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The Importance of Shape in Early Lexical Learning

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We ask if certain dimensions of perceptual similarity are weighted more heavily than others in determining word extension. The specific dimensions examined were shape, size, and texture. In four experiments, subjects were asked either to extend a novel count noun to new instances or, in a nonword classification task, to put together objects that go together. The subjects were 2-year-olds, 3-year-olds, and adults. The results of all four experiments indicate that 2- and 3-year-olds and adults all weight shape more heavily than they do size or texture. This observed emphasis on shape, however, depends on the age of the subject and the task. First, there is a developmental trend. The shape bias increases in strength and generality from 2 to 3 years of age and more markedly from early childhood to adulthood. Second, in young children, the shape bias is much stronger in word extension than in nonword classification tasks. These results suggest that the development of the shape bias originates in language learning—it reflects a fact about language—and does not stem from general perceptual processes.

Within the first few years of life, children learn many hundreds of words for different kinds of natural objects and artifacts. As many have noted, the rapidity and accuracy of this learning present a puzzle: The information objectively

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present to the child at the time of learning is in many ways inadequate to specify the meaning of any particular word.

Consider the example of a child learning the word that represents the meaning *rabbit* from his mother's ostensive definition. The child observes some object as his mother points and says "rabbit." The child could guess that *rabbit* means *rabbit*, but there are many different, equally reasonable, descriptions of the same scene. The child might guess that the word refers to a particular part or property of the rabbit or to the rabbit's relation to some other aspect of the scene (cf Quine, 1960). Even if the child assumed that the word referred to concrete whole objects, the question of category level would remain: the word rabbit might refer to some higher level category such as 'animal,' or to some lower level category such as 'Himalayan spotted rabbit.' In short, there are many kinds of categories in a given scene to which a given noun might refer. Given this mapping problem, how do children discover the particular category to which a particular noun refers?

One possibility is that the child brings to the word-learning task certain initial hypotheses about the likely referents of words. For example, reasonable arguments and supporting data exist to suggest that young children assume that nouns refer to objects, rather than relations or attributes, and to what objects look like rather than what we can do with them or where we can find them (Bloom, 1973; Brown, 1973; Gentner, in press; Masur, 1982). These initial hypotheses could be due to perceptual similarities that are irresistibly present to the young child even prior to language learning; or these hypotheses could in some way be more specifically linked to the language-learning task. We have in mind Markman and Hutchinson's (1984) demonstration that in a word-learning task, young children categorize objects into taxonomic groups, but, in a nonword learning task, they categorize those same objects thematically. Apparently, the categories picked out by words are not completely coextensive with the categories that are salient to children in all contexts.

In this paper, we consider the possibility that young children might hold initial hypotheses about which dimensions of perceptual similarity are important in determining the extension of a novel count noun. Our examination of children's uses of perceptual dimensions in word learning might seem to run counter to the current emphasis on nonperceptual bases for categorization (for review, see Murphy & Medin, 1985). We agree that relations beyond "mere appearance" (Gentner, 1983) must ultimately figure in children's and adults' understanding. There are compelling logical arguments (Armstrong, Gleitman, & Gleitman, 1983; Fodor, 1981) and empirical demonstrations of this point. For example, older preschoolers consider mechanical and real monkeys to look alike, but they judge real monkeys and snakes to have more similar insides (Carey, 1985). Further, 3½ and 4-year-old children who are taught new facts about an object (e.g., crow) extend such knowledge to other objects of the same kind, even if the objects differ considerably in appearance (e.g., flamingo) but not to objects of a different kind even if similar in appearance (e.g., bat; Gelman & Markman, 1986).

This evidence shows that nonperceptual factors are important in the representation of concepts. Such evidence does not, however, imply that perceptual similarities are not also important. Indeed, for the purpose of naming objects, perceptual similarity would sometimes seem to be more critical than deeper similarities are not also important. Indeed, for the purpose of naming objects, perceptual similarity would sometimes seem to be more critical than "deeper" ical monkey by the same name. Further, young children, especially, might be expected to emphasize perceptual similarities in naming objects as they have limited knowledge of deeper similarities (Carey, 1985). We consider these issues more fully in the general discussion. For the present, our point is that whereas perceptual similarities are surely not the whole story, they are just as surely part of the story and they are the part on which we focus here.

The particular issue that motivates the present studies is the possibility that certain dimensions of perceptual similarity are weighted more heavily than others in determining the extension of a count noun. We consider shape, size, and texture, and we ask the following specific questions. First, upon hearing a new word and seeing some novel object, will the young child generalize to new items on the basis of the object's shape, its size, its texture, all of these, or none of these? Second, if there is a dimensional bias, is it strictly a lexical one (pertaining to word formation) or is it a more general perceptual phenomenon?

We chose to consider shape, size, and texture as a starting point in this endeavor because these perceptual properties are common to all concrete objects and are detectable even by prelinguistic infants (Ruff, 1984). We assume that the child's problem in learning words is to select just those properties that might be relevant for naming objects. Potentially relevant dimensions, then, are those that pertain to all concrete objects. Further, there is suggestive evidence that dimensional biases do exist: specifically, that shape has some special status over other perceptual attributes. In a variety of classification tasks, including adults' object recognition (Biederman, 1985), adults' and children's classification of basic level objects (Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976) and label learning (Bornstein, 1985; Heibeck & Markman, 1987; Au & Markman, 1987; Clark, 1973), shape appears to be the primary determinant of response choices. It is this possibility, that shape is somehow special in the naming and categorizing of objects, that motivates our studies.

Although there is suggestive evidence that shape is special, documentation of that privileged status is not easily accomplished. The central problem concerns the measurement of psychological similarity. Consider a situation in which a particular object, say a 6-inch square, is judged to be more like a 12-inch square than like a 6-inch circle. In this situation, shape preference is tested by examining preference for a single shape relative to a single size (see Heibeck & Markman, 1987; Au & Markman, 1987; Soja, Carey, & Spelke, 1985). We cannot conclude from this choice that shape is a more important dimension than is size in classification. After all, the psychological difference between a square and a circle may simply be greater than that between the two size values employed. If we made the size differences larger, size, not shape, might control performance. Ideally, what one needs is a common metric of similarity, independent of classification performance, with which to compare changes on different perceptual dimensions. Unfortunately, similarity scaling techniques are not straightforward and, in addition, are not suitable for our youngest subjects.

