CHAPTER 3

Learning How to Learn Words

An Associative Crane

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Children produce their first word when they are about a year old. Over the next several months, they add new words to their productive vocabulary slowly, one word at a time. In contrast, children a year older learn words, particularly object names, rapidly. They are so good at this task that upon hearing a single object named, they will correctly generalize that name to other members of the category (e.g., Golinkoff, Mervis, & Hirsh-Pasek, 1994; Markman, 1989; Smith, 1995; Waxman, 1994).

Consider this example drawn from observing the word learning of a child. When the child was 22 months old, she saw her first tractor. It was a big, green John Deere tractor that was working in a field. The adult accompanying the child told her that it was a "tractor." Several days later, the child spontaneously generalized the name "tractor" to another tractor. This new tractor was not green, not a John Deere, and not in a field. Still, the child knew it was a tractor. It was as if the child already knew the kinds of things that are tractors before hearing the first one named. But how could the child know what tractors are before ever seeing one? Moreover, how could the child know from the first naming instance that the adult was talking about tractors rather than farm equipment more generally, or John Deeres more specifically, or big things, or green things, or things in fields? How, from *a single instance of naming,* could this young child so rightly know the category of things to which the name referred? This chapter attempts to answer that question.

First, however, we need to decide what kind of an answer we want. Dennett (1995) offers a guiding metaphor in his discussion of Charles Darwin's theory of evolution. Recall that Darwin's big claim is that the intelligent adaptations of species are created out of the algorithmic workings of natural selection. Dennett characterizes natural selection as the "crudest, most rudimentary, stupidest imaginable process" (1995, p. 75). Nonetheless, by accumulating tiny changes over very long periods of time, natural selection is said to create specialized smart adaptations. The main challenges to Darwin's theory, therefore, are evolutionary changes that seem too fast and too smart for the gradual progress of natural selection.

Here is the metaphor: According to Dennett, explanations of these too-fast, too-smart evolutionary leaps can take the form of either a skyhook or a crane. "Skyhooks" explain evolutionary leaps with mechanisms outside of evolutionary theory. For example, Kurt Gödel denied the plausibility that brains were the product of evolution as follows:

> I don't think the brain came in the Darwinian manner. In fact, it is disprovable. Simple mechanisms can't yield the brain. I think the basic elements of the universe are simple. Life force is a primitive element of the universe and it obeys certain laws of action. These laws are not simple and not mechanical. (quoted in Wang, 1993, p. 133)

The problem with skyhooks such as Gödel's "life force" is that the origin of the skyhook itself is unexplained. "Cranes," in contrast to skyhooks, explain evolutionary leaps with mechanisms consistent with evolutionary theory. Cranes are mechanisms that speed up evolution *but are also mechanisms that are made through the slow progress of natural selection.* Clearly, explanations in terms of cranes are both better and harder than explanations in terms of skyhooks, because the processes that make the crane are also explained.

Here is the relevance to the present chapter: Children's smart learning of object names is like the evolutionary leaps that challenge Darwinian theory. Smart one-trial learning of whole categories defies ordinary psychological mechanisms of trial-and-error learning. Thus, it is not surprising that some have attempted to explain word learning in terms specialized language mechanisms and even preknowledge about the possible meanings of words and possible kinds of categories (see, e.g., Markman, 1989; Soja, Carey, & Spelke, 1991). If word-learning mechanisms are to be cranes and not skyhooks, however, their developmental origins must be explained. This chapter explains how children's too-fast, too-smart learning of object names is the product of a crane, a mechanism that lifts children over the gradual progress of ordinary learning but that is itself made only gradually out of those same ordinary learning processes.

THE SHAPE BIAS

The word-learning crane that forms the centerpiece of this chapter is what is known in the literature as the shape bias. Young word learners often seem to assume that objects that have the same shape have the same name. Landau, Smith, and Jones (1988) reported the original result. They showed 2- and 3-year-old

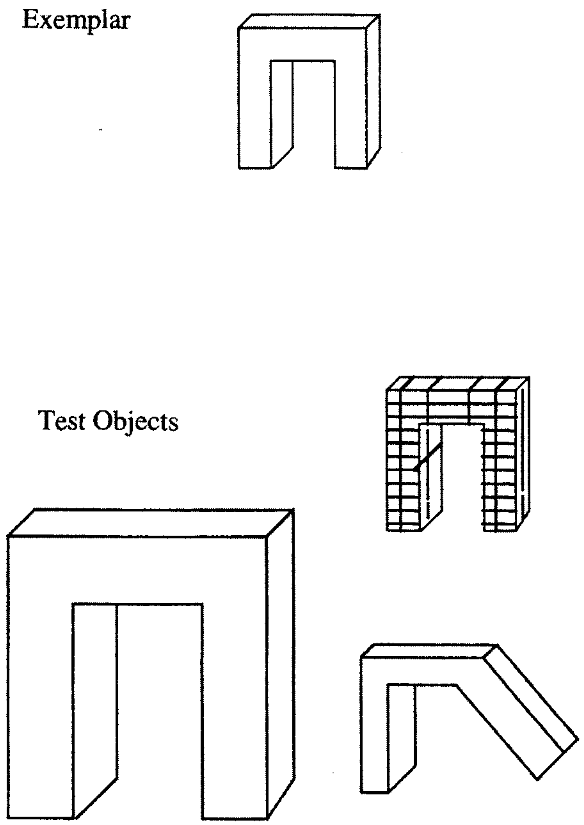

FIGURE 3.1. Examples of the Stimuli Used by Landau, Smith, and Jones (1988). These stimulus objects and all others represented in the figures in this chapter were three-dimensional objects made of wood, clay, metal, cloth, and plastic.

children the novel wooden object illustrated in Figure 3.1. The object was named with a new count noun, "This is a 'dax'." They then presented the children with the test objects, also depicted in Figure 3.1, and asked them about each, "Is this a dax?" Children generalized "dax" to test objects that were the same shape as the exemplar, not to test objects that were different in shape. The degree of children's selective attention to shape was remarkable. Children extended the name "dax" to same-shaped test objects that were 100 times the exemplar in size, as well as to those made of sponge or chicken wire.

Think about what this attention to shape does for young word learners. They do not need to figure out by trial and error what "dax" or "tractor" refers to; they know immediately that the word refers to the shape of the thing—not its color, texture, size, or location. If most of the object names that early word learners need to acquire also refer to categories of same-shaped things, then children can learn object names in one trial with few mistakes. Critically, studies of the structure of basic-level object categories suggest that these categories are well organized by shape (Rosch & Mervis, 1975; Biederman, 1987).

This shape bias in children's object-name learning has been demonstrated in many different studies and by many different experimenters using both specially constructed and real objects (e.g. Imai, Gentner, & Uchida, 1994; Keil, 1994; Gathercole & Min, 1997; Soja, 1992). Moreover, control studies have shown that biased attention to shape is specific to the task of learning an object name and is not evident in other kinds of categorization or similarity-judgment tasks (e.g., Landau, Smith, & Jones, 1988; Imai, Gentner, & Uchida, 1994; Soja, Carey, & Spelke, 1991). This fact tells us that young children do not go around in their everyday lives always attending only to the shapes of objects. Rather, the shape bias appears to reflect specifically a child's knowledge about how words map onto object categories.

The shape bias helps explain how children can, from hearing one object named, learn the category of objects to which the name applies. But how can we explain the shape bias?

AN ASSOCIATIVE-LEARNING ACCOUNT

Associative learning is the most fundamental and universal mechanism of psychological change (e.g., Clark, 1993; Kelly & Martin, 1994; Shanks, 1995). Like natural selection, however, associative learning has its skeptics: It seems too slow, too errorful, too probabilistic, too stupid to be the creative force behind developmental achievements—such as the learning of object names—that are fast and nearly right from the start (e.g., Keil, 1994; Pinker, 1989). This incredulity notwithstanding, this chapter shows that dumb associative learning *is* enough to build the crane that then makes object-name learning smart.

One hundred years of research in psychology tells us that whenever one perceptual cue is regularly associated with another, the presence of the first will come to automatically increase attention to the second (e.g., Allport, 1989; James, 1950; Rescorla & Wagner, 1972). The automatic control of selective attention by associative learning is one of the most widespread and well documented phenomena in all of psychology. The control of attention by associated cues is demonstrated in experimental studies by presenting the organism with some cue (or cluster of cues) that probabilistically predicts the relevance of some other property in the task. For example, bushy eyebrows might predict the relevance of chin shape in classifying faces (e.g., Medin & Wattenmaker, 1987; Medin, Altem, Edelson, & Freko, 1982). The laboratory evidence indicates that if such a predictive relation—even if imperfect and only probabilistically true—is in the input, then whenever the predictive cue is present, attention to the associated property is increased. This is a truly basic process, one that goes forward continuously in infants, children, adults, and nonhuman animals (e.g., Kelly & Martin, 1994; Kruschke, 1992; Lewicki, Hill, & Sasak, 1989; MacIntosh, 1965; Medin & Wattenmaker; Younger, 1990). It is also a process that could create the shape bias. This is an interesting idea: The shape bias—a mechanism that enables children to bypass the gradual progress of ordinary learning—may itself be made by ordinary learning.

