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Children's Theories of Word Meaning: The Role of Shape Similarity in Early Acquisition

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This research contrasts two important proposals as to children's assumptions about word meanings: the taxonomic assumption proposal and the shape bias proposal. Both proposals agree that children focus on groups of "like kind" in word meaning extension, but they differ in their assumption as to the nature of "likeness" for young children. We tested the two proposals by separating and comparing category membership and perceptual similarity in a word/no-word match-to-sample task. Two age groups of children, 3- and 5-year-olds, were shown a standard picture (e.g., an apple) and three other pictures: a taxonomically similar object (e.g., a banana), a perceptually similar object (e.g., a ball) and a thematically related object (e.g., a knife). They were asked either: "This is a *dax;* show me another dax" or "Find the one that goes with this one." There were two main results. First, both age groups showed a pronounced shift from thematic-based to shape-based responding when novel words were given. Second, a developmental shift was found from shape responding to taxonomic responding in the presence of a novel word.

These results suggest that perceptual similarity (in particular, shape similarity) is very important in early word meaning, but that children gradually shift their attention to deeper properties. We conjecture that this early focus on perceptual similarity may help young children learn categories, gradually bootstrapping them to a sense of taxonomic relations that goes beyond perceptual similarity.

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Children are amazingly efficient word learners. Carey and Bartlett (1978) demonstrated that children are able to map a concept onto a novel word, at least approximately, with a single exposure (see also Heibeck & Markman, 1987). The process of "fast mapping" is paradoxical given the well-known complexity involved in inferring the referent of an unknown word (Quine, 1960). Recent research has led to significant gains in understanding the assumption children use to constrain possible word meanings (e.g., Carey, 1982; Clark, 1987; Gelman & Markman, 1986; Markman & Hutchinson, 1984; Markman & Wachtel, 1988; Soja, Carey, & Spelke, 1991; Waxman & Gelman, 1986; Waxman & Kosowski, 1990).

This research concerns the assumptions children use in extending noun meanings to other referents. Given that a word has been applied to an object (by Markman's *whole-object* assumption), on what basis do children decide how to extend the label to other objects? There is considerable evidence that children have special knowledge about meanings (Gelman & Markman, 1986; Markman & Hutchinson, 1984; Waxman & Kosowski, 1990). For example, Markman and Hutchinson presented 4-year-olds with a standard (e.g., *cow*) and two choice pictures, of which one was taxonomically related (*pig*) to the standard and the other was thematically related (*milk*). In the labeling condition, they gave a nonsense word such as *dax* to the standard and asked the children to "find another dax." In the control condition, no label was given and the children were asked to "find another one." Markman and Hutchinson found that children made above-chance selection of the taxonomic alternatives when a novel noun was given, although they clearly preferred thematic items in the control condition. Markman's *taxonomic* constraint formalized the notion that young children implicitly know that meanings of nouns are organized around categorical relations rather than thematic relations (Markman, 1989; Markman and Hutchinson, 1984; Waxman & Gelman, 1986).

Perceptual Bias

In contrast to the research described so far, other research has suggested a perceptual bias in children's noun meanings. Children's focus on perceptual qualities such as shape in early object terms was pointed out in research on spontaneous production (Bowerman, 1978; Clark, 1973) and picture naming (Anglin, 1977). For example, Clark reported many examples of overextensions based on shape (e.g., the word *moon* was extended to cakes, round marks on windows, round marks in books, the letter "O," etc.).

Gentner (1978) examined the information that enters into children's early meaning by pitting perceptual similarity against functional similarity. She taught children names for two artificial objects that differed both in form and function. After children learned the names for the two objects, they were shown a hybrid object that looked like one of the objects but functioned like the other. Even though young children were most attracted by the function (that of providing candy), over 80% of the 2- to 5-year-olds responded based on form similarity.

Gentner thus argued that children have clear, if implicit, hypotheses about what enters into word meaning and that these hypotheses are distinct from their interests (see also Tomikawa & Dodd, 1980).

Recently, Landau, Smith, and Jones (1988; see also Jones, Smith, & Landau, 1991; Smith, Jones, & Landau, 1992) have made a strong case for the importance of perceptual similarity, particularly shape similarity, in young children's word meanings. For example, they taught 2- and 3-year-olds and adults a word for an artificial object (e.g., a U-shaped wooden object) and then presented them with other objects that varied from the original along one perceptual dimension with other dimensions kept constant. When asked whether the test objects could be named by the same word as the original object, young children and adults all focused heavily on shape, giving less weight to other dimensions such as size, texture (Landau et al., 1988), and color (Smith et al., 1992; see also Baldwin, 1989; Ward, Vela, Perry, Lewis, Bauer, & Klint, 1989). Subjects were more influenced by the nonshape dimensions in the no-word condition. These suggest that the general perceptual effects discussed earlier may stem largely from an early focus on common shape. Therefore, we employ Landau et al.'s term, the *shape bias,* rather than the *perceptual bias.*

Integration of the Two Views

Although both the taxonomic assumption and the shape bias proposals represent significant advances, each leaves important questions unaddressed. For example, although the taxonomic proposal asserts that children know that nouns are generally extended taxonomically (or as we might more neutrally put it, categorically), it does not explicitly address how children represent taxonomic knowledge nor by what processes they apply it. As Lucariello, Kyratzis, & Nelson (1992) pointed out, there appear to be different forms of category knowledge, such as knowledge of functional relations (Nelson, 1973) and of participating in event schemas (Lucariello et al., 1992; Nelson, 1983). Another important question in clarifying the status of the taxonomic constraint is to specify to what extent children's nonperceptual, deep internal properties are separable from perceptual information in the representation of taxonomic categories. This question cannot be unambiguously answered by most of the previous studies that support the taxonomic assumption proposal (D'Entremont & Dunham, 1992; Markman & Hutchinson, 1984; Waxman & Gelman, 1986; Waxman & Kosowski, 1990) because in these studies (as in normal experience) perceptual similarity was correlated with membership in taxonomic categories. For example, in the triad used by Markman and Hutchinson, the cow (the standard) and the pig (the taxonomic alternative) were perceptually more similar to each other than were the cow and the milk (the thematic alternative). Thus, it is possible that children's shift towards the categorical choice when a noun label is used is influenced by perceptual similarity (especially shape similarity; see Jones & Smith, 1993).

The foregoing arguments suggest that the taxonomic proposal is incomplete. However, the shape bias proposal is also clearly incomplete. It might indeed enable children to form basic level groupings, if only approximately (Rosch, Mervis, Gray, & Boyes-Braem, 1976; see also Tversky & Hemenway, 1984), but it cannot explain how children go beyond the basic level to learn names for superordinate categories like *furniture,* whose members show great perceptual variation. As Soja, Carey, & Spelke (1992) pointed out, it also cannot account for cases in which perceptually similar objects do not belong to the same category (e.g., *basketball, orange*). Thus, we need to ask not only whether children show an early shape bias, but also how they go beyond basic level object names and how their knowledge about nonperceptual properties of a category interacts with the shape bias at different stages in development.

In sum, important questions have been left unaddressed by the previous two proposals. The taxonomic assumption proposal does not explain the basis for children's early taxonomic categories and how children form them. The shape bias proposal lacks an explanation of how children learn category names beyond the basic level. A natural way to address these lacunae is to combine the two proposals in a view that could be called the shape-to-taxonomic-shift hypothesis.