Our approach was to examine judgments across a range of magnitudes of difference. If a dimension has a privileged status in categorization, then that status ought to be evident across a range of stimulus values. For example, if, in our illustrative task above, a child chose the 6-inch square and 12-inch square as belonging together, we would then ask whether he or she would also judge a 36-inch square as belonging. Thus, although we did not precisely specify the psychological similarity space, we attempted to construct stimuli that would test the limits of any privileged dimension. In this way, we attempted to determine if shape has a privileged status in word learning and, if so, if that status changes with development.

EXPERIMENT 1

In this experiment, we taught subjects a consonant, vowel, consonant (CVC) name for each of two nonsense objects. We then employed two different methods to assess the relative importance of the shape, size, and texture dimensions in extending these CVC names to other novel objects. The first method was a yes/no categorization task. Subjects were presented with the named exemplar and asked if test items were also called by that name. Although this yes/no procedure is subject to potential response biases, especially in the younger children, we chose it nonetheless because it seemed to correspond to the manner with which we use words in everyday situations. Unless one has very atypical examples, an object either is called a chair or is not. We supplemented this measure with a second, forced-choice procedure in which subjects were asked which of two test items was the better instance of a named category. This forced-choice measure should be less prone to response biases and also should be particularly revealing of the relative weightings of the three perceptual dimensions.

Method

Subjects. Twenty-two subjects at each of three age levels participated: 2-year-olds (24 to 36 months, M = 28 months); 3-year-olds (36 to 42 months, M = 38 months); and college students. The yes/no method was used at Indiana University to test 12 subjects in each age group. The forced-choice method was used at Columbia University to test 10 subjects in each age group. The child subjects in both cases were drawn from local preschools and files of birth announcements.

Stimuli. Two sets of nonsense objects were constructed (see Figure 1). The standard for one set, the Dax, was a 2 inches tall × 2 inches wide, blue, wooden "U" shape. The standard for the second set, the Riff, was an unpainted, wooden, deformed circle, approximately 2 inches in diameter.

Each test set for this experiment consisted of seven objects: a duplicate of the standard (Standard*) and two changes each of size, texture, and shape (see Changes 1 and 2, Figure 1). The two size changes differed from the standard only in size: For example, the Dax Size 1 stimulus was 2½ inches rather than 2 inches and the Size 2 stimulus was 8 inches. The two texture changes differed from the standard only in texture: in the Dax set, the Texture 1 stimulus was cloth-covered wood and the Texture 2 stimulus was made of stiff sponge. In the Riff set, the Texture 1 stimulus was sandpaper-covered wood and the Texture 2 stimulus was bubble-pak-covered wood. The two shape changes differed from the standard only in shape: The Shape 1 and Shape 2 stimuli in each set were as shown in Figure 1.

Procedure. In the yes/no procedure, subjects were shown a single standard (i.e., the Dax) and told its name ("This is a Dax"). The standard remained in view throughout the entire procedure. Subjects were then shown the seven test objects one by one and asked, "Is this a Dax?" The two sets (Dax and Riff) were presented in separate blocks. Each test object was queried twice. Order of items was random within a block, and the order of blocks was counterbalanced within each age group. In total, then, there were 28 trials per subject, 4 trials for each of seven test object types (Standard*, Size 1, Size 2, Texture 1, Texture 2, Shape 1, Shape 2).

In the forced-choice procedure, subjects were shown a standard and told its name. With this standard in view, subjects were then presented with pairs of objects and asked, "Which of these is a Dax (or Riff)?" In this manner, each subject judged 18 unique pairwise contrasts. Six trials contrasted each of the two values of the three dimensions with the Standard*; and 12 trials contrasted each of the two values of the three dimensions with each other (e.g., values 1 *vs.* 1 and 2, 2 *vs.* 1 and 2 for each pair of dimensions). Half of the subjects were assigned at random to judge the Dax set; half judged the Riff set. Within each set, the 18 trials were presented in one of three random orders.

Results and Discussion

Analyses of the results were done separately for each method.

Yes/No Procedure. Table 1 shows the proportion of trials on which each type of test object was accepted as a member of the named category. There were no differences between judgments of the Dax and Riff sets; therefore, the data were collapsed across stimulus sets. As is evident in Table 1, adults accepted objects as instances if they were the same shape as the standard—that is, differing from the standard in size only (Size 1, Size 2) or in texture (Texture 1,

