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Matching and Naming Objects by Shape or Function: Age and Context Effects in Preschool Children

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Three experiments tested preschoolers' use of abstract principles to classify and label objects by shape or function. Three- and 4-year-olds were instructed to match objects by shape or function. Four-year-olds readily adopted either rule, but 3-year-olds followed only the shape rule. Without a rule, 4-year-olds tended to match by shape unless object function was shown during matching (Experiment 2). Three-year-olds' ability to use a function rule was tested in several conditions (re-presenting functions; reminders to "use the rule"; repeating rule on every trial). None induced consistent function matching (Experiment 3). Supplemental memory and verbal tasks showed that 3-year-olds have trouble using function as an abstract basis of comparison. Naming data, however, show that preschoolers are learning that object labels are based on function. The results show preschoolers' growing flexibility in adopting abstract generalization rules and growing knowledge of conventions for extending words.

For over three decades, researchers have debated whether children classify objects by common shape or common function. Infants' first object concepts might be based on dynamic properties related to function (Madole, Oakes, & Cohen, 1993; Mandler, 2000), and toddlers' first object words might be based on functions (Nelson, 1979). Alternately, young children might classify and name objects on the basis of static perceptual properties such as shape (Clark, 1973; Inhelder & Piaget, 1964). In older children and adults, it has been claimed, function determines object kind:

Bloom (1996) proposed that object kind is based on intended use. By contrast, some researchers emphasize the role of object shape in recognition or classification (Biederman, 1987). Fundamentally, these different emphases imply contrasting accounts of how children learn to classify objects in covert thought as well as in overt acts of organization (e.g., sorting) and symbolization (e.g., naming). Put another way, are object kinds rooted in how the objects look or in how they are used?

Early studies (e.g., Gentner, 1978; Prawat & Wildfong, 1980; Tomikawa & Dodd, 1980) seemed to support the hypothesis (Clark, 1973) that preschoolers extend object labels by shape. Recent studies also suggest that children younger than 4 or 5 years extend object labels on the basis of shape (Graham, Williams, & Huber, 1999; Landau, Smith, & Jones, 1998; Merriman, Scott, & Marazita, 1993) and irrespective of function (Smith, Jones, & Landau, 1996). Older children and adults, in contrast, attend preferentially to functional similarity.

Nelson (1979) disputed the early claims, arguing that toddlers' shape-based naming errors (e.g., calling a round candle *ball*) stem from ignorance of the referent's function. That is, shape information is utilized only in the absence of reliable function information. Several subsequent studies showed that young children, if given the opportunity to see and explore objects' affordances, classify even dissimilar-looking objects by function (Corrigan & Schommer, 1984; Smitsman, van Loosbroek, & Pick, 1987). More recent studies showed that 2–4-year-olds use function to judge object similarity (e.g., Smith et al., 1996) and to extend object labels (Kemler Nelson, 1995, 1999; Kemler Nelson, Frankenfield, Morris, & Blair, 2000).

Recent research repudiates "either/or" accounts of children's attention to object shape and function. Just as Rosch, Mervis,

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Gray, Johnson, and Boyes-Braem (1976) showed that both shape and function inform adults' object classification, there is evidence that both attributes influence preschoolers' inferences about objects. Though a majority of studies report that preschoolers (especially 2- and 3-year-olds) predominantly group objects by shape, the imbalance is difficult to interpret because many studies have used procedures that limit or exclude information about test items' functions. Many studies had children sort or label static objects or even pictures of objects. The latter method might test children's ability to draw inferences about function from static pictorial representations, but it does not tell us how children classify or sort real objects in dynamic, interactive contexts. Also, preschoolers rely on shape and color more for inferences about pictures than for inferences about objects (Deák & Bauer, 1996). Thus, allowing children to interact with real objects in dynamic events is critical for assessing their capacity to use function information to name, group, or classify objects (Kemler Nelson, 1999).

Nevertheless, it is unclear how preschoolers use function information to classify objects, even in dynamic events. Graham et al. (1999) and Smith et al. (1996) found a shape bias in preschoolers' inferences about novel words for objects even after the functions were demonstrated, whereas Kemler Nelson, Frankenfield, et al. (2000) found that 4-year-olds consistently generalize novel words according to object functions and that 3-year-olds do so as well, but less regularly. Kemler Nelson, Frankenfield, et al. (2000) explained the discrepancy in terms of two contextual factors: Both a plausible link between structural features and function and longer allowed decision times increased preschoolers' use of function information to extend novel words. Thus, task context as well as age seem to influence whether a preschooler will use function information to generalize novel words (see also Corrigan & Schommer, 1984). Note that the demands of inferring novel word meanings might reduce children's use of information that is not apparent or that induces memory load. Word learning might conversely increase children's use of information that is readily apparent and diagnostic. Function is usually a dynamic property, and so it might need to be inferred or recalled, especially from static arrays (or pictures). Shape, though, is perceptible even in static displays. Moreover, a temporary, heuristic reliance on shape would be adaptive when cognitive resources are challenged, because shape is highly correlated with function. In fact, conflicting findings might partly be an artifact of the stark, unnatural independence of shape and function in experimental tasks and of the cognitive load imposed by asking children for multiple successive inductive judgments about several novel objects and novel words.

These speculations raise questions about preschoolers' developing use of function and shape information to make inferences about objects. Most generally, in what circumstances will preschoolers classify or group objects by function, assuming such information is available? How, if at all, are younger preschoolers limited in this regard? Prior evidence does not indicate whether, even in optimal conditions, 3-year-olds can systematically group objects by function. Several recent theories emphasize developmental changes in cognitive control over the selection of criteria for inference and generalization (Karmiloff-Smith, 1994; Zelazo & Frye, 1998). In general, 3-year-olds seem to have limited ability to use abstract principles (e.g., rules) to make inferences or decisions. Perhaps infants and toddlers occasionally use function to make

inferences, but they cannot do so in a controlled manner until age 4 or 5. This criterion—adopting a principle or rule of generalization and using it consistently despite competing response options—might not emerge until the age of 4 years or older. This level of control is important because some kinds of judgments about objects entail considering function *per se*. For example, a representational object, such as a dinosaur-shaped crayon, might be labeled by its appearance (i.e., *dinosaur*) in the context of pretend play. But if a child is asked “What is this thing *really*?” or “What is it used for?”, *crayon* is a more appropriate response. Four-year-olds make this distinction, but 3-year-olds, though they produce both words, do not discriminate which word refers to the referent's function (Deák, Yen, & Pettit, 2001).

These issues, concerning children's expanding ability to select and apply an abstract criterion to group or classify objects, raise two subsidiary questions. First, how does the ability relate to children's use of function information for other judgments? Second, how is it influenced by contextual factors other than those tested by Kemler Nelson, Frankenfield, et al. (2000)?

This investigation explores preschoolers' tendency to match objects by either shape or function and to do so consistently in response to specific task demands. Task demands were specified by verbal instruction, with examples and feedback. Prior work (Deák & Bauer, 1995) showed that 4-year-olds use such input to select an approach for an inductive task. Children's responsiveness to verbal instructions is important because adults use them to specify tasks, goals, strategies, and procedures. By instructing 3- and 4-year-olds to sort objects by shape or function (Experiment 1), we tested their readiness to adopt a specified principle for grouping or matching objects. By subsequently presenting diverse test items, we tested whether children would apply the principle in a controlled, consistent manner. By including a control group whose instructions did not specify a critical attribute, we assessed children's baseline preferences for shape and function grouping, and changes in these preferences with age.

The first subsidiary question (i.e., whether children use function for other kinds of judgments) was addressed in Experiments 1 and 2 by administering a naming task following the matching task. Because many reports of preschoolers' shape-based responding come from novel word induction tasks, this tests whether *any* lexical generalization task will focus 3-year-olds' attention on shape or whether such a focus stems from the demands of making inferences about novel words. Asking preschoolers to name objects, without imposing novel words, should tell us whether they believe objects' labels are extended by shape or by function. The naming task also tests children's flexibility, specifically, the degree to which they can shift attention from one property or similarity to another as task demands change. In particular, will children who have matched items by shape also label objects by shape? Although the two tasks differ in many regards, there are reports that preschoolers, especially those younger than 4 years, tend to perseverate across successive, discrete problems involving the same items (Deák, 2000; Zelazo, Frye, & Rapus, 1996). It is thus possible that matching responses will influence subsequent naming, particularly in 3-year-olds. Prior research has used between-subjects designs to investigate preschoolers' use of function and shape in lexical and nonlexical tasks (e.g., Smith et al.,

1996), so we do not know whether the same child can rapidly shift attention from shape to function, or vice versa, across tasks.

The second subsidiary question, regarding context factors that support function-based generalization, was addressed in Experiment 2 by comparing preschoolers' tendency to match by function when function information was more or less available. Corrigan and Schommer (1984) showed that toddlers use function information more readily when it is made available via a dynamic demonstration. We tested whether older preschoolers also are influenced by function availability and whether this can explain some reported findings of shape-based responding. In Experiment 3 we examined whether clarifying social demands and reducing cognitive demands would increase 3-year-olds' tendency to follow function-matching instructions.