The shape-to-taxonomic-shift hypothesis parallels patterns observed across cognitive development: such as the perceptual-functional shift (Bruner, Goodnow, & Austin, 1956), the characteristic-to-defining shift (Keil, 1989; Keil & Batterman, 1984), and the relational shift (Gentner, 1988). As Gentner and Rattermann (1991) reviewed, research across many different paradigms suggests that similarity for young children is at first highly conservative and perceptually bound. Transfer occurs only when the target is similar to the original both in its attributes and relations (e.g., Baillargeon, 1991; DeLoache, 1990; Gentner, Rattermann, Kotovsky, & Markman, in press; Gentner & Toupin, 1986; Smith, 1984, 1989; Smith & Kemler, 1977; Sugarman, 1982). With experience in the domain, however, there is a relational shift. Children become able to perceive common higher order relations independent of an object's attributes: Their sense of "likeness" becomes more abstract. Applying these ideas to word learning, we might expect that children's early word-based categories should reflect local object similarities (such as form similarity) if young children believe that words refer to categories of like objects. As children's domain theories deepen, abstract relational likenesses amplify or supplant the initial categories. Thus the shape-to-taxonomic shift hypothesis states that early word meanings are strongly based on shape similarity and that the stronger sense of the taxonomic assumption—a bias strong enough to enable children to extend nouns solely based on common relations and nonvisible properties, with little reliance on perceptual similarity—may not appear until relatively late in development.

An Empirical Test

In order to test the three proposals, we separated taxonomic relations and shape similarity in constructing materials. What predictions do each of the proposals make when taxonomic category and shape similarity are in conflict? The extreme version of the taxonomic assumption proposal predicts that children will extend word meanings based on nonobvious taxonomic relations rather than shape similarity (as long as some knowledge about nonperceptual taxonomic relations is available). The extreme version of the shape bias proposal predicts that children will extend word meanings based on common shape. The shape-to-taxonomic-shift hypothesis predicts an initial shape bias followed by a preference for using deeper commonalities.

Despite ample research supporting both the strong taxonomic assumption and the strong shape bias, there has been little attempt to compare them directly. One study that did so is that of Baldwin (1992). She compared children's preference for taxonomic versus shape extensions to a given word-object pairing and found evidence for considerable shape responding as well as some taxonomic responding in 3- to 5-year olds. These results are intriguing, but they leave open the crucial question of the nature of the developmental pattern. Our study (which was designed independently of Baldwin's) differed also in that we directly compared the three alternatives instead of pitting two at a time in different triad tasks.

In order to separate taxonomic relations from shape similarity, we used the word/no-word matching paradigm used by Markman and Hutchinson (1984), but included three alternatives instead of two: a thematic alternative, a taxonomic alternative (which was related to the standard taxonomically but bore little shape similarity to it) and a shape alternative (which was similar to the standard in terms of overall shape, but bore no categorical relation to it). As in the previous studies (Markman & Hutchinson, 1984; Waxman & Kosowski, 1990), subjects were assigned to either the word or no-word condition. (The word condition might better be labeled as the *novel noun* condition, but for simplicity we will use the usual label of *word.*)

The predictions and questions are as follows. First, if young children make the assumption that possible word meanings are based on likeness, a preference shift away from thematic relations would be expected between the no-word and the word conditions. Thus, even 3-year-olds should rule out thematic alternatives as possible candidates for word meaning extension in the word condition, even though they might tend to choose them in the no-word condition (Smiley & Brown, 1979; see also Bauer & Mandler, 1989; Greenfield & Scott, 1986). The next question is the nature of this likeness: If children shift from thematic responding in the word condition, do they then choose taxonomic responses or shape responses? Finally, does this pattern change with age? The shape-to-taxonomic-shift hypothesis predicts developmental change from shape responses to taxonomic response in the word condition.

EXPERIMENT 1

Method

Subjects. Sixty children of two age groups, thirty 3-year-olds and thirty 5-year-olds, participated. They were enrolled in preschool programs serving middle- and upper-middle class families in suburban Chicago. The 3-year-olds ranged in age from 2;11 (years; months) to 4;4 (M = 3;9) and consisted of 17 boys and 13 girls. The 5-year-olds ranged in age from 4;6 to 6;0 (M = 5;5) and consisted of 16 boys and 14 girls. Three other children were eliminated because their responses appeared to be location-based.

Thirty college students also served as subjects for course credit in an introductory psychology course. The subjects were randomly assigned to either the word or the no-word condition, with approximately equal numbers of men and women in each condition.

Stimuli. There were 11 sets of colored pictures of objects familiar to children in their everyday environment. Of the 11, two were used for familiarization and consisted of three drawings: the standard picture and two alternatives. One of the choice pictures was identical to the standard picture and the other was a picture of an object that bore no relation to the standard picture. The remaining nine sets, listed in Table 1, were the experimental materials (see Figure 1 for the pictures for a sample set). They consisted of four pictures each, each picture containing one, two, or three identical objects.[1] The number of objects per picture was kept constant within a set. In each set, one picture served as the standard (e.g., a *necklace*), and each of the three alternatives was related to the standard in a different way. The first alternative (the taxonomic alternative) belonged to the same taxonomic category as the standard,[2] but did not perceptually resemble the standard (e.g., a *ring*). The second alternative (the shape alternative) was similar to the standard in shape, but bore no categorical relation to the standard (e.g., a *jump rope*). The third alternative (the thematic alternative) was thematically related to the standard, but had no perceptual or categorical similarity to it (e.g., a *woman*). Because our concern was with shape similarity rather than overall perceptual similarity, no picture was the same color as another picture within the same set.

[1] The reason that each picture contained more than one object in some item sets is that we also conducted a parallel cross-linguistic study using Japanese children (Gentner, Uchida, & Imai, in preparation). In the Japanese study, however, we included a classifier condition, in which a nonsense word was given in the syntactic position for a classifier, that is, after a numeral. Because a classifier in Japanese appears only with a numeral, we used a counting task and therefore needed to vary the number of objects (one, two, or three) across items.

[2] The taxonomic alternatives were selected on the basis of sharing category membership with the standard at a level above the basic level but still relatively specific. We avoided very abstract categories such as "concrete object." The taxonomic alternative always shared a more specific category level with the standard than did the thematic alternative. For example, in Set 2, although the thematic item *milk* can be considered to be in the same taxonomic category (*food*) as the standard (*cookie*), the taxonomic alternative (*candy*) shares a more specific category (*sweets*) with the standard. The fact that the adults almost never selected thematic alternatives throughout the nine-item sets in Experiment 3A, even in the item sets in which the thematic item could potentially belong to the same taxonomic category as the standard, is evidence that the category relations represented by taxonomic alternatives were more compelling than those represented by thematic alternatives.

Table 1. Materials in Experiments 1 Through 3

Set	Standard	Taxonomic	Shape	Thematic
1	apple	grapes	balloon	knife
2	cookie	candy	coin	milk
3	necklace	ring	jump rope	woman
4	banana	strawberry	feather	monkey
5	carrot	potato	nail	rabbit
6	drum	flute	bucket	drumsticks
7	sandwich	hamburger	wood block	orange juice
8	birthday cake	pie	hat	present
9	plate	square tray	compact disk	fried chicken

Adult Shape Similarity Ratings. In order to make sure that the shape alternatives were perceptually more similar to the standard than the other two alternatives, we asked 22 students enrolled in a psychology course at Northwestern University to rate the shape similarity between the standard and each of the three alternatives. This was done for each of the nine stimulus sets using a scale of 1 (very dissimilar) to 7 (very similar). The presentation order was counterbalanced across subjects.

The mean similarity rating and standard deviation for each of the three alternatives across the nine sets were: taxonomic alternatives, $M = 2.54$, $SD = 0.59$; shape alternatives, $M = 6.06$, $SD = 0.66$; and thematic alternatives, $M = 1.65$, $SD = 0.69$. A series of dependent t tests (t tests for differences) was conducted on the difference between the similarity score of the shape alternative and that of the taxonomic and the thematic alternatives for each of the nine test trial sets. In every test set, the rated shape similarity to the standard was significantly higher for the shape alternative than for either of the other two alternatives.