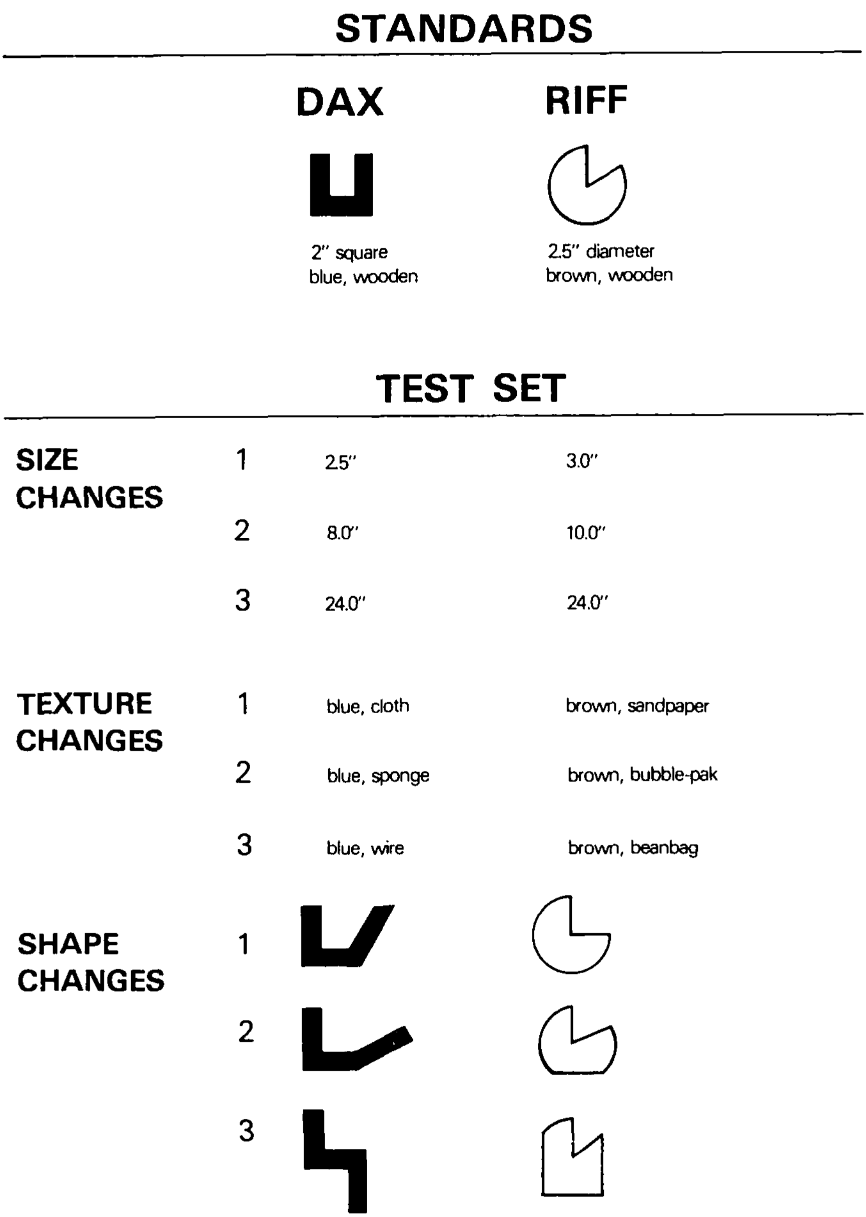

Figure 1. Stimulus sets for all experiments. Stimuli are specified in terms of how they differ from the standard. A duplicate of the standard was always included in the test set, whereas subsets of size, texture, and shape changes were used for different experiments. See text for details.

Table 1. Experiment 1: Proportion of Yes Responses for Each Object Type in the Yes/No Procedure

Dimension and Magnitude of Difference for Test Objects	Age Group		
	2-Year-Olds	3-Year-Olds	Adults
Standard	.96	.98	1.00
Size changes			
1	.93	.98	1.00
2	.93	.95	1.00
Texture changes			
1	.88	.95	1.00
2	.96	.95	1.00
Shape changes			
1	.88	.91	.12
2	.69	.50	.06

Texture 2). They uniformly rejected the test items that differed from the standard in shape (Shape 1, Shape 2). Both groups of children accepted all test objects as instances except objects differing by the larger amount in shape (Shape 2). In other words, they accepted all objects that were the same or similar in shape. These results are consistent with our expectations: Differences in shape between a standard and a test object seemed to matter more than differences on either of the other two dimensions.

Given the lack of variance in the adult responses, only the children's data were submitted to a 2(age) $\times$ 3(dimension) $\times$ 2(magnitude of difference) analysis of variance for a mixed design. This analysis yielded significant main effects of dimension, $F(2,44) = 13.09, p < .01$, and magnitude of difference, $F(1,22) = 5.71, p < .05$. There was no effect of age. The dimension by magnitude of difference interaction was also reliable, $F(2,44) = 13.23$, $p < .01$. Post hoc analyses (Tukey's $HSD = .11, a < .05$) indicated that test objects differing from the standard in shape were rejected substantially more often than those differing on either of the other two dimensions. The latter were accepted equally often. The dimension by magnitude of difference interaction appears to be due to the greater rejection of the Shape 2 test item over the Shape 1 test item. The two values on each of the other two dimensions were accepted equally often. Thus, only differences in shape seemed to matter in this procedure.

Forced-Choice Procedure. The forced-choice procedure was designed to circumvent any response bias in the yes/no procedure, and, more importantly, to gauge how the dimensions were ranked relative to one another. We evaluated this question by calculating the proportion of times all four objects (values 1 and 2, Dax and Riff) differing from the standard on a particular dimension were chosen over objects differing on the contrast dimension. Table 2 shows the proportions of acceptances by each age group of items differing from the exemplar in size, texture, and shape.

As in the yes/no procedure, adults always preferred the object that preserved the same shape as the standard and largely disregarded changes in the size or texture of the test objects.

The choices of both groups of children, between texture versus size changes or shape versus size changes, did not deviate from chance. However, both the 2- and 3-year-olds reliably chose objects with texture changes as better exemplars of the novel nouns than objects with shape changes. Thus, in the one set of contrasts where the children showed a significant preference, the dimension which they chose to preserve was, once again, shape.

It would seem that objects that were the same shape as a standard but differed

Table 2. Experiment 1: Proportion of Acceptances of Each Object Type in the Forced-Choice Procedure

Dimension and Magnitude of Difference for Test Objects	Age Group		
	2-Year-Olds	3-Year-Olds	Adults
Size changes 1–2 chosen			
versus Standard	.40	.75	.20
versus Texture 1–2[a]	.47	.50	.58
versus Shape 1–2	.65	.65	.83*
M Proportion[b]	.53	.61	.60
Texture changes 1–2 chosen			
versus Standard	.30	.50	.00*
versus Size 1–2[b]	.53	.50	.42
versus Shape 1–2	.73*	.87*	.78*
M Proportion	.62	.65	.48
Shape changes 1–2 chosen			
versus Standard	.15	.35	.00*
versus Size 1–2	.35	.35	.17*
versus Texture 1–2	.27*	.13*	.22*
M Proportion	.28	.26	.16

Example: 2-year-olds chose Size changes 1 and 2 over Shape changes 1 and 2 on 65% of trials.

*For contrasts involving Standard, $\chi2$ (1, N = 20) > 3.84, p < .05. Critical values are .89 < 0 < .11. For all other contrasts, ×2 (1, N = 40) > 3.84, p < .05. Critical values are .725 < 0 < .275.

[a]Size versus Texture is, of course, the inverse of Texture versus Size.

[b]Each subject received one trial contrasting the identity item (Standard) with the two changes on each of the three dimensions (total = 6) and four trials contrasting the two changes on each of the three dimensions with each other (e.g., size vs. texture changes; size vs. shape changes, etc., total = 12 trials). Because of the unequal numbers of trials, the mean proportions indicated above are not equal to the column means.

in size or texture may be as good instances of a category as the standard itself. This is seen in the children's data, in the fact that they sometimes select objects differing from the standard in some way other than shape over a replication of the standard itself. This result is not as odd as it first seems. If given the choice between two equally good cupcakes, some children might choose the bigger one.

