new nouns, and suggests that this knowledge comes from a vocabulary of individual names that (mostly) name things in the same way. (p. 1019)

Whatever knowledge children and adults bring to word extension, it seems unlikely that this knowledge is identical to that which underlies mass–count quantification. This is of central importance because much of what is currently known about the mass–count distinction in language acquisition uses word extension as a measure of competence.[12] Any theory built solely on the basis of data from word extension tasks may not capture the full extent of the mass–count acquisition problem and may consequently posit inadequate mechanisms for acquisition.

How Do Children Acquire the Mass–Count Distinction?

The argument thus far has been that the mass–count distinction is asymmetrically related to individuation and that its semantics cannot be adequately described by appeal to referent properties like shape, substance, and solidity, which constitute

---

strongly yoked to quantity judgment, perhaps due to adults' distinction between quantification based on linguistic individuals (i.e., those defined by grammatical criteria) versus perceptual individuals (i.e., those defined on the basis of spatiotemporal criteria). Although a given entity may be treated as an individual by the perceptual system (e.g., as defined by spatiotemporal criteria for object-hood), it may not be encoded as an individual by the linguistic system. This is clear in cases such as the word *stone,* which individuates as a count noun but not as a mass noun, even if the thing being referred to remains constant.

[12]Other tasks have been used to test cross-cultural differences in object construal (e.g., similarity judgments, stimulus ratings, and tasks that ask participants to recall details of arrays such as the number of items that were presented; see Li, Dunham, & Carey, in preparation; Lucy, 1992). However, these tasks do not manipulate mass–count syntax to examine its effect on interpretation and, thus, address a slightly different question: How does having a syntactic distinction affect encoding of object properties? For example, Lucy finds that speakers of Yucatec-Mayan (which lacks count nouns) are less likely to recall the number of objects in an array relative to speakers of English (which has count nouns). As Lucy suggests, these results might be due to count syntax making number more salient to speakers of English. However, another possibility is that the differences between groups might also reflect other cultural factors (see Mazuka & Friedman, 2000). In either case, the studies do not directly address the interpretation of mass–count syntax in languages that make the distinction, like English.

aspects of lexical semantics. This leads us to suggest that an adequate theory of mass–count acquisition must attribute a special significance to count syntax, and must do so by appeal to its relation to individuation.

The acquisition theory that we propose accounts for mass–count semantic asymmetry by positing a corresponding syntactic asymmetry, such that all grammatical features have a consistent interpretation across all usages. Specifically, our claim is that the mass–count distinction emerges from the existence of (a) noun features that distinguish noun phrases from other phrases and (b) count features that exist in a subset of noun phrases. Noun phrases that lack count features are by default mass nouns and, thus, do not have a special interpretation in the way that count syntax does. Following our discussion in Barner and Snedeker (2005), we propose that count features have the semantic function of licensing a lexical root's principle of individuation, such that nouns used in count syntax are forced to quantify over individuals.

Based on this framework, the acquisition of count morphosyntax is straightforward. Given that individuation is canonically expressed by count nouns, children acquiring language could first isolate a set of nouns that denote individuals and then subject these nouns to distributional analysis to discover their morphosyntactic properties (as initially defined by their prelinguistic knowledge of abstract individuals and their bias to construe physical objects as individuals; see the introduction and Bloom, 1999). In languages like Chinese or Japanese, this analysis would fail to uncover a morphosyntactic expression of individuation like count syntax and, thus, result in a language with essentially mass nouns only (for arguments that Chinese has only mass nouns, see Chierchia, 1998; Krifka, 1995). However, in languages like English, where the vast majority of individuating nouns are accompanied by count morphosyntax, distributional analysis of individuating nouns would result in the isolation count syntax from other noun environments and, thus, in a distinction between mass and count. Importantly, this procedure makes no appeal to mass syntax *per se,* and posits no special mapping between specific semantic categories and mass nouns. As a result, the account does not rule out the possibility that some mass nouns might denote individuals. Although the proposed acquisition procedure assigns a privileged relation between individuation and count syntax, it leaves completely open the possibility of mapping individuation to particular mass nouns *after* count syntax has been isolated.

