Research Article

OBJECT NAME LEARNING PROVIDES ON-THE-JOB TRAINING FOR ATTENTION

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Abstract—*By the age of 3, children easily learn to name new objects, extending new names for unfamiliar objects by similarity in shape. Two experiments tested the proposal that experience in learning object names tunes children's attention to the properties relevant for naming—in the present case, to the property of shape—and thus facilitates the learning of more object names. In Experiment 1, a 9-week longitudinal study, 17-month-old children who repeatedly played with and heard names for members of unfamiliar object categories well organized by shape formed the generalization that only objects with similar shapes have the same name. Trained children also showed a dramatic increase in acquisition of new object names outside of the laboratory during the course of the study. Experiment 2 replicated these findings and showed that they depended on children's learning both a coherent category structure and object names. Thus, children who learn specific names for specific things in categories with a common organizing property—in this case, shape—also learn to attend to just the right property—in this case, shape—for learning more object names.*

Learning names for things requires attention to the right object properties. For example, learning which things are called "cup" in English may require that a child attend especially to object shape, because in English, shape is the perceptual property that matters most for determining which objects are included in the category "cup" (Biederman, 1987; Rosch, 1973; Samuelson & Smith, 1999). Young children are remarkably successful at forming object categories organized around the same properties as the categories of the adults in their language communities. But how do children know which properties to attend to? Which properties are the right ones for learning object names?

We have previously suggested that attention gets on-the-job training (Landau, Smith, & Jones, 1988; Smith, 1995). The idea is that learning object names contextually tunes attention, making it skilled in the task of learning object names. Smart attention leads to the more rapid formation of individual categories, and to an accelerated rate of object name learning. In short, we propose that on-the-job training of attention is directly and causally related to on-the-job performance. We report here the first experimental test of this claim that learning object names, through changes in attention, feeds back on itself.

Previous research shows that children do become more skilled at learning object names as language learning progresses. First, children add object names to their vocabularies at slow rates initially, then more rapidly as they approach their second birthday, and by 3 years of age, children are highly skilled word learners (see Bloom, 2000, for a review). Second, during the same developmental period, young children become more systematic in their generalizations of newly learned object names in artificial-noun-learning tasks, at first generalizing ob-

ject names asystematically, then generalizing the names for artifacts systematically by shape (e.g., Samuelson & Smith, 1999).

The first 300 nouns that young children learn tend to be names for concrete-artifact categories that adults judge to be well organized by shape (Samuelson & Smith, 1999). Individual exceptions among early learned categories show that shape is not uniformly privileged in defining object categories. Nonetheless, we have shown that shape is a good cue for determining membership in an overwhelming majority of common-object categories (Samuelson & Smith, 1999; see also Biederman, 1987; Rosch, 1973). And there is evidence that young children may learn to use that cue to good effect. Previous research indicates that children's attention to shape co-develops with acceleration in the rate of learning object names.

Figure 1 illustrates four proposed steps through which learning object names and attention to shape may be bidirectionally and causally related.[1] Step 1 is mapping names to objects—the name "ball" to a particular ball and the name "cup" to a particular cup, for example. This is done multiple times for each name as a child encounters new instances. The objects that get the same name are likely to be similar in shape (Samuelson & Smith, 1999). This learning of individual names for things thus sets up Step 2—first-order generalizations about the structure of individual categories, that is, the knowledge that balls are round and cups are cup shaped. This first-order generalization should enable the learner to recognize novel balls and cups.

Another higher-order generalization is also possible. Because many of the object categories that children learn are shape based, children could also learn the second-order generalization that object names in general span categories of similarly shaped things. As illustrated in Step 3, this second-order correlation requires generalizations over specific names and specific category structures. But making this higher-order generalization should enable the child to extend any object name, even one encountered for the first time, to new instances by shape. Step 4 illustrates the potential developmental consequence of this higher-order generalization—attention to just the right property, shape, for object name learning, and thus the more rapid acquisition of object names.