Overall, for both children and adults, test objects differing from the standard in size or texture were accepted equally often. Objects differing from the standard in shape were accepted less than half as often as either of the other two types of test objects.

Summary

Together, the results from the yes/no and forced-choice procedures present a coherent picture: Adults uniformly rejected items as instances of a lexical category if they differed from the standard in shape. They were quite willing, however, to accept items that differed from the standard in either size or texture.

Both 2- and 3-year-old children showed a similar but less marked tendency to emphasize shape in their judgments. In the yes/no procedure, only shape changes were rejected and only when the shape difference was large. In the forced-choice procedure, objects differing in shape were rejected more often than objects differing on either of the other two dimensions at all age levels. Apparently, shape is in some way special in object categorization even for young children.

EXPERIMENT 2

In this experiment, we tested the limits of the special status of shape which we observed in Experiment 1. We did this by adding an extreme deformation on each dimension. We again presented subjects with the 2″ wooden standards from Experiment 1. We also retained the Size 2, Texture 2, and Shape 2 test objects from Experiment 1 but also added new, more extreme, test objects: Size 3 (2′ objects); Texture 3 (chicken-wire Dax and beanbag Riff); and Shape 3 (see Figure 1). We reasoned that, if shape alone is crucial for category membership and differences on the other two dimensions are irrelevant, then both children and adults should happily accept 2′ Daxes and beanbag Riffs.

Method

Subjects. The subjects were 22 2-year-olds (aged 24 to 30 months, $M = 28$ months), 22 3-year-olds (aged 36 to 42 months, $M = 38$ months), and 22 adult undergraduates. Subjects came from the same subject pools as in Experiment 1. Again, the yes/no procedure was used at Indiana University to test 12 subjects in each age group, whereas the forced-choice procedure was used at Columbia University to test 10 subjects in each group.

Stimuli and Procedures. The Dax and Riff standards from Experiment 1 were used. Once again, six of the test objects differed from the standard in size, texture, or shape. The seventh was identical to the standard. The actual stimulus objects and amounts of difference from the standard overlapped with those previously used. The test objects as shown in Figure 1 and as labelled by the dimension and magnitude of difference from the standard were Size 2, Size 3, Texture 2, Texture 3, and Shape 2, Shape 3.

The yes/no and forced-choice procedures were identical to those used in Experiment 1.

Results

The data were analyzed in the same way as in Experiment 1. Proportions of yes responses for each object in the yes/no condition are shown in Table 3. Proportions of acceptances for objects on each dimension of difference from the standard in the forced-choice procedure are shown in Table 4.

Yes/No Results. As in Experiment 1, the adults rejected the items differing from the standard in shape and were quite willing to accept even the extreme deformations of size or texture. The children's judgments were less clear cut. An analysis of variance on their data revealed no main effect of age, $F(1,22) = 1.70$, ns, but reliable effects of dimension, $F(2,44) = 10.52$, $p < .01$, magnitude of difference $F(1,22) = 6.87$, $p = .01$, and an age × dimension interaction $F(2,44) = 7.53$, $p < .01$. The effect of dimension appears due to greater rejections of the shape deformations, followed by texture, then by size. The source of the age × dimension interaction appears to be the strong 'yes' bias of the 2-year-olds who, as shown in Table 3, did not respond differentially to any of the test objects. In

Table 3. Experiment 2: Proportion of Yes Responses for Each Object Type in the Yes/No Procedure

Dimension and Magnitude of Difference for Test Objects	Age Group		
	2-Year-Olds	3-Year-Olds	Adults
Standard	.96	1.00	1.00
Size changes			
2	.94	.98	1.00
3	.85	.94	1.00
Texture changes			
2	.85	1.00	1.00
3	.88	.88	1.00
Shape changes			
2	.85	.58	.00
3	.83	.42	.00

Table 4. Experiment 2: Proportion of Acceptances of Each Object Type in Forced-Choice Procedure

Dimension and Magnitude of Difference for Test Objects	Age Group		
	2-Year-Olds	3-Year-Olds	Adults
Size changes 2–3 chosen			
versus Standard	.40	.40	.15
versus Texture 2–3[a]	.35	.50	.65
versus Shape 2–3	.50	.73*	.95*
M Proportion[b]	.42	.57	.67
Texture changes 2–3 chosen			
versus Standard	.65	.50	.10*
versus Size 2–3[a]	.65	.50	.35
versus Shape 2–3	.55	.90*	1.00*
M Proportion	.65	.66	.56
Shape Changes 2–3 chosen			
versus Standard	.35	.25	.00*
versus Size 2–3	.50	.27*	.05*
versus Texture 2–3	.35	.10*	.00*
M Proportion	.41	.20	.02

Example: 3-year-olds chose Size changes 2 and 3 over Shape changes 2 and 3 on 73% of trials.

*For contrasts involving Standard, χ^2 (1, N = 20) > 3.84, p < .05. Critical values are .89 < 0 < .11. For all other contrasts, ×2 (1, N = 40) > 3.84, p < .05. Critical values are .725 < 0 < .275.

[a]Size versus Texture is, of course, the inverse of Texture versus Size.

[b]Each subject received one trial contrasting the identity item (Standard) with the two changes on each of the three dimensions (total = 6) and two trials contrasting the two changes on each of the three dimensions with each other (e.g., size vs. texture changes; size vs. shape changes, etc., total = 12 trials). Because of the unequal numbers of trials, the mean proportions indicated above are not equal to the column means.

contrast, the 3-year-olds accepted objects differing from the standard in size and texture, even when they differed by a large amount (Size 3, Texture 3), but rejected objects differing in shape.

Forced-Choice Results. The results from the forced-choice procedure, shown in Table 4, parallelled those obtained with the yes/no task. Once again, the adult subjects accepted only the objects that are the same shape as the standard, despite marked variation in size or texture. The 3-year-olds showed a similar, though less strong, pattern of responses, preserving the shape of the standard in preference to both its size and its texture. The 2-year-olds, however, did not show any clear evidence that shape took precedence in their choices. Indeed, the choices of the 2-year-olds do not appear to have been guided by any shared preferences at all.