Where might children be exposed to cues that reliably predict the category relevance of shape? One possibility is in early word learning itself. Children may begin learning object names with no special mechanisms to speed that learning. Instead they may, at first, have to learn object names through the grinding away of ordinary trial-and-error learning. This idea fits the fact that in its earliest stages, word learning *is* slow and errorful. At first, children *do* make such mistakes as calling all vehicles from bikes to planes "car"; or calling oranges, fingernails, and plates "moon"; or calling swans and robins "duck" (for further examples see Clark, 1973; Macnamara, 1982; Mervis, 1987; Mervis, Mervis, Johnson, & Bertrand, 1992). In the beginning, children apparently need multiple repeated examples to figure out just what is the class of objects that gets called "car" or "moon" or "duck." Critically, however, these early experiences in learning object names may present children with linguistic cues reliably associated with categorization by shape. As these associations are learned, the linguistic cues may shift attention to shape whenever an object is named, such that subsequent learning of object names is neither slow nor errorful. Accordingly, my colleagues and I examined the early vocabularies of young children to determine whether they exemplified the kinds of statistical regularities that could, through ordinary learning, create a shape bias.

STATISTICAL REGULARITIES AMONG EARLY LEARNED NOUNS

Any claim that some developmental achievement emerges from statistical regularities in the input requires an examination of that input to determine whether it contains the hypothesized regularities. As a first step, the studies summarized below assessed the statistical regularities in the input by measuring the words children *know* rather than the words they *hear.* The reasoning is this: The statistical regularities in the input that are hypothesized to create the shape bias do so neither by their mere existence nor all at once as an atemporal fact about the world. Rather, the statistical regularities in the input can have their effect on individual children only if they are learned. Thus, the early words *known* by children serve as a good starting point for examining the hypothesis that the shape bias is learned.

The First Hundred Nouns

In one study, my colleagues and I (Smith, Gershkoff-Stowe, and Samuelson, 2000) asked the parents of eight children to keep diaries of every word spoken by the children. Children began the study when they had about 20 nouns in productive vocabulary and remained in the study until they had 100 nouns. (One child moved and therefore left the study prior to this point). Table 3.1 presents the mean and range of the ages, number of total words, and number of all nouns (count, mass, and proper) in productive vocabulary at the start of laboratory visits and at the end of the experiment. Table 3.2 lists the frequencies of lexical items of several conceptual kinds at three levels of vocabulary development: 0–25 nouns, 26–50 nouns, and 51 or more nouns. When children produced fewer than 25 nouns, most of those nouns were names of artifacts or animals or were proper nouns. As the number of nouns in productive vocabulary grew, the biggest increase was in names of artifacts—such words as "car," "ball," "pen," "cup," and "book." It is interesting that artifact terms dominate early nouns, because several theorists have suggested that artifact categories are the most robustly organized by shape (Keil, 1994; Jones & Smith, 1998; Soja, Carey, & Spelke, 1991).

To determine the statistical properties manifest in these early noun vocabularies, we classified each noun in the diary records by its syntactic properties in the adult language and by the similarities among the objects to which the noun referred. Syntactic category is relevant because count-noun syntax could be the explicit cue linked to attention to shape (see Landau, Smith, & Jones, 1988; Soja, Carey, & Spelke, 1991). Table 3.3 provides the criteria we used to make the syntactic judgments (see also Gathercole & Min, 1997). Table 3.4 shows the proportion of nouns of different syntactic types as a function of the three levels of noun vocabulary development. As is apparent, count nouns dominate early noun vocabularies from the beginning.

We determined the category structure of each noun by asking adults about the similarities among objects in each category. Specifically, we presented 20 undergraduates with the entire list of nouns from the eight children. We asked them to indicate for each lexical item whether members of that category were similar in shape, color, or material. From these adult judgments, each lexical item was designated as shape based, size based, color based, or material based if 75% of the adults judged the members to be similar on that property. Note that individual lexical items could be deemed by these criteria to be organized by more than one property. For example, by the adult judgments, "bubble" is a shape-based category and a material-based category, whereas "cup" is a shape-based category.

The central result from these analyses is shown in Table 3.5, which gives the proportion of count nouns at three levels of vocabulary development that, by adult judgment, refer to objects similar in shape. As is apparent, almost all of these count nouns refer to shape-based categories. Moreover, fewer than 20% of the count nouns at each level of vocabulary development were deemed to be organized by material or color. These facts mean that children must repeatedly hear count noun frames such as "This is a _______" and "Here is another _______" used to refer to categories of similarly shaped things. The degree of association between count-noun syntax and shape-based categories among first-learned nouns seems certain to teach that count nouns name objects by

TABLE 3.1. Changes in Children's Productive Vocabulary across the Experiment

	First Laboratory Visit	Last Laboratory Visit
Mean age (months)	17.4	21.4
(Range)	(16–19.75)	(18.5–23.75)
Mean total words	42.1	134.4
(Range)	(27–74)	(82–194)
Mean nouns	17.5	78.8
(Range)	(10–24)	(51–123)

TABLE 3.2. Mean Cumulative Types of Nouns at Three Levels of Children's Productive Vocabulary Development

Types of Nouns	0–25 Nouns	26–50 Nouns	51-Plus Nouns
Proper nouns (includes "mama," "dada")	4.25	6.50	9.88
Character names (e.g., "Ernie," "Big Bird")	0	2.00	5.00
Other people (e.g., "fireman," "boy," "kids")	1.00	1.38	1.75
Artifacts	7.50	17.6	32.75
Animals	4.90	8.62	12.25
Food	3.00	6.25	10.88
Body part	1.62	2.50	4.87
Other (e.g., "dirt," "wind," "snow")	.62	3.00	7.00

TABLE 3.3. Criteria Used to Classify Nouns According to Syntactic Categories (by Adult Usage)

Noun Classification	Criteria
Proper noun	Cannot be preceded by an "a" or by numerals, has no plural form, cannot be preceded by "much"
Count noun	Can be preceded by "a" and by numerals, has a plural form, cannot be preceded by "much"
Mass noun	Cannot be preceded by "a" or by numerals, has no plural form, can be preceded by "much"
Other	Occurs in mass and count forms, such as "cake"; includes also character names, such as "Ernie" that may be used as proper nouns or with count syntax

TABLE 3.4. Proportion of Nouns of Each Syntactic Type at Three Levels of Vocabulary Development

Cumulative Nouns	Count Nouns	Proper Nouns	Mass Nouns	Other
0–25	.73	.18	.06	.02
26–50	.70	.14	.06	.08
51 plus	.68	.08	.10	.14

shape. Indeed, given all that is known about attentional learning, this correspondence should cause count-noun syntactic frames to become context cues that automatically shift attention to shape.

Nouns on the MacArthur Communicative Development Inventory

Samuelson and Smith, 1999, provides further supporting evidence for the idea that early learned nouns present the kinds of regularities that could create a shape bias. In this study, we examined the statistical regularities presented by the categories named by the 312 nouns in the animal, vehicle, toy, food and drink, clothing, body part, small household item, and furniture and room sections of the MCDI. This parental checklist is a reliable measure of the productive vocabulary of 16- to 30-month-old children. It was developed from extensive studies of parental diaries and in-laboratory testing of children's early vocabularies (see Fenson et al., 1993). Thus, it is a reasonable proxy for the typical early nouns that children learning English encounter.

We asked adult subjects to indicate whether each noun on the MCDI named objects similar in shape, color, or material and whether it referred to solid or nonsolid things. We also instructed adults in the criteria listed in Table 3.3 and asked them to place each noun in a syntactic category: 85% agreement among the adult judges was the criterion for designating a single noun as, for example, shape based or nonsolid or a count noun.

Figure 3.2 summarizes the key regularities by these measures in terms of

TABLE 3.5. Proportion of Shape-Based Count Nouns, by Adult Judgment, at Three Levels of Vocabulary Development

Cumulative Nouns	Proportion of Shape-Based Count Nouns
0–25	.98
26–50	.94
51 plus	.93

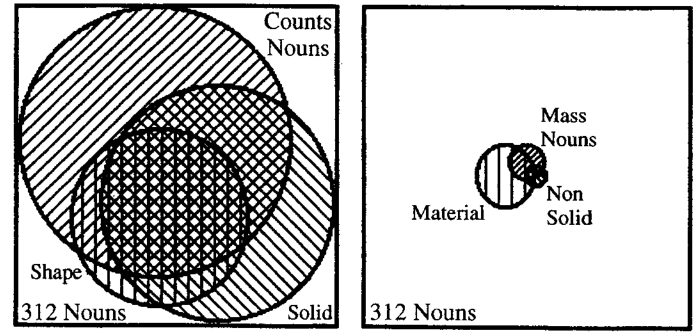

FIGURE 3.2. Venn Diagrams of 312 Nouns. The circles represent the relative number and overlap among nouns on the MCDI that are count nouns, refer to objects of similar shape, and are solid (*at left*) and that are mass nouns, refer to objects of similar material, and are nonsolid (*at right*).

