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The Growth of Flexible Problem Solving: Preschool Children Use Changing Verbal Cues to Infer Multiple Word Meanings

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Flexible induction is the adaptation of probabilistic inferences to changing problems. Young children's flexibility was tested in a word-learning task. Children 3 to 6 years old were told 3 novel words for each of several novel objects. Children generalized each word to other objects with the same body shape, the same material, or the same part as the first object. Each word was preceded by a different predicate (i.e., "looks like a …," "is made of …," or "has a …") that implies a different attribute (shape, material, or part, respectively). Three-year-olds showed limited use of predicates to infer word meanings, and they used predicates from previous trials to infer the meanings of later words. 4- to 6-year-olds used predicate cues more consistently and made inferences that were implied by the most recent predicate cue. Notably, 3-year-olds performed near ceiling in a control task that eliminated the need to use probabilistic inductive cues (Experiment 3). The results suggest that flexibility develops as a function of (a) sensitivity to between-problem variability and indeterminacy and (b) ability to decontextualize the most recent verbal cue to guide of inductive inferences.

The epitome of human reasoning is the ability to solve variable, novel problems while ignoring irrelevant information. This is difficult for adults (Dominowski,

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1995; Duncker, 1945; Luchins, 1942), and it is particularly difficult for young children. This study explored how preschool children solve novel inductive problems that require selecting an object from an array that includes objects selected on previous problems. Inductive problems were posed by unknown words, the meanings of which could be inferred from variable, verbal contextual cues.

FLEXIBILITY AND INFLEXIBILITY IN CHILDREN'S PROBLEM SOLVING

There is abundant evidence that preschool children, when making inductive inferences, attend to subtle task variations and to contextual information. For example, when 4-year-olds are asked to find the object "most like" a standard, they select one with a similar appearance, but when asked to find "the same kind of thing," they select an object with nonobvious similarities that define an abstract category (Deák & Bauer, 1995). In lexical tasks, children also show early sensitivity to verbal context. For example, even 2-year-olds seem to use syntactic information to interpret unfamiliar words (Naigles, 1990). By age 4 or 5, children use syntax to classify a novel nominal as a proper name, count noun, mass noun, or collective (Bloom & Kelemen, 1995; Brown, 1957; Katz, Baker, & Macnamara, 1974). Brown, for example, showed that children use articles and quantifiers to decide whether a noun refers to discrete objects (e.g., "*a few* ZABS") or uncountable "stuff" (e.g., "*more* ZAB").

This evidence of context sensitivity stands in contrast with evidence that preschoolers have difficulty adapting to changing problems even if each problem is very simple. Many children perseverate in tasks that require shifting between two responses. For example, in the day–night Stroop task (i.e., saying "day" when shown a picture of the moon and "night" when shown a picture of the sun), 3- and 4-year-olds make up to 40% errors (Gerstadt, Hong, & Diamond, 1994). In the Dimensional Change Card Sort task (DCCS; Frye, Zelazo, & Palfai, 1995; Zelazo, Frye, & Rapus, 1996), children sort cards that depict, for example, red or blue flowers or cars. Children are first instructed to sort by one dimension (e.g., shape), and after several trials they are explicitly told to switch to the other dimension (e.g., color). Most 3-year-olds and some 4-year-olds continue to follow the first rules, even if they demonstrate knowledge of the rules and are reminded of the new rules on every postswitch trial. These results demonstrate perseveration: persistence of a response that was appropriate for an earlier problem but not for the current problem. Perseveration is thought to characterize preschoolers' problem solving (Luria, 1959).

We do not understand why preschoolers are sensitive to subtle contextual cues yet are inflexible when solving series of simple problems. To address this, we asked preschoolers to solve a series of changing induction problems. Each problem required children to generalize a novel word, the meaning of which could be inferred from *predicate cues*, phrases like “is made of …” or “has a …” that constrain the meaning of the subsequent word. Unlike most studies of word learning, this task requires flexible induction because children hear several novel words for each object, and each word follows a different predicate. Children can use predicates to assign unique meanings to each word. Each problem requires a choice among several competing responses because each word can be generalized according to one of several matching attributes (body shape, material, or part). To understand the rationale for this procedure, we must consider how children infer word meanings from context.