We provide experimental support for this proposal in the following two experiments. The participants were 17 months of age at the start of the experiments and 19 months at the end—too young to systematically extend object names by shape. In multiple sessions, we taught the children specific names for specific things in artificial categories transparently organized by shape (Step 1 in Fig. 1). We then tested

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1. This four-step model may seem to require a similarity space already organized by shape. In that case, perceiving and representing shape would constitute a prior constraint. However, recent simulations have shown that it is at least mathematically possible for nondimensional similarity spaces to become dimensionally organized as a consequence of category learning (Smith, Gasser, & Sandhofer, 1997). Thus, it is an open question whether the learning proposed here is built upon, or itself creates, representations of shape.

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children's first-order generalizations of these names to new instances (Step 2). Next we tested for the higher-level association proposed in Step 3. Would children know that a novel name given to one never-before-seen object spans a whole category of similarly shaped things? Finally, we examined Step 4: Would knowledge of this higher-level association result in accelerated object name acquisitions?

EXPERIMENT 1

Method

Participants

Eight male and 8 female children were recruited. They were 17 months old (M = 17 months 1 day; range: 16 months 22 days–17 months 15 days) at the start of the study. Four males and 4 females were randomly assigned to a training condition, and the remainder to a baseline condition.

Training stimuli and procedure

Step 1: training. The 7 weeks of training consisted of once-a-week play sessions in which each child in the training group was taught four novel names—"wif," "zup," "dax," and "lug." Each name was associated with two unique objects that differed in all properties except shape (see Fig. 2). All objects were three-dimensional things (approximately 10 cm × 10 cm × 10 cm) constructed of materials with contrasting textures: wood, metal, cloth, sponge, fur, plastic, and Styrofoam. The two exemplars for each category were played with together, and separately from objects in the other three categories. The experimenter, parent, and child played with each exemplar pair for 5 min. The experimenter named each exemplar at least 10 times, saying, for example, "This is a _____. Let's put the _____s in the wagon."
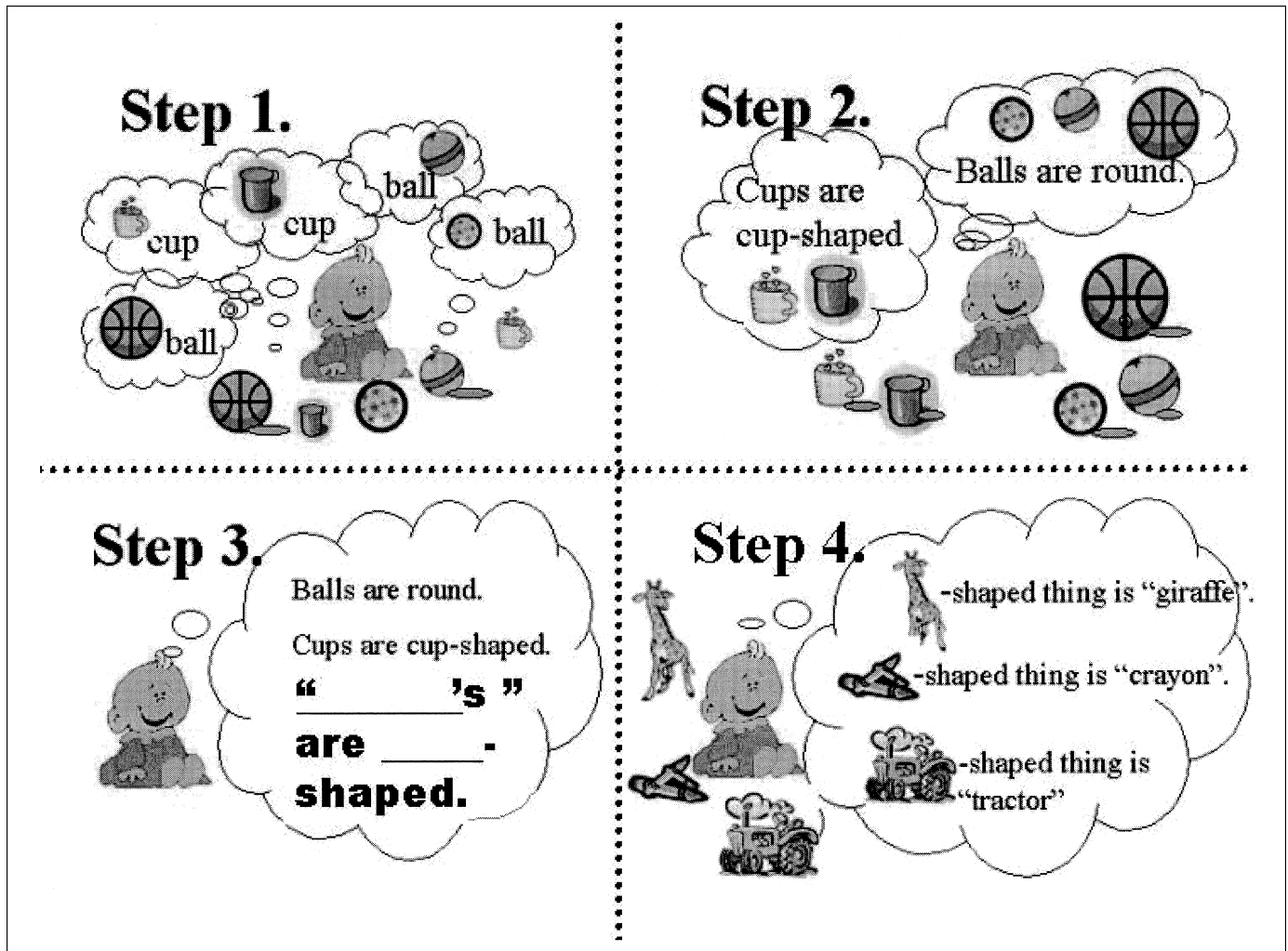