Venn diagrams. In these diagrams, the relative size of each circle represents the relative numbers of nouns of that kind and the size of overlap between intersecting circles represents the numbers of nouns that are jointly of both kinds. The circles on the left depict the relative number of count nouns, names for solid things, and names for categories organized by shape. The circles on the right represent the relative number of mass nouns, names for nonsolid substances, and names for things in categories organized by material. What the figure shows is that many early nouns are count nouns, many refer to solid objects, and many name objects in shape-based categories. Moreover, count nouns, solid things, and shape similarity *go together.* Thus, there are two cues—syntax and solidity—that could cue attention to shape. The circles on the right show that there are many fewer nouns in this corpus that are mass nouns, name nonsolid things, and name categories organized by material. However, nonsolidity, mass-noun syntax, and material-based categories are correlated. This small cluster of nouns is interesting because several studies suggest that children generalize names for nonsolid substances by material, not by shape (see Imai & Gentner, 1997; Soja, 1992), an issue that is discussed later in this chapter.

Summary and Implications

The nouns that children learn early are predominantly count nouns that name solid objects of a particular shape. This fact is important because it means that the statistical regularities needed to *build* a shape bias exist among early nouns. I emphasize the word "build" because building implies a process over time. If the shape bias is a word-learning crane that is itself built out of associative processes, then it must be built one encountered word at a time. For an individual child, the statistical regularities must *emerge* over the course of early word learning. Each noun encountered and acquired will strengthen and weaken associations among clusters of properties. Only when a sufficient number of nouns has been learned will the association strengths that control attention stably reflect the principal regularities.

A key prediction from this associative learning account is this: Children's noun generalizations should *change* as they learn more and more nouns. At first, generalizations of a newly learned noun to new instances should reflect only the grossest regularities. As more nouns are learned, generalizations of novel nouns should reflect subtler statistical truths about how nouns map to categories. The extant evidence, including facts about early noun learning not usually discussed under the rubric of the shape bias, fits this description.

THE DEVELOPMENTAL TREND IN NOVEL-NOUN GENERALIZATION

The associative-learning account provides a unifying explanation of many phenomena in the artificial-noun learning literature—phenomena emerging both before and after the shape bias per se. This section reviews these global changes that occur in noun generalizations with development and their congruence with the idea that, as children learn nouns, they are also learning statistical regularities that then help them learn more nouns.

From Overall Similarity to Shape Similarity

There are more pervasive regularities in early noun vocabularies than those illustrated in Table 3.5 or Figure 3.2, regularities so pervasive, in fact, that it is easy to overlook them. One is that nouns of all kinds (proper, count, and mass) are used to name concrete, that is touchable, stuff—not abstract objects, not relations. Another is that the entities with the same name are *perceptually* similar to each other—in one way or another. Thus, before children know that *count* nouns name things similar in *shape,* we might expect them to know that perceptually similar things have the same name. The extant evidence from children younger than 2 years of age accords with this expectation.

In one relevant study, Waxman and Hall (1993) presented 15- and 21-month-old children with triads of objects. Waxman and Hall named one object, the exemplar, with a new noun and asked the children to indicate which of the two remaining objects had the same name. One test object shared some perceptual features with the exemplar; the other test object shared virtually none. For example, if the named object was a carrot, the test objects would be a tomato (somewhat similar) and a rabbit (not at all similar). That is, the researchers asked the children to choose whether the name applied to something that was

somewhat similar to the named object or to something that was not similar at all. Both younger and older children tended to pick the item most similar to the named object, showing that they already knew that nouns span categories of perceptually similar things.

A study by Woodward, Markman, and Fitzsimmons (1994) suggests that even this most rudimentary association—between naming and overall similarity—emerges between 13 and 18 months. In their artificial noun learning task, these researchers, too, presented children with triads containing two perceptually similar objects and one perceptually dissimilar object. For example, on one trial, the child was presented with a single strainer that was named. Then the child was asked to select another object by that name. The two objects that the child could choose between were a second strainer and a clip. Critically, on some trials, the target test object (e.g., the second strainer) was *identical* to the named exemplar; on other trials, it was *perceptually different but similar overall* (differing, for instance, in color). The 13-month-olds succeeded unambiguously in choosing the target when the target was identical to the exemplar, but they chose randomly in three of four experiments when the target differed even slightly from the exemplar. The 18-month-olds, however, succeeded both when the target was identical to and when it was merely similar to the named exemplar. Thus, it seems, the generalization of a just-heard object name to a discriminably different but similar object becomes increasingly robust in the earliest stages of noun learning.

Do children this young know that it is shape similarity in particular that matters for naming solid objects? There is no evidence that they do. The earliest age at which selective attention to shape has been demonstrated is 24 months (see Imai, Gentner, & Uchida, 1994; Landau, Smith, & Jones, 1988; Soja, 1992). Moreover, the results of several studies indicate that the selectivity and certainty of attention to shape in the task of generalizing a novel object name increases substantially between 24 and 36 months of age (Landau, Smith, & Jones, 1988, 1992, 1998; Imai & Gentner, 1997).

Overall, then, there is a developmental progression in the generalization of object names: from generalization to similar objects to generalization to objects specifically like the exemplar in shape. Such progressive refinement of attention in the task of naming is just what is expected of a learner who must discover, one learned word at a time, the statistical regularities between words and categories.

Words Then Count Nouns *Become* Special

The proposal that word-learning cranes are built by the same associative mechanisms that govern learning in other domains implies that words are not intrinsically special in their ability to organize attention to categories. Rather, that specialness is a product of learned associations.

Namy and Waxman (1998; see also chapter 4 in this volume) reported results supporting this idea that words *become* special in their ability to direct children's attention to categories of similar things. In a task nearly identical to that used by Waxman and Hall (1993), Namy and Waxman presented 18- and 26-month-olds with a triad of objects: an exemplar and two choice objects, one perceptually similar to the exemplar and one highly dissimilar to the exemplar. For example, one triad consisted of a van, an airplane, and a whale. The first condition matched one used by Waxman and Hall: the exemplar object was named with a novel name, and, the child was asked, using that name, to select among the two choice objects. It was the second condition that was new: the exemplar was referred to—not with a spoken name—but with a hand gesture, and the child was asked, using the gesture, to select among the two choice objects. The younger children, 18-months-olds, chose by similarity in both conditions. Apparently, for younger children, any associate of an object can work to push attention to similar objects. The older children, in contrast, chose by similarity only in the name condition; they responded randomly when signaled by a gesture to make a choice. These results suggest that words are not special attention cuers initially but become special through their continued and repeated use by others to bring attention to objects. The accrued consequence of these continued experiences is that words become the privileged means by which one directs the attention of another—that is, the privileged way of referring.

My laboratory has collected some preliminary data consistent with this idea. A longitudinal pilot study examined the spontaneous generalizations of gestures and names of 12 children. Half the children were 17 months old and half were 20 months old at the start of the 6-week experiment. During each weekly session, children played with the four pairs of objects illustrated in Figure 3.3. The objects in each pair were always the same shape but differed dramatically in color and material. One object in each pair was the exemplar; one was the test object. During the play period with each pair, the experimenter looked at the exemplar, named it, and made a gesture specific to the exemplar while looking at the exemplar at least eight times. For example, the experimenter expressively put her hands over her head while looking at the "zop" exemplar. She neither named nor gestured while looking at the test object.

Our question was how readily children would begin to use the object name or gesture to refer to objects. Thus our dependent measures were the number of times the children spontaneously named the exemplar and test object and the number of times they spontaneously made the characteristic gesture while looking at the exemplar or the test object. Figure 3.4 shows the mean number of names and gestures offered by the children over the 6 weeks of the experiment.

