

## Known and Novel Noun Extensions: Attention at Two Levels of Abstraction

*Hanako Yoshida and Linda B. Smith*

Two experiments tested the hypothesis that names direct attention at two levels of abstraction: Known names direct attention to the properties most relevant to the specific category; novel names direct attention to the shape, the property most generally relevant across known object names. English-speaking and Japanese-speaking 3-year-olds were shown a novel object that was named with (a) known nouns referring to things similar in shape or similar in material and color, and (b) novel nouns. Given known nouns, children attended to shape when the name referred to a category organized by shape, but they did not when the name referred to a category organized by other properties. Children generalized novel names by shape. The results are discussed within the debate between shape-based and taxonomic categories.

The study of children's early categories is characterized by two competing classes of explanations: One characterizes children's categories as primarily conceptual; the other characterizes children's categories as primarily perceptual. There have been several recent suggestions that this opposition is ill-founded (Ahn & Luhmann, *in press*; Goldstone & Barsalou, 1998; Rakison, *in press*) primarily because there is no coherent definition or consensus agreement on what counts as perceptual. Furthermore, there is ample evidence that young children have knowledge about categories that goes beyond the surface similarities of things (e.g., Gelman, 1996; Gelman & Bloom, 2000; Mandler & McDonough, 1998). There is also ample evidence that children have knowledge about the perceptual properties that matter for different kinds (Jones, Smith, & Landau, 1991; Massey & Gelman, 1988; Quinn, Eimas, & Tarr, 2001; Rakison, 2000; Rakison & Cohen, 1999). We return to these issues in the General Discussion. For now, we note that the dispute has been highly productive in that it has motivated many useful empirical studies on early categories. In the experiments reported here, we focused on a conflicting pattern found in several of these studies. We tested a unified explanation of the results that is based on Smith's (1995, 2000) proposal that word learning tunes attention to the properties of objects that are particularly relevant for naming.

### *Background*

The phenomena of interest concern arguments in the literature over whether children's categories are taxonomic or shape based. A taxonomy is any classification system that hierarchically groups entities by their similarities. Thus, taxonomic and shape-based classifications (or one based on any perceptual similarity) do not constitute a logical opposition. However, in the literature on cognitive development, a "taxonomic" classification has taken on an additional meaning, one that is based on conceptual rather than perceptual similarities.

In one programmatic series of experiments, Waxman and colleagues (Waxman & Hall, 1993; Waxman, Lynch, Casey, & Baer, 1997; Waxman & Markow, 1995) examined how young children generalize novel names for known kinds. For example, Waxman and Namy (1997) presented children with toy objects that realistically depicted well-known categories. For example, one set consisted of a toy carrot, a toy rabbit, and a toy tomato. The child was told a novel made-up name for the carrot, for example, "Look! That's a toma!" and then asked whether the rabbit or tomato was most like the originally named exemplar (e.g., "Which goes best with the toma?"). The widely replicated result is that young children systematically choose the taxonomically related object. On the argument that tomatoes and carrots are not perceptually similar, Waxman and Namy concluded that children use conceptual knowledge (e.g., that both tomatoes and carrots can be eaten) to form categories. One possible criticism of this conclusion is that carrots are more perceptually similar to tomatoes (particularly in shape and parts such as stems) than they are to rabbits, and

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Hanako Yoshida, Department of Psychology, Indiana University; Linda B. Smith, Department of Psychology and Program in Cognitive Science, Indiana University.

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Correspondence concerning this article should be addressed to Linda B. Smith, 1101 E. 10th Street, Department of Psychology, Indiana University, Bloomington, IN 47405. Electronic mail may be sent to smith4@indiana.edu.

thus perceptual similarities may have contributed to children's choices.

A second program of research has examined how children generalize novel names for novel things, and these studies have consistently shown that children generalize object names (and particularly artifact names) by shape (Graham, Williams, & Huber, 1999; Landau, Smith, & Jones, 1988, 1998). The task in these studies is very much like that used in the Waxman and Namy study. One key difference is that the objects are all novel; indeed, they are typically constructed in the laboratory. For example, in one study, Landau et al. (1988) presented preschool children with a roughly U-shaped wooden object and told the children "This is a dax." Children were then presented with a variety of test objects that varied in shape, size, and material and were asked which of these were called by the same name (e.g., "Show me the dax.") Children systematically generalized the name to all new instances that matched the original in shape despite marked differences in material (e.g., wood vs. metal mesh) or in size (increased 100 times). This widely replicated result suggests that children name objects (and form object categories) by shape. Smith (1995, 2000) specifically suggests that children learn to attend to shape as a product of learning object names, as a consequence of the fact that most early-learned object names refer to things in categories well organized by shape (Rosch, 1973; Samuelson & Smith, 1999). However, from the point of the view of the question of whether categories are (primarily) conceptually or perceptually based, these studies provide no clear answer as they did not pit a perceptual solution against a conceptual solution. Thus, one has no way of knowing whether children's choices were driven by shape similarity alone or perhaps by conceptual knowledge about the general importance of shape for function and design (Gelman & Bloom, 2000).

### *Three Conflicting Studies*

The experiments reported here also did not directly address whether categories are principally conceptual or perceptual but instead focused on how object names may organize attention, directing it to particular perceptual properties. The present study was motivated by past attempts to pit taxonomic and shape-based categories against each other in studies of children's noun extensions. In one study, Imai, Gentner, and Uchida (1994) presented children with pictures of known objects but named them with a novel name. For example, in one trial, children

were shown a picture of a birthday cake and told that in a puppet's language, it was called a *dax*. The children were then shown three pictures and were asked which of these was also a *dax*: a close shape match (a top hat), a taxonomic match (a pie), or a thematic match (a birthday present). Imai et al. found that 3-year-olds consistently generalized the name to new instances by shape and not to the taxonomically related instances. (Older children, 5-year-olds, generalized the names to the taxonomically related instance.) These results, then, seem to suggest that shape similarity controls younger children's name extensions.