Inferring Word Meanings From Predicate Cues

Young children hear many words that they do not understand. Every novel word poses a problem of induction because its meaning is indeterminate (Quine, 1960). Listeners can use context, however, to infer meaning. Contextual cues are focused in the utterance containing the novel word. These cues include linguistic elements—morphemes, words, and phrases—that narrow down possible meanings. For example, rather than simply pointing to a zoo animal and saying “elephant!” a parent might say to a toddler, “*Look at the big* elephant!” or “*That* elephant *has a long nose*!” Such predicate cues have the potential to greatly facilitate word learning.

Children are sensitive to predicate cues. Preschoolers attend to syntactic cues, as previously discussed. But syntactic cues are only part of the picture. Consider two utterances: “The blop frummed the grecking SNOXES” and “The dog chased the fleeing SNOXES.” Both provide the same syntactic information, but the latter includes semantic information about *snoxes.* Preschool children utilize semantic cues: Goodman, McDonough, and Brown (1998) found that 2-year-olds use familiar predicate verbs to infer novel nouns. Preschoolers also learn new words by using semantic cues that imply inclusive (e.g., “A PUG is a kind of dog”) or contrastive (e.g., “… the CHROMIUM one, not the red one”) category relations (Au & Markman, 1987; Callanan, 1989; Clark & Grossman, 1998).

Together, local syntactic and semantic cues can powerfully guide inferences about word meaning. Yet the range of possible predicate cues for open-class words (e.g., nouns and verbs) is enormous. Predicate cues are unpredictable. Although adults sometimes use canonical predicate frames to teach children new words (Callanan, 1985; Masur, 1997), children also, certainly, hear many novel words in noncanonical predicate contexts.

Children also sometimes hear several novel words in close succession. For example, children might hear multiple novel words in enriched settings (e.g., a zoo or science museum) or new environments (e.g., a new day care center). Children also likely overhear many novel words in adults' conversations. In such contexts it is particularly likely that predicate contexts are diverse and unpredictable. For children to infer word meanings, they must adapt to changing and unforeseen predicates. Yet evidence that preschoolers fail to adapt to alternate versions of simple problems (e.g., Gerstadt et al., 1994; Zelazo et al., 1996) suggests that such flexibility is beyond them. Perhaps preschoolers who hear several novel words within a brief time can use the first word's context to infer its meaning but cannot shift their cognitive "set" to interpret a new word in a different context. Thus, preschoolers' word learning might be subject to *temporal* and *sequential* constraints on flexible induction. This possibility has received virtually no attention in the child language literature.

Testing Children's Flexible Induction of Word Meanings

In this investigation, 3- to 6-year-olds made inferences about the meanings of several unknown words. Children heard a word for a standard object and generalized the word to one of four objects: one with the same body shape as the standard, one made of the same material, one with the same affixed part, and a nonmatching "foil." A sample object set is shown in Figure 1, with the standard at top center. Body shapes, materials, and parts were all novel to children, so any word could hypothetically refer to any of these attributes. The specific meaning of each word was implied by its predicate context. Each of the three words for an object followed a different predicate: either "This one *looks like a(n)* ________," or "This one *is made of*________," or "This one *has a(n)*________."

Predicates were chosen to imply different attributes and thus refer to different categories. The predicate "is made of" implies material syntactically (i.e., mass noun are associated with substances) and semantically. Four-year-olds are sensitive to count versus mass syntax (Gordon, 1985) and to the implications of "made of" (Dickinson, 1988). In contrast, 3-year-olds are less sensitive to these implications is equivocal (Dickinson, 1988; Gordon, 1985). It is therefore an open question whether 3-year-olds will generalize words following "is made of …" to same-material objects.

The predicate "has a …" implies an object part. In reference to inanimate objects, "has a" specifies a part–whole (i.e., meronymic) relation (Winston, Chaffin, & Herrmann, 1987). There is no systematic evidence of preschoolers' sensitivity to this association.