Fig. 1. The proposed four-step model by which object names and attention to shape come to be related. In Step 1, the child maps names to individual objects. First-order generalizations about the structure of individual object categories are made in Step 2. In Step 3, the child makes a higher-order generalization across learned categories about the common structure of named object categories—that is, that categories are organized by similarity in shape. Finally, in Step 4, the child has learned to attend to shape in novel name learning, leading to rapid name acquisitions.
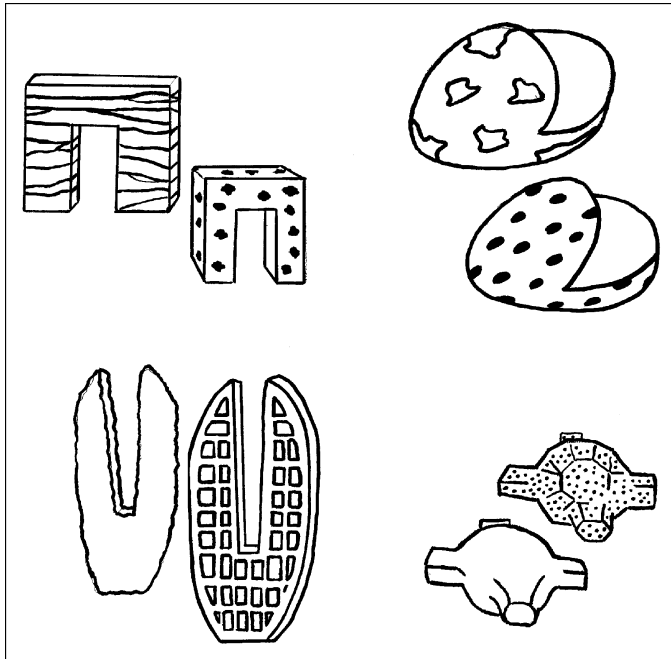
Fig. 2. Illustration of the training stimuli in Experiment 1. The stimuli included two exemplars for each of four novel object categories with novel names. Exemplars of the same category had the same shape, but differed in size, texture, and color.

Halfway through the 5 min, the experimenter brought forward a third, contrast object that differed from the exemplars in shape but matched one exemplar in color and the other in texture. The purpose was to heighten the perceptual salience of the identical shapes of the category exemplars. The experimenter made sure the child was attending, then said, "Oh, that's not a _____," and put the object away.

Step 2: first-order generalization. The children in the training condition were tested in the first-order-generalization task at Week 8. On each trial, the experimenter held up one trained exemplar, named it with the trained name (e.g., "This is a zup"), and asked the child to get another object by the same name (e.g., "Where's the zup? Get the zup."). The three choice objects were all novel to the child. One matched the exemplar in shape only, one in color only, and one in texture only. There was one trial using each of the eight training exemplars (i.e., two trials for each lexical category). These eight trials were presented in one of two random orders.