A study by Gelman, Croft, Fu, Clausner, and Gottfried (1998) suggests that taxonomic relatedness contributes to young children's extensions of object names beyond shape similarity. This study presented children with known objects named with known names. They found that 2-year-old children were more likely to generalize a well-known name such as *dog* to instances that were both taxonomically and shape related (a cow) than to objects that were just related in shape (a chair). They concluded that shape alone was not the sole controlling factor organizing children's object categories.

Notice that in the Imai et al. (1994) study, children were presented with known object kinds but novel names. In the Gelman et al. (1998) study, children were presented with known object kinds and known names. The Landau et al. (1988) study presented a third task: novel objects and novel names. Table 1 shows the results of orthogonally combining these two factors: novelty of name and novelty of object. Three cells in the table are filled by studies in the literature: Known objects and known names lead to taxonomic-based name generalizations, known objects and novel names lead to shape-based generalizations, and novel objects and novel names lead to shape-based generalizations.<sup>1</sup> The studies reported here provide new data relevant to the empty cell: novel objects but known names. This cell provides a key test of a unifying account of the whole pattern.

### *The Attentional Learning Account*

Smith (1995, 2000) proposed that the shape bias in novel noun generalization is the product of attentional learning. Analyses of the first 300 nouns that children learn indicate that most of these early nouns

<sup>1</sup>Waxman and Namy's (1997) experiment also fits the case of a novel name and known object. However, their study confounded shape and taxonomic similarity, and thus it does not provide unambiguous evidence.

Table 1  
*The Combination of Two Factors Relevant to Children’s Categorizations Manipulated Across Experiments in the Literature: Familiarity of the Name Provided and Familiarity of the Object*

	Known names	Novel names
Known objects	Gelman et al. (1998) Taxonomic-based name generalization	Imai et al. (1994) Shape-based name generalization Jones et al. (1988)
Novel objects		Shape-based name generalization

name things in categories well organized by shape (Samuelson & Smith, 1999; Smith, Colunga, & Yoshida, 2003; see also Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976). There are exceptions to this general rule; shape is not always a relevant property (e.g., cheese) nor is shape always the only relevant property (e.g., towel). These exceptions are important because they show that shape is not uniformly privileged in defining object categories. Nonetheless, most early object names do refer to things in shape-based categories. Thus, Smith (1995) argued that there is a sufficiently strong association between naming concrete things and shape similarity that linguistic cues associated with naming (e.g., “This is a \_\_\_”) and with basic level categories (“Here is another one”) effectively cue attention to shape.

Smith, Jones, Landau, Gershkoff-Stowe, and Samuelson (2002) specifically proposed that this learning is based on generalizations at two levels of abstraction. Figure 1 illustrates the proposed account. Learning begins with the mapping of a name to an object, for example, the name *ball* to a particular ball, the name *cup* to a particular cup, and the name *pumpkin* to a particular pumpkin. For each name this is done multiple times as the child encounters new instances. Typically, objects that are named by the same name are similar across one or more perceptual dimensions (as well as conceptual dimensions). By hypothesis, this learning of names for individual things leads to first-order generalizations about the structure of individual categories, for example, to the knowledge that balls are round, that cups are cup shaped, and that pumpkins are orange and pumpkin shaped. This first-order generalization enables the learner to recognize and name novel balls, cups, and pumpkins. The association between object names and the specific properties relevant for that category

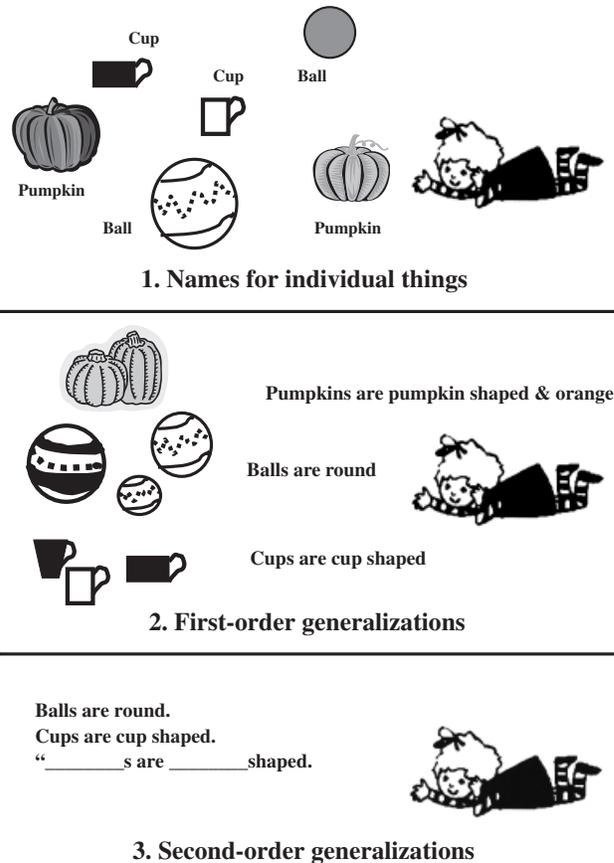


Figure 1. Three steps in learning about lexical categories.

means the object name should direct attention to those specific properties. In this way, the name *ball* should come to direct attention to the perceptual properties relevant to the category ball, the name *cup* should come to direct attention to the perceptual properties relevant to the category cup, and the name *pumpkin* should come to direct attention to the perceptual properties relevant to the category pumpkin.