Experiment 1

Given the choice to group or match objects by shape or function, what will preschoolers do? Can a priori preferences be preempted by specific instructions, and can preschoolers generalize an abstract matching principle to diverse items? Do these preferences and abilities change between 3 and 4 years of age? Finally, how will preschoolers name objects that they have matched by one or the other attribute? That is, are naming and matching independent responses?

These questions were addressed by showing 3- and 4-year-old children trios of objects (see Figure 1) and asking them to match a hybrid object in each set to an object with the same shape or to one with the same function. For example, one set included a penlight (hybrid), a pen (same shape), and a flashlight (same function). Each object's function was demonstrated, and the child was allowed to explore its affordances. The child was then asked to group the hybrid with one of the two other objects.

To assess children's use of socially specified demands (i.e., instructions) to select responses, we presented two training trios first, with explicit instructions to use one attribute and with feedback. After training, children matched eight test hybrids, each with a distinct shape and function, with no further instructions or feedback. Children in the *shape-instruction* group were instructed to match by shape. Those in the *function-instruction* group were instructed to match by function. Analysis of these groups' performance will determine whether children adopt an abstract matching principle specified verbally by an adult and apply it consistently. It



Figure 1. Sample stimulus trio: left, same-shape object (mug); middle, hybrid object (sifter); right, same-function object (ricer).

is possible that children will sort consistently by one attribute not because of instructions but because of a prior inclination to select that attribute. To test this hypothesis, we asked a third, *nonspecific-instruction* group to match each hybrid but did not specify which attribute to use. Besides revealing prior preferences, this group provides a baseline rate of spontaneous, consistent use of a matching principle.

After completing the matching task, children named every test object. Open-ended naming data can tell us whether children produce labels based on function, shape, both, or neither. For example, a child might call the penlight *light*, *pen*, *pen-light*, or another unrelated name. If, for instance, a child calls both the penlight and the same-function object *light*, it will indicate spontaneous function-based classification. Unlike the matching task, the naming response is elicited without overt demands to adopt a particular rule or even to directly compare objects in a trio. Of course, naming carries other learned demands, such as labeling conventions in the child's language community. Open-ended naming thus serves as another index of children's tendency to classify by shape or function, but under different task demands.

We hypothesized that preschoolers would tend to match static objects by shape in the absence of specific instructions but could be compelled by instructions to match by function or to match more consistently by shape. This hypothesis is based on findings (see above) that children younger than 5 years often prefer to classify objects by shape and on evidence that contextual factors can shift preschoolers toward function-based classification (Keller Nelson, Frankenfield, et al., 2000). More generally, verbal instructions and feedback in experimental tests can shift 1–4-year-olds' sorting or matching responses (e.g., Bauer & Mandler, 1989; Deák & Bauer, 1995; Zelazo & Reznick, 1991), so these kinds of social input are often effective. There is, however, little evidence on preschoolers' developing ability to transfer a principle or rule from an instruction or example to dissimilar test items (but see Brown, 1989). Adults take this kind of transfer for granted, but it might be learned gradually during childhood as a social convention within formal educational settings. Thus, a secondary hypothesis was that 3-year-olds would be less likely than 4-year-olds to consistently generalize a verbal instruction. This hypothesis fits with Zelazo et al.'s (1996) finding of a discrepancy between 3-year-olds' understanding and use of a rule that conflicts with a prior rule. Another hypothesis, following Merriman, Jarvis, and Marazita (1995) and Smith et al. (1996), was that 3-year-olds would generalize object names by function less frequently than would 4-year-olds. Finally, on the basis of findings that preschoolers adapt inferences to different task demands, we predicted some independence of the matching and naming responses.

Method

Participants

Forty-eight 3-year-olds (21 girls and 27 boys; mean age = 3 years 6 months; range = 3 years 0 months to 3 years 11 months) and 48 four-year-olds (26 girls and 22 boys; mean age = 4 years 6 months; range = 4 years 2 months to 4 years 11 months) participated. One child was replaced for failure to complete the task. Children were primarily White and middle class and were recruited from preschools and university-maintained databases in an upper midwestern city and a southeastern city. Participants received a small gift.

Table 1
Stimuli Used in Experiments 1–3

Shape match	Function match	Hybrid
Instruction sets (Experiments 1 and 3)		
Bulb-shaped bottle	Ornamental light bulb	Large light bulb
Heart-shaped bracelet	Pencil sharpener	Heart-shaped pencil sharpener
Test sets		
Lyre	Drum	Lyre-shaped drum
Wood cube	Plush jingling sphere	Plush jingling cube
Pewter mug	Potato ricer	Flour sifter
Toy football	Telephone	Football-shaped telephone
Egg-shaped timer	Tea infuser with handle	Egg-shaped tea infuser
Disk-shaped tape measure	Corn-shaped harmonica	Disk-shaped pitch pipes
Rectangular eraser	Round magnet	Rectangular magnet
Pen	L-shaped flashlight	Penlight

Materials

The stimuli consisted of 10 object trios, which are described in Table 1. Each trio included a hybrid object, a same-shape object with a different function, and a same-function object with a different shape. Other properties (e.g., color, size) were either held constant or varied across objects in a set. Two trios were used for instruction trials; the other eight were used for test trials.

Procedure

Children were tested individually in a quiet laboratory room on a university campus. The child was seated facing the experimenter, with the objects from all 10 trios haphazardly piled nearby. After establishing rapport with the child, the experimenter suggested that the child “look at all these things and play with them” and then “put them away in boxes.” Trios were presented one at a time. Each trio was placed in front of the child, with the hybrid object in the middle and the shape and function matches on either side (position counterbalanced). The experimenter demonstrated each object’s function (order counterbalanced). For example, the experimenter placed tea in the egg-shaped infuser (hybrid) and swirled it in a cup until the water turned brown. The experimenter then performed the same actions with the different-shape infuser (same function) and twisted the egg-shaped kitchen timer (same shape) to make it tick and ring. After each demonstration, the child was given the object and encouraged to produce its function. After the child manipulated each object, the experimenter suggested, “Let’s put these away so we can look at some more things.” The same-shape and same-function objects were placed in two identical boxes, equidistant from the child. The experimenter asked the child to put the hybrid with one other object.

Instruction trials. Children were assigned to one of three groups. Each group completed two trials with one of three instructions specifying how to sort hybrid objects.¹ The order of presentation of the two instruction trios was counterbalanced.

In the nonspecific-instruction group, the experimenter placed the same-shape and same-function objects in boxes, indicated the hybrid, and asked, “Which one does this one go with? Which box does it belong in?” After the child completed the trial, the experimenter said, “Okay. Thank you.”

The shape-instruction group was told to match instruction hybrids by shape. After placing objects in boxes, the experimenter indicated the hybrid and asked, “Can you put this one with the one that is the same shape? Can you put it with the one that’s shaped the same?” Children received feedback (e.g., “That’s right, put it with the one that is the same shape

... see, they’re the same shape” or “Actually, *these* are the same shape, see? So they go in the box together. . .”).

The function-instruction group was told to match instruction trio hybrids by function. The experimenter asked, “Can you put this one [the hybrid] with the one that works the same? Can you put it with the one that does the same thing?” The instruction was reiterated with different phrasing in order to facilitate comprehension. Children received feedback.

Test trials. During test trials, children were not told how to match hybrids. They were asked, “Which one does this one [the hybrid] go with? Which box does it belong in?” Children were not reminded of instructions, nor was feedback given. The order of the test trios was randomized; each child received a permutation of this order so that each set was presented first equally often.

Labeling task. After matching all 10 trios, children were asked to name each object. The experimenter showed them a large box and asked for help putting the objects away. Children were asked to “tell me the names of all these things.” The experimenter handed the child each object in turn and asked, “What do you call this?” After responding, the child placed the object in the large box. Object order was constrained so children never labeled two objects of the same trio or type (i.e., shape match, function match, hybrid) successively, and the first object named was different for every child.

Results

Matching

The number of test hybrid objects matched by function (out of 8) was entered in an analysis of variance (ANOVA) with age (3- vs. 4-year-olds) and instruction (shape vs. function vs. nonspecific)

¹ When testing began, some 4-year-olds were assigned to a control group that did not receive instruction trials. Because this was not an optimal control, additional 4-year-olds were recruited for the nonspecific-instruction group. Thus, 4-year-olds were randomly assigned to the function- and shape-instruction groups, but later-recruited 4-year-olds were disproportionately assigned to the nonspecific-instruction group. This assignment is probably not a problem because the latter group performed much like the original control group ($M = 30\%$ vs. 27% function-based matches, respectively).

between subjects.² The instruction effect was significant, $F(2, 95) = 32.5, p < .001$. Post hoc t tests revealed that each group differed from the other two (two-tailed, all $ps \leq .01$). The nonspecific-instruction group matched a mean of 2.8 hybrids by function (i.e., 35%; or 65% by shape); the shape-instruction group matched a mean of 1.2 hybrids by function (i.e., 15%; or 85% by shape); and the function-instruction group matched a mean of 5.1 hybrids by function (i.e., 64%; or 36% by shape). Each group's mean differed significantly from chance (i.e., 4 out of 8).