Following the acquisition of the mass–count distinction, how are object-mass nouns like *furniture* or *jewelry* acquired? To begin, the acquisition of familiar terms (e.g., jewelry) should be straightforward (e.g., the child need only note the conjunction of mass syntax and individuation). However, the explanation for how new object-mass terms enter a language is more complex. Our proposal is that such nouns are acquired when children hear mass–count ambiguous expressions used to refer to groups of distinct individuals (e.g., "Don't jump on the blicket," where multiple blickets are present; see Barner & McKeown, 2005; Barner & Snedeker, 2005). This is likely to occur in one of two contexts: (a) A speaker uses a singular count noun to refer to a single member of a larger set, or (b) a speaker utters a plural count noun, but the plural morpheme is either inaudible or otherwise not yet accessible to the child (e.g., evidence from Kouider, Halberda, Wood, & Carey, 2006, indicates that children can use verbal agreement to distinguish singular and plural nouns before being able to use bound plural morphology). In either case, the child might interpret novel nouns that lack singular–plural morphosyntax as mass nouns whenever they are taken to refer to multiple individuals. Such a scenario could readily occur in the case of a noun like *furniture* (which is a count noun in French and Spanish). The expression, "Don't jump on the furniture," uttered in French (i.e., *Ne saute pas sur le meuble*) leaves open either a mass or count interpretation of the word *meuble.* However, if uttered in the presence of multiple things, the child may infer that it refers to all of them, note the lack of plural morphology, and conclude that the word is a mass noun that denotes discrete physical objects and quantifies by number.

This account of the origins of object-mass nouns receives support from a recent experiment by Barner and McKeown (2005). This experiment was based, in part, on a study by Gordon (1985), which explored whether the number of objects in an array can be used by children to classify novel nouns as mass or count. Gordon (1985) presented novel names in mass–count ambiguous syntax and used them to name either one object or an array of several identical objects: "Look at my garn." He found that when children first saw only one object, they were more likely to subsequently pluralize the noun (i.e., treat it like a count noun) when referring to a group, compared to when they originally saw multiple individuals. Using this method, Barner and McKeown tested 4-year-old children who had clearly mastered the mass–count distinction. Children were tested using the simple and complex objects of Experiment 1 above were also tested using the word extension task to evaluate their interpretation of the nouns they learned. Like Gordon (1985), we found that children were more likely to pluralize nouns when they were first used to name a single object, for both simple and complex objects (see the first chart in Figure 6). However, we also found that when children failed to pluralize, they were significantly less likely to extend words by shape, particularly for simple objects (see the second chart in Figure 6). The limitations with word extension notwithstanding, this result does suggest that there is a semantic differentiation of nouns that corresponds to pluralization behavior and thus confirms Gordon's (1985) intuition that a failure to pluralize is indicative of mass noun subcategorization. Importantly, we also found that children extended around one half of nonpluralized nouns by shape when they denoted complex objects. In fact, their word extension behavior for pluralized versus nonpluralized nouns maps almost perfectly onto the word extension data for Experiment 1 above (see Figure 6). Combined, these pluralization and word extension results indicate that children might acquire object-mass terms under conditions where novel mass–count am-

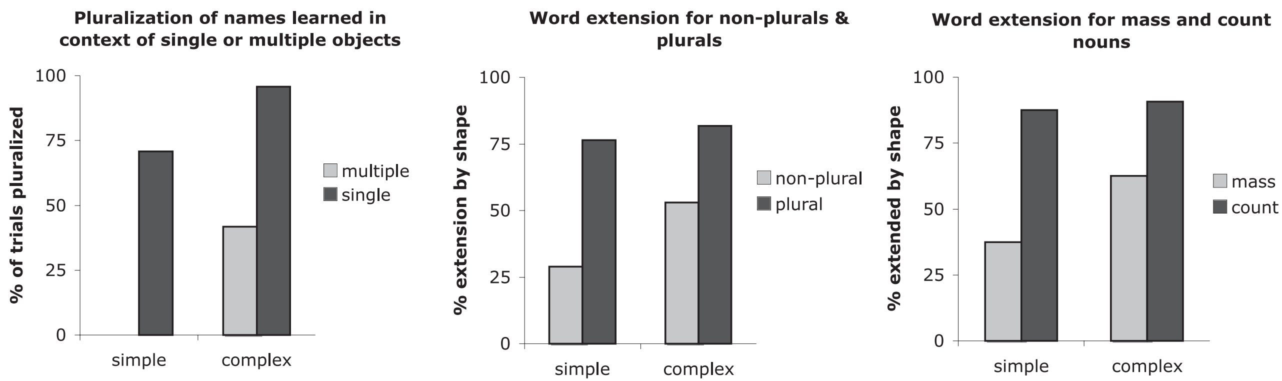


FIGURE 6 Pluralization of words learned in the presence of single or multiple objects (for both simple and complex stimuli and word extension for pluralized and unpluralized nouns, when acquired in the presence of single or multiple objects; Barner & McKeown, 2004); word extension data from Experiment 1.