As the figure shows, the younger children spontaneously produced the experimenter's gestures from the start, and they spontaneously generalized these

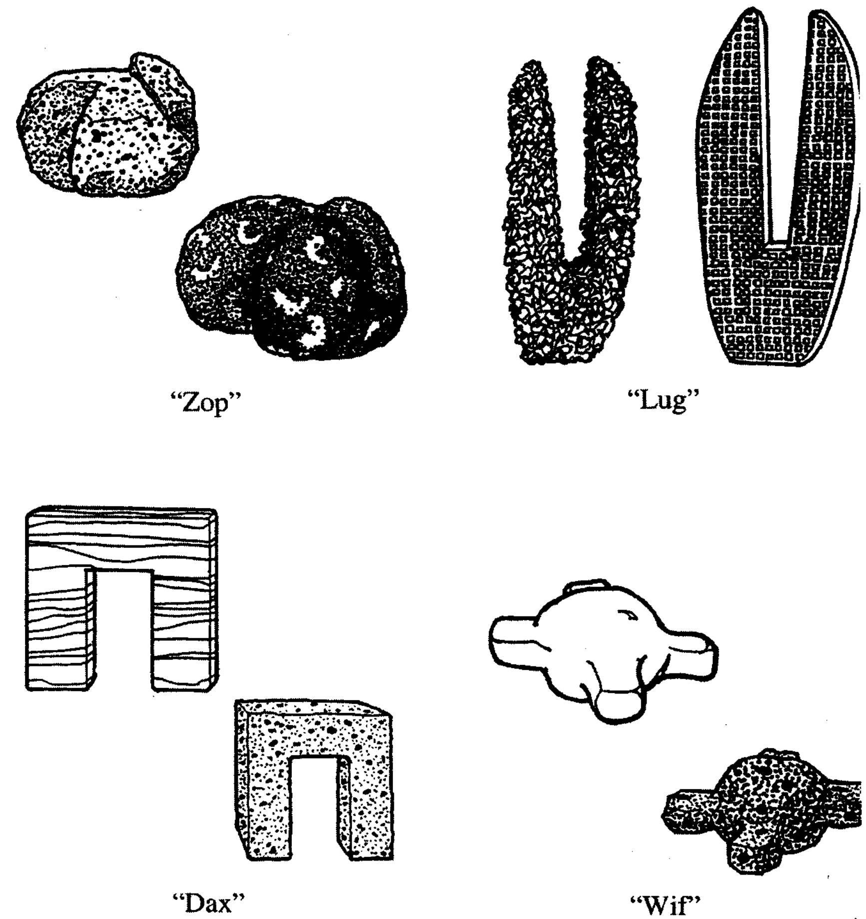

FIGURE 3.3. Stimulus Objects Used in the Name and Gesture Pilot Study.

gestures to the similar test objects. Clearly, gestures are readily linked to objects and readily generalized to similar objects. The production of spontaneous names shows a different course. The younger children were much less likely to produce the spontaneous names, possibly because of the difficulty in *saying* the words. However, by Week 3, all of the youngest children had spontaneously named at least two of the exemplar objects, but at Week 5 only one child had ever spontaneously generalized an exemplar name to a test object. For the youngest children, object names were more closely tied than were gestures to the particular object with which they had been paired.

For the older children, in contrast, words were generalized more often to similar objects than were gestures. The older children could and did make all gestures, mimicking the adult actions from the start, and they generalized these

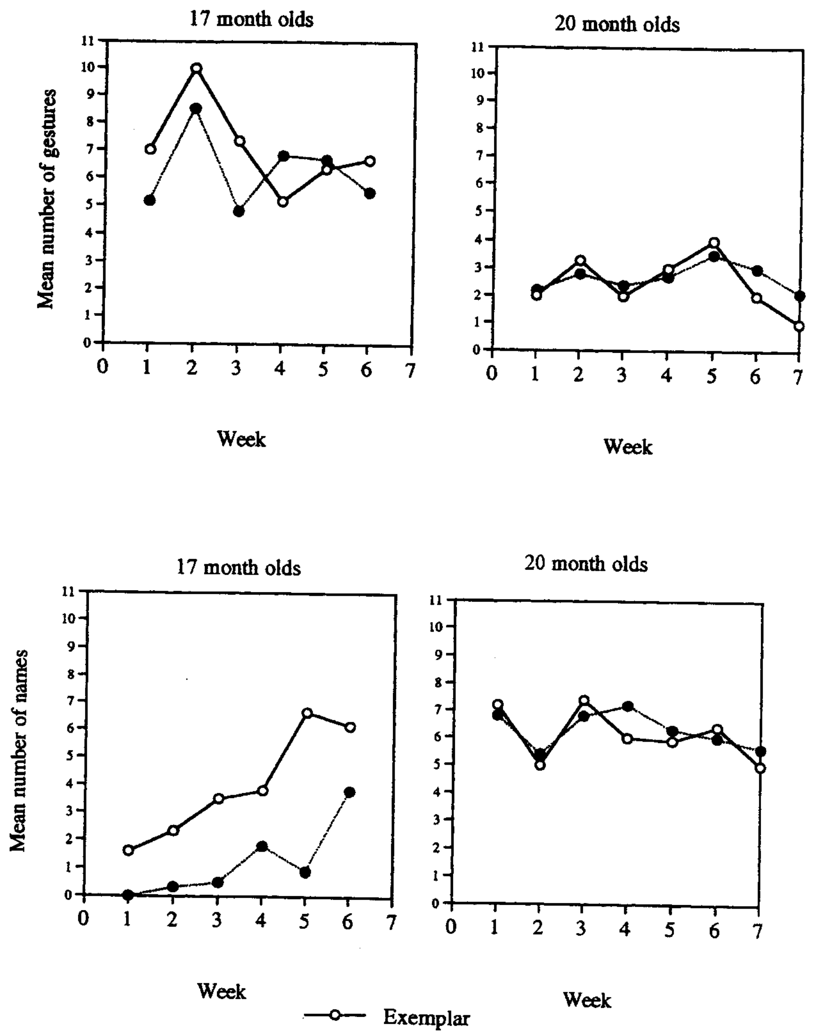

FIGURE 3.4. Spontaneous Generalizations of Gestures and Names to Test Objects (*filled circles*) and to Exemplars (*open circles*).

actions to similar items. However, the older children were more likely to name objects spontaneously than to gesture spontaneously, and they generalized names to new objects as soon as they began producing the names. These results, along with those of Namy and Waxman (1998), suggest that over the course of early word learning—as the act of naming becomes associated with categories of similar items—nouns *become* the privileged way to refer to objects of similar kind.

As children learn even more nouns, they should learn that it is not just any word but a particular kind of word that names objects. And they should learn

that it is not just global similarity but shape similarity specifically that is relevant to naming. The evidence suggests that as word learning progresses, count-noun syntax takes precedent in cuing attention to shape. For example, several studies have shown that 2- (and under some conditions 3-) year-old children generalize new words to new objects by shape both when the novel word is presented in a count-noun syntactic frame ("This is a dax") and when it is presented in an adjectival frame ("This is dax one.") However, although older children generalize novel count nouns by shape, they generalize novel adjectives by properties other than shape (see Smith, Jones, & Landau, 1992; Au & Laframboise, 1990; Landau, Smith, & Jones, 1992; see also Waxman, 1994).

In sum, as children learn more and more words, words *become* privileged organizers of attention, and specific linguistic cues—syntactic frames of count nouns as opposed to adjectives—come to increasingly direct attention to specific kinds of properties and similarities. If words gain their power as a result of associations accrued in the course of language learning, the gradual empowerment and differentiation of linguistic cues is just what is expected.

Learning Other Correlations and Other Predictive Cues

If the processes that create the shape bias are general associative mechanisms, then they should create noun-learning cranes other than just the shape bias—as long as there are other statistical regularities among linguistic entities, object properties, and category structures. There is evidence in the literature for at least two additional attentional biases in the context of noun learning.

Solid Things and Nonsolid Stuff. As Figure 3.2 shows, there are statistical regularities peculiar to the naming of nonsolid substances in addition to those relevant to the naming of solid substances. That is, nonsolid substances tend to be named by material rather than shape and by mass nouns rather than count nouns. However, Figure 3.2 also shows that, early in word learning, children tend to know many fewer names for nonsolid than for solid substances. These statistical facts about the structure of early noun vocabularies suggest that (1) children should (given a sufficient number of learned names for nonsolid substances) generalize a newly encountered name for a nonsolid substance to new instances by material, (2) children's attention to material over shape when learning a new name should increase when the name is presented in the context of mass-noun syntax, and (3) children's attention to material in the context of nonsolid substances and mass syntax should emerge later or more weakly than does their attention to shape in the context of a solid object and count syntax.

All three of these predictions have empirical support (see Soja, Carey, &

Spelke, 1991; Soja, 1992; Imai & Gentner, 1997; Gathercole & Min, 1997; Samuelson & Smith, 1999). In one relevant study, Soja (1992) presented 24- and 30-month-old children with solid or nonsolid exemplars named with either a count noun ("This is a mel") or a mass noun ("This is some mel"). The solid exemplars were made from wood or hardened clay; the nonsolid exemplars were made from such substances as hair gel and face cream. Soja found that solidity and count syntax pushed attention to shape and nonsolidity and mass syntax pushed attention to material. Moreover, the effects of solidity and syntax were stronger for 30-month-olds than for 24-month-olds. And, critically, solidity and count syntax were much stronger forces on children's generalizations than were nonsolidity and mass syntax—just as they should be if the strength of the attentional bias in children depends on the strength of the association in the nouns they learn.

Objects with Eyes and Feet. My colleagues and I (Jones, Smith, and Landau, 1991) hypothesized that artifact and animal categories differ in their organizational structure. Based on our own intuitions, we speculated that textural properties—being feathered or furry—as well as shape similarity were critical in organizing animal categories. We recently confirmed these intuitions by asking adults to judge the similarities among animal artifact categories named by nouns on the MCDI. More specifically, 15 adults judged the categories named by 43 animal and 82 artifact terms (vehicles, toys, small household objects) on the parent checklist. Adults judged animal terms to name objects that were principally rounded rather than angular (84% of the animal names) and to name objects that had a characteristic texture (93% of the animal names). In contrast, adults only infrequently judged the artifact terms to name objects that were rounded (39% of the artifact names) and to name objects with a characteristic texture (33% of artifact names). Adults in this study also judged shape to be relevant to category membership for 68% of the animal categories and 79% of the artifact categories. These regularities suggest that children could learn that animal and artifact categories are organized differently and could therefore know, upon hearing a novel object named, that shape and texture matter if it is an animal but that only shape matters if it is an artifact.