The age effect was not significant, $F(1, 95) < 1$, but the Age \times Instruction interaction was, $F(2, 90) = 9.70, p < .001$. Table 2 shows the mean number of function matches in each age and instruction group. Four-year-olds adopted either instruction but matched mostly by shape when given nonspecific instructions (each group differed significantly from the other two). Three-year-olds also matched by shape more after shape instructions than after nonspecific instructions, $t(30) = 3.9, p < .001$, but did not respond to function instructions. The latter group differed neither from the nonspecific-instruction group, $t(30) < 1, ns$, nor from chance, $t(15) < 1, ns$.

A related question is whether children matched consistently by one attribute, either spontaneously (i.e., without specific instructions) or by instruction. Consistent use of a matching criterion was defined as 7 or 8 out of 8 test hybrids matched by the same property (i.e., shape or function) at $p < .05$ by binomial theorem. However, because $p < .05$ is a criterion for group differences, not individual performance, and because preschoolers' performance is inherently variable in many tasks (Siegler, 1996), we also examined consistency using a less stringent criterion of 6 or more hybrids matched by the same property (binomial $p < .19$).

Table 3 shows the numbers of 3- and 4-year-olds who matched consistently by function or shape in each group, according to the ≥ 7 and the ≥ 6 criteria. By the more stringent criterion, at least half of 4-year-olds in each group matched consistently, and over 75% did who received a specific instruction. This is notable because objects and properties differed from trial to trial, and children received no feedback or reminders. The tendency to transfer an abstract instruction increased with age: Though 75% of 3-year-olds consistently followed the shape instruction, fewer than 20% followed the function instruction. The tendency to spontaneously adopt a consistent principle also developed: In the nonspecific-instruction groups, half of 4-year-olds but only one 3-year-old spontaneously adopted a matching "rule"—invariably

Table 2
Mean Numbers (and Standard Deviations) of Test Hybrid Objects Matched by Function, by Age, and Instruction Group in Experiment 1

Age	Instruction group		
	Nonspecific	Shape	Function
3-year-olds	3.6 _b (1.3)	1.4 _c (1.8)	3.7 _b (2.3)
4-year-olds	2.1 _c (1.8)	1.0 _c (1.9)	6.4 _a (2.4)

Note. The maximum is 8.0. Mean shape-matching responses can be obtained by subtracting the given means from 8.0. Means with different subscripts are significantly different from one another at $p < .05$.

Table 3
Number of Children Who Matched ≥ 7 [or ≥ 6] Out of 8 Test Hybrid Objects by the Same Attribute (Shape or Function), by Instruction Group and Age in Experiment 1

Attribute	Instruction group		
	Nonspecific	Shape	Function
3-year-olds			
Shape	1 [4]	12 [13]	2 [3]
Function	0 [0]	0 [1]	3 [4]
4-year-olds			
Shape	8 [11]	13 [13]	2 [2]
Function	0 [1]	0 [0]	12 [13]

Note. Numbers are out of 16 children per cell.

shape. This age difference is significant, Fisher's exact $p < .008$. The numbers of consistent children differed overall across age and instruction group, $\chi^2(1, N = 96) = 12.18, p < .001$.

These patterns do not change under a looser (≥ 6) criterion: 81% of 4-year-olds consistently followed either instruction, whereas 81% of 3-year-olds consistently followed a shape rule but only 25% followed a function rule. Most 4-year-olds (75%) spontaneously adopted a consistent rule when none was specified, as opposed to only 25% of 3-year-olds. The age difference is significant, $\chi^2(1, N = 96) = 8.35, p < .005$.

Labeling

To assess whether children's hybrid labels encoded similarity of shape or function, or both, or neither, we coded each for whether it matched the same-shape and/or same-function object label. The hybrid label was coded as function based if the same word named the same-function object but not the same-shape object. For example, 1 child called the harmonica and the pitch pipe *xylophone*. The hybrid label was coded as shape based if it also named the same-shape object but not the same-function object. For example, 1 child called both the lute and the lute-shaped drum *horseypaddle*. If the hybrid label was a compound of the same-function and same-shape labels, it was coded as both. For example, 1 child called the flashlight *lighter*, the pen *pencil*, and the penlight *lighter-pencil*. If all three objects received a different label, the hybrid label was considered uninterpretable unless it clearly referred to shape or function. For example, 1 child called the (hybrid) magnet *rectangle*, and this was coded as shape based. In most cases, though, conventional labels (e.g., *magnet*) were considered uninterpretable unless they matched another label. That is, without the context provided by several labels, we do not know which attribute, shape or function, compelled a conventional label's production. Two coders classified all labels, with 89% agreement. Disagreements were resolved by discussion.

² Matching analyses refer to function-based responses. The number of shape-based responses is always 8.0 minus the number of function responses, because the two are mutually exclusive and exhaustive.

Three-year-olds labeled 75% of hybrid objects, and 4-year-olds labeled 87% (most of the remaining responses were “I don’t know”). Table 4 shows the percentage of each type of label by condition and age. Three-year-olds produced more function-based (40%) than shape-based (28%) hybrid labels. This tendency increased with age: 4-year-olds produced almost three times as many function-based as shape-based hybrid labels.³ The trend is seen most clearly across 6-month age spans. Mean numbers of shape- and function-based labels produced by each of these four age groups are shown in Figure 2. Young 3-year-olds labeled hybrids by shape and function equally often, but with increasing age, children labeled relatively more hybrids by function. An ANOVA confirmed the significance of this linear increase in numbers of function labels, $F(1, 92) = 49.6, p < .001$.

Between-Tasks Comparison

Compared with differences in matching across instruction groups, the distribution of function- and shape-based hybrid labels was fairly constant. Figure 3 shows the percentage of function-based responses (matching or naming) across instruction groups and ages. The between-tasks contrast is most evident in 4-year-olds because their matching performance varied so greatly, but it holds true across children. An Age (3- vs. 4-year-olds) \times Instruction (shape vs. function vs. nonspecific) ANOVA of the number of function-based hybrid labels revealed a main effect of age, $F(1, 90) = 31.0, p < .001$: 4-year-olds produced more function labels ($M = 4.0, SD = 1.6$) than 3-year-olds ($M = 2.4, SD = 1.3$). There was, however, no reliable group effect, $F(2, 90) = 2.1, ns$, or interaction, $F(2, 90) = 1.4, ns$. Thus, function-based responses increased with age in both tasks, but instructions influenced only matching, not naming.⁴

Reanalysis of Labels

The tendency to label by function might be tied to hybrid object labels in particular, or it might be an artifact of our relatively conservative coding criteria. To check this, we completed a second

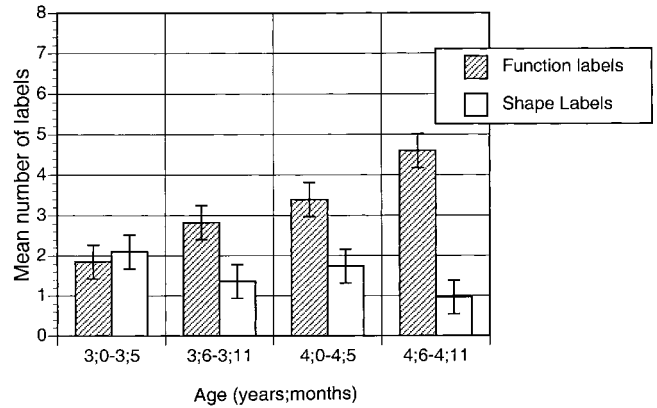


Figure 2. Mean number of shape-based and function-based hybrid labels (out of 8 total possible labels), by age (6-month intervals), in Experiment 1.

round of coding using more inclusive criteria to classify as many responses as possible as based in object shape or function.⁵ Any label judged to encode either shape or function was coded. Compound labels (e.g., *egg-clock, whistle-corn*) were classified by their root word. In this scheme, conventional terms for prototypical nonhybrid objects were considered ambiguous with respect to shape or function. These included *football, drum, block* (cube), *telephone*, and *ball* (plush sphere). However, conventional labels that named different-shaped objects from the same functional category (e.g., *baseball* for football) or superordinate kinds (e.g., *instrument* for pitch pipes) were coded as function based. Labels were coded as shape based if they named same-shape objects from a different kind (e.g., *block* for rectangular magnet, *fish* for tea-infuser, which was vaguely fish shaped) or geometric kinds (e.g., *square* for block, *circle* for ball, *shape* for any object). Unconventional labels and neologisms were considered function based if they referred to demonstrated function and ended in the instrumental inflection *-er* (e.g., *stirrer* for tea infuser, *blower* for pitch pipes) or encoded action or action-recipient in a simple locution of the form *X-thing* or *Xing-thing* (e.g., *tea-thing* or *stirring-thing* for infuser, *sand-thing* for sifter). By similar token, unconventional labels were considered shape based if they clearly referred to shapes or shape similarity (e.g., *eggy-thing* for egg-shaped infuser, *clocky* for round pitch pipes). Of course, some unconventional

Table 4

Mean Percentages of Hybrid Labels Encoding Shape, Function, or Both and Mean Uninterpretable Labels, by Instruction Group and Age in Experiment 1

Label	M	Instruction group		
		Nonspecific	Shape	Function
3-year-olds				
Shape	27.8	21.0	31.9	30.6
Function	39.9	47.0	33.0	39.8
Both	8.3	10.0	7.7	7.1
Uninterpretable	24.0	22.0	27.5	22.4
4-year-olds				
Shape	19.2	14.7	24.5	18.3
Function	57.6	56.0	54.5	62.4
Both	7.6	12.9	3.6	6.4
Uninterpretable	15.5	16.4	17.3	12.8

³ If children produced more labels in total for same-function than for same-shape objects, this result would be confounded. In fact, however, 3-year-olds produced labels for a mean of 6.3 out of 8 same-function objects and for a mean of 6.3 out of 8 same-shape objects. Four-year-olds produced a mean of 6.9 same-function object labels and a mean of 7.1 same-shape object labels—a marginal difference, $t(46) = -1.9, p < .07$, but one that actually provided more opportunities for shape-based naming.