Step 3: higher-order generalization. At Week 9, the experimenter used the same task to test whether the children had made the higher-order generalization that object names in general span categories of similarly shaped things. The children were tested on four completely novel lexical categories. The exemplars and test objects had novel names—"veet," "teema," "nim," and "gazzer"—and different shapes, textures, and colors from the objects in the trained categories (see Fig. 3). Two unique exemplars from each category were each tested once, for a total of eight unique trials, presented in one of two random orders.

Baseline data. The 8 children assigned to the baseline group received no training, but participated in the same generalization tests as the 8 children in the training group at Weeks 8 and 9.
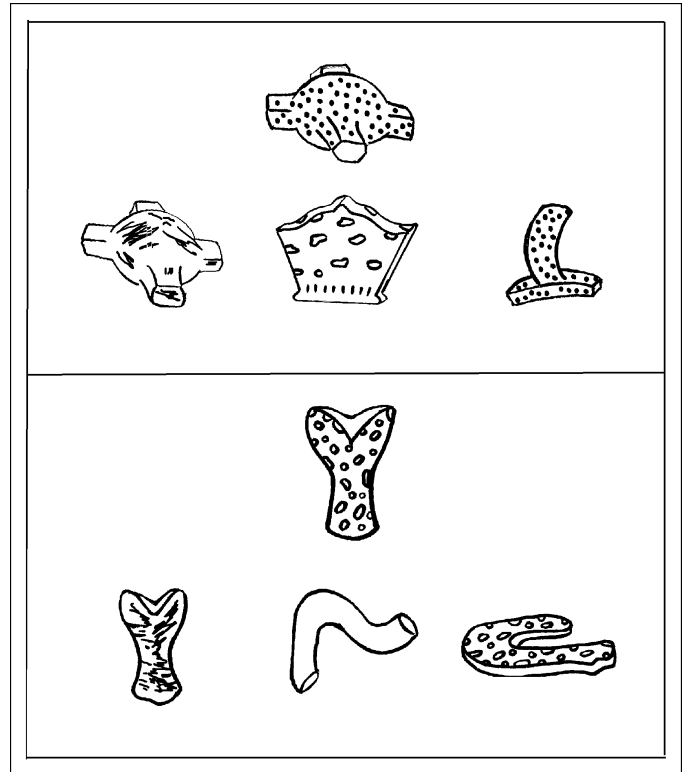

Fig. 3. Examples of stimuli used for testing the first- and higher-order generalizations in Experiment 1. An exemplar and three test objects for the first-order-generalization test are shown in the top panel. The test objects were novel and matched the trained exemplar in shape only, color only, or texture only. An exemplar and three test objects for the higher-order-generalization test are shown in the bottom panel. The name, exemplar, and test objects for this test were all novel. One test object matched the exemplar in shape only, one matched it in color only, and one matched it in texture only.

Step 4: accelerated vocabulary growth. Parents of children in both the training and baseline groups completed the same vocabulary checklists at Week 1 and again at Week 8. The checklist was the MacArthur Communicative Developmental Inventory (Fenson et al., 1993), a widely used and reliable parent checklist of common words and phrases in children's productive vocabularies prior to 30 months.

Results

First-order generalizations

During testing, the children in the training condition extended the trained names to new instances by shape 88% of the time, a rate well above that expected by chance ($p = .33$), $t(7) = 12.3$, $p < .001$. In contrast, the children in the baseline condition chose the shape-matching object at a rate approximating chance (36% of trials), $t(7) = 1.06$, n.s. Thus, the training led children to make the first-order generalization that the taught names referred not just to the trained instances, but also to other things like the trained objects in shape. Step 1, the mapping of names to specific instances, led to Step 2, generalized knowledge of the kinds of things in each of those trained lexical categories.

Naming Trains Attention

The higher-order generalization

During testing, the children in the trained group also generalized novel names for completely novel things to new instances by shape 70% of the time, which was again significantly different from chance performance, $t(7) = 5.44$, $p < .002$. The mean percentage of same-shape choices made by children in the baseline condition was 34%, $t(7) = 1.73$, n.s. Thus, children in the training condition made the second-order generalization as well as the first-order one. Learning four lexical categories well organized by shape produced both a strong tendency to extend each of the trained names to new objects by shape and a more general tendency to attend to shape when extending other novel object names.