However, a further higher order generalization is also possible. Because many learned object categories span things that are similar in shape and because no other property is so pervasively important across early object categories, children may also learn the second-order generalization, that object names in general span categories of similarly shaped things. Making such a higher order generalization would enable the child to extend any object name, even one encountered for the first time, to new instances by shape. The mechanistic plausibility of this account and the two levels of generalization have been demonstrated in series of simulations

using connectionist networks (Colunga & Smith, 2000; Samuelson, 2002; Smith, 1995).

This attentional learning account is relevant to the contradictory findings about taxonomic versus shape-based generalizations because it predicts two levels of linguistic cues that direct attention at two levels of abstraction. Known names should direct attention to the perceptual properties relevant for that category. Novel names should direct attention to the perceptual property most generally important across object categories. This account thus explains the contrast between the Gelman et al. (1998) and the Imai et al. (1994) results: Known names for categories activate attention weights associated with that category and, thus, a categorization that accords with the adult standard, a taxonomic classification. Novel names activate attention weights associated with all known nouns and, thus, categorization by shape.

Previous research has not provided a clear test of this idea because the effect of known object names has been examined only with known objects. However, if the preceding analysis is right, a known object name should cue attention to the properties relevant to that specific category even when the labeled object is novel and not a recognizable instance of any category. That is, the name—without strongly supporting perceptual cues from the named object—should exert control over attention. For example, children should attend to the color as well as the shape of non-pumpkin-like things when they are called “pumpkin.” Grouping real pumpkins by color as well as or instead of by shape might be taken as evidence for a taxonomic classification. Grouping nonpumpkins by color when labeled *pumpkin* is not evidence of a taxonomic classification in the usual sense; however, such a result would demonstrate the power of known category labels to direct attention to category-relevant properties.

#### *Rationale for the Experiment*

The logic behind Experiment 1 is clarified by considering the illustration in Figure 2. The top-most object, the exemplar, is an ambiguous shape and green in color. The idea is this: If a known name directs attention to properties relevant to the named category, one should be able to direct children’s attention to different properties of this object by labeling it with different names. For example, if the name *egg* refers to objects that are primarily similar in shape, the label *egg* may direct children’s attention to the shape of this thing, and in a categorization

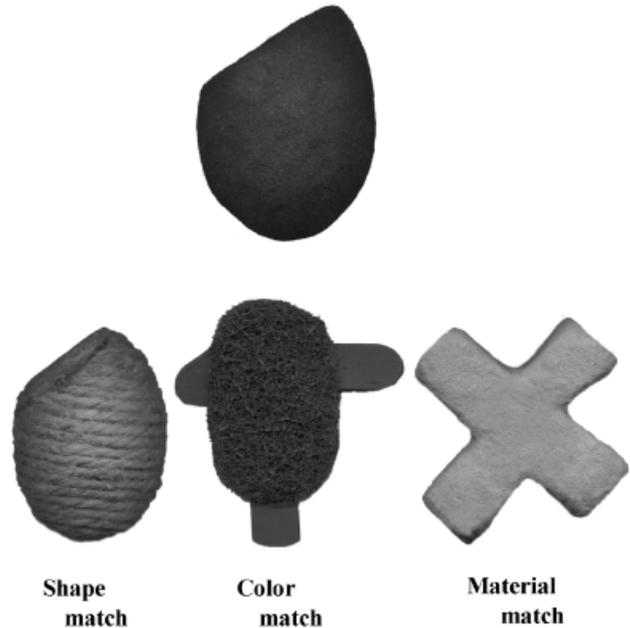


Figure 2. A sample stimulus set used in Experiments 1 and 2: an exemplar of green clay and three choice objects: a material match, a color match, and a shape match.

task, to the shape match. In contrast, if the label *pickle* refers to things of similar color and more variable shape, the name *pickle* might direct children’s attention to the exemplar’s color, and in a categorization task, to the color match.

Because the goal is to test the influence of naming on attention, and not the influence of perception on attention, we need pairs of nouns such that each noun could be used to label the same ambiguous form but such that one noun refers to a category more exclusively organized by shape and the other to a category less exclusively organized by shape. To this end, we selected six ambiguous forms and six pairs of nouns such that each noun could reasonably refer to the form and such one noun, the S+ noun (by adult judgment) referred to a category organized by shape and the other noun, the S– noun, referred to a category organized by material, color, or both (instead of or in addition to shape). If the word used to label the ambiguous object pushes attention to the specific properties associated with that lexical category, children should attend to the shape of the ambiguous form more when it is labeled with the S+ or shape-based category name than when it is labeled with the S– or less shape-based category name.

We tested this hypothesis in an experiment in which both monolingual English- and Japanese-

speaking children participated. We included these two groups of children to increase the generality of our conclusions. Our past research indicates that the category structures of early learned nouns are similar in both languages (Smith et al., 2003). If the attentional learning account is right, Japanese- and English-speaking children's first- and second-order generalizations should be the same.

### Experiment 1

We used a categorization task similar to that used by Imai et al. (1994) and Landau et al. (1988), among others. The child was presented with an object, told its name, and asked which one of three alternatives was called by the same name. In this experiment, the object was novel but the names are known. The experimental question was: Do children attend to shape more when the exemplar is named by a more shape-based (S+) noun than when it is named by a less shape-based (S-) noun?

