Relationship Between Count/Mass Nouns and Shape/Material Biases in Novel Word Learning Tasks

Rebecca Frausel

B.A., Psychology & English Literature

Honors Thesis, Spring 2011

Defense: March 30, 2011

Revised April 4, 2011

Committee Members:

Primary Advisor: Eliana Colunga, Assistant Professor, Department of Psychology

Matt Keller, Assistant Professor & Honors Council Representative, Department of Psychology

Bhuvana Narasimhan, Assistant Professor, Department of Linguistics
Abstract

Children use biases to learn novel words and extend these words to novel objects without having to give consideration to every possible meaning of the new word. Using Novel Noun Generalization Tasks, researchers have found that children 2-years-old tend to extend names for solid objects to other objects that are the same shape, which is called the shape bias (Landau, Smith, & Jones, 1988; Soja, Carey, & Spelke, 1991; Imai & Gentner, 1997). Children 2½-years-old also extend names for non-solid substances to things that have the same material, which is called the material bias (Dickinson, 1988; Soja 1992; Imai & Gentner, 1997; Landau, Smith, & Jones, 1992; Diesndruck & Bloom, 2003). In early vocabulary, count nouns tend to refer to solid objects and mass nouns tend to refer to non-solid substances (Samuelson & Smith, 1999). This study tests whether a child’s knowledge of count and mass nouns at age 24 months influences their performance on two NNGTs, one using solid objects and one using non-solid substances. Our results found that total number of nouns (count, mass, and ambiguous) in a child’s vocabulary does influence whether they exhibit the shape or material biases for either solid objects or non-solid substances. 24-month-olds with a larger noun vocabulary tend to extend the names of both solid objects and non-solid substances to shape, and 24-month-olds with a smaller noun vocabulary tend to extend the names of both solid objects and non-solid substances to material. We also found that both a larger number of count nouns and pro-shape bias words (nouns that describe categories of objects that are solid and match in shape) is negatively correlated with whether children pick material matches for solid objects. Thus, the more count nouns and pro-shape bias words a child has, the less likely they are to choose material matches for solid objects. These results show that attending to shape, not material, can create a larger vocabulary in 24-month-olds.
Introduction

A child’s acquisition of language is an amazing thing to witness. Children will go from babbling to learning eight to ten new words a day in just a few years (Carey, 1978; Miller, 1977). Children are fast-mappers, which means they can learn a new word after being exposed to it just one time (Landau, Smith, & Jones, 1988). This is remarkable, given the sheer number of things in the world that a new word could refer to. For example, if one shows a child a picture of a strange-looking brown fur-covered creature with large ears, a long snout, and a pointy, bare tale, and said the novel word “aardvark,” there are many different characteristics of the creature the child knows the word could refer to. For example, “aardvark” could refer to the whole animal, this particular animal (i.e. its proper name), the tail, the ears, the color, and so on. But children ages 3 years and up would assume that the word refers to the whole animal (Markman & Wachtel, 1988), and they would be correct.

How do children infer this knowledge based on just one instance of hearing a word? Children are so efficient because they seem to know a lot about how words map to meanings; they are biased learners. Despite the negative connotation the word “bias” implies, biases actually aid learning, because children don’t give consideration to every possible meaning of a word. Rather, children use the knowledge of the world they already have to determine which of the possible meanings of a word is most likely. In this case, children assume “aardvark” refers to the whole animal because of a bias called the Whole Object Assumption, where children assume that if they hear a novel word and the word could refer to an object, it refers to the whole object, not a part or other aspect of its being (Markman & Wachtel, 1988). Biases help children determine what a new word could refer to.
One way that researchers test what biases children exhibit is by using novel word learning tasks called Novel Noun Generalization Tasks (NNGTs). NNGTs are used to infer how children generalize a new word to novel objects. In these tasks, children are shown a novel object or substance (an exemplar), and told it has a novel name. The child is shown other novel objects/substances, some of which match in shape, some in material, some in color, etc., and is asked what else can be called by that novel name. Novel Noun Generalization Tasks are an excellent method to see what properties of an object or substance children are paying attention to, and therefore what they are biased towards.

This paper will try to determine if the types of words children have in their productive vocabulary influences what biases they exhibit. In this Introduction, we will begin by giving some background information about the biases we will be examining, the shape and material biases. We will then explain the types of words we are interested in, count and mass nouns, before describing the measurement used to determine the child’s productive vocabulary, the MCDI. Several previous studies have looked at the relationship between shape/material biases and count/mass nouns, and we will explain the key theories that have been proposed to explain the relationship. We will also describe some past studies observing the relationship, before describing the present study and our predictions. Our main research question is: Do the types of words, specifically count and mass nouns, that 24-month-olds know influence whether they exhibit the shape or material bias for solids or non-solids?

A. Shape and Material Biases

Two types of biases that children have been show to exhibit using NNGT's are the shape bias and the material bias. The shape bias is when toddlers 24 months and older extend names for solid objects to other objects that have the same shape (Landau, Smith, & Jones, 1988; Soja,
Carey, & Spelke, 1991; Imai & Gentner, 1997). Children learn that for solid objects, things that are the same shape tend to have the same name (for example, all things called “chair” are usually chair-shaped, regardless of the material or color). In addition, a typically developing toddler will begin to exhibit the material bias at about 30 months, which means they extend names for non-solid substances to other substances that are made of the same material (Dickinson, 1988; Soja 1992; Imai & Gentner, 1997; Landau, Smith, & Jones, 1992; Diesndruck & Bloom, 2003). For non-solid substances, children learn that things that are made of the same material tend to have the same name (for example, all things called “pudding” match in material, regardless of shape or color).