⁴ An Instruction \times Age \times Task (within: match vs. name) multivariate analysis of variance confirmed a significant Instruction \times Task interaction, $F(4, 176) = 16.5, p < .001$.

⁵ We thank an anonymous reviewer for this suggestion.

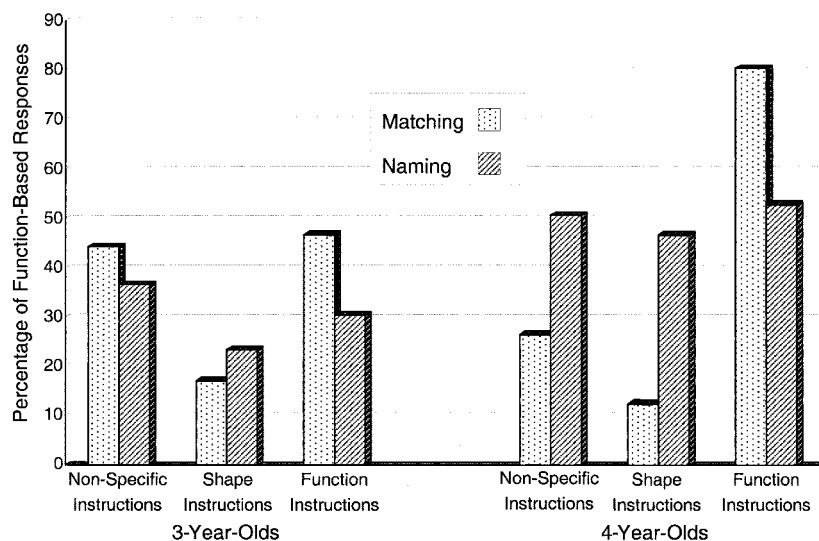


Figure 3. Mean number of function-based matching and naming responses, by age and condition, in Experiment 1.

labels were still uninterpretable (e.g., *cup* for infuser, *karate-thing* for lute-shaped drum, *grub* [sic] for eraser). Also, some complex locutions were produced; these are considered separately below. A second coder recoded 25% of each group (chosen at random); the mean kappa (Cohen, 1960) was 0.65.

The mean number of words produced per child, by age, are shown (with *SDs*) in Table 5, for each recoded label category (function based, shape based, conventional or uninterpretable, and “don’t know” or complex locutions). At both ages, children produced many more function-based than shape-based labels across all objects, but the ratio increased from over 2:1 to over 4:1 between 3 and 4 years.

Complex locutions typically described an object and seemed to be produced when a child wanted to comply but could not retrieve or produce a conventional term. Because children produced these in response to an adult’s request for a label, we assume they reflect the child’s belief about what a label *should* have encoded. It is interesting that virtually no locutions described an object’s shape or configuration of parts, whereas a mean of 0.93 locutions per child (*SD* = 1.8) described an object’s function (e.g., “you shake it and sand comes out”; “you make music with it”). A scant few

described other properties (e.g., color, material). Children apparently considered the naming task a request for function-based labels or descriptions.

As in prior analyses, we examined the relations between naming and matching responses. The between-tasks correlation of number of function-based responses was .10, indicating task independence. As a more focused test (suggested by an anonymous reviewer), we calculated the proportion of total labels that were function based. We used these to compare shape-instructed 3-year-olds who matched mostly by shape ($n = 14$) to function-instructed 3-year-olds who matched at least two hybrids by function ($n = 14$). This comparison tests whether the 3-year-olds’ naming responses were influenced by a prior matching rule they had actually followed (at least sporadically). These two groups produced 36% and 46% function-based labels, respectively, a nonsignificant trend, $t(26) = 1.7, p < .10$. However, the shape-sorting group produced relatively more shape-based labels (29%) than the function-sorting group (17%), $t(26) = 2.8, p < .01$. Thus, although preschoolers are acquiring a tendency to name objects by function, at 3 years the demands of an unrelated prior task (e.g., matching) can modestly influence their labeling. It is interesting that no such pattern was

Table 5
Mean Number (and Standard Deviations) of Recoded Function-Based, Shape-Based, or Uninterpretable Labels and Other Locutions, for All Objects, per Child in Experiment 1

Age	Label or locution type			
	Function based	Shape based	Uninterpretable	Other locution
3-year-olds	8.7 (3.9)	3.9 (2.4)	3.8 (1.3)	4.3 (4.9)
4-year-olds	12.9 (3.2)	2.7 (1.9)	4.3 (1.0)	2.2 (2.5)

Note. Each child could produce up to 24 labels; row means sum to less than 24 because children sometimes produced no response. Uninterpretable labels include conventional or unrelated labels, and Other locution includes complex descriptions and “don’t know” responses.

found in 4-year-olds, though they showed a stronger instruction effect in the matching task.

Discussion

How do children adopt and apply a principle of classification? Even when correlated attributes were placed in conflict, most 4-year-olds could focus on a socially specified abstract attribute and use it to group objects, though its manifestations varied across items. Throughout a 20–30-min task consisting mostly of object manipulation, punctuated by requests to place an object with one of two other objects, 4-year-olds maintained focus on either shape or function (according to instructions) without any reminders or feedback. Three-year-olds also readily and consistently matched by shape, but few consistently matched by function. Traditional theories (e.g., Inhelder & Piaget, 1964; Vygotsky, 1934/1986) would predict that function matching exceeds preschool children's abilities. For example, Piaget (1970) characterized preschoolers as static (i.e., incapable of causal reasoning) and perceptually bound (i.e., "captured" by overt similarity of appearance). These characteristics, in their extremes, would prevent controlled function-based comparisons. To better understand the meaning of the results, we briefly consider the demands of shape and function matching and then consider what the results say about 3-year-olds' and 4-year-olds' cognitive skills.

Consistent shape matching required categorical judgments of similarity of three-dimensional contour with respect to some features (e.g., edges and surfaces, configuration of parts) but not others (e.g., exact dimensions, amount of contour or contrast). Not only did size, color, and texture vary, but the projected retinal shape of any object varied with distance, perspective, and position; all are irrelevant to shape similarity. Thus, sorting by shape required knowing which differences in retinal projections are relevant to a concept of shape as denoted by the predicates "shaped like" or "the same shape as." It is interesting to note that we could find no studies of preschoolers' understanding of *shape* as an abstract dimension word. Matching-task results, however, suggest that 3- and 4-year-olds' concept of shape is a fair approximation of adults'.

Function also is a multidimensional, complex aspect of objects that, unlike shape, is rooted in potential for human action. An object's function is defined by the events afforded by its physical properties (shape, size, material, and configuration of internal and external parts) and intended by its human users. Judging which objects "do the same things" requires comparison of properties that afford participation in certain roles in certain kinds of events. It might also entail inferences about human users' intentions (Bloom, 1996). Matching by function apparently entails additional demands because few 3-year-olds consistently followed the instruction, though they can judge the functional similarity of objects (Smith et al., 1996) and extend novel object names by function (Kemler Nelson, Frankenfield, et al., 2000; Kemler Nelson, Russell, et al., 2000). Also, most 3-year-olds successfully produced objects' functions (prior to matching), suggesting that they encoded and remembered functions, at least briefly. Why, then, did so few 3-year-olds match by function?

An obvious possibility is that 3-year-olds did not grasp the instruction. We can assess this in a gross way by examining initial

responses to the two instruction items prior to feedback. Three-year-olds who were receiving function instructions matched a mean of 75% of instruction trio hybrids by function; those who were receiving shape instructions matched a mean of 97% by shape. These data must be interpreted cautiously, but they evoke the idea of an *abulic dissociation*, as described by Zelazo and Frye (1998): 3-year-olds can grasp the function rule but do not follow it in the context of a competing rule or association. Alternately, 3-year-olds might be able to grasp the rule and follow it but may fail to generalize it to other test items once direct instruction is withdrawn. This possibility would implicate social knowledge of how long to follow task demands (e.g., an instruction). In any event, the discrepancy between instruction and test performance makes a comprehension-based account less plausible. This discrepancy is further explored in Experiment 3.