In Jones, Smith, and Landau, 1991, we provided the pertinent evidence. We reasoned that one predictive cue of animacy is having eyes. Thus, children might learn to name objects with eyes by shape and texture but objects without eyes by shape alone. We tested this prediction by presenting 2- and 3-year-old children with the exemplars shown at the top of Figure 3.5. Half the children completed the task with the eyed objects and half with the eyeless objects. In each condition, we named the exemplar with a count noun (e.g., "This is a dax") and asked the children if each test object was also a "dax." Test objects matched the exemplar in shape only, texture only, or shape *and* texture (they differed

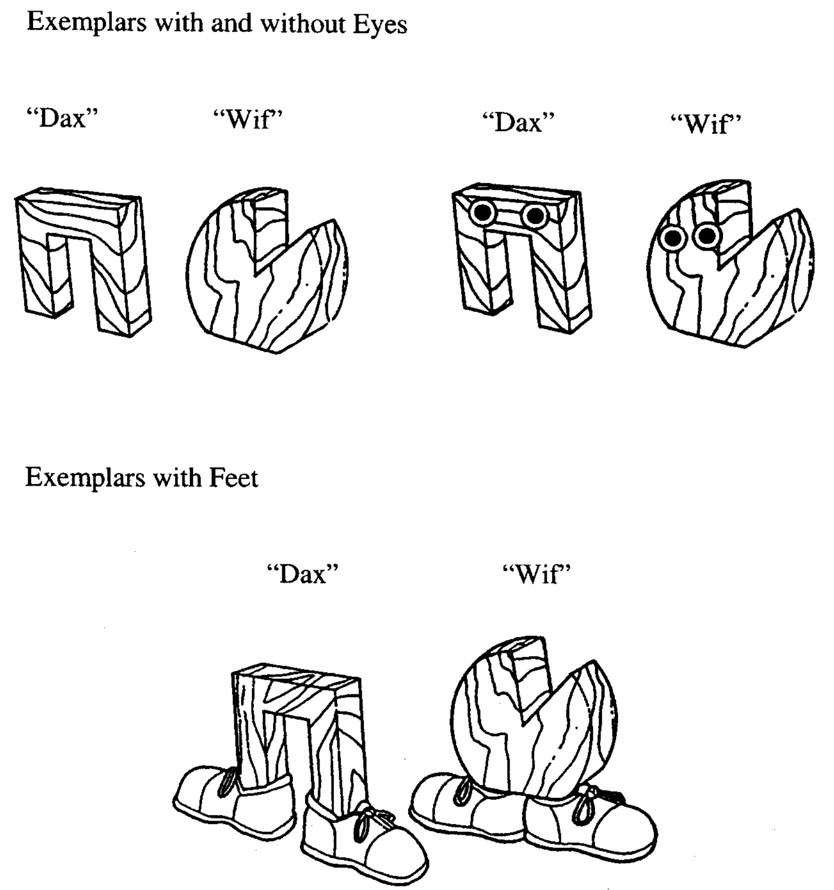

FIGURE 3.5. Exemplars Used to Contrast Children's Noun Generalizations.

from the exemplar in size). Two-year-old children generalized the name to objects having the same shape as the exemplar and ignored texture and size with both eyeless and eyed objects. Three-year-old children, on the other hand, generalized names of objects without eyes to all new objects that matched the exemplar in shape, regardless of texture; as predicted, however, they generalized names of objects with eyes only to new objects that matched the exemplar in both shape and texture. The fact that children know that shape matters in naming eyed and eyeless objects before they know that texture is additionally relevant for eyed objects fits the statistical learning account. Shape is relevant to many of the noun categories these children have learned; shape plus texture is relevant only to a subset of these categories, a subset cued by the presence of eyes.

In Jones and Smith, 1998, we replicated the eye effect using the cue of feet.

If children are statistical learners who gain knowledge of and then use whatever cues are present, then the perceptible property of feet should cue attention to texture just as eyes did; because having feet is correlated with having eyes, it should, as did eyes, predict category membership based on common shape and texture. The exemplars that we used to test this idea are illustrated at the bottom of Figure 3.5. Children's generalizations in this experiment closely replicated those found earlier for objects with eyes. Again, 2-year-olds generalized novel names by shape both when the objects did and did not have feet, but 3-year-olds generalized the novel names by shape when the objects did not have feet and by texture as well as shape when the objects did have feet. Apparently, children learn and use multiple cues to category organization at multiple levels.

Think about what this means: As children learn more and more object names, they will learn more and more about the co-occurrences of naming, object properties, and category structure. All these correlated cues will work to tune attention to properties that have, in the past, been most predictive of category membership *for categories of that kind.* When a child who already knows some nouns hears a new noun used to name a new object, he or she can zoom in on the appropriate features for that kind of object. Because the child can use statistical generalizations about category structure from previously learned categories, he or she does not have to learn by trial and error the relevant properties for each unique category.

The Taxonomic versus the Shape Bias. Because associative learning works continuously, it will build as many context-specific cranes as there are regularities among the categories being learned. This idea offers a reconciliation of two competing views of how and why children are smart learners of nouns. One view, the basis of this chapter, proposes a shape bias. The other view proposes a more conceptually based taxonomic bias (Markman & Hutchinson, 1984; Waxman & Gelman, 1986; Imai, Gentner, & Uchida, 1994; Keil, 1994; Bauer & Mandler, 1989). Typically, the two are seen as competing and opposing proposals. But the findings about eyes and feet suggest a reconciliation in that they show that there is not *just* a shape bias. Different attentional biases emerge with development for different kinds of categories. The shape bias has drawn a lot of attention because it is the first selective attentional bias. But it is first because it reflects the most broadly important property across many kinds of object categories. The eye, foot, and nonsolid substance results show that in other contexts, for other kinds of items, children develop other perceptual biases. Indeed, I bet that if we did the proper experiments, we would find many such "biases," at least among older word learners: attentional shifts to just the right bundles of properties relevant for categorizing vehicles, or machinery, or furniture, or food. This is a reasonable prediction: As children continually learn

clusters of correlated cues, they should learn finer-grained statistical regularities specific to specific kinds of categories.

Here, then, is the reconciliation of the taxonomic and shape biases: As these complex, context-sensitive attentional biases develop and multiply, they will instantiate a lot of knowledge about different kinds of categories. If this is so, learned attentional biases may well be the very mechanism through which an understanding of taxonomies is implemented. Children's knowledge of the kinds of things there are in the world and their attention to specific object properties in naming may both be manifestations of learning the same rich associative structures (cf., Markman, 1989).

HOW LEARNING WORDS CHANGES WORD LEARNING

This chapter began with the idea of the shape bias as a crane, a mechanism emergent from ordinary learning processes that then helps the child bypass the trial and error of ordinary learning. Two supporting lines of evidence have been presented this far: (1) the statistical regularities among linguistic entities, object properties, and category structures that are of the kind that could create learning biases and (2) the developmental trend suggests progress as children learn nouns toward increasingly refined attentional biases that reflect increasingly finer-grained statistical regularities in the language. This section presents a third and final line of evidence: the dependence of individual children's generalization of a newly encountered noun on the nouns that those individual children already know. Both studies are reported more fully in Smith, Jones, Landau, Gershkoff-Stowe, and Samuelson, 2000.

A Longitudinal Study

In a longitudinal study, we tracked the language growth of eight children from 15 to 20 months of age. Parents kept diaries of all new words spoken by their child, and the children came to the laboratory every 3 weeks to participate in an artificial noun-generalization task. At the beginning of the study, the children had very few words in their productive vocabulary (fewer than 15). At the end of the study, each child had over 150 words, and for each child more than half of these were specifically count nouns. Thus, if the shape bias is learned from learning words, the children in this study should not show a shape bias at the beginning, because they do not know many words, but they should show selective generalization for solid objects by shape at the end of the study, because by that time they have learned many count nouns—nouns that at this age level overwhelmingly refer to shape-based categories.