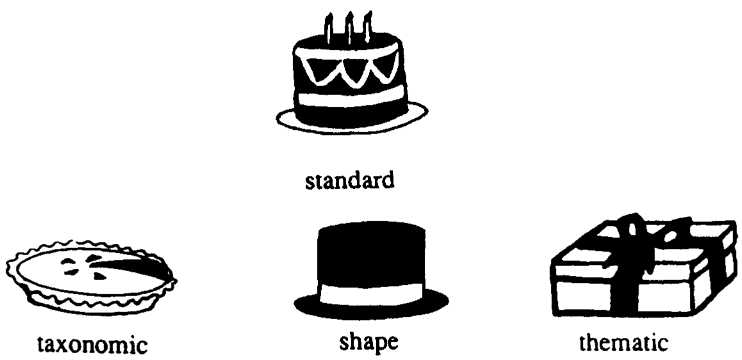

Figure 1. Sample material set used for Experiments 1 through 3.

Procedure. Children were tested individually in a quiet room in their preschools. They were randomly assigned to either the word or no-word condition. A puppet, "Jojo the baby dinosaur," was used to help engage children in the task.

In the word condition, the children were told by the experimenter that the puppet was learning "dinosaur talk." The experiment consisted of two phases: the familiarization phase and the test phase. During the familiarization phase, first a picture of a fish was shown and a novel label was provided to give the idea that the dinosaur words were different from English words. This was necessary to eliminate the possible effect of the mutual exclusivity bias (Markman & Wachtel, 1988) or lexical contrast (Clark, 1987). Because we used pictures of familiar objects for which we expected 3-year-olds to know most of the basic level names and some of the superordinate names, children might otherwise have thought that we were teaching new subordinate English words and thus might have avoided selecting a category choice. Two practice trials were then administered, in which the child was presented with a standard picture and the experimenter said to the child, "See? This is a *fep* in dinosaur talk. Can you help Jojo find another *fep?*" Only two choice pictures were presented in order to minimize difficulty. One of them was identical to the standard whereas the other was totally unrelated to the standard. No child failed to choose the identical picture both times. The test phase followed immediately after these practice trials and utilized the same procedure, except that the sets contained three alternatives: taxonomic, shape, and thematic alternatives, as previously described.

In the no-word condition, there was no familiarization phase. The child was asked to help the dinosaur play a "go with" game with the experimenter. The standard picture was presented and then three choice pictures were shown. The child was asked to choose the one that "goes with" the experimenter's picture.

In both conditions, the children were encouraged and praised, but no explicit feedback was given during the test phase. The order of presentation of the nine test sets was counterbalanced across subjects. The location of each of the three choices (i.e., taxonomic, shape, thematic) relative to the child was counterbalanced within each individual.

Adults were also tested individually, but without the use of the puppet. In the word condition, they were simply told: "Imagine that you are learning a new language you don't know. In that language, this (pointing to the standard) is a *fep*. Which of these (pointing to the three choices) can also be a *fep* in that language?" They received only the nine test trials without practice trials. The procedure for the adult subjects in the no-word condition was identical to that for the children in the same group, except that the puppet was not used.

Results

The mean frequency, standard deviation, and proportion of responses for each of the three alternatives by age and condition are given in Table 2. A clear difference in the response pattern was observed across the two conditions. In the no-

Table 2. Mean Frequency, Standard Deviations, and Percentage of Choices for Each of the Three Choices in Each Condition in the Three Age Groups in Experiment 1

	Alternatives		
	Taxonomic	Shape	Thematic
3-Year-Olds			
Word	0.93 (0.70)	6.13 (2.41)	1.93 (2.25)
	10%#	68%*	21%#
No-Word	1.60 (1.24)	3.46 (2.64)	3.93 (2.25)
	18%#	39%	44%*
5-Year-Olds			
Word	2.53 (2.13)	5.00 (2.97)	1.47 (1.80)
	28%	56%*	16%#
No-Word	1.93 (2.15)	2.60 (2.80)	4.46 (2.80)
	21%#	29%	50%*
Adults			
Word	5.80 (3.3)	3.00 (3.35)	0.20 (0.41)
	64%*	33%	2%#
No-Word	3.30 (2.61)	0.80 (1.93)	5.20 (3.14)
	33%	9%#	58%*

Note. The choices selected less than 25% or more than 41% are significantly different from chance by the binomial criterion, $p < .05$, two-tailed.
*Denotes significantly above chance level; #Denotes significantly below chance level.

word condition, the thematic alternatives were chosen most frequently in all the age groups. A marked shift away from thematic responding was observed in the word condition for all age groups, indicating that subjects were sensitive to the word-meaning task. However, within the word condition, the three age groups showed very different response patterns. Children, both 3- and 5-year-olds, selected the shape alternatives more often than the taxonomic alternatives, whereas adults selected the taxonomic alternatives almost twice as often as the shape alternatives. We first examine the children's response patterns and then compare them with that of adults. Because the dependent measure is response type frequency, the appropriate statistical test for a two-way design is an asymmetric log-linear analysis (i.e., the logit model), which is roughly analogous to an analysis of variance (ANOVA) with a dependent measure and independent variables (see Kennedy, 1992). Also, in the log-linear analysis we can make a direct comparison among the relative proportion of the three response types, which is impossible to do in ANOVA because the proportions of response types are not independent.[3]

[3] However, we conducted separate ANOVA analyses for each of the three response types as if the relative proportion of one response type were not dependent on the others. These analyses revealed

First, we examined whether the independent variables, age and condition, affect the relative proportion of taxonomic, shape, and thematic responses. Asymmetric log-linear models were fitted on a 2 (Age) × 2 (Condition) × 3 (Response Type) contingency table with the response type as the asymmetric response variable. The effects of age and condition were both highly significant, $\chi^2(2) = 11.73$ and $\chi^2(2) = 51.87$, respectively, both $p < .01$. The Age × Condition interaction was marginally significant, $\chi^2(2) = 5.15$, $p < .08$.[4] We next turn to analyses of each response type.

Thematic Responses. The proportion of thematic responses in the two groups of children was analyzed to determine whether we had replicated a part of Markman and Hutchinson's (1984) finding that children's preference for thematic relations shifts between the word and the no-word conditions. The children in both age groups made thematic responses significantly more often than expected by chance in the no-word condition (3-year-olds: 44%; 5-year-olds: 50%) but significantly less often than expected by chance in the word condition (3-year-olds: 21%; 5-year-olds: 16%) by the binomial criterion, $p < .05$, two-tailed (chance = 33%).[5] An asymmetric log-linear analysis was conducted collapsing shape and taxonomic responses together to further examine the contribution of age and condition on thematic responses. In the log-linear analysis on the 2 (Age) × 2 (Condition) × 2 (Thematic vs. Nonthematic response) contingency table with the last variable as the response variable, the condition main effect was found to be highly significant, $\chi^2(1) = 44.87, p < .001$. Neither age nor the Age × Condition interaction significantly affected the proportion of thematic responses. Thus, consistent with Markman and Hutchinson's findings, a significant shift away from thematic responses with novel nouns was observed between the no-word and the word conditions.

Shape Versus Taxonomic Responses. Next we turn to the central question of this study: whether the children extended novel nouns on the basis of tax-

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the same patterns of significance as the log-linear analyses with the following exceptions. In a 2(Age) × 2(Condition) ANOVA on the number of taxonomic responses using all the nine item sets, the Age × Condition interaction did not reach significance, $F(1, 56) = 2.14$, p = .142. In the same ANOVA using only the six familiar item sets, neither age nor the Age × Condition interaction effect was significant, $F(1, 56) = 1.95, p = .17; F(1, 56) = 3.12, p = .08$, respectively. The weaker results in the ANOVA analysis are not surprising given that the range of response frequency is fairly limited in our data and, especially when the three item sets were deleted from the analysis, the number of responses was not particularly large: Under this situation the violations of the assumptions of normality and homogeneity of variance were rather severe.

[4] These effects were actually obtained by conducting multiple hierarchical models and examining the residual of each model against the saturated model. This procedure is somewhat analogous to hierarchical regression analysis. The saturated model was employed because the residual of the main effect model (the model that included only age and condition main effects) was marginally significant.