Another possibility is that it is hard for 3-year-olds to match the functions of objects in a static display. When dynamic function information is not immediately available, 3-year-olds might not compare objects on that basis. This possibility is explored in Experiments 2 and 3. Another possibility is that 3-year-olds do not know which affordances are relevant for overt comparisons of function. Most artifacts have multiple affordances but only one *intended* function (Bloom, 1996). A knife is designed to cut certain substances, but it can be used to whittle, dig, pry, tap, or probe. Three-year-olds do not always identify which affordance of an object is intended (e.g., sucking up dirt for a vacuum cleaner) and which is incidental (e.g., making noise; Matan, 1995). Three-year-olds might interpret the locution, "does the same thing" as connoting *any* shared affordance, not the intended function. Because two objects (especially those with similar configurations) likely share *some* affordance(s), this would reduce matching by intended function. We address this possibility in Experiment 3.

A final possibility is that 3-year-olds treat each matching trial as discrete, rather than as a part of a temporally extended series of problems. There is evidence that 3-year-olds do not tend to synthesize or relate their own current and recent past activity (Povinelli, Landry, Theall, Clark, & Castille, 1999). Thus, 3-year-olds might not realize during test trials that the recent instruction pertains to the current problem. A default bias to sort static objects by shape, combined with the lack of synthesis of past and current activity, would yield exactly the results obtained: consistent shape-based matching only. This hypothesis is addressed in Experiment 3.

The results also speak to how children name objects according to shape or function. Both 3- and 4-year-olds tended to produce the same label for objects with the same demonstrated function, not for those with the same shape. This tendency was more pronounced when we considered children's labels for all objects, not just hybrids, under relaxed coding criteria. Even when children did not generate a concise object label, their default tendency (other than saying "don't know") was to describe objects' functions, not static physical attributes. This was not simply due to task demands, because the trend was largely independent of children's matching choices. Three-year-olds typically matched by shape but labeled by function. Adults also generalize labels by function (see Bloom, 1996). Apparently the knowledge that English words for objects are based on function emerges between 2 and 5 years. Notably, 2- and 3-year-olds also extend novel labels by function, if they have

seen the functions (Kemler Nelson, 1995, 1999; Kemler Nelson, Russell, et al., 2000). The results of Experiment 1 are consistent with this claim and inconsistent with the claim that 3-year-olds generalize object labels by shape (Smith et al., 1996). Such discrepant results might implicate unknown contextual or measurement variables. A critical question for future research is how older and younger preschoolers' naming varies across conditions of presentation and amount and type of interaction with objects. We would expect a flexible symbolic communication system to allow some contextual variability so that pragmatic and social demands can influence naming decisions (see Deák & Maratsos, 1998). Shape-based labeling will sometimes be adaptive: For example, while playing with an array of representational objects such as a doll house, calling every item "toy" would be uninformative, though it accurately names an encompassing functional category. In this situation, naming each item according to what it represents (i.e., by shape; e.g., "bed," "chair") will effectively differentiate referents.

Experiment 2

The finding that 4-year-olds classify objects by shape or function in response to a specific instruction highlights the dependency of children's classification and inference on task and social context (e.g., Deák & Bauer, 1996; Donaldson, 1978; Landau, Smith, & Jones, 1992; Markman, Cox, & Machieda, 1981). In addition, the finding that 4-year-olds tend to match by shape without specific instruction supports claims that preschoolers, by default, classify objects according to shape (Baldwin, 1989; Gentner, 1978; Landau, Smith, & Jones, 1988). This claim is further investigated by the current study.

Preschoolers' tendency to match by shape or function might depend on information available in a particular presentation context. If objects are static or disabled (e.g., turned off) while children classify them or select groupings, shape and function will not be equally available (Deák & Bauer, 1996). In static displays, objects' shapes are often constantly available. Function information, in contrast, is available only if the child attends to specific affordances, and even then, perhaps, only if the child recalls or infers the relevant function. Two-year-olds classify objects by function more if functions are displayed dynamically while an adult talks about the functions (Corrigan & Schommer, 1984). Here we tested whether simply changing how objects are displayed, from static to dynamic, shifts 4-year-olds' criterion for selecting function as a basis for matching.⁶ That is, does the sensitivity to dynamic function information found in 2-year-olds evolve, by age 4, into attentiveness to available dynamic information when generating an organized, controlled grouping strategy?

To answer this question, we reduced the asymmetry between availability of shape and function information for a redemonstration group. These children saw each hybrid object's function a second time while deciding how to match it.⁷ A control group matched objects in a static array, as in Experiment 1. Both groups received nonspecific instructions, so preliminary trials were eliminated. We predicted that 4-year-olds' tendency to match by shape would diminish or disappear in the former group. To replicate the finding that function-based labels predominate in 4-year-olds, we also had both groups name objects.

Method

Participants

Thirty-two 4-year-olds (16 girls and 16 boys; mean age = 4 years 5 months; range = 4 years 1 month to 4 years 11 months) were tested. Sixteen children were recruited for a redemonstration group. Sixteen children in a control group had been recruited and tested several months earlier (see Footnote 1). Both groups were recruited from the same university-maintained database. The recruitment procedure, population, and testing facilities were identical for both groups. The children were mostly White and middle class.

Materials

The eight test sets from Experiment 1 were used. Instruction sets were not used.

Procedure

The redemonstration and control groups followed identical procedures with the exception noted below. No instruction trials were given. After obtaining consent and establishing rapport, the experimenter presented the first test trio. After seeing all three objects' functions demonstrated, children were asked, "Which one does this one [the hybrid] go with? Which box does it belong in?" The experimenter made no specific reference to shape or function. In the redemonstration condition, the experimenter demonstrated the hybrid's function again while asking the question. In the control condition, the objects remained static and untouched on the table. All children named objects, as in Experiment 1, after the matching task.

Results and Discussion

The control group matched a mean of 2.4 ($SD = 1.9$) out of 8 hybrids by function (similar to the nonspecific-instruction group in Experiment 1, $M = 2.1$). The redemonstration group matched a mean of 4.4 ($SD = 2.1$) by function. The difference was significant, $t(30) = 2.76, p = .01$ (all tests two-tailed). The control group matched by function significantly less than expected by chance, $t(15) = -3.5, p < .01$; the redemonstration group did not differ from chance, $t(15) < 1$.

The numbers of children who applied a consistent matching principle reflect the group means. With the ≥ 7 criterion, in the redemonstration group 1 child consistently matched by shape, and 3 consistently matched by function. Five control group children consistently matched by shape, and none matched by function. This difference is significant, Fisher's exact $p < .05$. With the looser criterion (≥ 6), 4 redemonstration group children consistently matched by shape, and 5 matched by function; 9 control group children matched by shape, and 1 matched by function. This difference also is significant, Fisher's exact $p < .05$.

⁶ Corrigan and Schommer (1984) did not manipulate mode of presentation independently of social or linguistic cues.

⁷ To fully equate availability of function and shape information, we would have had to redemonstrate all three objects' functions simultaneously (enabling children to directly match functions as they can match shapes). Simultaneously demonstrating three objects' functions entailed great practical difficulties, however, so we reenacted only the hybrid functions. An open question is how matching preferences would change if all relevant function information was made available.

Without specific instructions, 4-year-olds preferred matching by shape unless function information was roughly equated in availability at the time of decision. In that situation, 4-year-olds were roughly divided in preference. The results therefore do not indicate a general bias in older preschoolers to classify by shape. Rather, they suggest that 4-year-olds select an abstract criterion for generalization from among the patterns of information available in the stimulus array. This raises an important question: Does availability dependence imply a difficulty “filling in” less accessible information or attributes (akin to perceptual boundedness; Piaget, 1970)? That is, are nonobvious attributes, such as functions, challenging but not impossible for 4-year-olds to imagine, recall, or infer? Or does the effect reveal factors that help children infer which attributes an adult deems important (i.e., demand characteristics)? That is, if an adult takes pains to make one attribute available or salient (e.g., repeatedly demonstrating an object’s function), this might indicate the adult’s intentions or desires, and guide the child to select that attribute as a basis for generalization. Resolving this issue will require future research in which task demands and social cues are independently manipulated.

Another question for future research is whether restricting shape information (i.e., obscuring it while children match objects) would decrease consistent shape matching. By the same token, would presentations that highlight incidental affordances rather than demonstrated functions reduce consistent function matching in older preschoolers?

Children’s object labels closely replicated those in Experiment 1. The redemonstration group produced 120 hybrid labels: 18 (15%) encoded shape, 62 (52%) encoded function, and 13 (11%) encoded both; the rest were uninterpretable. The control group produced 116 hybrid labels: 20 (17%) encoded shape, 64 (55%) encoded function, and 16 (13%) encoded shape and function. By the more inclusive coding criteria for all labels, children produced means of 12.1 (56%) function-based labels, 3.4 (16%) shape-based labels, 4.3 (20%) conventional labels, 1.6 (8%) nonconventional uninterpretable labels, and 0.8 function descriptions. To test whether function redemonstration increased the incidence of function-based labels, we conducted between-groups comparisons of mean numbers of function-based and shape-based labels; differences were small and nonsignificant, each $t(30) < 1$. In general, the groups produced very similar labels. Thus, a second demonstration of hybrid function did not increase function-based naming.