#### Method

*Participants.* The participants were 20 monolingual English-speaking children tested in Bloomington, Indiana, and 20 monolingual Japanese-speaking children tested in Niigata, Japan. English-speaking children's mean age was 34.31 months (*range* = 22.2 to 39.4 months). Japanese-speaking children's mean age was 33.46 months (*range* = 27.35 to 40.73 months).

*Stimuli: lexical categories.* The six noun pairs were: (a) boat/towel [boutu/taoru]; (b) egg/pickle [tamago/kyuuri-no tsukemono]; (c) door/blanket [doa/moufu]; (d) ball/pumpkin [bouru/kabocha]; (e) bat (baseball)/carrot [batto/ninjin]; (f) banana/paper [banana/kami]. The first noun in each pair was designated S+ (more shape based); the second was designated S- (less shape based). These 12 nouns are all typically known by 30-month-old children learning either English (Fenson et al., 1993) or Japanese (Ogura & Watamaki, 1997; Ogura, Yamashita, Murase, & Dale, 1993). We also asked the parents of the children in the experiment (using the English and Japanese versions of the MacArthur Communicative Development Inventory checklist) to indicate the nouns known by their children. By parent report, on average, 96% of these words were known by English-speaking children and each word was known by more than 70% of the children. By parent report, 73% of the 12 words were known by Japanese-speaking children and each word was known by more than 70% of the children except

one (baseball bat was reported to be known by 53% of the children).

To determine whether these nouns fit our characterization of being more or less shape based, we asked adults to make judgments of the category similarities. We did so in two judgment tasks. First, 13 native speakers of English and 13 native speakers of Japanese (tested in Niigata, Japan) were presented with each label individually. Using the same method as Samuelson and Smith (1999), we asked them to think of common, everyday instances of each category and to answer three yes/no questions about the instances named by each noun: "Are these the same shape?," "Are these the same color?," and "Are these the same material?" Japanese-speaking adults were asked the same questions in Japanese: "Sorera-wa onaji katachi-wo shite imasuka?" (for shape), "Sorera-wa onaji iro-wo shite imasuka?" (for color), and "Sorera-wa onaji zairyuu-de dekite imasuka?" (for material). The results indicate that the S+ terms in each pair were judged to be well organized by shape; the mean proportion of adults judging each term to be well organized by shape was .91 and .84 for the English- and Japanese-speaking adults, respectively. The S- terms were also judged to be well organized by shape; the mean proportion of adults judging each S- term to be well organized by shape was .65 and .72 for the English- and Japanese-speaking adults, respectively. Color and material were rarely judged to be relevant to the S+ terms (mean proportions were .38 and .44 of the English- and Japanese-speaking adults, respectively) but were commonly judged to be relevant for the S- terms (mean proportions were .73 and .71 for the English- and Japanese-speaking adults, respectively). Thus, by this measure, shape is relevant to many of the categories but is more relevant to the S+ categories than to the S- categories, and crucially, color and material are, in addition to shape, highly relevant for the S- terms but not the S+ terms. Thus, the S+ terms are more exclusively shape based than are the S- terms.

The second measure documented that for each term in a pair the S+ term is more shape based than its paired S- term. Specifically, a separate group of 13 native speakers of English and 13 native speakers of Japanese (tested in Japan) were presented with each pair of nouns. For each pair, they were asked, "Is shape more important for whether an object is a \_\_\_\_ or \_\_\_\_?" They were also asked, "Is color more important for whether an object is a \_\_\_\_ or \_\_\_\_?" and "Is material more important for whether an object is a \_\_\_\_ or \_\_\_\_?" Table 2 shows the proportion of S+ items chosen as more

shape based than their corresponding S – item. As is apparent, adults in both language groups overwhelmingly judged the S+ categories to be better organized by shape than the S – categories. Table 2 also shows the proportion of adults choosing the S – category as being better organized than the S+ category by the indicated nonshape property (the property judged to be most relevant to each S – category). As is evident, nonshape properties were judged to be more relevant to the S – category than to the paired S+ category. Thus, for each pair, the S+ item was judged to be more shape based and the S – was judged to be better organized than the corresponding S+ item on either color or material.

*Stimuli: the exemplar and test objects.* Six test sets were constructed, one for each pair of nouns. Each test set consisted of an exemplar and three choice objects. The exemplar for each noun pair was constructed to be clearly not a member of either

category but to share some minimal aspect of shape with instances of each category in the pair (e.g., to be round or to be horizontally elongated or to be flat). For example, the exemplar for the carrot/baseball bat pair was a bowling pin and the exemplar for the ball/pumpkin pair was tetrahedron. Each exemplar also presented a nonshape property that was, by the adult judgments of Experiment 1, critical to the category named by the S – noun. For example, for the ball/pumpkin exemplar, the tetrahedron was orange, the relevant color for the less exclusively shape-based pumpkin category. The exemplars for each pair are fully described in Table 3. For each exemplar, three choice objects were constructed. Each choice object matched the exemplar on one property (shape or color or material) and differed substantially from it on all others. For example, as shown in Figure 1, the three test objects for the egg/pickle exemplar consisted of (a) yellow clay roughly in the shape of an Y, (b) green steel wool in the shape

Table 2  
*Proportion of Adults Choosing the S+ Category as Better Organized by Shape Than Its Paired S– Category and Proportion of Adults Choosing Each S– Category as Better Organized than the Paired S+ Category on the Designated Nonshape Property*