Summary

The results of this experiment, in conjunction with Experiment 1, suggest that, in a word-learning task, the dimension of shape takes precedence over the dimensions of size and texture. This shape bias was most marked in adults, who call objects only with the same shape by the same name. In both experiments, the 3-year-olds also showed a tendency to apply the same name only to same-shaped objects. This preference was particularly notable in the second experiment, where the same-shaped objects that these children were matching with the standard were sometimes (on value 3 trials) strikingly different from the standard—in size (2″ vs. 24″) and in texture (wood vs. chicken wire).

Two-year-olds, however, who did show a small bias for same-shaped objects in Experiment 1, showed no such bias in Experiment 2. The reasons for this decrement in the 2-year-olds' performance are not clear. Perhaps children at this age have a particularly fragile set of hypotheses about dimensions that breaks down in the face of large changes in any one dimension, resulting in a generalized bias to respond 'yes'.

Taken together, the results from the children and adults suggest that, for naming objects, similarity in shape is more critical than similarity in either size or texture. The important remaining question is whether this preference for shape is specific to word learning, or reflects a more general perceptual bias. This is the principal question addressed by Experiment 3.

EXPERIMENT 3

In this experiment, we used the forced-choice task to directly pit a condition in which the standard is named against one in which it is not. In the word condition, we showed children a standard and said, "This is a Dax," and then asked which of two other objects was also a Dax. In the nonword condition, we showed children the standard, did not give it a name, and asked which of two other objects went with the standard. The question, of course, is if sameness in shape matters in the word condition but not to the same degree in the non-word condition.

To provide the strongest possible test of the importance of same shape, we pitted the Shape 2 and Shape 3 items against the maximal size and texture values (Size 3, Texture 3) from Experiment 2. In one trial, for example, subjects were shown the 2″ wooden standard used in Experiments 1 and 2 and then asked to choose between a 2-inch bent exemplar (Shape 2) or a 24-inch same-shaped exemplar (Size 3). It seemed to us that the choice of a 2′ same-shaped object over a 2-inch object that differed slightly in shape, was an unlikely result in a perceptual categorization task, even though it was the obtained result in the word-learning task in Experiment 2 for 3-year-olds and adults.

In sum, in this experiment we contrasted same-shaped objects that differed maximally in size and texture against objects that differed moderately and extremely in shape in both a word-learning and a perceptual categorization version of our forced-choice procedure. In addition, we included four replications of each type of contrast and thus gave 2-year-olds a better opportunity to show us any systematic response patterns they might have.

Method

Subjects. Twenty-four 2-year olds (aged 24 to 28 months, M = 26.5), 24 3-year-olds (aged 36 to 42 months, M = 39) and 24 adult undergraduates participated. All subjects were drawn from the Indiana pool described earlier.

Stimuli. The Dax and Riff standards were identical to those used in Experiments 1 and 2. The test objects were the Texture 3 and Size 3 objects and the Shape 2 and Shape 3 objects used in Experiment 2.

Design and Procedure. There were eight unique trial types: four unique from the Dax stimulus set and four unique from the Riff stimulus set. The four unique trials differed in terms of the two test objects: Shape 2 versus Size 3, Shape 2 versus Texture 3, Shape 3 versus Size 3, and Shape 3 versus Texture 3 (see Figure 1). Each one of these unique eight trials was repeated four times, for a total of 32 trials per subject. Trials were presented to subjects in one of two random orders.

Half of the subjects at each age level participated in the word condition; half participated in the non-word (perceptual categorization) condition. These two conditions differed only in instructions to the subjects. In the word condition, the standard was named on each trial ("This is a Dax [Riff]"). Then, as in the forced-choice method in Experiments 1 and 2, the subject was asked which of the two test objects was also a Dax/Riff. In the non-word condition, the subject was shown the standard and, following the usual procedure in perceptual categorization tasks (e.g., Smith & Kemler, 1977), was asked which of the two test objects went with the standard. Specific phrasings included "goes together," "matches," "belongs with," or "makes a group."

Results and Discussion

Table 5 shows the proportion of same-shape object choices in the word and nonword conditions. Consider first the adult data: The adults uniformly classified the same-shaped object with the standard in both conditions, despite the fact that the same-shaped object differed considerably from the standard in texture or size. Clearly, the special status of shape is not restricted to word-learning tasks for adults.

For the children, however, the dominance of shape over the other two dimensions depended on the condition. Categorizations by shape were much more frequent at both age levels in the word condition in which the standard was

Table 5. Experiment 3: Proportion of Same-Shape Choices in Word and Nonword Conditions

Dimension and Magnitude of Difference for Test Objects	Age Group					
	2-Year-Olds		3-Year-Olds		Adults	
	W	NW	W	NW	W	NW
Size 3 chosen						
versus Shape 2	.60	.40	.75	.48	1.00	1.00
versus Shape 3	.75	.54	.81	.64	1.00	1.00
Texture 3 chosen						
versus Shape 2	.71	.64	.79	.67	1.00	.98
versus Shape 3	.77	.66	.91	.73	1.00	1.00
M Proportion	.71	.56	.81	.63	1.00	.99

named than in the nonword condition. This conclusion about the children's performance is supported by a 2(age) × 2(condition) × 2(contrasting dimension) × 2(magnitude of shape difference) analysis of variance. The analysis yielded reliable main effects of condition, $F(1,44) = 7.21$, $p < .01$, contrasting dimension, $F(1,44) = 4.84$, $p < .05$, and magnitude of shape difference, $F(1,44) = 20.79$, $p < .01$. As is apparent in Table 5, same-shape choices were more predominant in the word than in the nonword condition, more likely when the same-shaped object differed from the standard in texture rather than in size, and more likely when the different-shaped object differed from the standard to a greater rather than a lesser degree.