The implications of "looks like a …" are more complex. The verb phrase was chosen to match the other predicates in conveying more information than the bare copula (i.e., "is a …"). "Looks like a …" implies that the next word, if it terminates the utterance, is a count noun. Landau, Smith, and Jones (1988, 1992) found that preschoolers generalize count nouns according to object shape. In our sets, how-

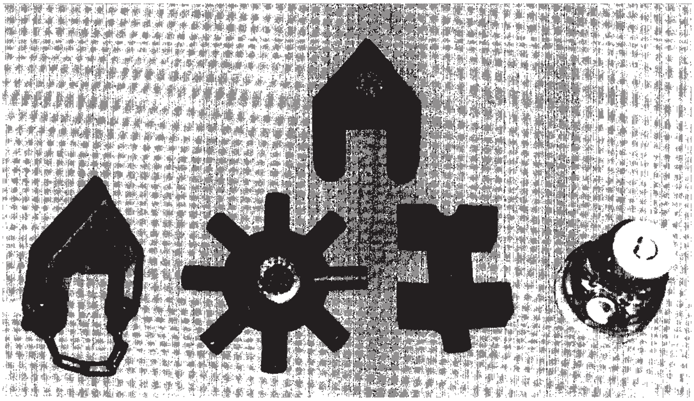

FIGURE 1 Representative stimulus set used in Preliminary Study 2 and Experiments 1 and 2. Counterclockwise from top center: standard, same-shape, same-material, same-part, and foil object.

ever, each standard differs from its body shape match by a subordinate part, which is shared by another (same-part) object. Thus, both objects partially match the standard's shape and are syntactically viable extensions of novel count nouns.

Although there is little empirical basis to predict whether preschoolers will generalize count nouns by body shape or part (but see Smith, Jones, & Landau, 1996), we can test this. A preliminary study was designed to test which object children judged most like the standard.

Children generalized three words for each object set. We can compare responses to the first word for an object to responses to the second and third words. After the first problem, there is interference from previous ones, so separating the first problem allows us to assess baseline sensitivity to predicate cues (first problem) versus flexibility in the face of interference from previous problems (second and third problems). If children generalize different words to different attributes, this will show flexibility (assuming that the children know the implications of the predicate). If preschoolers do not use predicate cues to infer word meanings, they will not be able to show flexibility. If they can use predicates but cannot flexibly adapt to changing contexts, they will generalize the first word, but not subsequent words, appropriately. Previous studies suggest that predicate-irrelevant responses will be perseverative. Perseveration—making the same inferences across changing problems or tasks—is a prototypical failure of flexibility, and it is typical of preschool children (Zelazo & Jacques, 1996). Preschoolers also, however, make unconventional inferences that are not perseverative but haphazard. Because children choose from four objects on every trial, our paradigm allows us to distinguish haphazard from perseverative errors.

PRELIMINARY STUDY

To assess children's attention to different matching attributes (i.e., body shape, material, and parts) in the object sets from Experiments 1 and 2, 3-, 4-, and 6-year-olds judged the similarity of each comparison object to its standard. Researchers have argued that preschoolers' inferences, including inferences about word meanings, are guided by perceptual salience (e.g., Inhelder & Piaget, 1964; Smith, Jones, & Landau, 1992, 1996). Although salience is difficult to define, we can objectively test whether preschoolers are more attentive to some attributes than others. Children's generalizations of words within a grammatical category (e.g., count nouns) are governed by some attributes (e.g., shape) more than others (e.g., material; Landau et al., 1988). In this study, words preceded by "looks like a …" are consistent with same-part as well as same-body-shape generalizations. If body shape matches are more compelling than part matches, this should guide children's inferences about novel count nouns following "looks like a … ." This study assesses which attributes children find, on average, most perceptually compelling.

Children from the age groups tested in Experiments 1 to 3 judged the similarity of each comparison object to its standard. Children heard no novel words. Sets were presented in a procedure similar to Experiments 1 and 2. Children's judgments were obtained by a serial choice task: After a child chose an object, it was excluded from subsequent trials. This yields a ranking of the four comparison objects from each set in order of perceived similarity to the standard.

Method

Participants

Ten 3-year-olds (5 boys, 5 girls, *M* = 3 years 9 months [3;9], range = 3;3–3;10), ten 4-year-olds (5 boys, 5 girls, *M* = 4;7, range = 4;2–4;9), and ten 5- and 6-year-olds (9 boys, 1 girl, *M* = 6;0, range = 5;9–6;3) participated. Children were recruited from a database maintained at the University of Minnesota. Most children were White and middle class.