These results confirm those of Experiment 1: 4-year-olds are learning that objects are conventionally labeled by function. It appears that when given sufficient information about objects’ functions, preschoolers tend to name objects by shared function. Because shape and function are normally correlated, the basis of children’s labels is usually equivocal. The current paradigm disambiguates most of children’s labels because many objects have atypical or unfamiliar shapes or functions, and because shapes and functions are dissociated. The pattern of data is maintained across two coding systems with different scope and criteria for inferring whether a label is based on shape or function; thus the results probably are not a coding artifact.

The function-based naming trend is not invariant: Children sometimes named objects by shape. What factors account for this variability? There is no evidence that social demand characteristics (e.g., prior instructions) or memory of functions explains it, be-

cause redemonstration did not affect naming. Other variables are suggestive but inconclusive. Some objects received a disproportionate number of shape-based labels; these included the wooden and plush cubes (often called *square* or *block*), the egg-shaped timer and infuser, the disk-shaped magnet, the corn-shaped harmonica, and the sifter (often called *cup*). These objects all have at least one of two traits: a canonical shape that children can readily name (e.g., cube, egg), and a function not obvious from visual inspection alone (e.g., twisting the top of an egg timer so it ticks and rings). Note, though, that other objects with these traits (e.g., eraser) received few shape-based labels, so the role of these object-specific traits remains highly speculative. Other potentially influential factors are discussed by Kemler Nelson, Frankenfield, et al. (2000) and Kemler Nelson, Russell, et al. (2000).

Merriman et al. (1995) also reported a relevant effect. They varied whether items akin to our hybrid objects (e.g., pencil-shaped eraser) were presented alone or alongside same-appearance and same-function objects (i.e., a real pencil and a prototypical pink eraser). Three- and 4-year-olds were more likely to accept appearance labels (i.e., *pencil*) for an object presented alone (74%) than for one presented alongside contrasting objects (45%). Although Merriman et al.’s participants were asked to select the referent of a specified label, not to produce labels, their results suggest that our participants would have produced fewer shape-based hybrid labels if the hybrids had been presented within the entire trio. This and other hypothetical context effects on naming warrant future investigation.

Experiment 3

Why do few 3-year-olds follow instructions to group artifacts by function? Even infants can perceive and attend to objects’ affordances (Brown, 1989; Madole et al., 1993), and the instruction trial responses in Experiment 1 suggested that many 3-year-olds at least minimally comprehended the instructions. Analysis of the matching task suggests several reasons why most 3-year-olds do not consistently follow instructions to match by function.

First, when exploring a set of objects, 3-year-olds might not attend to relevant affordances or might not notice that two objects share a given function. Alternatively, during matching decisions, children might forget the function that was demonstrated. Any object affords many interactions, but children were asked to compare and match objects by a specific demonstrated function. Encoding and recalling this function are crucial to performance. To determine whether encoding and recall failure account for 3-year-olds’ performance, we facilitated these processes in one group by redemonstrating the hybrid function while children made matching decisions (as in Experiment 2). This redemonstration group presumably would enjoy greater availability of function information and possibly show increased function matching as a result.

To assess whether 3-year-olds tend to encode and recall demonstrated functions, we asked 3-year-olds in other groups (described below) to reproduce hybrid objects’ functions. For a conservative test, we imposed a delay between demonstration and recall by requesting children to demonstrate the functions following the matching task. This procedure constitutes a strong test of 3-year-olds’ memory of demonstrated function.

Second, 3-year-olds might not generalize the matching rule from instruction trials to test trials. Failure to generalize might indicate that the instruction did not sufficiently influence 3-year-olds' decisions throughout eight subsequent test trials. Alternately, it might indicate that 3-year-olds do not notice the structural and procedural parallel between instruction trials and test trials. Finally, it might indicate that 3-year-olds do not perceive successive matching trials with different objects and functions as part of the same temporally extended activity or task. This latter possibility is central to interpreting age-related changes in consistency, because consistency depends on apprehending the structural similarity across discrete problems within a task.

To assess these possibilities, we had some 3-year-olds complete the task with instruction reminders. These were intended to support the child's generalization of the instructed rule to a series of dissimilar trials without actually restating the rule every time. In instruction trials, the task was called a "game" and the instruction, a "rule." In test trials, children were cautioned to "remember [think about] the rule of the game" before sorting each hybrid. Deák, Ray, and Pick (2002) found that this increased 3- to 5-year-olds' flexible response to changing matching rules. It might, by the same token, help 3-year-olds consistently follow a single rule, even one that is contrary to their prior preferences.

If 3-year-olds fail to generalize instructions to subsequent test trials, a strong manipulation would be to repeat the rule on every test trial. This would eliminate the demand to transfer or generalize the rule and so directly test whether 3-year-olds attend to, comprehend, and comply with the function instruction. Children in an instruction repetition group heard the function instruction on every trial. Though Zelazo and Reznick (1991) found that 2.5-year-olds did not reliably follow an intermittently repeated sorting rule, Zelazo et al. (1996) found that 3-year-olds followed a sorting rule repeated on every trial, even erroneously adhering to it after a new, contrary rule was imposed. Thus, repeating a function rule on every trial might help 3-year-olds. However, such controlled rule use depends partly on rule difficulty (Deák et al., 2002; Frye, Zelazo, & Palfai, 1995). Grouping objects by function is harder or less preferred for preschoolers than is grouping by shape (Deák et al., 2002), so stating a function rule on every trial might not be effective.

Third, if repeating the function instruction does not elicit consistent performance, an immediate question will be whether 3-year-olds comprehend the instruction. Consistent function-based matching requires knowing that the predicates "do[es] the same thing as" and "works like" refer to certain abstract, dynamic attributes. We cannot be certain that 3-year-olds understand this. To test comprehension, we administered posttests in which 3-year-olds answered questions about test objects. The predicate in some questions implied function; the predicates in other questions implied color or category label. That is, children were asked, of various objects, either "How does this work?" "What color is this?" or "What is this called?" If children only produce objects' functions in response to function questions, it will indicate comprehension of the predicates "do[es] . . . [with]" and "works [like/the same as]."

A final group provided a more powerful test of 3-year-olds' ability to follow the function instruction. Three-year-olds might be challenged in several regards described above, suggesting that

multiple contextual supports are jointly necessary for consistent use of a function-matching rule. To test this, we gave 3-year-olds in an enhanced instruction + support group additional practice and feedback with the function-sorting instruction. Recall that children in Experiment 1 completed two instruction trials. This procedure provides only minimal opportunity to shift to a nonpreferred matching criterion (e.g., function). If the child does not follow the instruction on the first trial, she or he receives feedback and one more opportunity to induce the rule. This procedure might be insufficient for younger preschoolers, who are less accustomed to following verbal instructions in formal tasks. Consequently, the new group completed two simpler problems prior to the original instruction trials. The first presented a pair of objects with different shapes but similar functions. The second presented a trio with two same-function objects and a distractor. As before, the experimenter demonstrated objects' functions while using the predicates (e.g., "See how it works . . ."), so this group heard the function-implying predicates twice as often as other groups. In addition, during test trials this group saw functions redemonstrated and heard reminders to think about the rule (as in the previous groups). Because this condition simultaneously introduces several supportive manipulations, it does not test enhanced training per se, but it assesses 3-year-olds' ability to match by function when instructions are clarified and cognitive demands are reduced.

Method

Subjects

Sixty-four 3-year-olds (29 girls and 35 boys; mean age = 3 years 6 months; range = 3 years 0 months to 3 years 11 months) were randomly assigned to one of four experimental conditions ($n = 16$). Children were recruited from preschools in a southeastern city and were predominantly White and middle class.

Materials

Stimuli were the 10 sets from Experiment 1. Two new instruction trial sets were added in the enhanced instruction + support condition. The first included a bubble pipe and a bubble wand. The second included a paper clip, a bottle of correction fluid, and a correction tape dispenser.

Procedure

Children were quasi-randomly assigned to the redemonstration, instruction reminders, instruction repetition, and enhanced instruction + support groups. Gender and age (younger vs. older 3-year-olds) ratios were equated across groups.

Preliminary and test trials. All groups except the enhanced instruction + support group completed two instruction trials and eight test trials, like the function instruction group in Experiment 1. As in Experiments 1 and 2, no child received feedback after the instruction trials.

Children in the redemonstration group were shown each hybrid's function again while they were deciding how to match it, as in Experiment 2. No reminders of the instruction were given.

While instructing the instruction reminders group, the experimenter referred to the instruction and the task as "the rule" and "the game," respectively, asked children to restate the rule, and explained how it applied to each same-function pair (e.g., "they both light up"). Then, on every test trial, the experimenter reminded children to "think about the

rule” before selecting the proper match. The experimenter never actually repeated the rule or gave corrective feedback.

Children in the instruction repetition group received standard instructions. However, they were told on every test trial to “Put this with the one that [works the same/does the same thing].”