The existence of the shape and material biases indicate that for early word learning, there is a relationship between shape and solids, and between material and non-solids. In other words, shape is the most salient feature of solid objects, and material is the most salient feature of non-solid substances. Children seem to know that solids are bounded, individuated objects, and therefore that shape similarities unite classes of objects. Non-solids are non-bounded, continuous substances united by material similarities. Semantically, there seems to be an ontological distinction between solids and non-solids, even very early in word learning, which dictates which perceptual features children pay the most attention to.

The shape and material biases speed up the word-learning process and make learning more efficient. Knowing the names for things helps children interact with the world in more meaningful ways. Furthermore, learning specific object names tunes attention to just the right property, and this attentional learning enables the rate of noun acquisition to take off (Smith et al., 2002). Once children have shape and material biases, their noun vocabulary explodes. This study will be significant because it will determine if known vocabulary will predict what biases a
child exhibits. Therefore, the opposite relationship exists, too: if we know what kinds of words to teach children to create biases, we can rapidly improve early productive vocabulary.

B. Count/Mass Nouns

The relationship between the shape bias for solids and material bias for non-solids parallels the relationship in English between two categories of nouns: count nouns and mass nouns. Count nouns are words such as “cat” and “clock” that can be pluralized (“cats,” “clocks”) and can be preceded by definite and indefinite articles (“the cat,” “a clock”). One can also use expressions such as “many” and “a few” with count nouns (“a few books”). Count nouns typically denote individuals, and we base judgments of “more” by number for count nouns (i.e. “many cats”). Both solid objects and count nouns denote individuals and tend to be categorized by shape.

Mass nouns, on the other hand, are words, such as “ice” and “sugar,” that cannot be pluralized (“ices” is not grammatical). Mass nouns can be preceded by expressions such as “much,” “more,” or no article (e.g. “more ice,” “sugar is sweet”), but cannot be preceded by expressions such as “these” and “every” (e.g. “these weather” is not grammatical). Mass nouns tend to denote an unindividuated construal; we base judgments of “more” by volume for mass nouns (i.e. “much water”). Both non-solid substances and mass nouns tend to be categorized by material. Not every language makes this distinction, but it exists in English.

C. MCDI

In this study, we will be determining the children’s productive vocabulary using a vocabulary checklist called the MacArthur Communicative-Development Inventories (MCDI). The MCDI is a parent-report checklist consisting of 680 of the most common words, including 312 nouns, known by toddlers ages 17-30 months. Parents check off the words that their child
can produce; an average 30-month-old child will produce 50% of the words on the MCDI. The MCDI has been shown to be a dependable and predictive way to measure language development variability among individual children (Desmarais et al., 2008). In addition, it is easy to administer.

Samuelson & Smith (1999) performed a study to determine the categorization of nouns found on the MCDI. The judgments of the nouns were done by adults, who evaluated syntactic category, type of noun, solidity/non-solidity, and similarities in shape/color/material for all 312 nouns on the MCDI. The adult judges (with an 85% agreement rate) determined that the MCDI includes 232 count nouns, 31 mass nouns, and 49 nouns that were classified as neither count nor mass nouns (such as “Coke” or “cake” that are used in both syntactic frames). They found that in early vocabulary, count nouns tend to label categories of solid objects and categories organized by shape; mass nouns tend to label categories of non-solid entities and categories organized by material substance (Samuelson & Smith, 1999) (See Appendix A for complete lists of count and mass nouns as categorized by the adults in the study). However, not all the correlations were equally strong and even the best correlations are imperfect. The diagrams below (Figure 1) show the relationship between solidity, syntax, and category organization in the 312 nouns used on the MCDI.

![Diagrams showing relationship between count, nouns, shape, and solids; and mass nouns, material, and non-solids, for nouns on the MCDI (Samuelson & Smith, 1999).](image-url)
The lopsidedness of the early lexicon suggests that children may start with just one-half of the object-substance distinction; it’s clear that solid objects are usually named by shape, but it’s less clear that non-solid substances are categorized by material. This is reflected in the wide breadth of different results many studies have generated in studying the relationship between count/shape and mass/material. Soja (1992) showed that children 2-2½-years-old were more likely to generalize a novel name for a solid exemplar by shape when it was presented in a count noun syntactic frame (i.e. “this is a dax”), and more likely to generalize a novel name for a non-solid exemplar by material when it was presented in a mass syntactic frame (i.e. “this is some dax”). But in another study, even when nouns were used in mass syntax, 3-year-olds would extend by shape about half of the time, and they based quantity judgments on number, rather than volume (Barner and Snedeker, 2006). This research shows that the relationship between shape, solidity, and count; and material, non-solidity, and mass, is not 1:1. But still, the solidity of an object/substance and the syntax used to describe it are related.

D. Theories Behind the Relationship

The relationship between the number of nouns a child produces and the biases they exhibit seems to be fairly well documented among young children. As Gershkoff-Stowe & Smith (2004) showed, when a child knows between 25 and 50 words, they have an equal chance of choosing a shape, material, or color match on a Novel Noun Generalization Task. But when the child knows more than 50 words, biases begin to emerge. As the number of nouns increased in the child’s productive vocabulary, the number of shape matches rose (Gershkoff-Stowe & Smith, 2004). But there is considerable debate on the idea of which distinction comes first: the count/mass distinction (syntax) or the shape/material biases (ontological categories, or
semantics). Do biases emerge as a product of word learning, or is word learning a product of biases?

Three theories have been proposed to explain the relationship. One theory is called attentional learning. According to this account, the shape bias results from learned associations between count nouns and shape similarities (Diesendruck & Bloom, 2003). The association refers only to count nouns because count nouns tend to refer to object categories. This process acts as a feedback loop: as children learn more words, their shape bias grows stronger, and vice-versa (Gershkoff-Stowe & Smith, 2004). Once the association between count nouns and similarity in shape is established, the extension of a novel name is driven by attention.