Materials

Six sets of novel objects were used. Each included a standard and four comparison objects (see Figure 1). Within each set, the standard matched each of three comparison objects on a different attribute (body shape, body material, or affixed part). The fourth comparison object was a foil. Body shapes were relatively complex and unfamiliar. Materials also were unfamiliar (e.g., wrinkled, incandescent mylar). Parts were unfamiliar, distinct in material and shape from the object body, less than one third of the size of the object body, and perceptually separable from the body. This adheres to current theoretical accounts of object part perception (Biederman, 1987; Hoffman & Singh, 1997; Tversky & Hemenway, 1984). The parts affixed to the same-body-shape and standard objects differed, and the shapes of the same-part and standard objects differed. Each foil was roughly the same size as its standard but different in body shape, material, and part. Foils were paired with the most similar looking standard, as judged by four adults.

Procedure

Children were shown each set three times, with the standard centered and closer to the experimenter and the comparison objects aligned in front of the child in a different left-to-right order on every trial. Children were asked, “Which of these looks most like this one [standard]?” The six sets were each presented once per trial block, in random order. This order was repeated in the second and third blocks. On every trial the child was asked, “Which of these [comparison objects] looks most like this one [standard]?” Chosen objects were excluded from subsequent trials.

Results and Discussion

Children’s similarity judgments are reflected in the order of objects chosen from a set, with lower numbers indicating earlier selection and greater perceived similarity to the standard. Across sets the average choice rank orders were 1.9 (*SD* = 0.5) for same-body-shape objects, 2.3 (*SD* = 0.7) for same-material objects, 2.5 (*SD* = 0.6) for same-part object, and 3.4 (*SD* = 0.3) for foils. Children’s agreement on order exceeds chance by Kendall’s coefficient of concordance, $W = .51$, $p < .01$. Children in every age group most often chose same-body-shape objects first. Children chose foil objects last, indicating that any matching attribute (i.e., body shape, material, or part) increased children’s perception of objects similarity.

The number of same-body-shape objects chosen first (*M* = 2.7, *SD* = 1.7) was significantly greater than chance (i.e., 1.5 out of 6), $t(29) = 3.9$, $p < .001$. Children chose marginally fewer same-material objects first (*M* = 1.7, *SD* = 1.7), $t(29) = 1.75$, $p = .09$, and significantly fewer same-part objects first (*M* = 1.5, *SD* = 1.6), $t(28) = 2.2$, $p < .04$, all tests two-tailed. Overall, 3- to 6-year-olds judged that same-body-shape objects look most like the standards. Because body shape matches were significantly more compelling than part matches, we expect children to generalize novel count nouns to same-body-shape objects (see Smith et al., 1996, Experiment 3).

EXPERIMENT 1

Experiment 1 tested whether young children use predicate cues to make inferences about the meanings of successive novel words. For each standard object, children made inferences about three novel words, each following a different predicate. This was meant to reflect the variability of everyday word learning: Objects and words were novel and diverse, and every trial featured a unique combination of objects, word, and predicate. Also, every problem required choosing from among several objects, manifesting a conflict between alternative, potential defining attributes. The first problem about a set could be resolved by choosing a perceptually compelling match or by attending to predicate cues. Subsequent problems could be solved by either strategy, or by repeating the previous response.

If prior responses are most compelling, children should perseverate. Previous studies (e.g., Zelazo et al., 1996) show that 3-year-olds tend to perseverate across problems. However, because this paradigm presents multiple alternative responses to each problem, some preschoolers (particularly 3-year-olds) might instead make idiosyncratic, changing responses. This would suggest that the child is uncertain which factor (i.e., compelling matches, predicate cues, or previous inferences) is most critical. If this "haphazard" response strategy declines with age, it will suggest a developing understanding that a word's predicate context is usually the best guide to its meaning.

This task is a strong test of flexibility because on later trials children must ignore not only perceptually compelling matches but also previous primed responses. To increase the likelihood that children would establish a response set that would be difficult to inhibit in later trials, trials were blocked into six successive novel word problems with the same predicate. This also permitted us to test children's tendency to utilize predicate cues without the difficulty of shifting attention because all novel words in the first block followed same predicate cue.