Vocabulary growth

Analyses of the category structures named by concrete nouns suggest that many of the object names children need to learn span categories of similarly shaped things (Samuelson & Smith, 1999). If this is so, then acquisition of the second-order generalization, generalized attention to shape in the context of naming, should lead to more rapid acquisition of object names. Figure 4 shows the productive-vocabulary

growth of the children, as reported by their parents, from the start of the experiment to Week 8. Words on the parental checklist were counted as object names if they referred to a concrete whole object (not to a part).

The numbers of object names and numbers of other words produced by each child at the pre- and posttests were entered into a 2 (group: training vs. control) × 2 (word type: object name vs. other) × 2 (pretest vs. posttest) mixed analysis of variance. As Figure 4 suggests, the three-way interaction of these variables was significant, $F(1, 14) = 15.44$, $p < .002$. Children in the training group showed on average an increase of 41.4 object names—that is, a 256% increase—in their productive vocabularies over this 8-week period, whereas children in the baseline condition showed a mean increase of only 13.8 object names (78%), $t(14) = 3.34$, $p < .01$. This increased rate of word learning for children in the training group was confined to object names: Children in the training and baseline groups did not differ in their acquisition of other words. In sum, the training made children better learners of object names in their everyday lives.

These results fit the developmental story outlined in Figure 1: Learning specific object names results in generalized attention to shape in the context of object naming, and in accelerated acquisition of new object names. However, there is an alternative explanation for
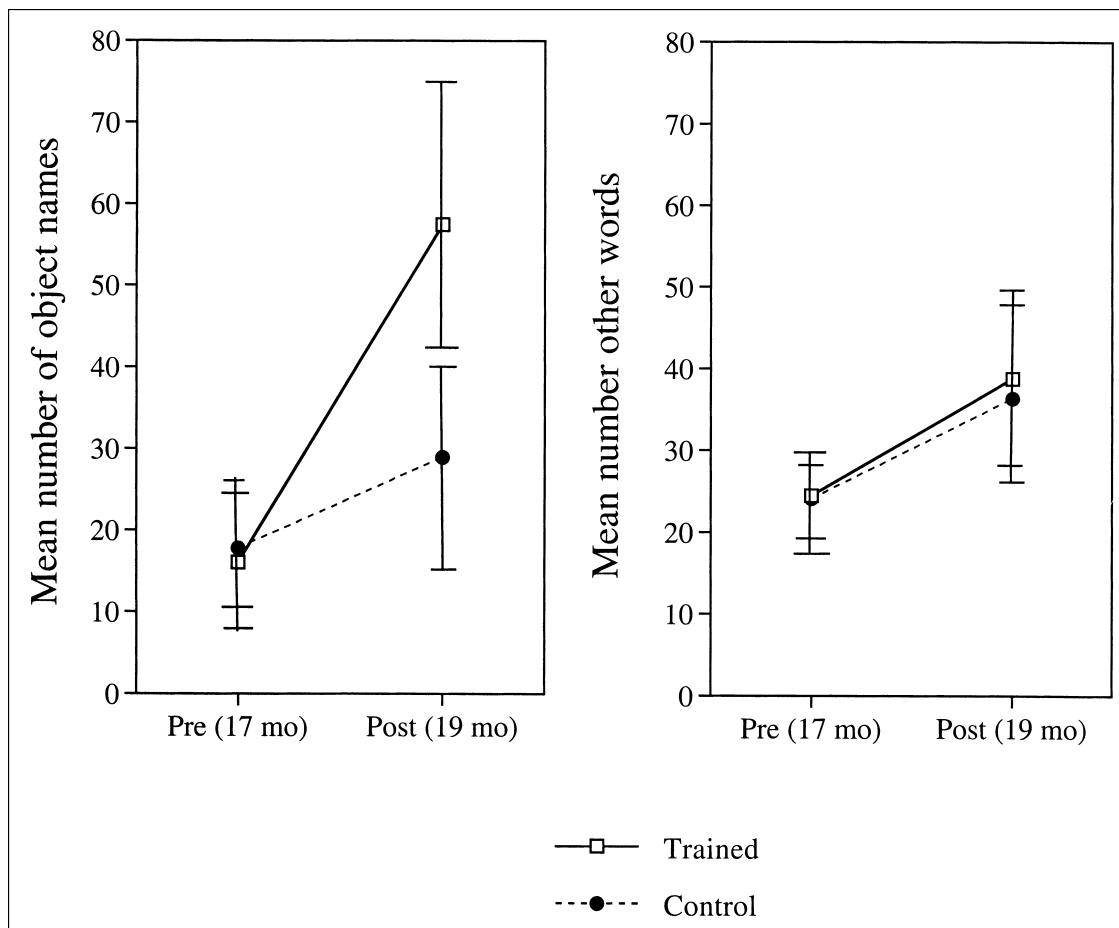