[5] All chance computations in the following sections were computed in this way.

onomic relations or shape similarity. As can be seen in Table 2, in the no-word condition, children's level of responding was at chance level for shape (3-year-olds: 39%; 5-year-olds: 29%) and below chance level for taxonomic responses (3-year-olds: 18%; 5-year-olds: 21%). Children showed a marked change in responding in the word condition, but this change was concentrated in increased shape responding. In both age groups, the children in the word condition made shape responses significantly more often than would have been expected by chance (3-year-olds: M = 68%; 5-year-olds: M = 56%). In contrast, 3-year-olds made taxonomic responses significantly lower than chance level (M = 10%) and 5-year-olds at chance level (M = 28%) in the word condition.

The data suggest that children paid attention to shape similarity rather than to taxonomic relations in extending novel nouns. Two log-linear analyses converged to confirm this pattern. In the first analysis, shape responses were compared with the other two response types. Here, the main effects for age and condition were both significant, $\chi^2(1) = 7.21, p < .01$ and $\chi^2(1) = 42.10, p < .001$, confirming greater shape responses in the word than in the no-word condition and in 3-year-olds than in 5-year-olds. The Age × Condition interaction did not make a significant contribution to the fit. In the second analysis, we examined taxonomic responses against the other two response types. The age factor was significant, $\chi^2(1) = 10.04, p < .01$, confirming more taxonomic responses for 5-year-olds than for 3-year-olds. However, there was no contribution of condition, $\chi^2(1) = 0.34$, contrary to the prediction of the strong taxonomic proposal. Most interestingly, a significant age and condition interaction was found, $\chi^2(1) = 4.50, p < .05$. As Figure 2 shows, 3-year-olds made *fewer* taxonomic responses in the word condition than in the no-word condition, significant by a binomial test, $z = 3.52, p < .001$, two-tailed. In contrast, as predicted by the shape-to-taxonomic shift, 5-year-olds made *more* taxonomic responses in the word condition than in the no-word condition, $z = 2.57, p < .01$, two-tailed.

Comparison Between Adults and Children. The adult pattern for thematic responses was similar to the pattern observed in the children. That is, the adults made thematic responses at well above chance level in the no-word condition (M = 58%) and very rarely in the word condition (M = 2%). Thus, not surprisingly, the adults showed a strong shift away from thematic relations in extending noun meaning.

A marked difference between adults and children was observed in the relative proportion of taxonomic and shape responses in the word condition. In sharp contrast to the strong preference for the shape responses by the children, the adults selected the taxonomic alternatives almost twice as often as the shape alternatives (64% vs. 33%). Interestingly, adults made significantly more taxonomic responses than 5-year-olds in the word condition, $z = 11.88, p < .0001$, but not in the no-word condition, $z = 1.32, p > .05$.

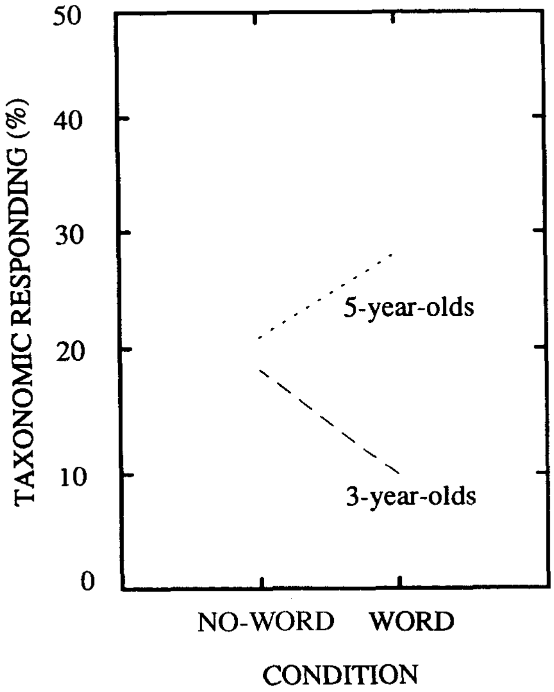

Figure 2. Interaction between age and condition with respect to taxonomic responses.

Discussion

There were three important findings. First, both children and adults shifted away from thematic relations when they extended the meanings of novel words. This finding is consistent with demonstrations by Markman and Hutchinson (1984) and others (Baldwin, 1992; D'Entremont & Dunham, 1992; Gentner, 1978; Waxman & Kosowski, 1990), that children have implicit theories about word meanings. Second, contrary to the strong taxonomic assumption proposal, both 3- and 5-year-old children relied chiefly on shape similarity rather than taxonomic relations as a basis for word meaning extension (see Baldwin, 1992, for converging evidence). Third, the shape-to-taxonomic-shift hypothesis was supported: There was a significant increase in the relative proportion of taxonomic responses in the word condition with age. Although the number of taxonomic responses also rose in the no-word condition, the increase was greater in the word condition, as indicated by the significant interaction between age and condition. The early shape bias with words was so strong that 3-year-olds made taxonomic responses significantly *less* often with labels than without them. However, by 5 years of age, it seems that this strong shape bias has been weakened and in part replaced with the taxonomic assumption: The 5-year-olds selected more taxonomic alternatives with labels than without them, although shape responses still predominated. Finally, adults in the word condition showed a strong taxonomic preference. This pattern suggests that the strong taxonomic assumption is unlikely to be a constraint that guides children from the onset of language acquisition. Rather, it appears that children are guided by shape similarity early on and that this shape bias is gradually supplemented by deeper taxonomic knowledge.

In sum, the evidence in Experiment 1 supports the shape-to-taxonomic-shift hypothesis. However, before drawing conclusions, two concerns should be pointed out. One is that some picture sets utilized multiple identical objects (see Footnote 1). We were concerned that this might have confused children and led them into a more perceptual orientation. However, as discussed earlier and in the General Discussion, Baldwin (1992) obtained converging evidence for early dominance of shape similarity over taxonomic relations using only pictures of single objects. Thus our findings do not appear to have resulted from the number of items depicted. The second concern is whether children were sufficiently familiar with our items to have made an informed choice. The shape-to-taxonomic-shift hypothesis assumes a role for increasing category knowledge in promoting the shift. Nonetheless, the extreme case of little or no category knowledge does not provide a fair test of the taxonomic assumption, because children might simply have focused on shape due to the fact that no categorical information was available. To check children's understanding of the nonperceptual taxonomic relations represented in our materials in Experiment 2, we asked another group of 3-year-olds to sort pictures based on the common salient function shared by the standard and the taxonomic alternative for each test set.

EXPERIMENT 2

Method

Subjects. Ten children (4 boys, 6 girls) ranging from 3;0 to 4;3 (M = 3;6) participated. They were from the same population as the children in Experiment 1.

Procedure. The four pictures in each set were displayed in front of the child. The child was asked to help the puppet choose pictures that fit some common function. For example, the experimenter said, "Jojo likes things that girls wear," for Set 3, or "Jojo likes things that he can eat," for Set 1. If the child selected only one picture, the experimenter asked if there were more pictures that Jojo would like.

Results and Discussion

Scoring. A response was scored as correct when the child selected both the standard and the taxonomic alternative and *no others*. A response was scored as correct whether the two were selected spontaneously at once or the second picture was selected after the prompt: "Are there any more pictures?"

Overall Performance. Overall, the 3-year-olds were correct 77% of the time. The sharp contrast between young children's baseline category knowledge and their performance in the word condition in Experiment 1 (3-year-olds: 10%; 5-year-olds: 28%) indicates that their low taxonomic performance in Experiment 1 cannot be attributed to a lack of abstract knowledge about categories.

Item Analysis. The performance in Experiment 3 was not uniform across all items: Children performed more successfully on some item sets than others. The sets on which children performed relatively poorly were Set 2 (Sweets: *cookie, candy*), Set 3 (jewelry: *ring, necklace*), and Set 6 (instruments: *drum, flute*), correctly sorted 60%, 60%, and 50% of the time, respectively. The other six sets were sorted correctly 80% of the time or more.