S+ items		S– items	
Boat (English)	1.00	Towel (English)	.69 (material)
<i>fune</i> (Japanese)	1.00	<i>taoru</i> (Japanese)	.77 (material)
Banana (English)	.69	Paper (English)	.69 (material)
<i>banana</i> (Japanese)	.85	<i>kami</i> (Japanese)	.77 (material)
Door (English)	.85	Blanket (English)	.54 (material)
<i>doa</i> (Japanese)	.92	<i>moufu</i> (Japanese)	.77 (material)
Egg (English)	.85	Pickle (English)	.92 (color)
<i>tamago</i> (Japanese)	1.00	<i>Kyuuri no tsukemono</i> (Japanese)	.69 (material)
Bat (English)	.85	Carrot (English)	.92 (color)
<i>batto</i> (Japanese)	1.00	<i>ninjin</i> (Japanese)	.92 (color)
Ball (English)	.69	Pumpkin (English)	.92 (color)
<i>bouru</i> (Japanese)	.85	<i>kabocha</i> (Japanese)	.85 (color)

Table 3  
*The Noun Pairs and Exemplar Object Used for Each Pair in Experiment 1*

Noun pair (More/less exclusively shape based)	Exemplar
Egg/pickle	Green wooden mound
Door/blanket	Blue rigid cloth trapezoid
Banana/paper	White coarse paper formed into a sausage shape
Bat/carrot	Orange wooden bowling pin
Boat/towel	Brown cloth half circle
Ball/pumpkin	Sparkling orange tetrahedron

of a oval with three protrusions, and (c) brown jute wound in the same shape as the exemplar. Across the sets, the largest stimulus object was approximately 10 cm × 10 cm × 10 cm and the smallest was 10 cm × 7 cm × 5 cm. In pilot testing with adults, none of the exemplars nor choice objects were spontaneously labeled with one of the target nouns. Thus, without the guidance of words, none of the stimulus objects are recognizable instances of the 12 lexical categories.

*Design and procedure.* The experiment began with three warm-up trials using replicas of real objects named by their real names to ensure that children understood the task of selecting objects of the named kind from the choice set. The stimuli for the warm-up trials were structured so as not to bias attention to any particular property. For example, on one warm-up trial the child was shown a hat and told, "This is a hat/*Kore-wa boushi dayo.*" The child was then presented with three choice objects and was asked, "Show me the hat/*Boushi-wo misete.*" One choice object was another hat that differed in shape, color, and material from the original. For example, if the warm-up exemplar was a paper party hat, the choice object was a straw sun hat. The other two choice objects were distracters that did not match the exemplar in any way (e.g., a toy shoe and a spoon). Three warm-up trials using unique objects were also given; no feedback was provided and all children responded correctly on these trials.

Each child was tested with each of the six exemplars. For each child, three exemplars were named with the S+ noun and three were named with the S- noun. The exemplars named with S+ and S- nouns were counterbalanced across children in each language condition. The order of trials was randomly determined for each child.

### Results and Discussion

Both the English-speaking and Japanese-speaking children selected the shape-matching choice object when the exemplar was named with the S+ noun; mean proportion shape choices (standard deviations) were .82 (.22) and .87 (.21), respectively. Both groups of children were much less likely to choose the shape-matching choice object when the exemplar was named with the S- noun; means (standard deviations) were .23 (.20) and .38 (.31) for English-speaking and Japanese-speaking children, respectively. Each child's numbers of shape matching choices was submitted to a 2 (language) × 2 (noun: S+ / S-) ANOVA for a mixed design. The analysis revealed only a highly reliable main effect of noun,

Table 4  
Proportion of English- (E) and Japanese- (J) Speaking Children Choosing the Shape-Matching Choice Object, Given the S+ or S- Label

Object	S+	Object	S-
Boat	E 1.00 J 1.00	Towel	E .10 J .20
Egg	E .80 J 1.00	Pickle	E .50 J .40
Door	E .50 J .60	Blanket	E .10 J .50
Ball	E .70 J 1.00	Pumpkin	E .10 J .30
Bat	E .90 J .70	Carrot	E .50 J .50
Banana	E 1.00 J .90	Paper	E .10 J .40

$F(1, 38) = 57.74, p < .001$ . Children selected the shape-matching object when the exemplar was named with a noun adults judged to refer to things similar in shape but often selected objects that matched on other properties when the exemplar was named with a noun adults judged to refer to things similar in other properties or other than shape. As shown in Table 4, this pattern characterizes each of the noun pairs.

These results tell us that names of things by themselves activate attention to the perceptual properties relevant to that category. Children know that boats are boat shaped, that towels are made of terry cloth, and that pumpkins are orange. Children's knowledge about specific categories includes knowledge about the perceptual properties relevant to that category. Because children attended to different properties of the same exemplars and test objects given different names, the results show the power of names by themselves to direct attention.

A number of researchers have contrasted children's categorization performances in naming and nonnaming tasks and found that children often perform differently when objects are named by known names (Gelman & Markman, 1986; Waxman & Namy, 1997). Some of these researchers have suggested that this is because naming takes children away from perceptually based categories and toward conceptually based categories. Naming is likely to activate known conceptual properties of familiar categories and may even act as a feature of the category, enabling groupings of perceptually dissimilar things (Sloutsky, Lo, & Fisher, 2001; see also Welder & Graham, 2001). However, the present results show that known object names also tune

attention, directing it to the specific perceptual properties relevant for that kind.

## Experiment 2

The results in Experiment 1 show that children have learned the relations between specific category labels and the properties relevant to those categories, the first-order generalizations in Figure 1. The statistical importance of shape across concrete object categories, however, means that children can also make a second-order generalization and learn a more general relation between naming and object categories, one that transcends specific knowledge about specific categories. The plausibility of learning this higher order generalization has been demonstrated in several simulation studies in which connectionist models have been taught noun categories structured in the same ways as the first 300 nouns learned in English and in Japanese (Colunga & Smith, 2000; Samuelson, 2002; see also, Smith, 1995). These networks develop second-order generalizations such that they extend novel names for novel things in highly systematic ways that reflect the statistical regularities across all the learned noun categories. There is ample evidence in the literature that children also extend novel names for novel things in highly systematic ways, specifically, that they generalize novel names for novel objects to new instances by shape (e.g., Landau et al., 1988, 1998; Samuelson & Smith, 2000).