Quine (1960) proposed another theory. He hypothesized that ontological categories emerge as a product of language learning using syntax, or that syntax guides semantics. Children begin to distinguish between different types of ontological categories (such as solid and non-solid) only when they learn syntax. Children work out the use of determiners on their own, and through generalizations, learn the ontological distinction between objects and substances (Quine, 1960). Quine’s theory has two main proposals: (1) Children are only able to distinguish among different types of word meanings involving different types of quantification when they learn the syntax of quantification; in other words, that they do not make the object/substance categorization until they have acquired count/mass syntax. He also claims that (2) until children learn count/mass syntax, they lack any concept of individual solids and continuous non-solid substances. These semantic distinctions between solids and non-solids do not guide the learning process, but are a result of it.

Soja, Carey, & Spelke (1991) proposed an alternative theory to explain the relationship: that children approach the task of language learning with a pre-existing set of ontological
categories, and they use these categories to discover count/mass syntax; in other words, that *semantics* guides *syntax*. As Soja, Carey, & Spelke (1991) found, there is no correlation between the productive control of count/mass nouns, and the children’s ability to differentiate between solid and non-solid exemplars. This contradicts Quine, who believed that children do not initially distinguish objects from substances. But as Spelke (1985) showed, pre-linguistic infants conceptualize solid objects in a way that differentiates them from non-solid substances, which indicates that children do not need syntax to know there is a difference between solids and substances.

This suggests that there is another way count/mass syntax could influence the shape/material biases: the count/mass subcategorization could affect the children’s interpretation of that word. It is not the syntax itself that points, but what the speaker is intending to communicate. As Soja (1992) writes, any solid object can be construed either as an individual (“a chair”) or a kind of substance (“some wood”); similarly, any substance can be construed as a kind of substance (“some mud”) or an individual (“a puddle”). The words we choose refer to the nature of what we intend to communicate, and not inherently the nature of the *stuff*. Children, therefore, could believe that count nouns pick out individuals and mass nouns pick out portions of substance. Since words depend so much on context, perhaps a child’s prior word knowledge influences how they interpret the meaning of new words.

Soja, Carey, & Spelke (1991) tested this proposal using 2-2½ year olds. They used a Novel Noun Generalization Task where the children were taught a new word that labeled either an object or a substance. The children were asked what else could be called by that new word. On the solid trial, their choices were a shape match (but different material), or three or four small pieces of the same material. On the substance trial, their choices were a new substance in the
same shape as the exemplar, or three or four pieces of the original substance. The study found that on the object trials, children chose the object of the original shape; in the substance trial, children chose the pieces of the substance. This indicates that children base their inferences about word meanings on an initial categorization of the labeled entity as an object or a substance. When they looked at the children’s vocabulary, they found that there was no correlation between their productive control of count/mass syntax and their ability to differentiate the two kinds of trials (Soja, Carey, & Spelke, 1991).

Soja (1992) performed another experiment to determine whether syntax or perceptual features were more important to children 2-2½-years-old. She achieved this by reversing the syntax pairing so syntax and ontology conflicted: objects were labeled with mass nouns, and substances were labeled with count nouns. She found that on the object trials, even children in the conflicting condition still responded according to shape. For the substance trials, there was more of an effect of the conflicting syntax, in that children were more apt to construe the substance as a token of a kind of substance when it was labeled by a mass noun. This suggests that children are sensitive to syntax when the entity labeled is a non-solid substance (Soja, 1992).

E. Description of Study and Predictions

The current study seeks to determine if a child’s vocabulary composition predicts whether they exhibit the shape or material bias for either solid objects or non-solid substances. We will observe the child’s vocabulary composition and compare it to their performance on two NNGTs: one using solid objects and one using non-solid substances. We will observe children at age 24 months, which is the age Soja, Carey, & Spelke (1991) found the shape bias emerges. In addition, we wanted to examine children at a young age because by the time they are more than 3½ years, they have mastered the relevant natural language syntax (Soja, Carey, & Spelke,
1991); thus, it is not clear whether their ontological categorizations precede or follow their acquisition of the syntax. We are specifically focusing on one aspect of the child’s vocabulary composition: the child’s knowledge of count and mass nouns. We want to know whether their noun vocabulary’s composition influences their performance on the NNGTs. Soja, Carey, & Spelke (1991) tested productive command of count/mass syntax by obtaining speech production samples from each child and assessing his or her mastery of noun phrase syntax. However, for the purposes of our experiment, we are using the number of count and mass nouns a child has in their productive vocabulary as a proxy for mass-count noun knowledge.

Most of the prior research has been done solely on the shape bias and count nouns, or on the shape/material biases with no assessment of productive vocabulary. No one has performed research to see if mass or count nouns influences either the shape or material biases. Our predictions for this study are that children with an excess of count nouns will choose shape matches for both the solid and non-solid conditions; children with more mass nouns will choose material matches for both non-solid and solid conditions. Eventually, when the child’s vocabulary gets large enough (as predicted by Gershkoff-Stowe & Smith, 2004), the Generalized Shape and Material Biases will disappear and be replaced by the shape bias for solids and material bias for non-solids (See Table 2). This study will be unique in determining if there is a relationship between these two facets of early child language development.
We are proposing these hypotheses because previous research has shown that the number of nouns a child has in their vocabulary influences whether they exhibit the shape bias (Gershkoff-Stowe & Smith, 2004), and a child’s expectations about what a word means will influence how they interpret it (Soja, 1992). This means novel words given to a child in a Novel Noun Generalization Task are open to the child’s interpretation. When children have a small vocabulary, the knowledge of words a child already has could dictate how future knowledge is acquired, at least until the child acquires enough count and mass nouns to exhibit both biases.

Quine believed that a child would not be able to differentiate between solid objects and non-solid substances until they learn syntax. Our proposal does not go quite so far, but does suggest that prior knowledge of count and mass syntax does matter. If a child knows a lot of words for objects that describe solid individuals that match in shape, they might generalize this pattern even to non-solid substances, and vice-versa. The types of words that children know early in language learning could influence the child’s expectations about the word’s meaning.