Category Knowledge and the Shape-to-Taxonomic-Shift. The item analysis indicated that basic category knowledge based on nonperceptual functions is relatively less available for Sets 2, 3, and 6. When we calculated the proportion of taxonomic responses for these item sets separately, we found some evidence that children made fewer category-based word meaning extensions and made more shape responses in these three item sets than the rest. In Experiment 1, for 3-year-olds taxonomic responses made up 4% of the total for these three sets and 13% for the remaining six sets; for 5-year-olds taxonomic responses made up 20% of the total for the three sets and 32% for the other six sets. Although this pattern is not strong, it is suggestive. That taxonomic word meaning extension was more prevalent in the sets for which category knowledge was relatively more accessible suggests that the shift from shape-based to category-based word meaning extension may occur at different times for different categories. This suggestion that the shift to taxonomic responding occurs earlier for more familiar categories is consistent with Gentner and Rattermann's (1991) thesis that domain knowledge drives children's shift from object-based similarity to relational similarity.

Reanalysis of Experiment 1. Given that some item sets were relatively (but not totally) unfamiliar to the 3-year-olds and that these unfamiliar items yielded fewer taxonomic responses than the familiar items, we were concerned that the strong shape bias we found in Experiment 1 might simply reflect lack of category knowledge. To examine this possibility, the data from Experiment 1 was rean-

Table 3. Percentages of Taxonomic, Shape, and Thematic Responses for the Six Familiar Item Sets in Experiment 1

	Alternatives		
	Taxonomic	Shape	Thematic
3-Year-Olds			
Word	13%#	58%*	20%#
No-Word	22%#	38%	41%
5-Year-Olds			
Word	32%	52%*	16%#
No-Word	21%#	26%	53%*

Note. The choices selected less than 23.3% or more than 42% are significantly different from chance by the binomial criterion, $p < .05$, two-tailed.

*Denotes significantly above chance level; #Denotes significantly below chance level.

alyzed using only the six items that yielded taxonomic sorting 80% of the time or more in Experiment 2.

The new results, shown in Table 3, although slightly more taxonomic than the previous results shown in Table 2, still show a strong shape bias. The shape alternative (3-year-olds: 58%; 5-year-olds: 52%) were still preferred over the taxonomic alternatives (3-year-olds: 13%; 5-year-olds: 32%) in the word condition. An asymmetric log-linear analysis on the 2 (Age) × 2 (Condition) × 2 (Taxonomic vs. Nontaxonomic responses) contingency table with the last variable as the response variable yielded the same results as in the previous analysis: There were significant effects of age, $\chi^2(1) = 4.17, p < .05$, and of the Age × Condition interaction, $\chi^2(1) = 5.01, p < .05$, but no significant effect for condition. Binomial tests again revealed that 3-year-olds in the word condition made fewer taxonomic responses than those in the no-word condition, whereas 5-year-olds in the word condition made more taxonomic responses than those in the no-word condition.

The fact that we obtained a similar pattern even when we included only the item sets that were highly familiar to children shows that the shape bias can apply even when children have knowledge of the categories (though there is evidence that children respond more taxonomically with experience in the category).

These results are rather surprising given previous findings in related tasks, such as induction from categories, that very young children make inferences about nonobvious properties of categories based on category membership rather than appearance when the two are in conflict (e.g., Gelman & Coley, 1990; Gelman & Markman, 1986). We have interpreted these results to suggest that young children arrive at an implicit hypothesis that nouns refer to categories of like objects[6], where "like" initially means "highly similar in shape." But another possibility is that children may believe from the start that taxonomic relations are important, but expect perceptual similarity to be correlated. Faced with a task that separates perceptual from conceptual similarity, perhaps children simply chose the shape alternative out of confusion. After all, words are sometimes extended on the basis of shape, ignoring ontological or taxonomic categories, such as when "bear" is used to refer to a toy bear (see Landau, Smith, & Jones,, 1988, 1992; Soja, Carey, & Spelke, 1991, 1992; Wisniewski & Gentner, 1991). Given this ambiguity observed in language, it is possible that the children in Experiment 1 might have been confused over whether we were asking about possible metaphorical extensions or about word meanings. In fact, the data from the adult subjects (33% of total responses in the word condition were shape responses) may indicate some such confusion about the task.

Putting it another way, perhaps the children in Experiment 1 assumed in essence that the word was a basic-level term and therefore expected its extensions to have high perceptual similarity, including shape similarity (Rosch et al., 1976). Because they could not find any alternative satisfying this expectation, they might have given up their taxonomic assumption and extended the word perceptually. Thus, the children in fact might have shown a focus on taxonomic relations if they had realized that the novel noun was meant to refer to a superordinate category name.

Another concern might be raised by the use of "dinosaur language." We used this to forestall the possibility that children would resist applying new names because of the mutual exclusivity bias. But possibly children thought that dinosaur language was different from "people's language." If this is the case, it is difficult to explain why the children avoided the thematic alternatives in the word condition. But maybe they believed that no language (even dinosaur language) could ever be organized around thematic relation, but thought that shape-based word meaning was possible for dinosaurs but not for humans.

In Experiment 3, we performed a pretraining exercise designed to clarify the task and to highlight superordinate category relations. We used a variant of Callanan's (1989) "multiple instance strategy," which has been shown to promote children's understanding that a novel word denotes a superordinate category. Two instances from the same superordinate category that did not resemble each other were shown and named by the same word. After two such training trials, children were given the test trials as in Experiment 1. If the shape bias found previously in Experiment 1 merely reflected confusion about the task, then they should focus on taxonomic relations when given instructions that emphasize those relations.

[6] There is evidence that children do not use a shape bias for nonobjects such as nonsolid substances (Soja, Carey, & Spelke, 1991) and even for simple solid objects in the case of Japanese children (Imai & Gentner, 1993).

If, on the other hand, the results of Experiment 1 reflect children's best current theories of word meaning extension, then they should still continue to show a shape bias in the word condition.

In order to examine whether such an increase in taxonomic responding (if any) is specific to the taxonomic assumption, and not merely due to some general effect of training (e.g., Bauer & Mandler, 1989), we conducted a no-word condition in addition to the word condition. If taxonomic responding increases due to a nonlinguistic general training effect, then the increase in taxonomic responding should be approximately the same for children in the no-word condition as for those in the word condition. However, to the extent that children believe that nouns are organized around taxonomic relations, then children in the word condition should show a greater increase in taxonomic responding than those in the no-word condition.

Prior to conducting Experiment 3 with children, we tested adults' performance. We expected that adults given category instructions would extend word meanings taxonomically nearly 100% of the time.

EXPERIMENT 3A

Method

Subjects. Fifteen college students who were enrolled in an introductory psychology course participated in the experiment for course credit. For adults, only the word condition was used.

Stimuli. The nine stimulus sets used during the test phase were identical to those used in Experiment 1. However, the stimuli for the familiarization phase were changed. Three sets consisting of a standard and two alternative pictures were used. In each set, the correct alternative was related to the standard in terms of taxonomic relations at a superordinate level but did not bear much perceptual similarity (either in shape or color) to the standard. The incorrect alternative was unrelated to the standard. The three sets were: (1) a *gray cat,* a brown big dog, and a blue triangle; (2) a *motorcycle*, an airplane, and three red squares; (3) a *yellow flower,* a green tree, and a bone.

Procedure. Three pretraining trials were carried out prior to the test trials. As before, subjects were told to assume that they were learning words in a language they did not know. A nonsense label was given to the standard and subjects were asked to choose the alternative that could be labeled by the same name as the standard. No subject chose any incorrect alternatives during pretraining. The test trials were identical in materials and procedures to those used in Experiment 1. No feedback was given during the test trials.

Results

As expected, the adults made taxonomic responses almost all the time (94%). As Table 4 shows, the shape and thematic alternatives were selected only 4.5% (6 out of 135 responses) and 1.5% (2 responses) of the time, respectively.[7] Given that this pretraining and instruction seemed successful in reducing or eliminating task confusion, we applied this technique to children.