The stimuli used in the laboratory task are shown in Figure 3.6. They in-

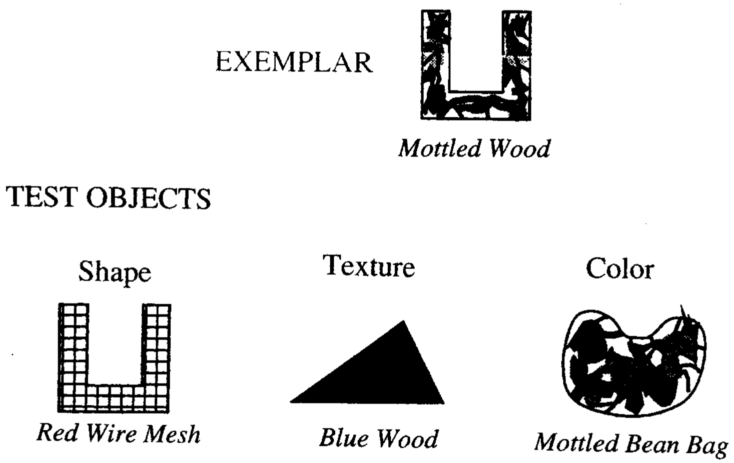

FIGURE 3.6. Exemplar and Test Objects used in the Longitudinal Study of the Emergence of the Shape Bias.

cluded an exemplar object made of wood and three test objects that matched the exemplar in either color, shape, or texture. The task began when the experimenter put the exemplar and three test objects on the table in front of the child. The experimenter picked up the exemplar and said, "This is a dax. Look. This is a dax." Then while still holding the exemplar, the experimenter held out her other hand, palm up, and said, "Give me a dax. Give me another dax."

Figure 3.7 shows children's generalizations by shape as a function of the number of nouns (proper, mass, and count) in their productive vocabulary. As expected, shape choices did not predominate early in the study, when children knew few nouns, but did so reliably by the end, when they knew many. More specifically, *after* all eight children had 50 nouns (and on average 35 count nouns) in their productive vocabulary, they began to extend the novel word "dax" systematically to the same-shaped test object. Moreover, by adult judgments, over 90% of these first 35 count nouns referred to categories well organized by shape. This fact supports the proposal that the shape bias is a statistical generalization from already learned object names.

If this shape bias is a crane that lifts noun learning, however, then the shape bias once formed should alter the course and speed of noun learning. That is, by the present account, the shape bias is not just an *effect* of noun learning; it is also a *cause* of which nouns are easily learned in the future. If hearing count-noun syntax automatically shifts attention to shape, then the acquisition of count nouns—nouns that in early vocabularies overwhelming refer to shape-based categories—should accelerate. We sought support for this idea in a training study.

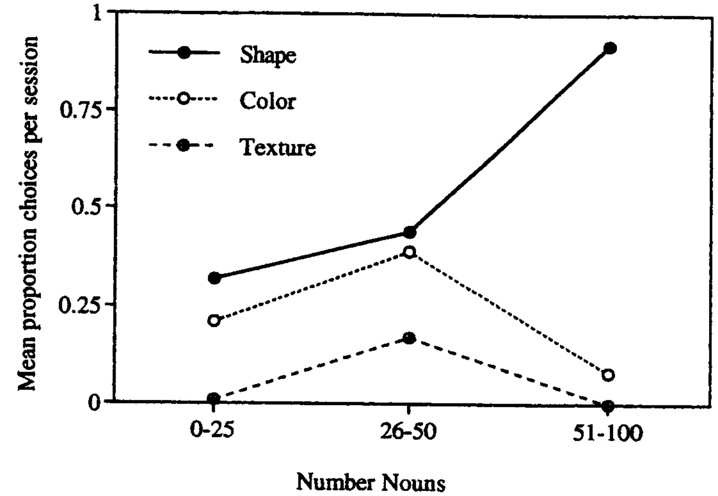

FIGURE 3.7. Choices of the Test Objects as a Function of the Number of Nouns in Children's Spoken Vocabulary.

A Training Study

The strongest possible evidence for the idea that word-learning cranes are built is the ability to build one experimentally. And the strongest possible evidence that the shape bias alters the course of noun learning is the ability to show than an experimentally made shape bias changes how children learn real nouns outside the laboratory. We attempted this powerful test of the associative-learning account by teaching artificial lexical categories that were well organized by shape to children who did not yet know many words. The subjects were eight children who were 17 months of age and who had, on average, 14 count nouns in their productive vocabulary by parent report on the MCDI. These children came to the laboratory once a week for 9 weeks and for 7 of those weeks received extensive training on four different novel categories—all well organized by shape. The top of Figure 3.8 illustrates the training stimuli for one lexical category.

Each lexical category was trained as follows: The experimenter placed the two exemplars for a category on the table and named them—for example, "This is a zup. Here is another zup." As illustrated in Figure 3.8, these two exemplars differed in many ways but were identical in shape. The experimenter and child played with the two objects for 5 minutes, during which time the experimenter repeatedly named the objects—for example, "Put the zup in the box. Can you put the zup in the wagon?" Halfway through a play session with one pair of exemplars, the experimenter placed a nonexemplar for that category (see Figure

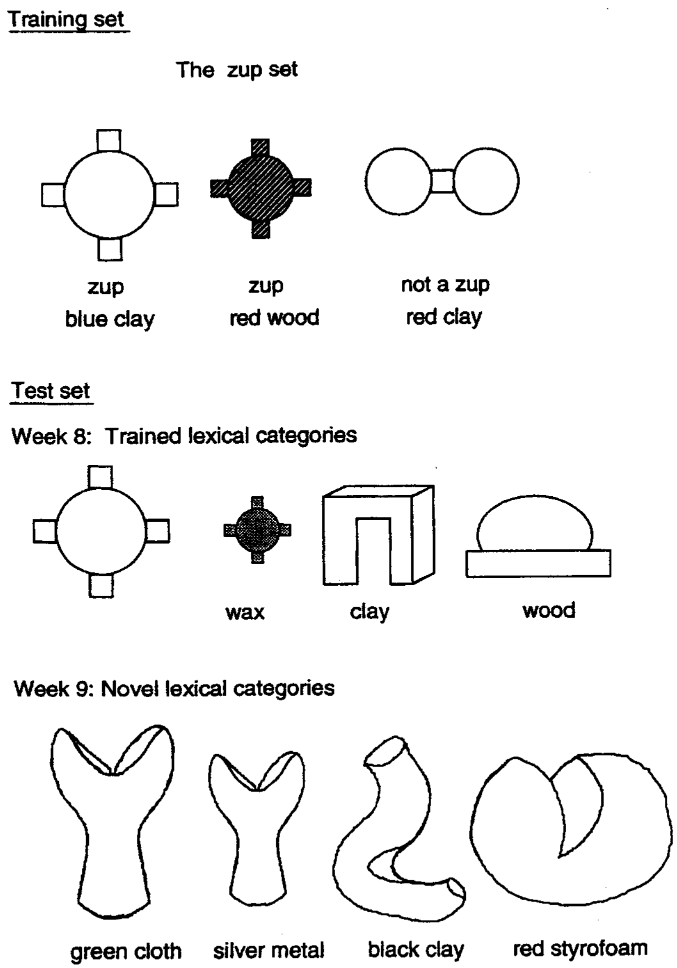

FIGURE 3.8. Training Set and Two Test Sets Used in the Training Study.

3.8) briefly on the table. The experimenter announced that this just introduced object was not a member of the category (e.g., "*That's* not a zup!") and immediately removed it. The nonexemplar matched each exemplar in one nonshape attribute but differed from both exemplars in shape, thus providing the child with evidence as to the kinds of items that are *not* in the lexical category.

For the first 7 weeks, the experimenters trained the children as described above once a week for each of four lexical categories. On Weeks 8 and 9 of the experiment, the children participated in two test sessions that asked them to generalize what they had learned over the first 7 weeks. The first test session, Week 8, measured children's generalizations of the trained lexical categories to new items. The middle section of Figure 3.8 shows the stimuli used to test gen-

eralization of the "zup" category. The test began when the experimenter placed one of the trained exemplars on the table along with three new objects, one that matched the exemplar in material, one that matched it in color, and one that matched it in shape. The experimenter picked up the exemplar and said, "This is a zup" and then instructed, "Get me a zup." Given the 7 weeks of training, the exemplar is not a novel object and the label is not a novel name for these children. Thus, if the children have learned that the specifically trained names refer to objects of a particular shape, they should generalize these already learned names to the novel object that is the same as the exemplar in shape.

On Week 9, the experimenters tested the children in a novel-noun generalization task structured in the same way as the generalization task at Week 8. However, as illustrated by the sample stimulus set at the bottom of Figure 3.8, all the objects and names were new. This generalization task thus tests the critical prediction that learning specific categories well organized by shape transforms the act of naming into a contextual cue that automatically shifts attention to shape. If the 7 weeks of intensive training on shape-based categories has caused the linguistic context of naming to cue attention automatically to shape, than these children should form and generalize *new* names on the basis of shape.

This experiment also included eight control children, who were selected at the same time as the children in the trained group. They were 17 months old at the start of the 9-week experiment and had, on average, 16 count nouns in their productive vocabulary. These children, however, did not participate in the 7 weeks of training. Instead they returned to the laboratory for other experiments and for the generalization tasks of Weeks 8 and 9, when they and the children in the trained group were 19 months of age. Since the control children had not received intensive training in shape-based lexical categories and did not know many count nouns, the expectation was that they would not selectively attend to shape in the generalization tasks at either Week 8 or Week 9.