The purpose of the present experiment was twofold. First, we showed that this shape bias in the context of a novel name extends to the novel forms used in Experiment 1. Second, we asked how strong this shape bias given a novel name should be. We were specifically interested in comparing children's shape choices in Experiment 1 given the S+ known names with their shape choices given a novel name. This comparison is relevant because there are two very different hypotheses about the mechanisms that underlie children's second-order generalizations. One possibility is that children form a rule "shape matters for object categories" and apply that rule as a default first guess about category given a novel name. If this is so, one might expect attention to shape given a known name for a shape-based category and a novel name to be comparable. More specifically, one might predict that novel names applied to the same object used in Experiment 1 would result in shape-based extensions equal to those observed with the S+ category names. A second possibility, and the one predicted by connectionist implementations of the attentional learning

account (Colunga & Smith, 2000; Smith, 1995) is that children do not form explicitly represented rules, but instead their second-order generalizations directly reflect the statistical regularities over all known noun categories. If this is so, attention to shape given a novel noun should be less than that given an S+ noun. This is because the second-order generalization will reflect all known nouns (S+ and S-), whereas the first-order generalization reflects only the specific (and strongly shape-based) S+ category.

Accordingly, Experiment 2 is the same as Experiment 1 except that all objects were named with novel nouns. The prediction was that both English-speaking and Japanese-speaking children would attend to the shape of these things. The question of interest is whether the shape choices will be as strong as or weaker than the shape choices in the S+ condition of Experiment 1.

## Method

*Participants.* The participants were 10 monolingual English-speaking children tested in Bloomington, Indiana, and 10 monolingual Japanese-speaking children tested in Niigata, Japan. The English-speaking children's mean age was 36.5 months (*range* = 24 to 40.2 months). The Japanese-speaking children's mean age was 36.15 months (*range* = 27.2 to 40.5 months).

*Stimuli, materials, design, and procedure.* All aspects of the stimuli, procedure, and design were the same as Experiment 1 except that the nouns employed in Experiment 2 were replaced with the novel names: *sippo*, *fodo*, *lom*, *dero*, *yev*, and *bog*. In English, each exemplar was named with the novel name in the context of "This is a \_\_\_\_" and the child was asked, "Can you get me a \_\_\_\_?" In Japanese, each exemplar was named with the novel name in the context of "*Kore-wa \_\_\_\_ dayo*," and the child was asked "*\_\_\_\_ -wo totte kureru-kana?*"

## Results

Given novel names for novel things, both English- and Japanese-speaking children formed categories organized by shape, a perceptual property relevant to most (but not all) of the object categories for which young children have already learned names (Samuelson & Smith, 1999; Smith et al., 2003). English-speaking children generalized the novel names for these novel objects by their shape 71% of the time and Japanese-speaking children generalized the novel names for these novel objects by their shape

78% of the time; these two levels of choosing the shape-matching object did not differ reliably,  $t(18) < 1.00$ . However, for both the English- and Japanese-speaking samples, the frequency of shape choices in this experiment was reliably less than that in the S+ condition of Experiment 1,  $t(28) = 2.20$ ,  $p < .05$ , for the English sample, and  $t(28) = 4.92$ ,  $p < .01$  for the Japanese sample. This fits the expectation of a graded statistical learner rather than a rule learner.

### General Discussion

The main finding is that the words used to name objects direct attention at two levels of abstraction. Known object names direct attention to the particular perceptual properties relevant to that category. Novel names and the linguistic frames in which they are embedded direct attention to the properties that are most statistically relevant across the categories a child already knows. This finding fits contemporary understandings of attentional learning (Kruschke & Blair, 2000; Medin & Schaffer, 1978; Shepard, Hovland, & Jenkins, 1961). Properties and events that co-occur cue attention to each other. Known names co-occur with specific clusters of properties, the properties that characterize recognizable things called by that name. Thus, known names act as attentional cues for those properties. In contrast, the linguistic cues associated with naming any object co-occur with all nameable things and thus cue attention to the most statistically relevant properties across all known object categories. Shape is pervasively relevant across many object categories; therefore, children generalize novel names by shape.

The present findings and our interpretation of them help resolve empirical contradictions in the literature. They explain why shape appears to dominate in novel noun generalization tasks but not when known objects are named by known nouns (e.g., Gelman et al., 1998). The results also help put the shape bias in its proper place in lexical learning. The shape bias is the system's best guess about the likely relevant properties given limited knowledge about the specific object category. In any novel task, a smart system should attend to the property or properties that have been most generally relevant for similar tasks in the past. Thus, given a novel object, novel name, and no other relevant information, children smartly attend to the shape of the named thing. However, for each to-be-learned category, attending to shape will only be a best first guess. As the child learns more about the specific category, the child will learn about other properties (percep-

tual and conceptual) that are also relevant to that category.