Method

Participants

Thirty-six 3-year-olds (16 boys, 20 girls; *M* = 3;6, range = 3;3–3;9), thirty-six 4-year-olds (15 boys, 21 girls; *M* = 4;6, range = 4;3–4;9), and eighteen 5- and 6-year-olds (8 boys, 10 girls; *M* = 6;1, range = 5;9–6;3) were tested. Three 3-year-olds and one 4-year-old were replaced for failure to complete the study or experimenter error. Children were recruited as in the preliminary study.

Materials

Materials included the six object sets, each with a standard, same-body-shape, same-material, same-part, and foil object, as described in the preliminary study. Eighteen novel words were used for attributes of the standards: *addend, alloy, enamel, entity, granite, infix, latex, mylar, nodule, ovoid, plexus, polygon, rebec, segment, styrene, syrinx, toggle,* and *trove*. Low-frequency English words were used to ensure credible English phonological structure.[1]

Six pairs of novel objects were constructed for the familiarization phase. Two pairs had matching body shape, two had matching materials, and two had matching parts. The body shapes, materials, and parts were not nameable by children and were different from the test objects.

Procedure

Testing took place in a quiet laboratory room. The child and experimenter were seated across a small table.

Familiarization phase. To ensure that preschoolers understood the predicate cues, children were sensitized to the implications of each predicate. Children saw, one at a time, six pairs of objects, each with the same body shape, material, or part. The experimenter presented a word with the relevant predicate (e.g., "This one *is made of* porcelain. This [other] one is made of porcelain, too"), then pointed out the relevant attribute (e.g., "See, they're both hard and smooth and shiny."). Predicate order was the same as the block order in the test phase.

Test phase. Testing immediately followed familiarization. On each of 18 trials, children generalized a novel word from a standard to one of four objects. Trials were divided into three blocks, each with 1 trial per object set. Each block featured a different predicate: "looks like a(n)," "is made of," or "has a(n)." Predicate order was counterbalanced. Sets were presented in one of six random orders, and this order was repeated in each block. Words were also assigned in one of six

[1]Because these are real words, it is possible that a few children knew one or two actual meanings. This probably is not a serious concern because (a) no child demonstrated knowledge of any word; (b) the critical findings (discussed next) center on younger children, who are less likely to know any of these words; and (c) words were randomly assigned to objects, so prior knowledge would not have helped make appropriate inferences.

random orders, and random orders were assigned so that each child received a unique combination of set order and word order.

On each trial, children were encouraged to examine every object. The experimenter then placed the comparison objects, in random order, in front of the child. The experimenter held up the standard and labeled it using one of the predicates: “This one *looks like a(n)* [NOVEL WORD],” “This one *is made of* [NOVEL WORD],” or “This one *has a(n)* [NOVEL WORD].” The sentence was repeated to ensure that the child heard it. The experimenter then indicated the other objects and asked, “Which one of these also [*predicate*] [NOVEL WORD]?” During this time, the experimenter looked at the child’s face to avoid nonverbal cueing. After the child chose an object, the experimenter said, without inflection and without regard to the child’s choice, “Good job. Thank you.” The entire procedure took about 30 min to administer.

Results

Age Differences

The numbers of same-body-shape, same-material, and same-part responses in each predicate block by 3-, 4-, and 6-year-olds are shown in Figures 2, 3, and 4, respectively. From 3 to 6 years of age, children more consistently generalize count nouns following “looks like a …” to same-body-shape objects, mass nouns following “is made of …” to same-material objects, and count nouns following “has a …” to same-part nouns.

To test for age differences in use of predicate cues, we designated 6-year-olds’ modal responses *predicate appropriate*. Their modal responses in the “looks like a,” “is made of,” and “has a” blocks were same-body-shape, same-material, and same-part objects, respectively (see Figure 4). These responses are consistent with conventional interpretations. For example, a single common part or material, absent common shape, defines few object categories. We might nonetheless count same-part responses to “looks like a” as appropriate because they are syntactically viable. This would not reflect the observed developmental trajectory, however, and in any event, substituting this liberal criterion impacts none of the findings except as noted.[2] Total appropriate choices show no reliable gender difference, $F(1, 88) < 1.0$, so this factor was excluded from subsequent analyses.

Analyses were conducted to assess age differences in utilization of predicate cues, and age differences in flexibility, controlling for baseline utilization of predi-

[2]A full report of these analyses is available upon request.