Fig. 4. Increase in vocabulary size, by parental report, from the beginning ("Pre") to the end ("Post") of Experiment 1. Results are shown separately for the children in the training and control groups for new object names (left) and new words in all other categories (right). Error bars show standard errors of the means.

the results of Experiment 1, namely, that the parents of children in the training condition, because of their participation in the experiment, took steps to encourage growth in their children's vocabularies. Experiment 2 addressed this issue by providing very similar experiences to parents of children in the experimental and control conditions.

EXPERIMENT 2

Experiment 2 included three between-subjects conditions. In the replication condition, we replicated the training in Experiment 1. In the varied-category-structure condition, children were taught four names for four categories, just as in Experiment 1, but two of the categories were organized by similarities in color and two of the categories were organized by similarities in texture. Thus, there was no basis for a higher-order generalization that names span categories organized by a single property. In the no-name condition, children were taught about four categories, each well organized by shape, but no names were provided. If names are necessary to make the higher-order generalization, then this training condition would not provide the necessary input for generalized attention to shape nor for an acceleration in the rate of acquisition of object names.

These two additional training conditions also provide information pertinent to the alternative explanation of the results in Experiment 1 (i.e., that parents continued the laboratory training at home). Specifically, parents in all three conditions came to the laboratory for repeated visits, and parents in the replication and the varied-category-structure condition had very similar experiences, hearing the experimenter repeatedly naming objects for their children.

Method

Participants

The participants were 24 children who were 17 months old ($M = 17$ months 3 days; range: 16 months 14 days–17 months 10 days) at the start of the 8-week study. (We reduced the study by 1 week to fit into the semester schedule.) Children were randomly assigned to the three conditions such that there were 4 boys and 4 girls in each condition.

Training

The training stimuli for the replication condition and the no-name condition were the same as in Experiment 1. In the varied-category-structure condition, the eight training objects used in the other two conditions were rearranged to create two categories each consisting of a pair of objects matching in color, and two categories each consisting of a pair of objects matching in texture.

The training procedures in the replication condition and the varied-category-structure condition were identical to those in Experiment 1 except there were only 6 weekly training sessions. The training procedure for the no-name condition was identical except that none of the objects were ever named during training; instead, the experimenter said such things as, "Oh, here is one, here is another. Let's put them both in the wagon."

Testing

The tests of the first-order and second-order generalizations were structured as in Experiment 1 and were given at Weeks 7 and 8, respectively. For the first-order-generalization test, the names were the

same names as had been applied to these same exemplars during training for children in the replication and varied-category-structure conditions, but were novel for children in the no-name condition. For the second-order-generalization test, the exemplars, the names, and the choice objects were all novel for all children.

Vocabulary measure

Parents completed the MacArthur checklist at each weekly session for the 8-week experiment.

Manipulation checks

To ensure comparable experiences in the three conditions, two scorers blind to the hypotheses counted the number of times the experimenter directed attention to each object in a training pair, the number of times the experimenter directed attention jointly to both objects, the number of times the child looked at each object, and the number of times (in the two labeling conditions) that the experimenter named each object. Each measure was analyzed by a condition-by-training-week analysis of variance. None of the analyses yielded any main effects or interactions that approached significance, $p > .63$ in all cases.