EXPERIMENT 3B

Method

Subjects. Sixty-eight children participated, and of these, eight children (six 3-year-olds, two 5-year-olds) were eliminated from the analyses because of an apparent location bias. The final population of 60 children was divided into two groups of 30 by age: (1) 3-year-olds ranging from 3;0 to 4;4 (M = 3;6, 14 boys, 16 girls); and (2) 5-year-olds ranging from 4;6 to 5;9 (M = 5;2, 15 boys, 15 girls). All 60 were enrolled in preschool programs in the same suburban area as the children in Experiment 1. None of the subjects had participated in Experiment 1.

Procedure. As in Experiment 1, children in the 3- and 5-year-olds groups were randomly assigned to either the word or no-word condition with approximately an equal number of boys and girls in each condition. The procedure was the same as that in Experiment 1 except for the familiarization phase, which was as follows.

In the word condition, the child was told that the puppet was learning dinosaur talk. The child then received three practice trials with the same three pretraining sets used in Experiment 3A. As in Experiment 1, a standard picture (e.g., a cat) was shown with a novel label and the child was asked which of the two alternatives was named by the same word. If the child selected the correct alternative (a dog), the experimenter put the correct alternative next to the standard and said "You are right. This is a fep (pointing to the standard) and this is also a fep (pointing to the correct choice). They are both feps in dinosaur talk because they are both *animals.*" She then proceeded to the next trial. When the children selected the incorrect picture (a blue triangle), they were corrected and an expression was given. The experimenter said, "No, I don't think so. I think this is a fep (putting up the correct alternative next to the standard). They are both feps,

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[7] When adult subjects selected a shape alternative, we asked for justification after all the trials were completed. The justification usually found the shape similarity salient (while realizing that the objects were different kinds of things). In two cases, subjects misunderstood the picture at first glance (e.g., the picture of an Oreo-like cookie was mistaken for a button). When we explicitly asked adults to choose "the categorically related" picture after the justification, they were all able to select the taxonomic alternative.

because they are both animals." She then proceeded to the next trial. The pretraining trials were performed in a fixed order, from Set 1 through Set 3. When the three trials were finished, any set in which the child had failed to choose taxonomically was repeated. Prior to the experiment, we decided to drop subjects either when they failed all of the three trials or when they still could not choose the correct alternative when the failed trial was repeated. None of the subjects were dropped for these reasons.

The children in the no-word condition also received pretraining to emphasize superordinate-level category relations. The same three sets were used as in the pretraining in the word condition. The children were asked to choose one of the alternatives that "goes with" the standard. During the pretraining trials, when children selected the correct alternative, the experimenter said, "You are right. This (the correct alternative) goes with this (the standard) because they are both animals." When they were incorrect they were told "No, I don't think so. I think this goes with this. Do you know why? Because they are both animals."

In both conditions, the procedure during the test phase was identical to that in Experiment 1: No feedback was given except for encouragement.

Results

Results of Experiment 3B. Table 4 summarizes the proportion of each choice type observed in each of the two conditions as well as the mean and the standard deviation in the two age groups and the adults.

If children believed word extension follows taxonomic relations and had merely shown a shape bias in Experiment 1 because of task confusion, then taxonomic alternatives should be favored over shape alternatives in the word condition in this experiment. This possibility was not supported. Although the overall number of taxonomic responses did increase relative to the number in Experiment 1, neither the 3-year-olds nor the 5-year-olds in the word condition preferred the taxonomic alternatives to shape alternatives. Shape alternatives were still selected significantly more often than chance in both age groups (3-year-olds: 49%; 5-year-olds: 43%). In contrast, the proportion of taxonomic responses did not differ from chance in either age group (3-year-olds: 29%; 5-year-olds: 38%) by the binomial criterion, $p < .05$, two-tailed (chance = 33%). As in Experiment 1, an asymmetric log-linear analyses was conducted on a 2 (Age) × 2 (Condition) × 3 (Response Type: Thematic, Taxonomic, and Shape) contingency table. Only the condition main effect was significant, $\chi^2(2) = 39.20$, $p < .0001$. Age was only marginally significant, $\chi^2(2) = 4.99$, $p = .08$, and no significant interaction between age and condition was found. We then contrasted the taxonomic responses to the other two response types and found that as in Experiment 1, condition did not affect the proportion of taxonomic responses. In contrast to the results of Experiment 1, however, age also did not affect the proportion of taxonomic responses, nor was there any interaction between Age × Condition.

Table 4. Mean Frequency, Standard Deviations, and Percentage of Choices for Each of the Three Choices in Each Condition in the Three Age Groups in Experiment 3A and 3B

	Alternatives		
	Taxonomic	Shape	Thematic
3-Year-Olds			
Word	2.60 (1.55)	4.40 (2.77)	2.00 (1.92)
	29%	49%*	22%#
No-Word	3.00 (2.13)	2.66 (1.44)	3.33 (1.54)
	33%	30%	37%
5-Year-Olds			
Word	3.40 (2.50)	3.87 (2.99)	1.73 (1.80)
	38%	43%*	19%#
No-Word	2.80 (1.97)	1.60 (1.80)	4.60 (1.55)
	31%	18%#	51%*
Adults			
Word	8.46	0.41	0.20
	94%*	4.5%	1.5%#

Note. The choices selected less than 25% or more than 41% are significantly different from chance by the binomial criterion, $p < .05$, two-tailed.
*Denotes significantly above chance level; #Denotes significantly below chance level.

However, when the three less familiar item sets as found in Experiment 2 (Sets 2, 3, 6) were excluded from the analysis, a marginally significant Age × Condition interaction was found, $\chi^2(1) = 3.43, p = .06$. Binomial tests revealed that, as in Experiment 1, 3-year-olds made fewer taxonomic responses in the word condition (M = 30%) than the no-word condition (M = 39%), whereas 5-year-olds made more taxonomic responses in the word condition (M = 44%) than in the no-word condition (M = 34%), $p < .01$, two-tailed. This analysis revealed no main effects for age or condition.

Comparison Between Experiment 1 and Experiment 2. The results so far have not supported the possibility that children's failure to demonstrate a taxonomic assumption in Experiment 1 was due to task confusion. We nonetheless wished to check a second indicator. As discussed earlier, if the children in the word condition in Experiment 3 showed a greater increase in taxonomic responses over Experiment 1 than those in the no-word condition, this would provide some evidence for a taxonomic assumption. To test this, we examined whether the interactions involving experiment and condition (i.e., either the Experiment × Condition interaction or the Experiment × Condition × Age interaction) were significant. A 2 (Experiment) × 2 (Age) × 2 (Condition) × 2

(Taxonomic vs. Shape/Thematic Responses) contingency table was submitted to an asymmetric log-linear analysis to test this possibility. The hypothesis was not supported. Whether the analysis included all of the nine item sets or only the six familiar item sets, neither Experiment × Condition nor Experiment × Condition × Age reached significance at $p < .05$.

Discussion

In Experiment 3, we tried to make clear to the children that we were asking about taxonomic relations. However, even with pretraining in which taxonomic relations were explicitly emphasized (and which virtually eliminated nontaxonomic responding for adults), children's taxonomic responding was still at chance levels, and both age groups in the word condition selected shape alternatives significantly more often than expected by chance. Furthermore, the same striking Age × Condition interaction observed in Experiment 1 for taxonomic responses was observed here when only familiar items were included in the analysis. Whereas 5-year-olds showed the expected increase in taxonomic responding with novel nouns, 3-year-olds made *fewer* taxonomic responses in the word condition than in the no-word condition (as in Experiment 1), in spite of the categorical emphasis given during the pretraining. Further, the lack of a significant Experiment × Condition interaction or Experiment × Age × Condition interaction between Experiment 1 and Experiment 3B provided no support for a language-specific effect due to taxonomic pretraining. Although pretraining with two perceptually dissimilar instances from the same superordinate category did help children pay attention to taxonomic relations, the increase seems rather general and not specific to word meaning extension. As Waxman and Hall (1993) pointed out, the existence of nonlinguistic training effects for enhancing children's taxonomic performance is not at all inconsistent with the existence of specific linguistic biases. Our point here is simply that this pretraining appears not to have had differential effects.