The fact that attention to shape is a gross generalization and a first step rather than the product of category learning does not mean that an initial bias to extend novel object names by shape is irrelevant to early noun learning. Three recent studies show a tight developmental link between novel noun generalizations by shape and the rate of nominal vocabulary growth. In a 9-week longitudinal study and in replication of that study, Smith et al. (2002) taught 17-month-old children to attend to shape in a novel name–novel object laboratory task. Over the 9-week period of training attention to shape, these children's acquisition of English object names outside the laboratory grew by 256%; children in a control condition who did not receive training to attend to shape increased their object name vocabularies by only 78%. Using a different training procedure and control, Samuelson (in press) independently replicated this same training effect on vocabulary growth. Finally, in a 6-month longitudinal study of children's acquisition of their first 100 nouns, Gershkoff-Stowe and Smith (2002) found that object name acquisitions accelerate at the same time children first show a shape bias in novel noun extension tasks. These three findings suggest that attention to shape promotes the learning of object names, as it should because shape is relevant to many early-learned object categories. Given no more specific knowledge about a category, a shape bias enables children to make a roughly right first cut and in so doing may speed up acquisition of the lexical category. Forming an initial category based on shape may even help children discover the other properties (both perceptual and conceptual) that are relevant to the category by bringing together similarly shaped things that are likely members of the same category.

The present finding that known and novel names direct attention differently also has implications for several broader issues: the problem of feature selection, the dispute in the literature over shape-based versus taxonomic categories, and the larger debate between perceptually and conceptually based categories. We consider each of these in turn.

#### *Feature Selection*

A major theoretical problem in the study of human categorization is the problem of feature selection. How, when encountering a novel object, does an individual know which features are relevant for determining category membership? As Murphy

and Medin (1985) noted, selecting the right features for classifying an object seems to require already knowing the relevant category. For example, color matters more for determining whether something is a pea than for determining whether it is a ball. How, when encountering some object (a potential pea or ball) does one know whether to attend to its color?

Smith's (2000) attentional learning account offers one solution to the feature-selection problem: Cues that are predictive of the category relevance of other properties will direct attention to those properties. Language provides particularly systematic cues and thus, by hypothesis, should become a potent controller of attention. If we are asked whether some object is a pea, we should automatically heighten attention to color.

It is important that language is not the only cue that can guide feature selection in category-relevant ways. Any property that reliably predicts the relevance of other properties for categorization should shift attention in category-appropriate ways and do so at multiple levels of abstraction. Consistent with this idea, there is evidence that children make second-order generalizations over the perceptual properties characteristic of animals. Early learned animal categories tend to be organized by multiple similarities and not just shape (Jones & Smith, 2002). Children appear to have made the appropriate second-order generalization; the presence of eyes or limbs (cues regularly associated with categories of animates) causes children to form categories based on multiple similarities and not just shape, even when placed on objects with no other animal-like properties (Jones & Smith, 2002).

Children should also make first-order generalizations based on perceptual cues alone. The correlated properties characteristic of well-known category instances should each heighten attention to each other. For example, the hands, numbers, and roundness of the face of a clock should each accentuate attention to the other correlated properties, making each more relevant than it would be if presented alone. These effects of correlated cues have been documented in studies of category learning by adults (Medin, Altom, Edelson, & Freko, 1982). The idea that children make first- and second-order generalizations over perceptual cues suggests a new prediction: Increased specificity of perceptual cues (just as with increased specificity of linguistic cues) should lead to more finely tuned and category-specific attention. Put in other words, the more category-specific cues offered by the object or by language, the more children should

attend to category-specific properties rather than just shape.

A new study by Chouinard and Markman (2001) supports this prediction. They asked whether Imai et al.'s (1994) finding that children made shape-based extensions of novel names applied to familiar things was due to the stimuli used. Specifically, Imai et al. used drawings of objects not three-dimensional lifelike depictions. Chouinard and Markman replicated the Imai et al. study, comparing children's novel name extensions when the labeled items were three-dimensional representations of known kinds or line drawings of known kinds. They found that children's name extensions by taxonomic kind increased relative to their extensions by shape when the labeled items were three-dimensional representations rather than line drawings. This makes sense if the richer perceptual features of the three-dimensional objects cued children to the relevant perceptual (and conceptual) features. Chouinard and Markman's result is also interesting for what it implies about the underlying mechanism. All the objects—three-dimensional and drawings—were recognizable to the children, and thus it cannot simply be that children's conceptual knowledge led them to taxonomic categories in the three-dimensional condition but not in the line-drawing condition. Rather, it has to be that the perceptual properties of the named entities mattered and cued the selection of category-relevant perceptual and conceptual features.

#### *Shape-Based Versus Taxonomic Categories*

The evidence presented in these experiments does not directly address the question of whether children's categories are more conceptually or perceptually based because these experiments did not assess children's conceptual knowledge but only their knowledge about perceptual properties. It is here that the studies make their contribution by showing that children have knowledge about the perceptual properties relevant to specific categories and that known category names direct attention in category-specific ways.

Table 5 shows the pattern of results across the 2 × 2 combination of known and novel names with known and novel objects. Known names lead to categories organized by the specific properties relevant to that category; novel names lead to categories organized by shape. Children's classifications in the cell corresponding to known objects and known names are typically characterized as taxonomic classifications because such classifications

Table 5  
*Perceptual Properties Relevant to Children's Categorizations*

	Known names	Novel names
Known objects	Gelman et al. (1998) Label specific	Imai et al. (1994) Shape
Novel objects	Present study Label specific	Jones et al. (1988) Shape

correspond to adult lexical categories, which are taxonomically organized. Children's classifications in the cell corresponding to known names but novel objects would not be labeled taxonomic; indeed, they are by adult lexical standards incorrect extensions.