Children in the enhanced instruction + support group completed four instruction trials, including two new trials. In the first, a bubble pipe and a bubble wand were demonstrated, and children were encouraged to try them and describe their function. Children then were told to put the items together in a box because they “do the same thing” and “work the same.” In the second trial, children saw the functions of a paper clip, correction fluid, and correction tape demonstrated (e.g., the experimenter corrected a stray pencil mark). Children were told to put the correction tape in a box with the one that “works the same” and “does the same thing.” Children then received the two original instruction trials. Feedback was given in all four trials, and the association between demonstrated function and the predicates (“do . . . with” and “works [like]”) was explicated. In addition, the instruction and the task were referred to as “the rule” and “the game.” During test trials, children saw hybrid functions demonstrated again and were reminded to “think about the rule” before making the matching response.

Posttests. After completing the matching test, a subset of children ($n = 11$, none of whom saw functions redemonstrated) were asked to demonstrate the functions of the first four test hybrid objects (the first objects were used for a more difficult recall test). The experimenter asked, “Show me how this works. Can you show me what it does?”

In a second posttest, 14 different children who did not see functions redemonstrated were shown nine objects, one at a time, in random order. These objects (flashlight, pen, penlight, telephone, football, football telephone, wood cube, plush sphere, plush cube) were used because their functions could be demonstrated without props, they were readily labeled (as shown in Experiments 1–2), and their colors were easily labeled. Each child was asked, about three objects (randomly selected), “How does this work? What do you do with it?” Each child was asked, about three other objects, “What color is this?” Of the remaining three objects, each child

was asked, “What is this? What is it called?” Question order was randomized.

Results

Children did not primarily match by function, even with simple manipulations to reduce memory demands or clarify instructions and task demands. Recall that 3-year-olds in the function-instruction group of Experiment 1 sorted a mean of 3.8 out of 8 (47%) hybrid objects by function. By comparison, the redemonstration group sorted a mean of 3.7 ($SD = 2.4$) test hybrid objects by function, the instruction reminder group sorted a mean of 3.9 ($SD = 1.8$) by function, and the instruction repetition group sorted a mean of 4.2 ($SD = 2.6$) by function. None of these means differ from chance. The enhanced instruction + support group, however, sorted a mean of 5.2 ($SD = 2.1$), or 65%, of test hybrids by function. This mean is significantly above chance, $t(15) = 2.2$, $p < .05$.

The number of function matches across groups was compared with an ANOVA, which revealed no significant group effect, $F(3, 60) = 1.3$, *ns*. Figure 4 shows the means for each group, along with the nonspecific-instruction and function-instruction groups from Experiment 1 (for comparison).

The number of children in each group who consistently matched by shape or function is shown in Table 6. In the redemonstration, instruction reminder, and instruction repetition groups, from 2 to 4 (12%–25%) children matched ≥ 7 test hybrids by function (from 3 to 6, or 19%–37%, matched ≥ 6). In the enhanced instruction + support group, 6 children consistently matched by function, $p < .0001$ by binomial theorem. Note, however, that 6 out of 16 is significantly fewer than the 12 out of 16 function-instructed

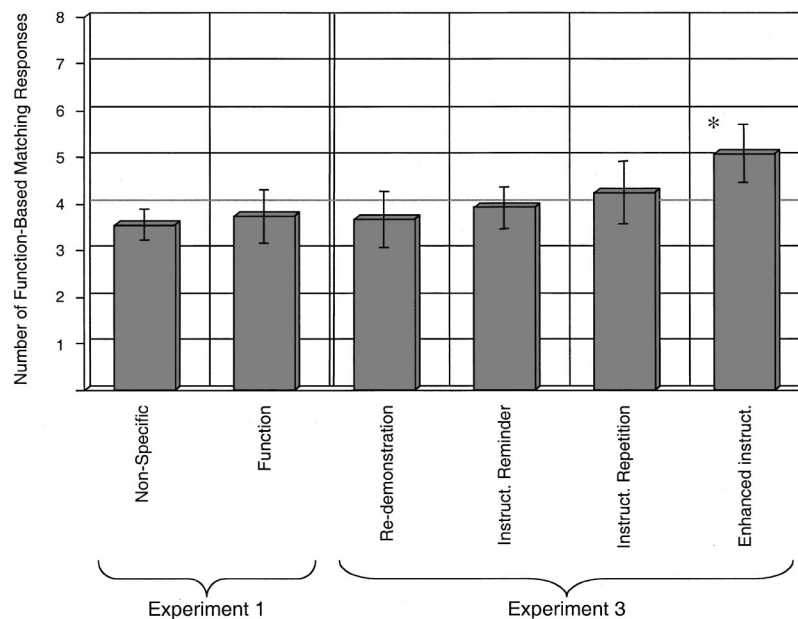


Figure 4. Mean number of function matches by 3-year-olds in Experiments 1 and 3, by condition (Instruct. = Instruction). Maximum correct = 8.0; chance = 4.0. *Mean exceeds chance, $p < .05$.

Table 6
Number of 3-Year-Olds Who Matched ≥ 7 [or ≥ 6] Out of 8 Test Hybrid Objects by Shape or by Function, Across Groups in Experiment 3

Attribute	Instruction group			
	Redemonstration	Instruction reminders	Instruction repetition	Enhanced instruction
Shape	3 [5]	1 [3]	3 [6]	0 [3]
Function	3 [5]	2 [3]	4 [6]	6 [8]

Note. Numbers are out of 16 children per cell.

4-year-olds who sorted by function with no additional training or support in Experiment 1, $\chi^2(1, N = 32) = 4.6, p < .05$.

Children in the first memory posttest correctly reproduced a mean of 95% ($SD = 10\%$) of object functions, following a delay of over 20 min during which they saw at least 12 other functions. Thus, 3-year-olds reliably encoded and recalled demonstrated functions. Perhaps, however, 3-year-olds impulsively produce an object's function when it is handed to them. If so, correct function demonstrations would not conclusively show that a child understood the question. The second posttest resolves this problem: Children appropriately responded to 39 out of 42 naming questions (93% category labels), 42 out of 42 color questions (100% color words), and 40 out of 42 function requests (95% function demonstrations). Clearly, 3-year-olds recall an object's specific function long after it is demonstrated, and they specifically retrieve or select this information in response to questions about function.

Discussion

These results address some hypotheses about 3-year-olds' failure to adopt a function-sorting rule. Simply showing children the hybrid object's function again, while they decided how to match it, did not increase their compliance with the function instruction. Nor did calling the instruction a "rule" and reminding children to "remember the rule." These findings are notable because the same manipulations had significant effects in other studies: the former in Experiment 2, the latter for children in some conditions of Deák et al. (2002).

It is perhaps surprising that few 3-year-olds followed the function instruction even when it was repeated in every trial. This suggests that 3-year-olds (in Experiment 1 or in the instruction repetition group) did not merely forget the instruction or fail to generalize it. It does, however, fit the hypothesis that 3-year-olds do not comprehend the instruction. However, other findings do not fit this account. First, 3-year-olds in Experiment 1 usually followed the function rule during instruction trials. Second, the enhanced instruction + support group had more practice with the instruction and were the only 3-year-olds to systematically match by function, yet they did so less than function-instructed 4-year-olds and not significantly more than other 3-year-olds. Least compatible with a simple comprehension-based account is the finding that 3-year-olds uniformly made correct, discriminative responses to posttest function questions. Three-year-olds therefore seem to understand some vernacular locutions that imply function. We cannot rule out the hypothesis that the function instructions

confused 3-year-olds, however, because the specific wordings of matching instructions and posttest questions were somewhat different (i.e. "Which one works the same?" vs. "Show me how it works"). This difference might offer a clue to 3-year-olds' difficulty (see below). Finally, the posttests confirm that 3-year-olds did encode and remember demonstrated functions, even after many minutes and intervening demonstrations.

A final possibility is that 3-year-olds' performance was compromised by sets that were particularly difficult to match by function. For example, some hybrid/same-function pairs might have differed in manner of action, making functional similarity less obvious and confusing the 3-year-olds. To test this, we compared matching choices across test trios. This revealed a significant item (i.e., trio) effect, $F(7, 54) = 6.9, p < .001$. Two sets—the lyre-shaped drum and sifter hybrids—elicited fewer function-based responses (item analysis of Experiment 1 shows a similar pattern). We therefore compared function matches across groups, excluding these two sets. The same pattern emerged: Only the enhanced instruction + support group matched significantly more than 50% of the remaining trios by function ($M = 71\%$), $t(15) = 2.8, p < .02$. The other groups sorted 50%–56% of the other trios by function, none exceeding chance.

These data show that most 3-year-olds do not readily adopt an instruction to group objects by function, whereas most 4-year-olds readily follow the instruction. Yet 3-year-olds display many relevant sensitivities: They readily recall the objects' functions, adopt at least some matching rules (3-year-olds in Experiment 1 increased shape matching following shape instructions), and understand requests that use verbiage similar to the function instructions. Thus, 3-year-olds fail to apply an abstract rule that seems within their grasp. This behavior is reminiscent of utilization deficits (Miller, Seier, Barron, & Probert, 1994), in which children fail to engage strategies within their abilities while under increased task demands, and abulic dissociations (Zelazo & Frye, 1998), in which preschoolers fail to follow a conditional rule despite having the requisite knowledge. These concepts are descriptive, however, not explanatory. How, then, can we *explain* 3-year-olds' failure to match by function?