Neither the main effect of age nor any of the interactions aproached significance. In other words, the 2-year-olds in this experiment were just as likely as the 3-year-olds to choose same-shaped objects and to ignore pronounced differences from the standard on the other two dimensions. The present results thus parallel the findings in Experiment 1, while contrasting with the data in Experiment 2. We have no ready explanation for the variable performance of the youngest children. It is entirely possible that their failure to show a consistent concern with shape in both methods in Experiment 2 was due to a combination of procedural and sampling factors. One possibility is that the youngest children were thrown off balance by the extreme values of the stimuli employed in both conditions in Experiment 2, so that they found it difficult to concentrate on the task at hand. Anecdotal support for this conjecture comes from the observation that introduction of the 2-foot Dax was often followed by several seconds of stunned silence. Although the same extreme stimuli were used in Experiment 3, the intermixing of Dax and Riff trials may have helped the children by setting up and emphasizing contrasting categories. In any case, the performance of the 2-year-olds across Experiments 1 and 3 indicates that they, too, accord greater importance to shape than to texture or size in classifying objects, but that their adherence to this criterion is fragile in comparison to that of the 3-year-olds and, especially to the adults.

Both groups of children contrasted with the adult subjects in the generality with which the shape dimension was emphasized. The children categorized consistently by shape in the word condition, where for each contrast, the same-shaped object was chosen more often than the different-shaped object. Such uniform choices by shape were not seen when the standard was not named. Thus, in the nonword condition, same-shaped objects were chosen more often than same-textured objects, but the same-sized object was often chosen over the same-shaped object. The important point is that it was *naming* an object that directed the child towards categorizing by shape.

In contrast to both 2- and 3-year-olds, adult subjects relied on shape for both word and non-word classifications. These results suggest that the specialness of shape begins as a lexical phenomenon at a relatively early point in language learning. As development proceeds, it seems either that the special status of shape is extended beyond the realm of language use to object categorization in general; or that object categorization in general comes to be treated by adults as a lexical task.

Adults not only used the same-shape criterion more extensively than young children: they also used it more strictly. Although both groups of children showed an overall tendency to prefer same-shape choices, the strength of this tendency depended on the dimension of contrast and the magnitude of difference. So, for example, shape dominated texture more than it did size, and same-shape choices were more likely when the contrasting shape change was large rather than small. Neither of these patterns appeared in the adults' data: For them, at least with our stimuli, shape was all that mattered.

In summary, the results of this experiment suggest that the emphasis on shape may originate in learning count nouns, but that, with development, the emphasis on shape may come to be more broadly applied to categorization tasks that are not explicitly lexical. We pursue this possibility of growth in the emphasis on shape in nonlexical contexts in the last experiment by asking if, in fact, 3-year-olds do weight shape more heavily than 2-year-olds in a nonword classification task.

EXPERIMENT 4

In this experiment, we extended the non-word condition of Experiment 3 to include all pairwise comparisons of Shapes 1, 2, and 3 with Sizes 1, 2, and 3, and of Shapes 1, 2, and 3 with Textures 1, 2, and 3. Our question was whether this more extensive examination of the similarity relations between the dimensions would reveal developmental differences between 2- and 3-year-olds in the status accorded to shape, within a wordless categorization task.

Method

Subjects. Subjects were 32 2-year-olds (aged 24 to 30 months, M = 28 months) and 32 3-year-olds (aged 36 to 42 months, M = 37 months). Twelve subjects at each age level were the same children as had participated in the nonword condition in Experiment 3. The remaining 30 children at each age level were drawn from the same subject pools as in the previous experiments.

Stimuli, Design, and Procedure. The stimuli were the same objects used in Experiments 1, 2, and 3. The 18 pairwise comparisons were divided among three groups, as follows: Group A (Shapes 2 and 3 against Size 3 and Texture 3); Group B (Shape 1 against Sizes 1 and 2, Textures 1 and 2; Shape 2 against Size 2 and Texture 2); and Group C (Shape 1 against Size 3 and Texture 3; Shape 2 against Size 1 and Texture 1; Shape 3 against Sizes 1 and 2, and Textures 1 and 2). The 12 subjects comprising Group A and their data were the very same as those in the nonword condition of Experiment 3.

The forced-choice procedure was again employed. Methods were identical to those used in the nonword condition of Experiment 3.

Results and Discussion

We analyzed these data first by calculating the proportion of times each object was chosen as most like the standard, in each of the paired comparisons in which that object participated. These proportions are given in Table 6. The variance in these proportions was divided amongst factors via a multiple regression analysis. The multiple regression, unlike an analysis of variance, allowed us to partial out the effects of the haphazard division of stimulus comparisons into Groups A, B, and C.

Table 6. Proportion of Acceptances of Each Same-shaped Object in Forced-Choice Procedure, as a Function of Shape of Contrasting Object

Contrast Object Rejected	Age	Size and Texture Changes Accepted							
		Size 1	Size 2	Size 3	M	Texture 1	Texture 2	Texture 3	M
Shape 1	2	.40	.40	.40	.40	.45	.48	.65	.53
	3	.60	.45	.40	.48	.58	.45	.52	.52
Shape 2	2	.80	.38	.31	.50	.78	.58	.60	.65
	3	.82	.48	.39	.56	.98	.82	.67	.82
Shape 3	2	.80	.78	.48	.69	.82	.98	.60	.80
	3	.91	.90	.56	.79	.98	.82	.71	.84
M	2	.67	.52	.40		.68	.68	.62	
	3	.78	.61	.45		.85	.70	.63	

Note: These data are shown in Figure 2 as proportions of objects accepted by 2-year-olds plotted against 3-year-olds. The means used for Size- and Texture-change acceptances are shown in the bottom two rows. The means used for shape-change acceptances can be calculated by subtracting the means for each shape change over Size and over Texture from 1.00.

The factors entered into the analysis were magnitude of shape difference (1, 2, and 3); contrasting dimension (Size or Texture); age (2 vs. 3) and group (A,B,C,), plus all of the interactions. An initial stepwise regression revealed that the four main effects together accounted for 79.5% of the variance in proportions of choices. None of the interactions was large enough to add significantly to the variance accounted for.

Subsequent multiple R2 calculations isolated the unshared variance attributable to each of the three main factors of interest. There was a reliable effect of magnitude of shape difference, $F(1,31) = 22.51$, $p < .001$, indicating that children were more likely to choose same-shaped objects over the different-shaped object when the shape difference was larger. There was also a reliable effect of contrasting dimension, indicating that children were more likely to choose the same-shaped object when it differed in texture than when it differed in size, $F(1,31) = 14.67$, $p < .01$. Third, there was a reliable effect of age, $F(1,31) = 5.47$, $p < .05$. Thus, even in a nonlexical task, the specialness of shape can be seen to increase between 2 and 3 years of age.