In light of these results, it may be useful to reflect on the use of the word *taxonomic* as a descriptor of children's category performance. Children's classifications are typically called taxonomic only when they are in accord with adult lexical categories. That is, children's groupings that put together objects that adults call by the same name are called taxonomic and these are contrasted with groupings of objects that adults would not call by the same basic or superordinate name (e.g., shape-based categories of novel objects or thematic categories). Experiment 1 shows that adults and children share knowledge about the perceptual properties relevant to specific lexical categories. Other findings show they share conceptual knowledge (e.g., Gelman & Bloom, 2000; Gelman & Markman, 1986). Thus, the underlying mechanism may be knowledge about specific lexical categories as defined by the adult standard and not knowledge about taxonomies in general.

Where in Table 5 does Waxman and Namy's (1997) result fall? Recall that they pitted thematic choices against taxonomic ones, such that the child had to choose whether a novel name for a carrot extended to a bunny (the thematic choice) or a tomato (the taxonomic choice, but also the best choice based on overall shape similarity). One possibility is that children's choices were shape based, that the novel noun activated children's attention to the most generally important category similarity. Another possibility is that children in this experiment used category-specific conceptual knowledge (e.g., about being eaten) to extend the name. This would suggest, contrary to Table 5, that children can access category-specific information even when given a novel name. This could be because Namy and Waxman, like Chouinard and

Markman (2001), used richly detailed and realistic objects.

#### *Perceptual and Conceptual Categorizations*

The present experiments were motivated by the idea that words cue and direct attention to the properties associated with the categories to which these words refer. Moreover, the claim is that the statistical regularities between words and properties cue attention at two levels of generalization: Known names cue attention to the particular properties pertinent to the specific kind; novel names cue attention to the property generally relevant across all known categories. There is no claim here that this is all that words do, no claim that the only function of words is to direct attention to perceptible properties. Many other studies suggest that the naming serves many functions, increasing the similarity of things (Sloutsky, Lo, & Fisher, 2001) as a cue for intended categories that override perceptual similarity (Welder & Graham, 2001) and as an intention to compare objects (Namy & Gentner, 2002). However, the present claim is that one function of words is to direct attention to the category-relevant properties of things. As such, the hypotheses motivating these experiments could be construed as firmly on the perceptual side of the perceptual-conceptual debate.

However, proponents on the conceptual side of this debate might offer an alternative account of the present findings. For example, they might argue that in the novel name condition of Experiment 2, it is not that naming cues attention to shape, but rather that children have conceptual knowledge of the general importance of shape to the function and design of common things (e.g., Gelman & Bloom, 2000; Kemler-Nelson, Russell, Duke, & Jones, 2000) and therefore children reason (conceptually) that shape is likely to be a relevant property. They might argue further that known names do not consistently take children to shape in Experiment 1 because known names take children to their conceptual knowledge about particular kinds, for example, to the knowledge that towels need to be made of a material that absorbs water.

Although these two accounts seem to differ fundamentally, they offer similar accounts at one level of analysis. That is, both accounts attribute the effect of known names to children's specific knowledge about specific categories and the effect of novel names to children's general knowledge about what is generally but not specifically true about nominal categories. The two accounts differ in the hypothesized content of the knowledge children bring to

bear and in the proposed mechanisms behind that knowledge. But, by both accounts, children have and use knowledge at two different levels of generalization. This is the main conclusion to be drawn from these experimental results.

Still, we believe our attentional learning account is preferable on these grounds: Our account is based on a mechanism, attentional learning, that is independently known to exist and is well documented (e.g., Kruschke & Blair, 2000; Medin et al., 1982; Medin & Schaffer, 1978). The account includes as its basic components the ability to perceive and discriminate words, the ability to selectively attend to the properties of things, and learned links between words and specific things. These are abilities that will have to be included in any complete conceptual account. Thus, a conceptual account of the present results will include the attentional learning account but will add to it the intervening construct of conceptual knowledge. This means that any phenomenon that is explainable by attentional learning will be explainable by the conceptual account. (If a set of propositions A can explain the data, then by necessity the set of propositions A+B can explain the data as well). Parsimony would thus seem to favor the attentional learning account.

Recently, there have been growing arguments from several directions that the perceptual-conceptual debate is not resolvable, not well defined, and not worthy of the attention it receives. Rakison (in press) has argued that the theoretical constructs of perception and conception are undefined, leaving theorists free to draw their line between the two wherever they see fit, and free to change that line as needed. Goldstone and Barsalou (1998; see also Smith & Heise, 1992) argue that perception itself is a product of category learning and thus the very features and dimensions that structure our experiences are themselves knowledge (or theory) laden. Ahn and Luhmann (in press) has argued that the developmental debate between conceptual and perceptual categories is misguided because it is organized around content such that salient dimensions such as shape are put on the perceptual side and dimensions such as intentionality, functionality, and nonobvious properties are put on the conceptual side. Ahn and Luhmann have pointed out that for intentionality (or functionality or nonobvious properties) to matter in categorization, they must be perceivable or have perceivable consequences, as she has put it. If, she has argued, intentions (or functionality or nonobvious properties) are perceivable, categories based on these properties are

fundamentally perceptual categories, just like those based on shape except that the perceivable consequences of intention, function, and so forth are more subtle, more transient, and less available to introspection. Barsalou (in press) and Rakison (in press) made similar points when they argued that all concepts must be grounded in perception.

Perhaps, then, it is better to leave the perception-conception debate to the past. In this newer theoretical context, the present results resolve prior contrasting experimental results showing that children sometimes form categories by shape but sometimes do not. The present experiments point to one critical experimental factor that matters: whether the names are known or novel. The results also indicate that children have category knowledge at multiple levels of abstraction. Moreover, words direct attention to these different levels of abstraction: Known names for known categories direct attention to the properties relevant for that category, whereas novel names direct attention to the properties most generally relevant across all known object categories.

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