Table 2. Predictions for Current Study

<table>
<thead>
<tr>
<th>Choice on NNGT with Solids</th>
<th>Choice on NNGT with Non-solids</th>
<th>Predicted Vocabulary Composition</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shape match</td>
<td>Shape match</td>
<td>More count nouns</td>
<td>Generalized Shape Bias</td>
</tr>
<tr>
<td>Shape match</td>
<td>Material match</td>
<td>Larger vocabulary (both count and mass nouns)</td>
<td>Shape Bias for Solids, Material Bias for Non-solids</td>
</tr>
<tr>
<td>Material match</td>
<td>Material match</td>
<td>More mass nouns</td>
<td>Generalized Material Bias</td>
</tr>
</tbody>
</table>

1 I am not including a hypothesis for Material Match for Solids and Shape Match for Non-solids because none of the participants exhibited this pattern.
Methods

A. Participants

These analyses come from data from 29 participants from the Boulder/Denver Metro area. Participants were compensated with $5 for travel, and the child also received a book as a prize. Children were recruited using the University of Colorado Cognitive Development Center Database, which is publicized through a letter from the Colorado State Health Department, and information at local daycares, preschools, and magazines. Of our participants, 14 are girls and 15 are boys. They visited the lab when they were 24-months-old ($M_{age} = 24.53, sd = 1.0$, range = 22.3 to 26.4). The children in the study came from middle-class families who spoke English as a primary language (although according to parent reports, seven of the participants were being raised in bilingual households: four Spanish, one French, one Marathi, and one Japanese.)

B. Stimuli

The stimuli consisted of a set of novel solid objects and a set of novel non-solid substances. The stimuli were all made in the lab. Each set contained an exemplar and five test objects. For the solid set, two test objects matched the exemplar in shape, but not material or color; one matched in material, but not shape or color; one matched in color, but not material or shape; and one matched in both color and material, but not shape (See Figure 3). In Soja, Carey, & Spelke’s (1991) experiment, the material match also matched exemplar in color, but in the sets used by Samuelson & Smith (1999), the material matches never matched in color. We decided to unconfound material and color by including a color match, a material match, and a color and material match. This meant that there were an equal number of matches of everything presented.

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2 The data is part of a larger longitudinal study that actually involved 34 participants (17 girls and 17 boys) who were recruited for a 12-month longitudinal study, which observed participants at monthly sessions (following the procedure described below) from 17-29 months. The data analyzed here comes from the children’s eighth visit to the lab.
to the child (two shape matches, two material matches, and two color matches). The exemplar was a yellow “bowling pin”-shaped object covered in yellow paper-mâché. The two shape matches were one covered in red tape and one covered in blue feathers. The color match was a smooth yellow L-shape. The material match was a lumpy figure covered in green paper-mâché. The color and material match was a yellow paper-mâché triangular polyhedron.

For the non-solid set, two of the test substances matched the exemplar in material, but not color or shape; one matched the exemplar in shape, but not color or material; one matched the exemplar in color, but not shape or material; and one matched the exemplar in both color and shape, but not material (See Figure 3). There were an equal number of matches of everything presented to the child (two material matches, two color matches, two shape matches). The exemplar was red toothpaste in the shape of a wide “M.” The two material matches were orange toothpaste and green toothpaste: the orange toothpaste was in the shape of an incomplete triangle, and the green toothpaste was in the shape of a squiggle. The color match was red sand in the shape of a circle. The shape match was brown seeds in the shape of a wide “M.” The color and shape match was red paint in the shape of a wide “M.” All stimuli in this set were presented on squares of white poster board, and were remade for each experimental session.
C. Procedure

At the session, parents read and signed a permission form for their child. After the form was completed, the child, parent, and experimenter moved to another room in the laboratory to perform the tasks.

1. Tasks

   a. Warm-up Task: The materials used for the warm-up task consisted of six common objects (three balls of different colors, a green spoon, an orange clip, and a yellow wheel). The purpose of the warm-up task was to familiarize the child with the procedure, and to get them comfortable with the idea of choosing some objects and not others. The experimenter asked the parent to refrain from naming any of the objects, but encourage their child to explore the objects, and encourage their child to answer the experimenter’s questions. The experimenter gave the child the objects to play with. The experimenter made sure the child looked at or held all the objects, which usually took one to two minutes. The experimenter then retrieved all the objects.
from the child and placed them on a tray. The experimenter held up one of the balls and said, “See the ball? Look at the ball!” The experimenter then handed the child the ball, and labeled it at least one more time. She then took the ball back and presented the other five objects on the tray to the child. Next, the experimenter said, “Can you help me find another ball? Is there another ball?” If the child chose the ball, she or he was praised. If the child chose one of the other objects, the experimenter would correct him or her, saying, “That’s not a ball! Can you help me find the ball?” This was continued until all the balls were given to the experimenter, or the child stopped choosing. Ideally, the child would say “No,” after being asked “Is there another ball?” but in most cases the child would just stop choosing.

b. **Solid NNGT**: The experimental trials were similar to the warm-up task, except they used novel stimuli and novel names. The first NNGT used the solid object set as described above. The relative positions of the objects on the tray were randomly determined for each trial. The child would be given one to two minutes to look at all the objects. Then the experimenter would hold up the exemplar and say, “See the palo (/ˈpɛloʊ/)? Look at the palo!” The experimenter gave the exemplar to the child to look at, making sure to name it once more. The experimenter presented the other five objects on the tray to the child and said, “Can you help me find another palo? Is there another palo?” The experimenter made sure to use count syntax when referring to the objects. The child’s responses were marked on a data sheet, including the order of choice.

c. **Non-solid NNGT**: For the Non-solid Novel Noun Generalization Task, the experimenter, parent, and child changed rooms so there would be no lingering effects of the first task. The second NNGT follows the exact same procedure. Again, an exemplar plus five non-solids (as described above) were shown to the child. The locations of the pieces of poster board
were randomly determined for each trial. The child would be given one to two minutes to explore all the non-solid substances. The experimenter would encourage the child to touch the substances, but to be very careful and to only touch them with one finger (to preserve their shapes). Parents would help the experimenter clean the child’s hands. The experimenter then moved the substances away from the child’s side of the table. The experimenter then would point out the exemplar and say, “See the mofet (/ˈma.fət/)? Look at the mofet!” The experimenter would push the other pieces of poster board toward the child and say, “Can you help me find more mofet? Is there more mofet?” The experimenter made sure to use mass syntax when referring to the substances. The child’s responses were marked on a data sheet, including order of choice.