In order to examine more closely this apparent growth in the emphasis of shape, we plotted the 3-year-olds' probability of choosing each object against the 2-year-olds' probability of choosing the same object. The plot for the Shape versus Size contrasts is shown in Figure 2A, and a separate plot for the Shape versus Texture contrasts is given in Figure 2B. If 2- and 3-year-olds emphasize shape to the same degree, then the probabilities of choice for all objects should fall close to the diagonals of these graphs. If on the other hand, the 3-year-olds systematically weight all shape differences, regardless of their magnitude, more

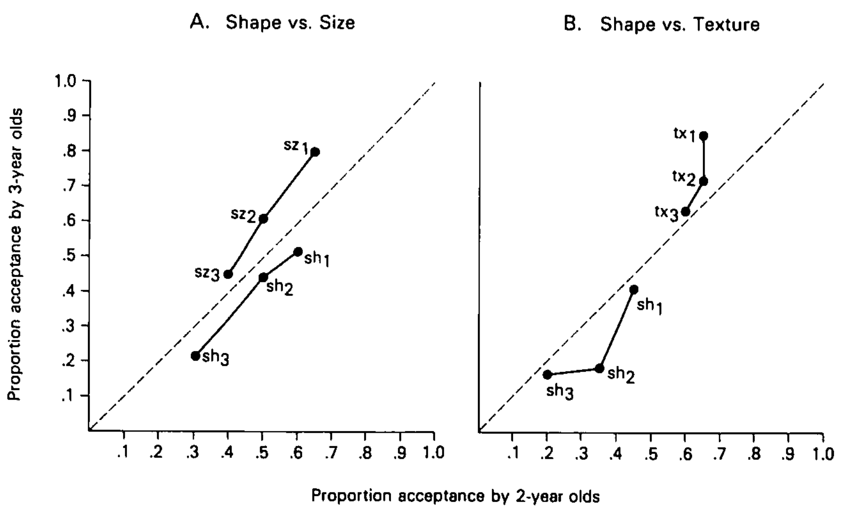

Figure 2. Proportion of same-shape and different-shape choices by 3-year-olds and 2-year-olds for Shape versus Size contrast and Shape versus Texture contrast. Objects chosen denoted by dimension and magnitude of difference from standard.

than do the 2-year-olds, then the paired probabilities for objects that do not differ in shape (i.e., Sizes 1, 2, and 3; Textures 1, 2, and 3) should fall above the diagonal. At the same time, the paired probabilities of choice for objects differing in shape (i.e., Shapes 1, 2, and 3) should fall below the diagonal. As is apparent in Figure 2, 3-year-olds systematically chose objects that were the same shape as the standard but different in varying degrees in size and texture, more often than the 2-year-olds.

One remarkable aspect of these results is the almost perfect linearity of the relationships between proportions of choices by the two age groups for the objects representing the Shape and Size change values in Figure 2A. We found that, within each dimension, values were ordinally scaled by the children as we hoped, that is, from 1 to 3. More strikingly, the linear relationship indicates that the intraobject distances on each dimension (i.e., between Shape 1 and Shape 2) were proportionately the same for each age group. What the figure suggests, then, is that the dimension of shape, not particular shape values, is emphasized and the dimension of size, not particular size values, is deemphasized, by the 3-year-olds.

This pattern is not so evident in the Shape versus Texture contrasts (Figure 2B), which probably reflects our particular choices of textured materials. However, the similar pattern of deviation of these paired probabilities from diagonality suggests that a similar increase in the importance of the shape dimension as a whole underlies the age difference in this case as well.

GENERAL DISCUSSION

We began by posing two specific questions about the role of perceptual similarity in children's learning of count nouns. First, we asked if young language learners accord the dimension of shape a special status when generalizing application of a label to new exemplars. Second, we asked if any such bias would be more likely to originate in general perceptual processes or in the language-learning process itself.

The results of our four experiments indicate that all of our subjects—2- and 3-year-olds and adults—showed a shape bias to some extent. Our data are thus consistent with previous findings of a shape emphasis in early word learning (Clark, 1973). However, the results extend and clarify previous findings by suggesting that the bias is not equally strong in all cases. First, there was a developmental trend: the bias increased in strength and generality from 2 to 3 years of age and more markedly from early childhood to adulthood. Second, in young children, the shape bias was more marked in classifications of labelled objects than in classifications of unlabelled objects. As in other recent studies, children seem to use different principles in responding to specifically lexical versus nonlexical tasks (cf. Markman & Hutchinson, 1984).

This pattern of results leads us to make the following, admittedly speculative, proposal. We suggest the development of a same-shape preference in children may originate in language learning, specifically in the process of learning count nouns. Many of the words acquired by early language learners do in fact partition the world according to the shapes of the objects in it (Rosch et al., 1976). We suggest that young children very quickly realize this, abstracting a rule from their early word-learning experience that says shape is the critical factor in decisions about the extensions of these nouns. They then use this rule when encountering new nouns and new classes, thus immensely simplifying and speeding up the mapping of the one onto the other. The use of such a same-shape rule suggests a solution to the oft-cited problem of how a very young child knows that the word *dog* refers just to dogs and not to cats or cows. Our notion is that dogs are perceptually similar in shape and, thus, given a rule to attend to shape, that members of the category "dog" can be identified perceptually. It is pertinent that overextensions, such as calling a cow a *dog*, appear to be quite rare and occur only in the earliest stages of language acquisition (Rescorla, 1980).

Of course, a rule that extends new words on the basis of shape will work only to the degree that those first words do, in fact, partition the world according to shape. We think there is compelling evidence for this critical assumption. One kind of evidence comes from the language itself. It is easy to think of cases where basic-level nouns ignore deep differences between objects while respecting shape similarity. A mechanical monkey and a real monkey are both called *monkey*. A 60-foot sculpture of a clothespin gracing downtown Philadelphia is universally recognized and labelled as a clothespin, albeit a 60-foot metallic clothespin. In these cases, qualifiers capture the differences, whereas the head noun captures the shape similarity. In contrast, it is difficult to think of any good cases at the basic category level where the category name ignores the shape identity of two objects and accords them different names on the basis of their deeper differences. One (weak) example is the doll/person distinction; but given the urgency of the inanimate/animate distinction in the case of human appearance, this special marking is not surprising.