biguous nouns are used to name groups of clear individuals (as indicated by factors like complexity; for details, see Barner & McKeown, 2004).[13]

When does the mass–count distinction first emerge in language acquisition? Recent studies of children's understanding of singular–plural morphology indicate that children begin to comprehend the quantificational properties of count nouns (and therefore the mass–count distinction, by our account) just before their second birthday. Wood, Kouider, and Carey (2005) report that in a manual search paradigm, 24-month-old children use singular–plural information to guide the retrieval of hidden objects (e.g., searching longer when told "there are blickets in the box" then when told "there is a blicket in the box"), but 20-month-old children do not. Similarly, Kouider et al. (2006) show this same early knowledge of singular–plural interpretation using a preferential looking paradigm. Again, 24-month-old children used singular–plural morphosyntax to guide looking to sets of one object (e.g., there is *a* blicket) or many (e.g., there are *some* blickets). In both studies, children exhibited this knowledge with both familiar and novel words. Importantly, this first knowledge of count quantification emerges by as early as 22 months of age (see Barner, Thalwitz, Wood, & Carey, 2005), a full 8 months before reliable effects of mass–count syntax are found in word extension. This supports the idea that the interpretation of mass–count syntax is based on quantification from the beginning, and that correlations between syntax and object properties (e.g., shape, solidity, etc.) are learned later in acquisition.

CONCLUSION

To conclude, we explored the relation between mass–count syntax and semantics and found that mass syntax fails to force an unindividuated construal of objects in 3-year-old children. This evidence suggests that bootstrapping models like Bloom's (1999) do not provide an adequate account of early mass–count acquisition. We also found that quantity judgment is more sensitive to adult knowledge of mass–count syntax than word extension. This argues for distinguishing between aspects of meanings that derive from mass–count quantification (e.g., individuation) and lexical meanings that are correlated with mass–count syntax (e.g., shape, solidity, substance). Just as the object–substance distinction does not derive from mass–count syntax, contrary to Quine (1960), it is also not the root of mass–count syntax, contrary to Macnamara (1982). Instead, we have argued that knowledge about shape, so-

[13]This idea is consistent with the claim of Wisniewski, Imai, and Casey (1996) that mass superordinate terms (which are often object-mass terms) are more likely than count superordinates to denote "groups of objects united by spatial, temporal, and functional contiguity" (p. 292) because referring to such groups should increase the likelihood of being acquired as a mass noun, and the heterogeneity of the groups should rule out interpretations whereby the mass noun in question refers to a substance (for a discussion, see Barner & Snedeker, 2005).

lidity, and substance is associated with mass and count frames following the acquisition of mass–count syntax and its relation with individuation. We have suggested that count nouns are distinct from mass nouns both semantically and syntactically because the mass–count distinction arises from a single syntactic feature in count noun phrases. This feature results in distributional differences between count and mass nouns and allows count nouns to license the expression of individuation by particular lexical items. This account permits a theory of acquisition where children use individuation as a cue to count syntax (individuating noun $\leftrightarrow$ noun count) while simultaneously allowing mass nouns to individuate.

ACKNOWLEDGMENTS

This research was supported in part by a fellowship from the National Sciences and Engineering Research Council of Canada to David Barner. Additional funding was provided by Grant NSF IIS 0218852 from the National Science Foundation.

We would like to thank Elizabeth Johnson, Sylvia Yuan, and Mahvash Malik for their help with recruitment, scheduling, and testing. Also, thank you to Peggy Li, Susan Carey, Laura Wagner, Yarrow Dunham, and members of the Lab for Developmental Studies at Harvard University for their useful comments on this research.