2. *MCDI*

After the tasks were completed, parents filled out the MacArthur Communicative-Development Inventories, as described above. They could choose to complete the inventory in the lab or to complete it at home. Parents usually filled it out within a week of their visit ($M_{\text{days}} = 6.42$, $sd = 9.36$, range = 0 to 35). In our instructions, we told parents to mark the words they have heard their child produce (differentiating between production and knowledge). We told parents that if their child systematically uses a different pronunciation of a word (for example, “sketti” for “spaghetti”), to mark the word anyway. If the child is knows multiple languages, we told parents to mark the words their child produces in all languages.

We used a modified calculator developed by Samuelson & Smith (1999) to calculate the number of words each child had in their productive vocabulary. We also determined the total number of nouns (count, mass, and ambiguous) and total number of count and mass nouns, as well as the number of words each child had that were *pro-shape bias* and *pro-material bias*. The
pro-shape bias words are count nouns that describe solid objects that match in shape \((n = 111)\); the pro-material bias words are mass nouns that describe non-solid substances that match in material \((n = 6)\). In the diagrams on page 7, these are the words where all the circles overlap; in Appendix A, these are the words in boldface.

Results

For this study, we proposed that there is a relationship between the number and type of nouns a child has in his or her productive vocabulary, and whether the child exhibits the shape or material bias for either solid objects or non-solid substances. Specifically, we proposed that if a child has more count nouns in their vocabulary, they will choose shape matches for both solid and non-solid trials. If a child has more mass nouns in their vocabulary, they will choose material matches for both solid and non-solid trials.

We measured whether the participants exhibited the shape and material biases using a formula weighting the choices they made on each of the Novel Noun Generalization Tasks. To incorporate information on order of choice, we converted their raw data into a weighted score as follows: their first choice received a score of three points, their second choice received a score of two points, and their third choice received a score of one point (choices after this received a score of zero points). We calculated four scores for each child: Solid-Shape, Solid-Material, Non-Solid Shape, and Non-solid-Material. The Solid-Shape score is the participant’s weighted score for shape matches on the solid task, and the Solid-Material score is the participant’s weighted score for material matches on the solid task. The Non-solid-Shape Score is the participant’s weighted score for shape matches on the non-solid task, and the Non-solid-Material
Score is the participant’s weighted score for material matches on the non-solid task (See Appendix B for a more detailed explanation of choice data coding and examples).

As mentioned above, we used a modified version of the calculator developed by Samuelson & Smith (1999) to determine the total number of words, nouns, mass nouns, count nouns, pro-shape bias words, and pro-material bias words, as reported by the parent on the MCDI.

Based on the children’s productive noun vocabulary, we divided the participants into four language groups: Group 1 had a productive noun vocabulary of <50 \((n = 4)\), Group 2 had a productive noun vocabulary of 51 to 155 \((n = 3)\), Group 3 had a productive noun vocabulary of 156 to 250 \((n = 9)\), and Group 4 had a productive noun vocabulary of >251 \((n = 13)\). These are the same group divisions of productive noun vocabulary used by Samuelson & Smith (1999).

The following graph (See Figure 4) shows the mean scores for the NNGTs divided by language group. In this graph, the blue bars (solid-shape) represent the shape bias for solids, the red bars (solid-material) represent the material bias for solids, the yellow bar (non-solid-shape) represents the shape bias for non-solids, and the green bars (non-solid material) represents material bias for non-solids.
Figure 4. Weighted scores for choices on NNGTs and productive noun vocabulary.

We performed a 2 (solidity: solid, non-solid) x 2 (dimension: shape, material) x 4 (language group: <50 nouns, 51-155 nouns, 156-250 nouns, >251 nouns) ANOVA and found a significant interaction between solidity and language group, $F(1,25) = 5.337, p = .006$. This indicates that their performance for solids and non-solids depends on the child’s language group. Number of nouns does influence their choices. Although post-hoc analyses did not reveal any significant values, it is possible to infer overall patterns from the data.

The participants in Groups 1 and 2, who have a productive noun vocabulary <155, trend towards a stronger material bias for both solids and non-solids. This supports the results found by Jones (2003). Jones found that children whom she considered late talkers (which she defined as being below the 30th percentile for total words on the MCDI, based on other children their age and gender) did not show the shape bias; instead, they systematically extended novel names to objects with the same material (2003). This supports the claim that the shape bias is an aid to object name acquisition. For the participants in Group 1, the mean percentile ranking for total number of words was 7.5%, and for the participants in Group 2, the mean percentile ranking for
total number of words was 40%, meaning Jones would most likely consider children in these groups late talkers. Our participants in Groups 1 and 2 who have <155 nouns in their productive vocabulary appear to have developed the wrong attentional bias for solid object naming. They pay attention to material for both solids and non-solids; this could explain why they have so few nouns.

On the other hand, participants trend towards picking shape matches for the solid trials in Groups 3 and 4, when noun vocabulary >156, which replicates the results found by Soja, Carey, & Spelke (1991). Children in these groups also trend towards picking shape matches for non-solids, which replicates the results found by Barner & Snedeker (2006). Our results show that 24-month-olds with a noun vocabulary >156 trend towards a Generalized Shape Bias; however, this is predicted by the total number of nouns, not just count nouns.