Results

First-order generalizations

Children in the replication and no-name conditions clearly learned that the trained categories were organized by shape, as they extended the name to the same-shape choice objects on average 66% and 62% of the time, respectively. Both levels of performance are reliably above the 33% level of chance, $ts(7) > 3.00$, $ps < .05$. It is interesting that the children in the no-name condition generalized the names by shape, because they had never heard these names before. This shows that these children had learned to attend to the shapes of the trained objects. Children in the varied-category-structure condition did not generalize names by shape, but rather attended appropriately to the colors and textures of the named things, generalizing names by the trained property for the specific category on average 67% of the time, $t(7) = 4.01$, $p < .05$. Thus, children in all three conditions made first-order generalizations—generalizing the name for a trained category to new instances by the property that organized the trained category.

The higher-order generalization

Only children in the replication condition, however, made the second-order generalization, extending novel object names to new instances by shape. They did so on average on 65% of the trials, a level of performance that differs reliably from chance (33%), $t(7) = 5.44$, $p < .002$. The children in the other two training conditions did not choose shape matches (nor color matches, nor texture matches) at levels that differed from that expected by chance alone: Choices of shape matches were made on average 32% and 34% of the time in the no-name and varied-category-structure conditions, respectively.

The findings in the no-name condition are particularly informative. These children made the first-order generalization, generalizing a newly learned name for a well-known category to new instances by shape, but they did not make the higher-order generalization that object names in general refer to things of the same shape. This suggests

that learning names, not just learning shape-based categories, is crucial to making the second-order generalization.

These results set up the next critical prediction from our analysis of the developmental process: If a generalized bias to attend to shape in the context of naming promotes the rapid acquisition of object names, then children in the replication condition should have shown accelerated vocabulary growth, but those in the other two conditions—who made first-order generalizations but not the second-order generalization—should not.

Vocabulary growth

Figure 5 shows the mean cumulative number of object names in the children's productive vocabularies, according to their parents' reports, for the 8 weeks of the experiment. Children in the replication condition showed an accelerated rate of object-name acquisitions relative to children in the other two conditions. Children's numbers of object names were submitted to a 3 (training condition) $\times$ 8 (test session) mixed analysis of variance. The analysis yielded a reliable main effect of session, $F(7, 147) = 42.07$, $p < .001$, and a reliable interaction between condition and session, $F(14, 147) = 4.58$, $p < .001$. Post hoc pair-wise comparisons (Neuman-Keuls, $p < .05$) indicated that children in the replication condition had more object names in their productive vocabularies by Session 5 than did children in the varied-category-structure condition, and by Session 7 they had more object names in their productive vocabularies than did children in the no-name condition. Although children in the no-name condition averaged more object names than children in the variable-category-structure condition, at no session was this difference statistically significant. A 3 (condition) $\times$ 8 (session) analysis of the numbers of words other than object names in the children's vocabularies yielded no reliable differences among the three training conditions.

These results provide strong support for the developmental process outlined in Figure 1: Learning names for things in categories similarly organized by shape tunes attention to just the right property—shape—for learning more object names. As a result, children add object names to their vocabularies at more rapid rates once they have made the higher-order generalization.

Could children be taught other higher-order generalizations based on properties other than shape? Because the proposed processes of learning are general, we expect that any consistent organizing property could be learned. Indeed, Jones and Smith (in press), in a training procedure similar to that used here, taught young children to generalize names for artificial objects with eyes by both shape and texture. Although we expect that children could learn a variety of such higher-order generalizations given the right training, this laboratory learning could have an effect on real vocabulary learning outside the laboratory only if the higher-order generalizations matched the regularities among the real categories to be learned. The present results provide strong evidence that the higher-order generalization of attending to shape in the context of naming matches the structure of the noun categories that very young children typically learn.