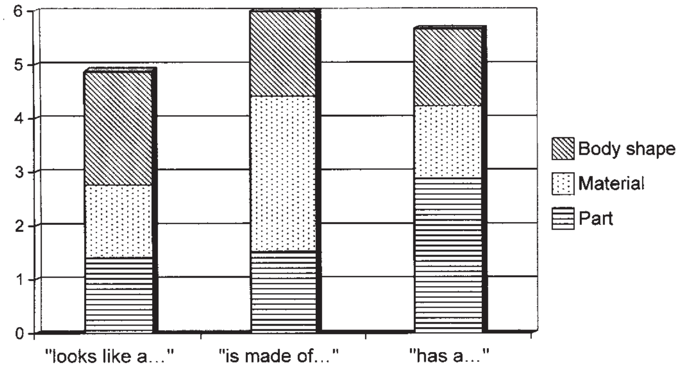

FIGURE 2 Mean number of same-body-shape, same-material, and same-part responses by 3-year-olds to words following the predicates "looks like a …," "is made of …," and "has a …." Column sums are less than 6 because children sometimes chose foil objects.

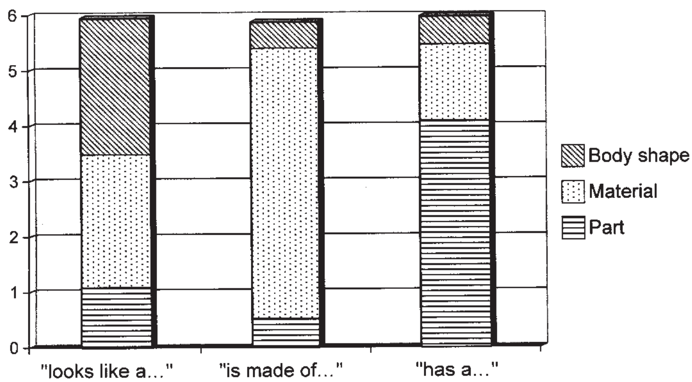

FIGURE 3 Distribution of same-body-shape, same-material, and same-part responses by 4-year-olds to words following the predicates "looks like a …," "is made of …," and "has a …."

cate cues. In all analyses in which children's performance is compared to chance, the probability of predicate-appropriate responses is set at 33%, as if children chose from only three objects rather than four. This conservative criterion compensates for children's infrequent (< 5%) selection of foil objects.

To assess age differences in baseline response to predicate cues, an analysis of variance (ANOVA) compared age groups by mean predicate-appropriate responses in the first block of problems, where there is no interference from previous problems. The relevant means (and standard deviations) are shown in Table 1. The means differed by age, $F(2, 87) = 4.9$, $p < .01$. Scheffé post hocs ($p < .05$, all tests

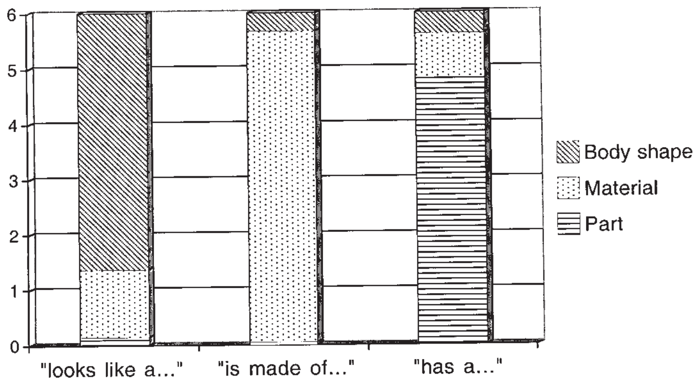

FIGURE 4 Distribution of same-body-shape, same-material, and same-part responses by 6-year-olds to words following the predicates “looks like a …,” “is made of …,” and “has a ….”

two-tailed) showed that 6-year-olds made significantly more appropriate choices than 3- and 4-year-olds. Note, however, that each age group made more appropriate responses in the first block than expected by chance: $t(35) = 4.2$, $t(35) = 5.9$, and $t(17) = 7.8$ for 3-, 4-, and 6-year-olds, respectively; all *p*s < .001. Without regard to flexibility, then, even 3-year-olds tend to use predicate cues to resolve lexical induction problems in the face of perceptually compelling distractors. This tendency becomes more consistent with age, however.