It is evident that there is a relationship between the total number of nouns and what biases children exhibit; however, the details aren’t clear. Because the number of nouns in a child’s vocabulary is highly correlated with their total number of words, total number of count and mass nouns, and total number of pro-shape and pro-material bias words, we will try to determine which words are causing the effect. For the purposes of analyzing the data, we will go from general to specific: first observing if the total number of words influences whether the participants pick shape or material matches on the solid and non-solid tasks; then total number of nouns; then count nouns and mass nouns; then pro-shape bias words and pro-material bias words.
A. Total Words

Partial correlation was used to explore the relationship between whether 24-month-olds exhibit the shape or material biases for either solids or non-solids (as measured by our weighted scores) and total number of words in their vocabulary, while controlling for age (See Table 5).

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<thead>
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<th>Non-Solid</th>
</tr>
</thead>
<tbody>
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<tr>
<td></td>
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<td></td>
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<tr>
<td></td>
<td>df = 26</td>
<td>df = 26</td>
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</tbody>
</table>

Table 5. Relationship between total number of words and choices on NNGT.

As the chart above shows, the total number of words in a child’s productive vocabulary is not correlated with whether they exhibit the shape or material biases for either solids or non-solids.

B. Total Nouns

Partial correlation was used to explore the relationship between whether 24-month-olds exhibit the shape or material biases for either solids or non-solids (as measured by our weighted scores) and total number of nouns in their vocabulary, while controlling for age (See Table 6).

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<th>Solid</th>
<th>Non-Solid</th>
</tr>
</thead>
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<td>df = 26</td>
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</table>

Table 6. Relationship between total number of nouns and choices on NNGT.

As the chart above shows, the total number of nouns in a child’s productive vocabulary is not correlated with whether they exhibit the shape or material biases for either solids or non-solids.

C. Total Count Nouns and Total Mass Nouns

Partial correlation was used to explore the relationship between whether 24-month-olds exhibit the shape or material biases for either solids or non-solids (as measured by our weighted scores) and total number of count and mass nouns in their vocabulary, while controlling for age (See Table 7).
As the table above shows, there is a marginally significant negative correlation between having more count nouns and choosing material matches on the solid NNGT ($r = -.295, p = .128, df = 26$), with higher numbers of count nouns being associated with fewer choices of material matches on the solid NNGT. This indicates that the more count nouns a child has in their vocabulary, the less likely they are to choose material matches for a solid object on a Novel Noun Generalization Task. As such, our hypothesis that the number of count nouns in a child’s vocabulary influences whether they pick shape matches on the solid NNGT is slightly supported, though in an unexpected way. Children are not more likely to pick shape matches, but they are less likely to pick material matches.

D. Total Pro-Shape Bias Words and Total Pro-Material Bias Words

Partial correlation was used to explore the relationship between whether 24-month-olds exhibit the shape or material biases for either solids or non-solids (as measured by our weighted scores) and total number of pro-shape bias and pro-material bias words in their vocabulary, while controlling for age (See Table 8).

**Table 7. Relationship between total number of count nouns and mass nouns, and choices on NNGT.**

**Table 8. Relationship between total number of pro-shape and pro-material bias words and choices on NNGT.**
As the table above shows, there is a marginally significant negative correlation between having more pro-shape bias words and choosing material matches on the solid NNGT ($r = -.303$, $p = .118$, $df = 26$), with higher numbers of pro-shape bias words being associated with fewer choices of material matches on the solid NNGT (See Figure 9). This relationship is stronger than the relationship between count nouns and material matches on the solid task. This indicates that the more words a child has in their vocabulary that are count nouns that name categories of solid objects that match in shape, the less likely they are to choose material matches for a solid object on a Novel Noun Generalization Task.

![Figure 9. Scatterplot showing relationship between the number of pro-shape bias words in a child’s productive vocabulary and material matches on the Solid NNGT.](image)

**Discussion**

Our original hypotheses predicted that the number of count and mass nouns a child has in their productive vocabulary influences whether they exhibit the shape or material biases for either solids or non-solids. As our results show, these hypotheses are mostly not supported. Toddlers with a larger noun vocabulary trend toward shape matches for both solids and non-solids, whereas toddlers with a smaller noun vocabulary trend toward material matches for both solids and non-solids. At 24 months, the number of count nouns and mass nouns is not correlated.
with whether children exhibit either the shape or material biases, although number of count
nouns is negatively correlated with choosing material matches for solid objects. These results can
still tell us a great deal about how a child’s productive vocabulary influences how they extend
novel words at 24 months, and also can tell us what improvements to make to future studies and
future directions to go.

A. What the Data Tells Us

First, it would appear that total number of nouns does influence the choices children
make on NNGTs. Children with more nouns in their productive vocabulary extend novel nouns
differently than children with fewer nouns in their productive noun vocabulary. Children with a
larger noun vocabulary (>156 nouns) tend to extend the names of both solid objects and non-
solid substances to shape, and participants with a smaller noun vocabulary (<155 nouns) tend to
extend the names of both solid objects and non-solid substances to material. Learning more
nouns teaches children to pay attention to shape, and not material; this is important because the
first 300 nouns that young children learn tend to be names for categories that adults judge to be
well organized by shape (Samuelson & Smith, 1999). Perhaps the reason the latter group’s
vocabulary is so small is because they do not yet have a shape bias for solids; this inhibits word
learning.