There are many clear cases at the superordinate level that would seem to devalue a same-shape rule. A label such as *mammal* points up the fact that a whale is in some important ways more like a cow than like the perceptually similar shark (see Carey, 1985; Gelman & Markman, 1986). However, the fact that the meanings of words come to include deeper similarities and differences among objects is not at odds with our claim. Cases like the whale–mammal example are usually experienced as violations of perceptually based categories and are late in the course of cognitive development. The relevant problem for a 2-year-old is not the definition of mammal, but rather what sorts of things are called "car." And what a 2-year-old language learner is likely to notice is that the yellow picturebook car and the blue family car, the beanbag car, the mechanical toy car, and the talking car on TV are all called *car*.

One could argue that the child is also noticing the *deeper* similarities among all of these instances of cars—the similar *function* (that is, conveyance) as well as the similarity in shape. Thus, perhaps our empirical data are merely the default result. Perhaps children infer that a word refers to the shape of an object only in the absence of richer information about function and other deep properties of the object. If we had conferred some function upon the Dax, the property most intimately related to its function might have been the one the child attended to. However, other studies have demonstrated that function is not always a critical factor in naming (e.g., Gentner, 1978; Tomikawa & Dodd, 1980). Clearly, the issue of whether functional information will weaken or eliminate the obtained shape bias is an empirical one, which we are now pursuing.

The value of an early emphasis on shape may also be questioned on the grounds that a simple perceptual dimension is insufficient to specify even the most basic lexical categories. Certainly, it is problematic that we cannot specify what same shape is; shape is a theoretically complex issue (e.g., Marr, 1982; Biederman, (1985) that we cannot resolve here. However, all that we require as support for our claim is that whatever objects are judged to belong to the same shape category be called by the same name. And it seems possible to us that however shape is theoretically specified, it may be sufficient for the differentiation of basic categories. The performance of pigeons supports this contention. Pigeons apparently exhibit very good classification skills for natural kinds—being able, for example, to classify oak trees with pine saplings rather than with houseplants or telephone poles (Hernstein, 1979). If pigeons can and do form complex categories such as trees largely on the basis of some perceptual properties, young children first forming lexical categories might well do the same.

Of course, humans ultimately have more to discover about categories than do pigeons. The meanings of words are rich, encompassing functional and taxonomic information, for example, as well as perceivable properties. However, these deeper similarities are highly correlated with shape. For example, shape is intimately related to function: square things are not rollable, and pointed things make less than optimal sittables. Thus, shape might provide a perceptible clue to deeper non perceptual similarities. It is even possible that languages may have evolved precisely to capitalize on the relationship between such perceivable properties and deep principles of category membership. This evolutionary possibility, however, does not foreclose the learning issue. After all, young learners master a great deal of vocabulary in a very short time, whereas principles of lexical categories must have evolved in response to the needs of human societies over centuries. The mechanisms underlying each outcome might well be quite different.

For the learner, shape may be the best clue to what a concrete object is to be called. Such a simple solution to the mapping problem would certainly be of benefit to the developing child. If both adults and children label objects by shape, then there is a basis for shared communication between them. Even though the child's meanings may be considerably less rich than the adult's, each will at least understand which objects the other is talking about. This shared reference could then provide the child with a way into the kind of linguistic interaction that helps him discover the deeper similarities—like that among mammals—that may violate shape-based classifications.

Thus, we believe that shape is a perceptual dimension that serves as a particularly potent cue to certain lexical categories. However, our data suggest that the child's emphasis on shape is not given but must be discovered, because the bias first appears between 2 and 3 years of age. It is the timing of this onset and growth of the emphasis on shape that suggests that the shape bias crystallizes through language learning. The child's apparent discovery that count nouns correspond to categories whose members have similar shapes is thus an example of how the structure of language itself may aid in the language-acquisition process. Our findings add to a growing body of demonstrations and speculations concerning the role of language structure in advancing language learning (Clark, Gelman & Lane, 1985; Gelman & Taylor, 1984; Kohn & Landau, 1988; Katz, Baker, & Macnamara, 1974; Landau & Gleitman, 1985; Shipley, Kuhn & Madden, 1983).

One final set of comments concerns the relation between our results and other findings about children's classifications. Markman and Hutchinson (1984) showed that children who spontaneously form thematic groupings of objects on the basis of their spatio–temporo–functional properties shift to forming taxonomic categories in explicit word-learning tasks. Thus, as in our experiments, the structuring of the request to classify as a naming task results in improvement, that is, in closer approximations to adult performance. This may be so in Markman's results and in ours because adults take instructions to classify as a directive to classify in accordance with lexical categories. This definition of the classification task clearly emerges with age, as shown in our data. Further, it is possible that Markman's finding of a shift to taxonomic categories corresponds to our finding of a shift in classification by shape; horses and dogs are more similar in shape than are dogs and bones.

A second trend in children's classifications that may initially seem at variance with our results is the so-called trend from classifying by holistic similarity to classifying by single dimensions. Our results would seem to suggest that quite young children can attend somewhat selectively to single dimensions (e.g., Smith & Kemler, 1977). However, the trend from classifying by many to fewer dimensions is not all or none (see, e.g., Smith, 1984; J. D. Smith & Kemler Nelson, 1984). Our results are consistent with a general trend toward more efficient selective attention. Young children may weight shape more than texture and size, but they do not completely ignore texture and size differences as do adults. Still, we think it interesting that perhaps the criterial use of dimensions in classification may have its origins in the experience of forming lexical categories and may well be evident in word-learning contexts long before it is detectable in more artificial classification tasks.

In sum, our results show that young children and adults accord special status to the shapes of objects when naming them. We suggest that this shape bias develops out of the word-learning task; that the earliest learned words, basic-level concrete nouns, do, in fact, divide the world largely according to shape; and that in learning this class of words, the child discovers that shape can serve as a readily perceivable and usually reliable cue to lexical category. Categorization by shape, then, provides both a basis for shared reference with adults and a correlational pathway to the discovery of object functions and taxonomic groupings. In these two ways, and probably in others, the language itself guides and aids the young child in his or her increasing mastery of conceptual and linguistic organizations.

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