REFERENCES

Barner, D., & McKeown, R. (2005). The syntactic encoding of individuation in language and language acquisition. In A. Brugos, M. R. Clark-Cotton, & S. Ha (Eds.), *BUCLD 28: Proceedings of the 28th annual Boston University Conference on Language Development* (pp. 61–72). Somerville, MA: Cascadilla.

Barner, D., & Snedeker, J. (2005). Quantity judgments and individuation: Evidence that mass nouns count. *Cognition, 97,* 41–66.

Barner, D., Thalwitz, D., Wood, J., & Carey, S. (2005). *The relation between non-linguistic and linguistic representations of one and more than one in late infancy.* Manuscript submitted for publication.

Bloom, P. (1994). Semantic competence as an explanation for some transitions in language development. In Y. Levy (Ed.), *Other children, other languages: Theoretical issues in language development* (pp. 41–76). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Bloom, P. (1999). The role of semantics in solving the bootstrapping problem. In R. Jackendoff, P. Bloom, & K. Wynn (Eds.), *Language, logic, and concepts: Essays in memory of John Macnamara* (pp. 285–310). Cambridge, MA: MIT Press.

Bloom, P., & Keleman, D. (1995). Syntactic cues in the acquisition of collective nouns. *Cognition, 56,* 1–30.

Braine, M. D. S. (1992). What sort of innate structure is needed to 'bootstrap' into syntax? *Cognition, 45,* 77–100.

Carey, S. (1993). Speaking of objects, as such. In G. Harman (Ed.), *Conceptions of the mind: Essays in honor of G. A. Miller* (pp. 139–159). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Carey, S., & Xu, F. (2001). Infants' knowledge of objects: Beyond object files and object tracking. *Cognition, 80,* 179–213.

Chierchia, G. (1998). Plurality of mass nouns and the notion of "semantic parameter." *Events and Grammar, 70,* 53–103.

Dale, P. S., & Fenson, L. (1996). Lexical development norms for young children. *Behavior Research Methods, Instruments, & Computers, 28,* 125–127.

Dickinson, D. K. (1988). Learning names for material: Factors constraining and limiting hypotheses about word meaning. *Cognitive Development, 3,* 15–35.

Donaldson, M., & Balfour, G. (1968). Less is more: A study of language comprehension in children. *British Journal of Psychology, 59,* 461–471.

Feigenson, L., & Carey, S. (2003). Tracking individuals via object-files: Evidence from infants' manual search. *Developmental Science, 6,* 568–584.

Feigenson, L., & Carey, S. (2005). On the limits of infants' quantification of small object arrays. *Cognition, 97,* 295–313.

Feigenson, L., Carey, S., & Hauser, M. (2002). The representations underlying infants' choice of more: Object-files versus analog magnitudes. *Psychological Science, 13,* 150–156.

Fenson, L., Dale, P. S., Reznick, J. S., Thal, D., Bates, E., Hartung, J. P., et al. (1993). *The MacArthur Communicative Development Inventories: User's guide and technical manual.* San Diego, CA: Singular.

Gathercole, V. (1985). More and more and more about more. *Journal of Experimental Child Psychology, 40,* 73–104.

Gillon, B. (1992). Towards a common semantics for English count and mass nouns. *Linguistics and Philosophy, 15,* 597–640.

Gillon, B. (1999). The lexical semantics of English count and mass nouns. In E. Viegas (Ed.), *The breadth and depth of semantic lexicons* (pp. 19–37). Dordrecht, The Netherlands: Kluwer.

Giralt, N., & Bloom, P. (2000). How special are objects? Children's reasoning about objects, parts, and holes. *Psychological Science, 11,* 497–501.

Gordon, P. (1985). Evaluating the semantic categories hypothesis: The case of the mass/count distinction. *Cognition, 20,* 209–242.

Gordon, P. (1988). Mass/count category acquisition: Distributional distinctions in children's speech. *Journal of Child Language, 15,* 109–128.

Imai, M., & Gentner, D. (1997). A cross-linguistic study on early word meaning. Universal ontology and linguistic influence. *Cognition, 62,* 169–200.

Imai, M., Gentner, D., & Uchida, N. (1994). Children's theories of word meaning: The role of shape similarity in early acquisition. *Cognitive Development, 9,* 45–75.

Kennedy, C. (1999). *Projecting the adjective: The syntax and semantics of gradability and comparison.* New York: Garland.