Second, it would appear that both total number of count nouns and total number of pro-
shape bias words in a 24-month-olds vocabulary negatively influences whether children choose
material matches for solid objects. Thus, the more count nouns and pro-shape bias words a child
knows, the less likely they are to choose material matches for solid objects. This indicates that
the more count nouns, and count nouns for solid objects that match in shape, that a child learns,
the less they pay attention to material. Material is not a part of how the words the child knows
are categorized; thus, count noun and pro-shape bias word knowledge facilitates ignoring material, as material is irrelevant in the process of the child’s word categorization. Our original hypotheses, that the number of count nouns a child has in their vocabulary influences whether they pick shape matches for both solids and non-solids, are mainly disconfirmed. A larger number of count nouns influences 24-month-olds only in that they are less likely to pick material matches for solid objects.

B. Limitations to Design of Study

There are some limitations to the design of our study. First, there are some potential problems with using the MCDI. The parents fill out the checklist, and since parents sometimes do not keep such a close inventory of their children’s productive vocabulary, they might forget to mark words their children say rarely. In addition, the percentile rankings reflect only age and gender, and do not include socioeconomic variables. Because the percentile rankings themselves were calculated using children whose parents had occupation/education levels exceeding the national average, and European-Americans were overrepresented (Fenson et al., 1993), the percentile rankings are likely skewed. In addition, Fenson et al. also reported that mothers with less education reported a larger vocabulary for their children than mothers with more education (1993). These potential problems with the MCDI could influence our results in unexpected ways by decreasing the accuracy of the participant’s productive vocabulary. However, other studies have shown that parents do accurately report the number of words their child can produce (Feldman et al, 2000). Since we are only concerned with the words the children produce, our MCDI results were most likely accurate.

In English, the majority of nouns are count nouns; thus, the majority of the nouns that children learn in early language learning are count nouns. This is reflected by the fact that of the
312 nouns on the MCDI, 232 are count nouns, and just 31 are mass nouns. Within these categories, only 111 of the words are pro-shape bias, and just 6 are pro-material bias. These low numbers, particularly for mass nouns, means the variability between children is extremely low. This lack of variability likely contributed to the fact that we didn’t get any significant results involving the number of mass nouns children had in their productive vocabulary.

We used the number of count and mass nouns as a proxy for knowledge of count and mass syntax. Soja, Carey, & Spelke (1991) tested productive command of count/mass syntax by obtaining speech production samples from each child and assessing his or her mastery of noun phrase syntax. This is a much more accurate method of determining when the participant has knowledge of count and mass syntax. Future studies on this area of research should follow Soja’s methods, as it offers a more precise reflection of the child’s syntactic knowledge. This solution would also alleviate the problem of lack of variability within the data, since Soja’s method gives much greater variety.

In addition, as stated in the Introduction, these results are actually a subset of a larger data set garnered from monthly visits to the lab. The data analyzed actually represents the participant’s eighth visit to the lab. There is the possibility that, since the participants came in so often, we were inadvertently teaching them something. Performing these analyses on participants who come in for only one session at 24 months could lessen the potential effects of multiple visits.

Finally, although our participants were pulled randomly from the University of Colorado Cognitive Development Center Database, Boulder’s population itself is biased toward white, middle- and upper-middle class families. When the parents originally sign their child up for the database, they are asked a number of additional questions, including what race they consider
their child and the education levels of the parents. Of the 34 participants originally recruited for the experiment, 24 were reported as “White,” one was reported as “Asian,” and nine had no race reported. For education level of the parents, 27 of the participants have at least one parent with a college degree or higher, and the remaining seven did not report education level for the parents. This demographic is relatively typical of Boulder, but is not representative elsewhere. It might be difficult to extrapolate these results across different cultures and socio-economic groups, since our group of participants had so little diversity. However, one advantage of using a homogenous sample is that the differences between the children are most likely due to individual differences in word learning, not to external factors such as socioeconomic status. In addition, our sample is similar to the sample Fenson et al. (1993) based the percentile rankings for the MCDI on, so those rankings are likely to be highly accurate.

C. Future Directions

One potential direction this area of research could take is ERP studies involving nominal coercion. Nominal coercion is when people use the incorrect determiner for a type of noun; for example, for a count noun like “cat,” one might use a determiner typically used with mass nouns and say, “some cat.” For a mass noun like “wood,” one might say “a wood.” In child language learning experiments, Soja (1992) performed an experiment with children 2-2½-years-old where she reversed the syntax pairing so syntax and ontology conflicted: objects were labeled with mass nouns, and substances were labeled with count nouns, effectively nominally coercing the participants. She did this thinking that she was providing her participants with a syntactic error.

However, studies of electrical signals given off by the brain show that nominal coercion actually produces the same effect as a semantic, not a syntactic, error. Event Related Potential, or ERP, studies are where experimenters measure the electrical signals given off by a subject’s
brain that are directly the result of a thought or perception. ERPs are useful in determining what a subject’s brain is doing when given different stimuli. Using ERP studies, it has been shown that people’s brains exhibit different effects for different types of errors in language. For example, people show a P600 effect for syntactic errors (Guntkr, Stowe, & Mulder, 1997). This means that after reading a sentence with a syntactic error, such as “He baking the bread,” there would be a positive voltage deflection occurring approximately 600ms after stimulus onset. In addition, subjects will show an N400 effect for semantic errors (Guntkr, Stowe, & Mulder, 1997). For example, if a person read the sentence “The cats bake the bread,” there would be a negative voltage deflection occurring approximately 400ms after stimulus onset; this is because the sentence contains a semantic error (i.e., cats don’t bake).

In an ERP experiment studying the effects of nominal coercion, Sikos et al. (2009) showed that adult subjects who read sentences that had been nominally coerced actually showed an N400 effect more consistent with semantic errors, not a P600 effect as had been predicted. This suggests that using the wrong determiner for a mass noun or a count noun actually causes adults to think about the noun in a different way semantically, not just that there is an error in syntax. Do children do the same? One could perform Soja’s (1992) experiment, involving nominal coercion of toddlers, with an added ERP component. One could use a variety of different ages of children, from toddlers and older, to determine when they begin to exhibit the N400 effect for nominally coerced nouns. Perhaps children who are nominally coerced by being given count syntax with substances do not show the N400 effect if they choose shape matches; since in their mind, they are choosing correctly within the frame of count syntax. Likewise, perhaps children given mass syntax with solid objects do not show the N400 effect if they choose material matches; since in their mind, they are choosing the correct match within the frame of
mass syntax. This information would give us more information about when children differentiate between count and mass nouns semantically, as well as the effect of syntax on their choices.