The main results are shown in Figure 3.9. Consider Panel 1 first. At Week 8, when the trained children were asked to generalize the trained names to new objects, they did so on the basis of shape. These children had clearly learned that the words taught to them in the experiment refer to objects of a particular shape. As expected, the control children, for whom this was a *new* word interpretation task, did not systematically attend to shape.

At Week 9, both the trained and control children heard novel objects named by novel nouns. However, as shown in Panel 2, the trained children, but not the control children, systematically generalized these newly learned names to other novel objects by shape. In brief, we taught the trained children four categories organized by shape, but the children learned more than just these categories. They learned to attend to shape when novel rigid objects were named. This generalized attentional shift *is* a learning bias. These children were thereafter biased to induce a shape-based category when a new object was named.

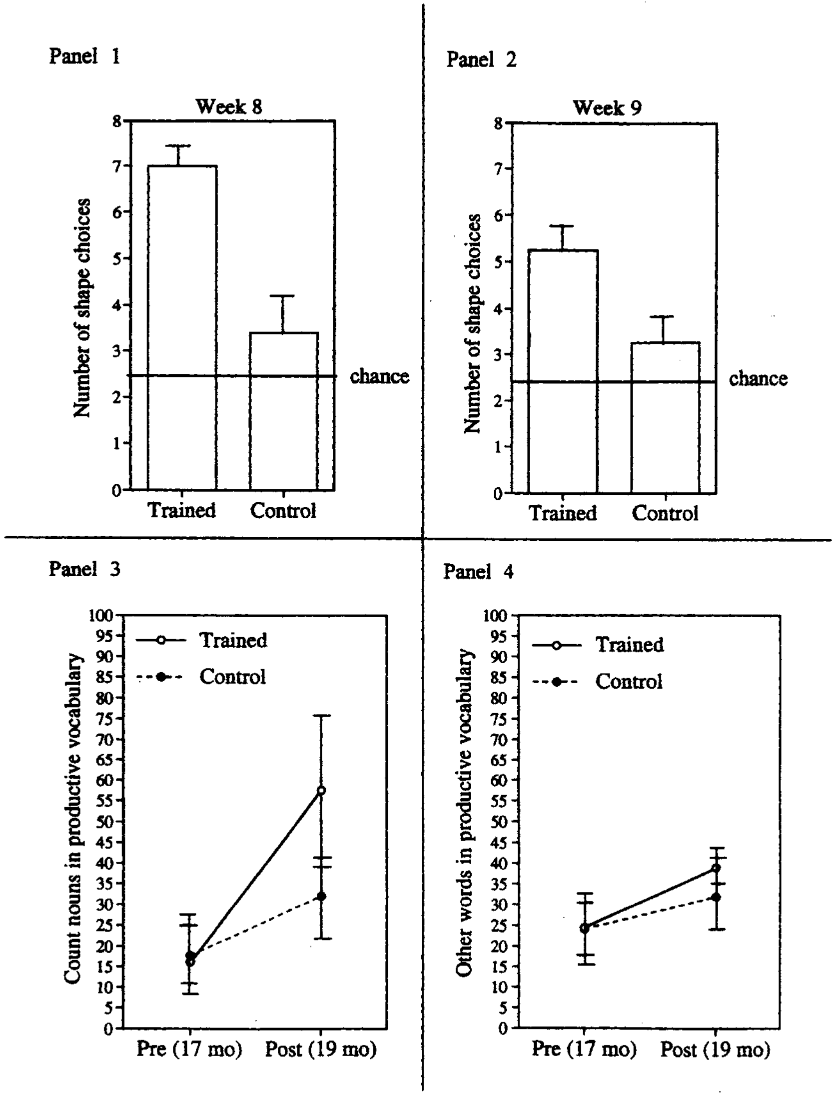

FIGURE 3.9. Results of the Training Study. Panel 1 shows the mean shape choices made by the children in the trained and control conditions at Week 8. Panel 2 shows the mean shape choices made at Week 9. Panel 3 shows the mean number of count nouns in productive vocabulary at Week 1 and Week 8. Panel 4 shows the mean number of words other than count nouns in productive vocabulary at Week 1 and Week 8.

Is this a crane that once formed "lifts" development, allowing it to make faster progress than expected by trial-and-error learning? The answer is yes. This trained bias to link nouns to shape-based categories accelerated object-name learning *outside the laboratory* for the children in the trained group. The parents of the children in both the trained and the control groups were asked to complete the MDCI again at Week 8, indicating all the words in their children's productive vocabulary at that point. The bottom panels of Figure 3.9 show the change in vocabulary from Week 1 to Week 8 for the two groups. The children in the training condition showed a 166% increase in the number of count nouns known. In contrast, children in the control condition showed only a 73% increase in the average number of count nouns. Notice that the training did not affect the rate of acquisition of words that are not count nouns. Thus, the children who were taught names for four artificial categories well organized by shape also learned, outside the laboratory, more names for real categories—categories of the kind typically well organized by shape—than did children who did not receive this training. Learning shape-based lexical categories creates a shape bias, which in turn promotes the rapid learning of object names.

I believe that we have reproduced in the laboratory and accelerated by several months the natural processes through which the shape bias is made. This shape bias is a developmental crane that enables children to induce a shape-based category from hearing a single thing named, and in this way, to often be immediately right about the extension of a category. One might ask: How could learning just four names for artificial categories generate this accelerated learning of real count nouns? After all, children in the control condition also learned object names outside the laboratory during this period—many more than just four—and they developed neither a shape bias nor an accelerated rate of vocabulary growth.

These facts can be explained as follows: First, our training presented unusually transparent shape-based category structures. Although most concrete object categories may be well organized by shape, not all are. Moreover, some real-world object categories that are well organized by shape also exhibit, within the category, similarities of color, size, texture, or movement. By isolating shape similarity in our training set, we made the property that is highly predictive of category membership in the world perfectly predictive in the laboratory. Second, our training *alone* may not have created the shape bias. If we taught children only these four new names and did not allow them to be exposed to any other naming outside of the laboratory, it is possible that there would be no shape bias evident in Week 9 testing. That is, learning in the laboratory and in the world may have worked together to create our results. In the initial weeks, the laboratory training may have created a slightly heightened attention to shape in the context of naming, which may have helped the children acquire several more count nouns outside the laboratory than they would have without the training. Given the statistical properties of early count nouns, this learning is likely to have caused at least a slight strengthening of the link between naming and shape, a link that would be reinforced by the continuing laboratory experience, which in turn would probably promote the learning of several more real count nouns between laboratory sessions, which would strengthen the link between count-noun syntax and shape even more, and so on. In brief, the laboratory created changes internal to the children that may have then changed what they attended to and learned outside the laboratory, causing a snowballing developmental effect several months earlier than the development would have occurred without our intervention. This may be what language learning is like in general: Each advance is a crane that prepares the way—that guides and lifts subsequent learning.

CONCLUSION

Figure 3.10 summarizes several of the developmental experiments reviewed here. Each curve summarizes the degree to which children generalize a novel label exclusively on the basis of shape, as a function of the age of the subjects, the kind of object labeled, and the syntactic frame in which the novel word ap-

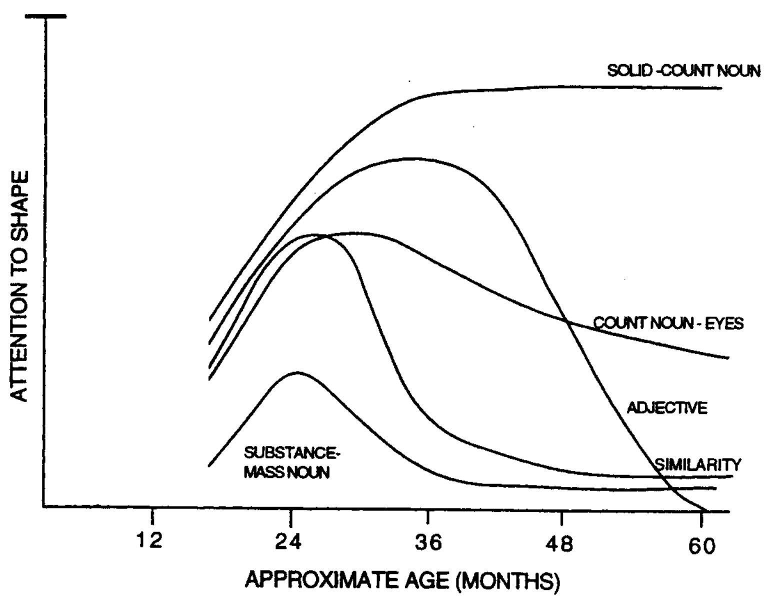

FIGURE 3.10. Curves Summarizing Results Across Many Experiments. The curves show exclusive attention to shape as a function of age and task, syntax, and object properties.

peared. Altogether, the evidence indicates that, with development, the shape bias becomes both stronger and more specific to count nouns and artifacts. Descriptively, attentional biases specific to animates, substances, mass nouns, and adjectives seem to differentiate out of an early bias to attend to the overall similarity of objects and then a bias to attend to shape. By the present account, attention to shape in the context of a count noun differentiates first because it is the most pervasive regularity among the early nouns that children know.