The results of Experiments 3 make it unlikely that the shape bias in Experiment 1 simply reflected children's confusion caused by the nature of the stimuli. Rather, the results suggest that young children's early focus on shape similarity in word meaning extension reflects a genuine assumption about word meanings.

GENERAL DISCUSSION

Four points emerge from this research. First, our results confirmed prior findings that young children have expectations about possible word meanings. There was a marked shift in response patterns between the word and no-word conditions. Second, children, both 3- and 5-year-olds, relied on shape similarity rather than taxonomic relations as a basis for extending novel nouns when the two were pitted against each other, even though they possessed knowledge of the relevant category. Third, there was a significant increase in taxonomic responses and a corresponding decrease in shape responses between 3 and 5 years of age, suggesting a gradual shift from the shape bias to a broader and more taxonomic approach to word meaning. Finally, children tended to perform more taxonomically when they had better understanding of the category, suggesting that the shift is driven by knowledge of the domain.

Our results support the central tenet of Markman's taxonomic constraint proposal, namely that children take nouns to refer to categories of like objects. What is at issue is how young children define "like." Our results do not support the strong interpretation of the taxonomic assumption, that even very young children extend word meanings based on nonobvious but causally deep properties. Rather, it appears that perceptual similarity—in particular, shape similarity—is an important determinant of young children's word extension. This finding is consistent with other results showing effects of perceptual similarity in early word meaning extension (Gentner, 1978; Landau, Smith, & Jones, 1988; Smith, Jones, & Landau, 1992; Taylor & Gelman, 1989; Tomikawa & Dodd, 1980; Waxman & Senghas, 1992) and early spontaneous word usage (Bowerman, 1978; Clark, 1973), as discussed earlier.

Comparisons With Previous Research

Our research has suggested that children's early word extensions are based largely on perceptual similarity. These results may seem at odds with other findings demonstrating taxonomic responding in very young children. For example, Waxman and Kosowski (1990) presented 2-year-olds with a standard item (e.g., a *bee*) and four choices, two of which belonged to the same superordinate category as the standard (e.g., an *owl*, a *butterfly*) and two of which were thematically related to the standard (e.g., a *beehive*, a *flower*). The items were selected from broad superordinate categories (e.g., *animals* including large animals, small animals, and birds; *food* including both fruit and vegetables). Nonetheless, in the noun labeling condition, the 2-year-olds selected taxonomic alternatives significantly more often than would have been expected by chance, and in the adjective and no-word conditions, taxonomic responding did not exceed chance level. Bauer and Mandler (1989) also performed a labeling/nonlabeling triad task with very young children using superordinate categories (e.g., *flower, plant*) and found that even the youngest group of subjects (19-month-olds) could respond based on taxonomic relations. They did not, however, find sensitivity to the use of linguistic labels, but this may have resulted from the already high level of taxonomic responding induced by their reinforcement technique (see Waxman & Hall, 1993). We return to these studies later.

In contrast to these apparently contradictory findings, Baldwin's (1992) recent investigation supports the claim that children initially extend noun meanings perceptually rather than taxonomically. As in the present research, Baldwin carried out a word/no-word paradigm using sets in which the shape alternative was perceptually more similar to a standard than a taxonomic alternative, but was not related to it taxonomically. Baldwin's study differed from ours, first, in that there was only one age group (3- to 5-year-olds) and, second, in that the standard was compared to only two alternatives at a time. She found that children shifted from thematic to shape responding and from thematic to taxonomic responding in the presence of noun labels. This latter finding is interesting because it is evidence of a word-based shift towards common taxonomic relations even with minimal shape similarity. However, because the children in her study ranged from 3 to 5 years in age, we cannot tell how closely this finding applied to the 3-year-olds in her study. Our results would lead us to expect this pattern from the 5-year-olds.

An important converging result is that when Baldwin (1992) directly contrasted a shape alternative and a taxonomic alternative in a triad, she found a significant *decrease* in taxonomic responding among 3- to 5-year-olds with words (66% in the no-word condition, 46% in the word condition) in favor of shape responding—the same pattern found among our 3-year-olds. Thus, overall, Baldwin's results are compatible with our own in suggesting greater initial reliance on shape similarity than on taxonomic relations in extending novel nouns. Our study extends this method to permit an examination of the development of these patterns. In our results, the paradoxical decrease in taxonomic responding with words was true for 3-year-olds but not for 5-year-olds.

How can we reconcile findings that very young children are sensitive to taxonomic relations with the findings by Baldwin (1992) and by us that 3- and 5-year-olds extend words on the basis of shape rather than taxonomic commonalities? First, in many of the studies supporting a taxonomic shift when words are used, the stimulus materials reflect the real-world correlation between perceptual similarity and conceptual similarity. Thus the finding of a taxonomic bias in those cases is compatible with the present results (e.g., D'Entermon & Dunham, 1992; Markman & Hutchinson, 1984). Perceptual similarity was not a central concern in the Waxman and Kosowski (1990) and Bauer and Mandler (1989) studies. Thus these studies did not include an alternative that was perceptually more similar than the taxonomic alternative. With natural categories such as were used in these studies, taxonomic alternatives tend to be more similar to the standards than do thematic alternatives.[8] To the extent that this was true, relative perceptual similarity would have supported the taxonomic choice. In fact, Gentner and Rattermann (1991) and Waxman and Hall (1993) have suggested that perceptual similarity may play an important role in the establishment of taxonomic categories.

A more general factor may be the nature of the categories used. Waxman and Kosowski (1990) used animals as the taxonomic categories in 9 out of 12 sets,

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[8] Sandra Waxman kindly provided us with the stimuli used in Waxman and Kosowski (1990) and we asked 20 undergraduate students at Northwestern University to rate the similarity in shape of the alternatives to the standard. The ratings indicated that the taxonomic items were perceptually more similar to the standard than were the thematic items in 10 of the 12 sets.

whereas our studies included none. A number of researchers have suggested that the animate–inanimate distinction appears very early (Carey, 1985; Dolgin & Behrend, 1984; Gelman, 1990; Mandler & Bauer, 1988). Mandler, Bauer, and McDonough (1991) demonstrated that 21-month-old infants were able to sort categorically when animals were contrasted with vehicles but not when tools were contrasted with musical instruments. Thus the difference between our results and the results of Waxman and Kosowski may stem from animal categories' being particularly accessible to children. Such an explanation fits with the "expertise" speculation we made concerning the results of our category-knowledge correlation: The more children know about a category, the more likely it is that they will have progressed beyond a purely perceptual word extension to conceptual extension.

Inducing Categories Versus Induction From Categories

Gelman and her colleagues have amassed an impressive body of research on children's induction from categories that suggests that the taxonomic assumption guides children in making inductive projections from one object to another. For example, when told that an animal has some new property, children are more likely to infer that another animal has that property if the animals are given the same category label (Gelman & Coley, 1990; Gelman & Markman, 1986). Gelman and her colleagues suggest that the label functions as a signal to seek an underlying category implying a rich system of both visible and invisible properties. This may include members that do not resemble other category members. Gelman and Markman demonstrated that 4-year-olds were able to draw inferences based on category labels even when perceptual information is in conflict with the category membership, and Gelman and Coley demonstrated that even 2-year-olds can draw inferences based on common categories, resisting crosscutting perceptual similarity.

How can we reconcile these findings with our finding that 3-year-olds are highly influenced by shape similarity in extending object labels? There are several points to be made here. First, there is evidence that children—even 4-year-olds—are not unaffected by perceptual similarity in category induction (Davidson & Gelman, 1990; Farrar, Raney, & Boyer, 1992). Davidson and Gelman varied perceptual similarity and common labels independent to create a 2×2 matrix of possible category members. When children were taught that a property applied to the standard and asked which other cases it could apply to, Davidson and Gelman found that 4-year-olds drew inferences based on perceptual similarity; there were no significant effects of the common label (Experiments 1 and 2). In their third study, Davidson and Gelman removed one of the two conflicting cases—either the high-similarity/different-label case or the low-similarity/same-label case—thus creating a more perceptually coherent category structure. Under these conditions they found a significant effect for labeling. However, perceptual similarity continued to have strong effects as well. For example, given common labels, children drew significantly more inferences to test objects that were perceptually similar to the target (70%) than to those that were perceptually dissimilar from the target (41%).