We offer two speculations. First, consider the difference in phrasing between the matching and the recall questions. Only the former requested a comparison. Perhaps preschoolers' difficulty is not in remembering or inferring function but in *comparing* the functions of dissimilar objects. This might reflect an information-processing limitation, for instance, in holding in mind two or more

complex events in which actors, agents, and patients participate in different transformations. This could be investigated by imposing different cognitive loads while preschoolers make inferences about function (e.g., by presenting more or fewer object functions or imposing concurrent processing demands). Note that preschoolers do incorporate function in judgments of overall object similarity (Smith et al., 1996), so function comparison is difficult only in some tasks. Perhaps the current task's cognitive demands (e.g., learning an abstract, socially conveyed rule) exceeded 3-year-olds' capabilities. Second, the least frequently function-matched hybrids both shared many affordances with their same-shape objects. For example, even though the pewter mug and the sifter did not offer the same affordances for sand or flour, they have similar affordances for larger-grained substances. By the same token, though only the same-shape lute afforded plucking, it shared with other objects a sound chamber that afforded drumming. Thus, matching objects by *demonstrated* function might be harder for 3-year-olds if distractor objects share incidental affordances.

General Discussion

The results support other recent findings (e.g., Kemler Nelson, 1999; Kemler Nelson, Frankenfield, et al., 2000; Kemler Nelson, Russell, et al., 2000) that preschool children are not restricted to classifying objects by shape or by function. Preschool children attend to both aspects of artifacts and shift attention between them in response to age-related and contextual factors. We focused on two contextual factors: social information specifying a response criterion (e.g., instruction) and type of generalization response (i.e., matching, naming). Other factors, such as available information about objects (e.g., static vs. dynamic) or repetition of instructions, moderate these factors. We first discuss the broad implications of the results, then discuss 3-year-olds' sorting and naming results, and finally discuss 4-year-olds' sorting and naming results.

These data contribute to a body of evidence that preschoolers' generalizations are highly task- and context-specific. This evidence is difficult to accommodate under traditional theories of cognitive development that emphasize age-related changes in static representational structures or capacities (e.g., Piaget, 1970). Pervasive findings of context specificity suggest that children's inference making and similarity selection—including naming, word learning, sorting, matching, inferring properties, and so forth—are best regarded as phenomena that emerge under constellations of properties of the child *and* his or her environment.

Three-year-olds respond selectively to verbal instructions specifying an abstract criterion for object grouping. One such instruction—match by shape—was systematically generalized to new test sets. Another, match by function, was systematically generalized by only a few children. It is not that 3-year-olds were rigidly disposed to match by shape; in fact, few 3-year-olds applied *any* matching principle consistently except when instructed to match by a preferred attribute (i.e., shape). That is, 3-year-olds were unlikely to adopt a controlled, consistent response strategy despite a predisposition to group items by one attribute.

The status of object function for 3-year-olds is not entirely clear. One possibility is that 3-year-olds can compare or group items by function except when some salient other property is in conflict. Yet shape is not simply so salient that generalizing by any other

attribute is prevented by a sort of “shape inertia.” For instance, 3-year-olds readily adopt a rule to sort by color even if shape is in conflict (Zelazo et al., 1996), though they prefer grouping by shape (Baldwin, 1989). Also, they command many component skills of function matching. They are interested in objects' functions and can recall demonstrated functions virtually perfectly. They comprehend locutions that imply function, similar to the matching instructions. Their failure to adopt a function rule is not attributable to a few confusing items. It is notable that some 3-year-olds match by function when the instruction and the demand to transfer it are clarified and when functions are emphasized. Even this regimen, however, did not yield uniform function matching by a majority of 3-year-olds.

Three-year-olds' difficulty might lie in maintaining an abstract concept of function as a criterion for diverse groupings or comparisons. Notably, though, even when told on every trial to match by function, 3-year-olds' performance did not exceed chance. Possibly after hearing the instruction several times, children stopped attending—in effect tuning the experimenter out. After all, during the experimenter's repetitive script, no corrective feedback was given, and if children had no reason to believe they were not correctly following the instruction, why should they carefully attend to each repetition? In general, 3-year-olds seem unlikely to focus on function similarities for controlled, deliberate judgments or overt comparison of diverse items. Perhaps they have difficulty maintaining a representation of function as an abstract criterion of comparison. Also, there is some indication that when comparing objects, canonical shapes, overlapping affordances, and nonobvious functions tend to reduce comparison of functions.

In contrast to their matching responses, 3-year-olds show a growing preference to generalize by function when labeling objects. Though the preference increases over the next 2 years (Merriman et al., 1995), this finding contradicts suggestions (Graham et al., 1999; Smith et al., 1996) that 3-year-olds trenchantly ignore function when extending words across referents. Perhaps in situations where 3-year-olds see many novel objects and hear many novel words, and must construct multiple mappings among them, they resort to a back-up strategy that reduces cognitive effort. Specifically, they might base their inferences on an attribute that is constantly and reliably available and correlated with function: shape. This strategy will be particularly useful in tests that exclude or obfuscate information about function. The finding that even 2-year-olds sometimes generalize by function (Kemler Nelson, 1999) suggests a gradual increase in attentiveness to function for lexical judgments, beginning in infancy (Madole et al., 1993) and continuing for at least 5 years (Merriman et al., 1995). Though shape-based labels will sometimes be especially available, convenient, or unambiguous, preschoolers usually respect the English convention of generalizing artifact labels by shared function (or perhaps intended function).

Four-year-olds generalize by shape and function differently from 3-year-olds. First, almost all 4-year-olds readily adopt either a shape or function instruction. Perhaps the most notable finding is that after only two examples, 4-year-olds transfer an abstract sorting criterion to a series of dissimilar items. What is the significance of this ability to flexibly adopt abstract, verbally specified rules?

Consider preschoolers' emerging ability to retrieve and update task demands from *explicit language* clues (Olson, 1977). Deák (2000) suggested that preschoolers vary in ability to select relevant task cues and to assess cues that signal a new task. For some inferential tasks, children must use explicit language cues (e.g., semantic content of a question). These cues might accompany each problem in a given social interaction (e.g., testing session or classroom activity), or they might be given at the outset of a series of problems (e.g., instructions), with the implicit expectation that the specified task demand will extend across multiple problems.

Young preschoolers do not always encode and interpret explicit language cues appropriately (Olson, 1977). In the current task, 4-year-olds showed a growing tendency to consistently apply a verbally explicated grouping principle. Far more 4-year-olds than 3-year-olds spontaneously applied a consistent matching principle when no specific instruction was given (Experiment 1). Of children not given a specific instruction, 35% of 4-year-olds, but only 6% of 3-year-olds, sorted consistently (≥ 7 out of 8 criterion). Of children given specific instructions, 84% of 4-year-olds versus 41% of 3-year-olds sorted consistently. Thus, the tendency to spontaneously adopt or consistently apply explicit language cues specifying an abstract generalization principle, even one that is contrary to the child's preferred response, increases from 3 to 4 years.

This raises questions of how children learn to use symbolic (e.g., verbal) cues and other social artifacts to govern cognition (Vygotsky, 1978), not just in isolated responses but across ongoing sequences of cognition and action. Children must internalize processes for using social cues (e.g., instructions) to govern the selection and synthesis of perceptual information, in the present and in the future. Between 3 and 5 years, children acquire principles for extending socially specified (e.g., explicit language) demands across tasks and problems. These data indicate that 3–5-year-olds are learning one such pattern: to wit, that naming objects entails function-based generalization, whereas matching or sorting objects is more open-ended and dependent on flexible responses to language cues. Other context variables—for example, how information is presented; how explicit verbal cues are stated, restated, and emphasized; and the range and variability of response options on each trial (Deák, 2000)—might critically affect transfer of task demands over time and across problems. To better understand these dynamics and their development, we eventually will require careful, theory-driven descriptions of children's home and preschool experiences, particularly the settings (e.g., classrooms) and routines (e.g., organized games) structured by means of explicit verbal cues (e.g., rules) given by social agents (e.g., parents, teachers). For example, a survey of preschoolers' everyday experiences grouping, matching, naming, or substituting objects by shape and function would be informative. Perhaps some widespread preschool task teaches 3–5-year-olds to classify objects by function, so that preschool experience predicts the age differences observed here. Of course, any such data would need to be interpreted in light of age-related changes in children's capabilities in tests that precisely control social experience and expertise.

The results of the present study reveal complex interactions underlying children's responses in inductive tasks. Children's tendencies to base their responses on shape or function as abstract criteria depend on several factors. These include knowledge of

relations between properties and tasks (e.g., naming vs. matching) and the availability of property information across display modes (e.g., static vs. dynamic). Matching performance is greatly influenced by preschoolers' growing ability to access function as an abstract criterion and their tendency to impose consistency as a demand for solving a series of related problems.

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