Krifka, M. (1995). Common nouns: A contrastive analysis of Chinese and English. In G. Carlson & F. Pelletier (Eds.), *The generic book* (pp. 398–411). Chicago: University of Chicago Press.

Kouider, S., Halberda, J., Wood, J., & Carey, S. (2006). Acquisition of English number marking: The singular plural distinction. *Language Learning and Development, 2,* 1–25.

Landau, B., Smith, L. B., & Jones, S. S. (1988). The importance of shape in early lexical learning. *Cognitive Development, 3,* 299–321.

Landman, F. (1991). *Structures for semantics.* Dordrecht, The Netherlands: Kluwer.

Li, P., Dunham, Y., & Carey, S. (2005). *Of substance: The nature of language effects on entity construal.* Manuscript under review..

Link, G. (1983). The logical analysis of plurals and mass terms: A lattice-theoretical approach. In R. Bauerle, C. Schwarze, & A. Stechow (Eds.), *Meaning, use, and interpretation of language* (pp. 302–323). Berlin, Germany: de Gruyter.

Lipton, J. S., & Spelke, E. S. (2006). Discrimination of large and small numerosities by human infants. *Cognition, 98,* B57–B66.

Lucy, J. (1992). *Grammatical categories and cognition.* Cambridge, England: Cambridge University Press.

Lycan, W. (1996). *Consciousness and experience.* Cambridge, MA: MIT Press.

Macnamara, J., (1972). The cognitive basis of language learning in infants. *Psychological Review, 79,* 1–13.

Macnamara, J. (1982). *Names for things: A study of human learning.* Cambridge, MA: MIT.

MacWhinney, B. (2000). *The CHILDES project: Tools for analyzing talk.* Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Mazuka, R., & Friedman, R. (2000). Linguistic relativity in Japanese and English: Is language the primary determinant in object classification? *Journal of East Asian Linguistics, 9,* 325–351.

McCawley, J. (1975). Lexicography and the count-mass distinction. In *Proceedings of the First Berkeley Linguistic Society Conference* (pp. 314–321). Berkeley: University of California.

Nelson, K., Hampson, J., & Shaw, L. K. (1993). Nouns in early lexicons: Evidence, explanations and implications. *Journal of Child Language, 20,* 61–84.

Palermo, D. (1973). More about less: A study of language comprehension. *Journal of Verbal Learning and Verbal Behavior, 12,* 211–221.

Papafragou, A. (2005) Relations between language and thought: Individuation and the count/mass distinction. In C. Lefebvre & H. Cohen (Eds.), *Handbook of categorization in cognitive science.* New York: Elsevier.

Quine, W. V. O. (1960). *Word and object.* Cambridge, MA: MIT Press.

Samuelson, L. K. (2002). Statistical regularities in vocabulary guide language acquisition in connectionist models and 15–20-month-olds. *Developmental Psychology, 38,* 1016–1037.

Samuelson, L. K., & Smith, L. B. (1999). Early noun vocabularies: Do ontology, category structure, and syntax correspond? *Cognition, 71,* 1–33.

Schlesinger, I. M. (1971). Semantic assimilation in the development of relational categories. In D. I. Slobin (Ed.), *The ontogenesis of grammar* (pp. 63–101) San Diego, CA: Academic.

Shippley, E. F., & Shepperson, B. (1990). Countable entities: developmental changes. *Cognition, 34,* 109–136.

Soja, N. N. (1992). Inferences about the meanings of nouns: The relationship between perception and syntax. *Cognitive Development, 7,* 29–45.

Soja, N. N., Carey, S., & Spelke, E. (1991). Ontological categories guide young children's inductions of word meaning: Object terms and substance terms. *Cognition, 38,* 179–211.

Subrahmanyam, K., Landau, B., & Gelman, R. (1999). Shape, material, and syntax: Interacting forces in children's learning of novel words for objects and substances. *Language and Cognitive Processes, 14,* 249–281.

Wagner, L., & Carey, S. (2003). Individuation of objects and events: A developmental study. *Cognition, 90,* 163–191.

Wisniewski, E. J., Imai, M., & Casey, L. (1996). On the equivalence of superordinate concepts. *Cognition, 60,* 269–298.

Wood, J. N., Kouider, S., & Carey, S. (2005). *The developmental origins of the singular/plural distinction.* Manuscript in preparation.