D. Conclusion

In sum, vocabulary does influence whether 24-month-olds exhibit the shape or material biases. Children with more (>156) nouns tend to extend the names of novel solids and non-solids on the basis of shape, and children with fewer (<155) nouns extend tend to the names of both solids and non-solids on the basis of material. Children with more count nouns and pro-shape bias words are less likely to extend novel names for solid objects to material matches. Previous research has shown that a shape bias in children speeds up word learning (Smith et al, 2002). Thus, one should teach children more nouns, and especially more count nouns and pro-shape bias words. This will enable the child to pay less attention to material, and more attention to shape, creating a shape bias. Given these categories of words, children can then more easily learn words that fit into these categories, creating a rapid word-learner.
References


Appendix A: Count and Mass Noun Categories on the MCDI. Taken from Samuelson & Smith (1999).

Count Nouns \((n = 232)\). **Pro-Shape Bias Words \((n = 111)\).**

<table>
<thead>
<tr>
<th>Alligator</th>
<th>Owl</th>
<th>Balloon</th>
<th>Strawberry</th>
<th>Ear</th>
<th>Can</th>
<th>Basement</th>
<th>Table</th>
</tr>
</thead>
<tbody>
<tr>
<td>Animal</td>
<td>Penguin</td>
<td>Bat</td>
<td>Belt</td>
<td>Eye</td>
<td>Clock</td>
<td>Bathroom</td>
<td>TV</td>
</tr>
<tr>
<td>Ant</td>
<td>Pig</td>
<td>Block</td>
<td>Bib</td>
<td>Face</td>
<td>Comb</td>
<td>Bathtub</td>
<td>Washing machine</td>
</tr>
<tr>
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<td>Pony</td>
<td>Book</td>
<td>Boots</td>
<td>Feet</td>
<td>Cup</td>
<td>Bed</td>
<td>Window</td>
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<tr>
<td>Bee</td>
<td>Puppy</td>
<td>Crayon</td>
<td>Button</td>
<td>Finger</td>
<td>Dish</td>
<td>Bedroom</td>
<td>Backyard</td>
</tr>
<tr>
<td>Bird</td>
<td>Rooster</td>
<td>Doll</td>
<td>Coat</td>
<td>Hand</td>
<td>Fork</td>
<td>Bench</td>
<td>Flag</td>
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<tr>
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<td>Sheep</td>
<td>Game</td>
<td>Diaper</td>
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<td>Glass</td>
<td>Chair</td>
<td>Flower</td>
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<td>Hose</td>
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<td>Turkey</td>
<td>Puzzle</td>
<td>Jacket</td>
<td>Mouth</td>
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<td>Door</td>
<td>Lawn mower</td>
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<td>Cow</td>
<td>Turtle</td>
<td>Story</td>
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<td>Plant</td>
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<td>Egg</td>
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<td>Plate</td>
<td>Play pen</td>
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<td>Lollipop</td>
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<td>Purse</td>
<td>Porch</td>
<td>Snowman</td>
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<td>Muffin</td>
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<td>Sweater</td>
<td>Blanket</td>
<td>Spoon</td>
<td>Refrigerator</td>
<td>Star</td>
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<td>Buttocks</td>
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<td>Swing</td>
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<td>Stove</td>
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Mass Nouns \((n = 31)\). **Pro-Material Bias Words \((n = 6)\).**

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<th>Sauce</th>
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<td>Snow</td>
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<td>Salt</td>
<td>Vanilla</td>
<td>Grass</td>
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Appendix B: Choice-Data Coding

SOLIDS:
5 choices: Shape, Shape, Material, Color, Material + Color
Weighted score: 1\(^{st}\) choice = 3 pts, 2\(^{nd}\) choice = 2 pts, 3\(^{rd}\) choice = 1 pt

<table>
<thead>
<tr>
<th>Participant</th>
<th>1(^{st}) choice, 3 pts</th>
<th>2(^{nd}) choice, 2 pts</th>
<th>3(^{rd}) choice, 1 pt</th>
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<th>Solid-Material</th>
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</thead>
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<td>Shape</td>
<td>Shape</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>LTP140</td>
<td>Color + Material</td>
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<td>Color</td>
<td>0</td>
<td>5</td>
</tr>
<tr>
<td>LTP195</td>
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<td>Shape</td>
<td>Color + Material</td>
<td>2</td>
<td>4</td>
</tr>
</tbody>
</table>

NON-SOLIDS:
5 choices: Material, Material, Shape, Color, Shape + Color
1\(^{st}\) choice = 3 pts, 2\(^{nd}\) choice = 2 pts, 3\(^{rd}\) choice = 1 pt

<table>
<thead>
<tr>
<th>Participant</th>
<th>1(^{st}) choice, 3 pts</th>
<th>2(^{nd}) choice, 2 pts</th>
<th>3(^{rd}) choice, 1 pt</th>
<th>Non-Solid-Shape</th>
<th>Non-Solid-Material</th>
</tr>
</thead>
<tbody>
<tr>
<td>LTP147</td>
<td>Shape</td>
<td>Material</td>
<td></td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>LTP172</td>
<td>Shape</td>
<td>Color + Shape</td>
<td>Color</td>
<td>5</td>
<td>0</td>
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<tr>
<td>LTP190</td>
<td>Material</td>
<td>Material</td>
<td>Color</td>
<td>0</td>
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<tr>
<td>LTP200</td>
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<td>Color + Shape</td>
<td>Material</td>
<td>2</td>
<td>4</td>
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