To assess age differences in flexibility, predicate-appropriate choices in the second and third blocks (which were subject to interference from previous problems) were compared by analysis of covariance, with age between-subjects and number of appropriate first block responses covaried to control age differences in baseline predicate utilization. Means (and standard deviations) are shown in Table 1. The age effect was significant, $F(2, 87) = 18.9$, $p < .001$. Scheffé post hocs ($p < .05$) showed that each age group differed from the others, and follow-ups showed that only 4-year-olds, $t(35) = 6.3$, $p < .001$, and 6-year-olds, $t(35) = 7.2$, $p < .001$, exceeded chance. Thus, on average, 4- and 6-year-olds, but not 3-year-olds, adapted their inferences to changing predicate cues.

To further assess developmental changes in flexibility, a second analysis examined changes in each child’s responses. The number of appropriate responses made by a child in the second and third blocks (averaged) was subtracted from the number in the first block. The mean difference was 0.9, 0.2, and –0.2 for 3-, 4-, and 6-year-olds, respectively. The mean for the 3-year-olds was marginally greater than zero, $t(35) = 1.9$, $p < .07$. Thus, 3-year-olds tended to make fewer predicate-appropriate responses (mean decline = 15%) when switching to a new word and predicate cue.

TABLE 1
Mean Number of Predicate-Appropriate Inferences in the First Block, and in the Average of the Second and Third Blocks, for Each Age Group in Experiments 1 and 2 (Novel Words/Attributes) and Experiment 3 (Familiar Words/Attributes)

	Predicate Block			
	First Block		*[Second+Third Block]/2*	
	M	*SD*	*M*	*SD*
Experiment 1				
3-year-olds	3.2	1.7	2.3	1.6
4-year-olds	3.9	1.9	3.7	1.7
6-year-olds	4.8	1.5	5.1	1.8
Experiment 2				
3-year-olds	4.1	1.2	2.2	1.0
4-year-olds	5.0	1.4	3.3	1.9
6-year-olds	4.5	1.2	4.9	1.7
Experiment 3				
3-year-olds	5.1	1.2	5.3	0.8
4-year-olds	5.7	0.6	5.8	0.3

Note. Experiment 1: *N*s = thirty-six 3-year-olds, thirty-six 4-year-olds, and eighteen 6-year-olds. Experiment 2: *N*s = fourteen 3-year-olds, eighteen 4-year-olds, and eight 6-year-olds. Experiment 3: *N*s = twelve 3-year-olds and twelve 4-year-olds. Designated predicate-appropriate responses were same body shape objects for “looks like a,” same-material objects for “is made of,” and same-part objects for “has a.” Maximum was six per block.

To examine how each predicate cue contributed to these results, appropriate responses to each cue were compared by ANOVA, with age and predicate order (i.e., first or second–third) between-subjects. Body shape responses to “looks like a …” increased with age, $F(2, 87) = 7.3$, $p < .002$. This interacted significantly with predicate order, $F(2, 87) = 3.3$, $p < .05$: Preschoolers’—but not 6-year-olds’—same-body-shape responses declined sharply in the second and third blocks.[3] Same-material responses to “is made of …” increased with age, $F(2, 87) = 15.9$, $p < .001$, and same-part responses to “has a …” increased significantly with age, $F(2, 87) = 5.4$, $p < .01$, but neither predicate showed significant order or

[3]With same-part responses also counted as appropriate, the age effect is not significant. This is because relaxing the criterion increases 3- and 4-year-olds’ appropriate responses more than it increases 6-year-olds’ responses. Three-, 4-, and 6-year-olds generalize “looks like a [COUNT NOUN]” to, respectively, $M = 2.1$, 2.4, and 4.6 same-body-shape objects and $M = 3.5$, 3.6, and 4.8 same-body-shape or same-part objects. Note that because the probability of choosing either a same-body-shape or same-part object is .67 (not counting foil objects), neither 3- nor 4-year-olds are above chance when this liberal criterion is applied.

Age × Order effects. Both predicates, however, showed a trend of fewer appropriate responses in later blocks, especially among preschoolers.