Wood, J. N., & Spelke, E. S. (2005). Infants' enumeration of actions: Numerical discrimination and its signature limits. *Developmental Science, 8,* 173–181.

Spelke, E. (1985). Perception of unity, persistence, and identity: Thoughts on infants' conception of objects. In J. Mehler & R. Fox (Eds.), *Neonate cognition: Beyond the blooming and buzzing confusion* (pp. 89–113). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Wynn, K. (1992). Evidence against empiricist accounts of the origins of numerical knowledge. *Mind and Language, 7,* 315–332.

Wynn, K. (1996). Infants' individuation and enumeration of actions. *Psychological Science, 7,* 164–169.

APPENDIX A

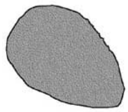
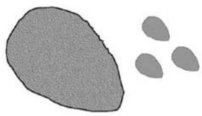
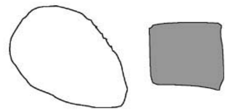
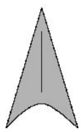
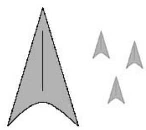
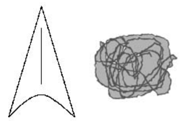
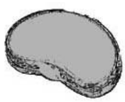
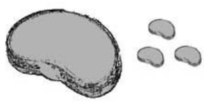
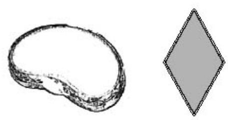
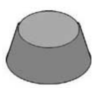
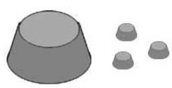
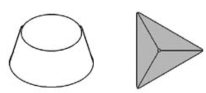
Name	Standard	Quantity judgment set	Word extension set
Fem (simple)	 red “sculpy” modeling compound (complexity = 1.75)	 volume ratio = 7.25:1	 shape match: styofoam half egg substance match: flat red “sculpy” square
Tannin (simple)	 brown terracotta arrow (complexity = 3.19)	 volume ratio = 4:1	 shape match: stone texture arrow substance match: tangled terracotta sphere
Tulver (simple)	 painted green clay kidney bean (complexity = 2.00)	 volume ratio = 4.75:1	 shape match: red wax kidney bean substance match: painted green clay diamond
Dak (simple)	 black Crayola-Magic cork (complexity = 2.31)	 volume ratio = 4:1	 shape match: white clay cork substance match: black Crayola-Magic tetrahedron

FIGURE A1 Drawings of simple solid objects from Experiment 1. Standard items are shown with their complexity ratings out of 7. Quantity judgment sets are shown with the ratio of the one large object versus the three small objects combined (by volume).

APPENDIX B

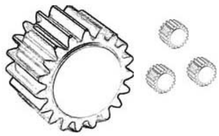
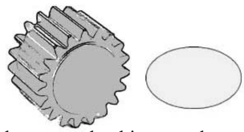
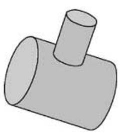
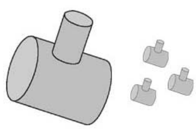
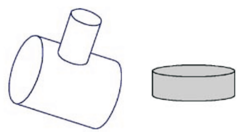
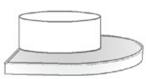
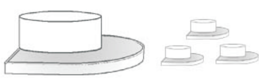
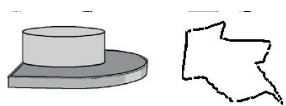
Name	Standard	Quantity judgment set	Word extension set
Fem (simple)	 orange playdoh gear (complexity = 5.13)	 volume ratio = 9:1	 shape match: shiny purple gear substance match: orange playdoh oval
Tannin (simple)	 suede –texture painted reamer (complexity = 6.20)	 volume ratio = 6.25:1	 shape match: metallic silver painted reamer substance match: suede mini palette
Tulver (simple)	 brass T plumbing fixture (complexity = 4.2)	 volume ratio = 4:1	 shape match: white plastic plumbing fixture substance match: copper ring
Dak (simple)	 white clay milk pump stand (complexity = 5.19)	 volume ratio = 6:1	 shape match: sparkly orange rubberized pump stand substance match: jagged flat white clay

FIGURE B1 Drawings of complex solid objects from Experiment 1. Standard items are shown with their complexity ratings out of 7. Quantity judgment sets are shown with the ratio of the one large object versus the three small objects combined (by volume).