GENERAL DISCUSSION

The four-step process we proposed and have empirically supported is inherently developmental. Each bit of individual learning changes the learner, and thus progressively changes what the learner finds easy to learn. The account is also rather ordinary in the mechanisms it pre-
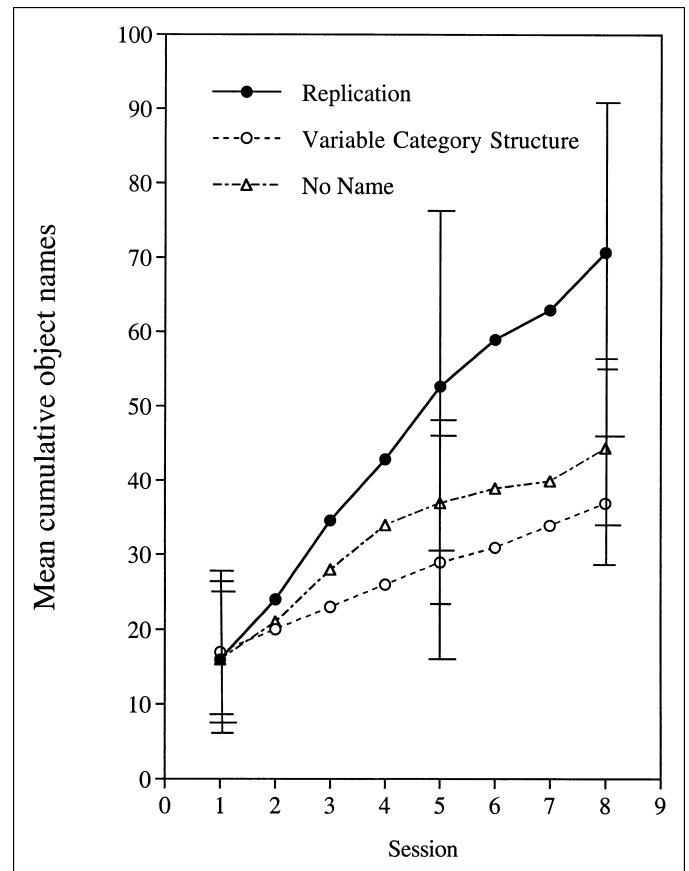

Fig. 5. Mean cumulative number of object names in children's productive vocabularies, by parental report, in Experiment 2. Results are shown separately for the three groups of children at each of the eight weekly sessions. Error bars show standard errors of the means.

sumes—namely, first-order and second-order generalizations across learned instances. However, like development itself, the experimental results are remarkable: Teaching children names for only four artificial categories, each well organized by shape, accelerates the learning of object names outside the laboratory.

Laboratory manipulations that alter the rate of learning outside the laboratory are not at present common in psychology. But this outcome was predicted by our account of the developmental process and by one of the most fundamental truths about learning: Learning changes what is subsequently easy to learn. What the present results add to this general truth is its application to early noun learning. We propose that learning specific object names tunes attention to just the right property and that this attentional learning enables the rate of noun acquisition to take off. The role of attention in this developmental process is strongly implied by the results: We trained children to attend to shape in the context of naming, and they learned object names more rapidly. Direct assessment of how category learning alters children's attention, likely modeled on the approaches of Goldstone, Nosofsky, and their colleagues (Goldstone, 1994; Kersten, Goldstone, & Schaffert, 1998; McKinley & Nosofsky, 1996), will be an important component of future work.

Although our lexical training mimicked what we believe to be the natural learning—that is, the tuning of attention—through which chil-

dren ordinarily become more rapid learners of object names, the training categories used in the experiments were unusual in being perfectly and exclusively organized by shape. Although most object categories named by common nouns are shape based, they are not necessarily nor solely so (Gelman, Croft, Panfang, Clausner, & Gottfried, 1998; Samuelson & Smith, 1999, 2000). Thus, our training may have accelerated the tuning of attention because we used these unusually transparent shape-based category structures.

In conclusion, these findings offer a new solution to one classic problem in the literature on early word learning—the "Gavagai" problem. Briefly, Quine (1960) described a situation in which a traveler with no knowledge of the local language sees a native speaker of that language point to the distance and say, "Gavagai!" The problem for the learner is that there is an infinite number of things to which the word might refer—whole objects, parts of objects (e.g., "tail"), properties of objects (e.g., "green," "soft"), and combinations of these (e.g., "a tail on green grass"). Given the indeterminacy of the intended category, how is this traveler, or the young child learning a first language, able to map the word to the right category? For the past 20 years, developmentalists have seen the best answer as being that built-in constraints cause all human learners to form lexical categories in the same way (for review, see Markman, 1989). Our results suggest that such constraints may not be needed. Attention is highly amenable to on-the-job training in the task of object name learning, and that training yields clear effects on on-the-job performance.

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