If we considered the increasing evidence from other languages, we would have to draw more curves on the graph in Figure 3.10. A number of recent studies of children learning Korean and Japanese as their first language suggest that these children also generalize object names to new objects by shape but that their shape bias is more restricted to objects of complex shape (Imai & Gentner, 1997) and to rigid objects with nondeformable shapes (Kobayashi, 1997; Samuelson & Smith, 1999) and is more easily challenged by information about object function (Gathercole & Min, 1997) than is the shape bias of children learning English. In brief, how children generalize a newly learned noun depends on the specific language they are learning. These cross-language studies in conjunction with the results of the training experiment strongly indicate that children's attentional biases in the task of learning object names—biases that promote the learning of certain kinds of words and categories—emerge out of the specific word-learning experiences of children.

REFERENCES

Allport, A. (1989). Visual attention. In M. I. Posner (Ed.), *Foundations of cognitive science* (pp. 631–682). Cambridge, MA: MIT Press.

Au, T. K., & Laframboise, D. E. (1990). Acquiring color names via linguistic contrast: The influence of contrasting terms. *Child Development, 61,* 1808–1823.

Bauer, P., & Mandler, J. (1989). Taxonomies and triads: Conceptual organization in one- to two-year-olds. *Cognitive Psychology, 21,* 156–184.

Biederman, I. (1987). Recognition by components: A theory of human image understanding. *Psychological Review, 94,* 115–147.

Clark, A. (1993). *Associative engines: Connectionism, concepts, and representational change.* Cambridge, MA: MIT Press.

Clark, E. V. (1973). What's in a word? On the child's acquisition of semantics in his first language. In T. E. Moore (Ed.), *Cognitive development and the acquisition of language* (pp. 65–110). New York: Academic Press.

Dennett, D. C. (1995). *Darwin's dangerous idea: Evolution and the meaning of life.* New York: Simon & Schuster.

Fenson, L., Dale, P. S., Reznick, S., Thal, D., Bates, E., Hartung, J., Pethick, S., & Reilly, J. (1993). *MacArthur communicative development inventories.* San Diego, CA: Singular.

Gathercole, V. C. M., & Min, H. (1997). Word meaning biases or language-specific effects? Evidence from English, Spanish and Korean. *First Language, 17,* 31–56.

Golinkoff, R. M., Mervis, C. B., & Hirsh-Pasek, K. (1994). Early object labels: The case for a developmental lexical principles framework. *Journal of Child Language, 21,* 125–155.

Imai, M., Gentner, D., & Uchida, N. (1994). Children's theories of word meaning: The role of shape similarity in early acquisition. *Cognitive Development, 9,* 45–76.

Imai, M., & Gentner, D. (1998). A crosslinguistic study of early word meaning: Universal ontology and linguistic influence. *Cognition, 62,* 169–200.

James, W. (1950). *The principles of psychology* (Vol. 1). New York: Dover Publications. (Original work published 1890)

Jones, S., Smith, L., & Landau, B. (1991). Object properties and knowledge in early lexical learning. *Child Development, 62,* 499–516.

Jones, S., & Smith, L. B. (1998). How children name objects with shoes. *Cognitive Development, 13,* 323–334.

Keil, F. (1994). Explanation, association, and the acquisition of word meaning. In L. R. Gleitman & B. Landau (Eds.), *Lexical acquisition* (pp. 169–197). Cambridge, MA: MIT Press.

Kelly, M. H., & Martin, S. (1994). Domain-general abilities applied to domain-specific tasks: Sensitivities to probabilities in perception, cognition and language. In L. R. Gleitman & B. Landau (Eds.), *Lexical acquisition* (pp. 105–141). Cambridge, MA: MIT Press.

Kobayashi, H. (1997). The role of actions in making inferences about the shape and material of solid objects among Japanese 2-year-old children. *Cognition, 63,* 251–269.

Kruschke, J. K. (1992). ALCOVE: An exemplar-based connectionist model of category learning. *Psychological Review, 99,* 22–44.

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

Landau, B., Smith, L. B., & Jones, S. S. (1992). Syntactic context and the shape bias in children's and adult's lexical learning. *Journal of Memory and Language, 31,* 807–825.

Landau, B., Smith, L. B., & Jones, S. (1998). Object shape, object function, and object name. *Journal of Memory and Language, 38,* 1–27.

Lewicki, P., Hill, T., & Sasak, I. (1989). Self-perpetuating development of encoding biases. *Journal of Experimental Psychology: General, 118,* 323–338.

MacIntosh, N. J. (1965). Selective attention in animal discrimination learning. *Psychological Bulletin, 64,* 125–150.

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

Markman, E. M. (1989). *Categorization and naming in children: Problems of induction.* Cambridge, MA: MIT Press.

Markman, E. M., & Hutchinson, J. E. (1984). Children's sensitivity to constraints on word meaning: Taxonomic versus thematic relations. *Cognitive Psychology, 16,* 1–27.

Medin, D. L., Altom, M. W., Edelson, S. M., & Freko, D. (1982). Correlated symptoms and simulated medical classifications. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 8,* 37–50.

Medin, D. L., & Wattenmaker, W. D. (1987). Category cohesiveness, theories, and cognitive archeology. In U. Neisser (Ed.), *Concepts and conceptual development: Ecological and intellectual factors in categorization* (pp. 25–62). Cambridge, England: Cambridge University Press.

Mervis, C. B. (1987). Child-basic object categories and lexical development. In U. Neisser (Ed.), *Concepts and conceptual development: Ecological and intellectual factors in categorization.* Cambridge, England: Cambridge University Press.

Mervis, C. B., Mervis, C. A., Johnson, K. E., & Bertrand, J. (1992). Studying early lexical development: The value of the systematic diary method. In C. Rovee-Collier & L. Lippsitt (Eds.), *Advances in infancy research* (Vol. 7, pp. 291–379). Norwood, NJ: Ablex.

Namy, L. L., & Waxman, S. R. (1998). Words and gestures: Infants' interpretations of different forms of symbolic reference. *Child Development, 69,* 295–308.

Pinker, S. (1989). Learnability and cognition: The acquisition of argument structures. Cambridge, MA: MIT Press.

Rescorla, R. A., & Wagner, A. R. (1972). A theory of Pavlovian conditioning: Variations in the effectiveness of reinforcement and nonreinforcement. In A. H. Black & W. F. Prokasy (Eds.), *Classical conditioning II.* New York: Appleton-Century-Crofts.

Rosch, E., & Mervis, C. B. (1975). Family resemblances: Studies in the internal structure of categories. *Cognitive Psychology, 7,* 573–605.

Samuelson, L., & Smith, L. B. (1999). *Statistical regularities among count/mass syntax, solidity, and category structure in early noun vocabularies. Cognition, 73,* 1–33.

Shanks, D. R. (1995). *The psychology of associative learning.* Cambridge, England: Cambridge University Press.

Smith, L. B. (1995). Self-organizing processes in learning to learn words: Development is not induction. In C. A. Nelson (Ed.), *Basic and applied perspectives on learning, cognition, and development: The Minnesota Symposia on Child Psychology* (Vol. 28, pp. 1–32). Mahwah, NJ: Erlbaum.

Smith, L. B., Gershkoff-Stowe, L., & Samuelson, L. (2000). The statisical structure of the first hundred nouns. In preparation.

Smith, L. B., Jones, S., Landau, B., Gershkoff-Stowe, L., & Samuelson, L. (2000). *The origins of the shape bias.* Manuscript submitted for publication.

Smith, L. B., Jones, S. S., & Landau, B. (1992). Count nouns, adjectives, and perceptual properties in children's novel word interpretations. *Developmental Psychology, 28,* 273–286.

Soja, N. (1992). Inferences about the meanings of nouns: The relationship between perception and syntax. *Cognitive Development, 7,* 29–46.

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

Wang, H. (1993). On physicalism and algorithism. *Philosophia Mathematica, 1,* 97–133.

Waxman, S. R. (1994). The development of an appreciation of specific linkages between linguistic and conceptual organization. In L. R. Gleitman & B. L. Landau (Eds.), *The acquisition of the lexicon* (pp. 229–250). Cambridge, MA: MIT Press.

Waxman, S. R., & Gelman, R. (1986). Preschoolers' use of superordinate relations in classification and language. *Cognitive Development, 1,* 139–156.

Waxman, S. R., & Hall, D. G. (1993). The development of a linkage between count nouns and object categories: Evidence from fifteen- to twenty-one-month-old infants. *Child Development, 64,* 1224–1241.

Woodward, A. L., Markman, E. M., & Fitzsimmons, C. M. (1994). Rapid word learning in 13- and 18-month-olds. *Developmental Psychology, 30,* 553–566.

Younger, B. (1990). Infants' detection of correlations among feature categories. *Child Development, 61,* 614–621.