Another point to consider is the familiarity of the categories. In the Gelman and Coley (1990) study with 2-year-olds, the categories and the properties were familiar (e.g., *rabbits/eat carrots*), so that children may have drawn on existing category knowledge. Finally, an additional intriguing possibility is that extending a word's meaning and drawing new inferences from a named category may not make use of exactly the same features.[9] Perhaps children rely initially on shape similarity in extending a newly learned word to other objects but weigh deeper nonperceptual commonalities more heavily than perceptual similarity when they draw new inferences based on a common category label.

This possibility receives some support from a study by Gelman, Collman, and Maccoby (1986). They studied 4-year-olds' use of gender categories to see whether inferring new categories on the basis of property information and inferring new properties on the basis of category information were symmetrical. The children in the *property inference* condition had to make inferences about nonperceptual properties based on category membership, whereas those in the *classification* condition had to determine category membership based on properties. Gelman et al. found that children made inferences about nonobvious properties based on category membership even when category membership conflicted with appearance. However, the reverse pattern was not observed in the classification task: The children relied on appearance rather than on the given properties in determining the gender of the target picture. The task of word meaning extension in the present study is similar to the classification task in Gelman et al.'s study. In both situations children had to decide which commonalities mattered in extending a category. If there is an asymmetry between extending a category name and drawing inferences based on category names, this would have contributed to the greater role of perceptual similarity in our studies (and those of Baldwin) than in the category-based inference studies of Gelman and her colleagues. This question awaits further research.

The Shape-to-Taxonomic Shift Is not Dichotomous

Neither the extreme taxonomic nor the extreme shape-based proposals were supported by our results. In particular, the results for 3-year-olds run counter to the strong interpretation of the taxonomic assumption, that children begin with essentially taxonomic biases. However, our data also failed to support the extreme version of the shape bias proposal, that even adults rely chiefly on perceptual similarity. The adults' relatively high spontaneous use of taxonomic relations in noun extension in Experiment 1 (over 60%) and the ease with which they adopted a purely taxonomic strategy in Experiment 3 (94%) indicate a developmental increase in the propensity for including deep category-relevant information in

[9] This distinction may be related to that between the core of a category and the information used to identify category members (Gelman & Medin, 1993; Nelson, 1974; Smith & Medin, 1981).

word extensions. This increase in taxonomic responding with age (and with availability of knowledge about particular categories), does not support a pure shape-based account.[10] At the same time, these results do not justify concluding that adults are purely taxonomic. Over 30% of the adults in Experiment 1 chose to extend the novel noun to the shape alternative rather than the taxonomic alternative. This is consistent with the evidence that adults continue to find shape similarity relevant in forming and extending word meanings (Jones & Smith, 1993; Landau, Jones, & Smith, 1992; Landau, Smith, & Jones, 1988; Smith, Jones, & Landau, 1992).

Can young children's assumptions concerning noun meaning extension be reduced to a pure shape bias? Our data do not allow us to decide this. It may be, as suggested by Baldwin (1992), that children believe that taxonomic relations and shape similarity are generally correlated and use shape similarity as the best indicator for determining membership in a taxonomic category. (In fact, this belief is often correct in the real world; see Medin & Ortony, 1989.) This possibility is somewhat undetermined by the finding that children who are taught about important functions of objects nonetheless prefer to name the objects by their (cross-cutting) shape similarity (Gentner, 1978; Landau, Smith, & Jones, in preparation). For example, Landau, Smith, and Jones taught young children about new objects by saying, "This is a dax. And this is what I can do with it," followed by a demonstration of a function that depended on the material of which the object was made (e.g., a *sponge* sopping up water). Although adults and older children extended the word partly on the basis of its material, younger children showed a strong shape bias. This finding parallels Gentner's (1978) finding that young children preferred to name a new object based on perceptual resemblance with a prior named object, rather than on the basis of a highly salient functional commonality (that of providing candy). However, it is still possible that the shape bias gives way in some contexts to other information about objects that is more causally central. Further research is necessary to determine the precise status of the shape bias in young children's approach to noun meanings.

The Causes of the Shape-to-Taxonomic Shift

The results here suggest that young children rely strongly on shape similarity in extending word meaning and gradually deepen their focus to include taxonomic

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[10] Although Landau et al. (1988) found that the noun shape bias became stronger with age, this result was observed in a task environment that did not involve competition with taxonomic alternatives. In their task, only novel nonsense objects were used. In that situation, shape is probably the best indicator for object categories. On this account, adults (correctly) showed a stronger shape bias than 2-year-olds because they were better able to suppress other salient perceptual aspects. However, consistent with the shape-to-taxonomic-shift hypothesis, adults were also more flexible than children in shifting their focus to other dimensions when these dimensions are made task-relevant (see Jones & Smith, 1993; Landau, 1993).

relations. But what is the mechanism that underlies this shape-to-taxonomic shift? One possibility is that there is a global change in children's assumptions about word meanings, perhaps a stage shift marked by increased cognitive competence (e.g., Inhelder & Piaget, 1958). We think it more likely that the change is gradual and knowledge-based. Our results suggest that the shift from a shape bias to a taxonomic assumption depends on the child's familiarity with the category and its conceptual domain, suggesting that the shift should take place at different times across different categories. This interpretation accords with the pattern of a knowledge-driven relational shift in development for other cognitive tasks (Brown, 1989; Carey, 1985; Chi, in press; Gentner & Rattermann, 1991).

Within the knowledge-driven view, an intriguing possibility is that the shape-to-taxonomic shift may in part be driven by the simple process of applying common labels to perceptually similar exemplars. Gentner and Rattermann (1991) argued that there is a mutually supportive relation between the development of language and the development of similarity. Children's initial word meanings are limited by the kind of similarity—conservative perceptual similarity—that is available to children with very scanty domain theories. But the acquisition of common terms promotes deeper categories, because (we conjecture) applying the same word to a set of objects prompts the child to compare and align the objects, resulting in the highlighting of commonalities, including abstract and relational commonalities (Gentner & Markman, 1994; Markman & Gentner, 1993a, 1993b). Thus, alignment invited by common labels may promote insight into deeper commonalities and permit bootstrapping from perceptually similar exemplars to less obvious exemplars (Gentner, Rattermann, Markman, & Kotovsky, in press; see also Karmiloff-Smith, 1991).

This view that words help children acquire deep taxonomic properties by promoting the alignment of attributes and relations may explain the somewhat puzzling gap in taxonomic performance between the word extension tasks (Experiment 1, Experiment 3) and the classification task based on functions (Experiment 2). As argued by Nelson (1974), young children often make function-based groupings of objects independent of naming (see also Mandler, 1993). However, the knowledge of function by itself does not guarantee adult-like taxonomic categories (Lucarielo, Kyratzis, & Nelson, 1992). We suggest that word learning is one force through which functional knowledge becomes aligned and integrated into a semantic and conceptual system (e.g., Smith & Sera, 1992).

Young children's reliance on perceptual similarity in word meaning extension does not necessarily imply that children are atheoretical, nor that they lack interest in the causal and functional properties of objects. The principle that words name *like kinds* is of major value in penetrating the linguistic system. Further, we suggest that a selective focus on shape may function as a kind of implicit theory about noun meanings. The advantage of common shape for such a purpose (aside from being fairly predictive of a word's extension) is that it can be applied consistently even when other knowledge is fragmentary. Thus it may be a drive for a uniform lexical principle than can be applied widely that draws children to the shape dimension. On this view, the initial shape bias, because it provides an entry into a large set of concrete noun meanings, is not a blind alley but a path towards more sophisticated meanings.

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