Count Noun Responses

As Figures 2 and 3 show, preschoolers who did not generalize "looks like a …" count nouns to same-body-shape objects did not necessarily select same-part objects (the other syntax-appropriate response). The question can be reversed, however: Did children generalize more count nouns preceded by "has a …" to same-part objects? This would show that children focused on the semantic (i.e., meronymic) implications of "has a," which establishes the same subcategorization frame as "looks like a." Three-, 4-, and 6-year-olds, respectively, chose $M = 2.9$, 4.1, and 4.8 same-part objects in the "has a …" block, and 1.4, 1.1, and 0.2 in the "looks like a …" block. The difference is significant for 3-year-olds, $t(35) = 4.7$, $p < .001$; 4-year-olds, $t(35) = 8.3$, $p < .001$; and 6-year-olds, $t(17) = 10.8$, $p < .001$. Children as young as 3 years of age, then, used a semantic cue to impute different meanings for different count nouns for the same object. Among 3- and 4-year-olds, this is attributable to the semantic implications of "has a," but not "looks like a," which did not elicit a consistent interpretation.

Individual Differences

These group differences do not capture qualitative differences in the sequences of inferences made by younger versus older children. To assess this, children's response patterns were classified as flexible, perseverative, or indiscriminate. *Flexible* children made more predicate-appropriate choices than expected by chance (at least 10 out of 18; $M = 14.2$). The probability of randomly making at least 10 predicate-appropriate choices (conservatively assuming $p = .33$) is .04 by the Binomial theorem. *Perseverative* children made fewer than 10 correct choices ($M = 6.5$) and switched fewer than 4 out of 12 successive choices ($M = 1.2$). These children either failed to inhibit primed responses or only responded only to the first predicate and repeated that response on every subsequent problem. A subset of this group was attribute biased: They made at least 14 out of 18 choices of the same attribute (e.g., same-part objects). These children might have been compelled by the first predicate cue, or by a preference for one particular attribute. *Indiscriminate* children were inflexible but not perseverative: They switched at least 4 choices ($M = 6.5$), but made fewer than 10 total predicate-appropriate choices ($M = 6.6$).

The proportions of children who produced each pattern are shown in Table 2. Flexible patterns increased from 31 to 89% between 3 and 6 years of age.

TABLE 2
Proportion of Children in Each Age Group Who Produced Each Response Pattern in Experiment 1

	Age Group		
Pattern	*3-Year-Olds*	*4-Year-Olds*	*6-Year-Olds*
Flexible	.31	.61	.89
Perseverative	.36	.28	.11
Indiscriminate	.33	.11	0

Note. *N*s = thirty-six 3-year-olds, thirty-six 4-year-olds, and eighteen 6-year-olds. See text for description of response patterns.

Perseverative patterns declined from 36 to 11%, and Indiscriminate patterns declined from 33 to 0%. The change in distribution of response patterns is significant, $\chi^2(4, N = 90) = 19.7$, $p < .001$.

Of 13 attribute-biased children (seven 3-year-olds, four 4-year-olds, and two 6-year-olds), 10 (77%; Binomial $p < .002$) selected predicate-appropriate objects in the first block and selected them again in subsequent blocks. These children either failed to inhibit their first response or treated later problems as repetitions of the first problem.

Performance Within Blocks

The incidence of perseverative response patterns suggests that some preschoolers failed to inhibit prior responses. Because there are multiple possible causes of perseveration, however, response shifts within blocks were examined. Recall that the same predicate was used throughout a block. If children perseverate because they fail to inhibit a primed response, they should make fewer appropriate responses at the beginnings of the second and third blocks than at the ends of these blocks (the first block is not relevant). Children's appropriate responses to the first two problems of the later blocks, and the last two problems of those blocks, were compared. The difference ($M = 0.1$) was not reliable. Perseveration apparently is all or none: Children either switch when the new block begins or perseverate through the entire block.

Discussion

Children as young as 3 years of age can flexibly utilize changing predicate cues to map different novel words onto different aspects of an object. This requires ignoring perceptually compelling responses, some of which are primed by previous responses. By age 6, children are adept at utilizing predicate cues to infer word meanings, regardless of previous inferences.

The data reveal two developing abilities between 3 and 6 years of age. First, older children more consistently use predicate cues, including syntactic and semantic elements, to make specific, conventionally appropriate inferences about novel words. This is shown by age-related increases in predicate-appropriate responses in the first block of problems. Whether increases stem from learning the implications of the predicates, from learning that predicates and words must be semantically and syntactically consistent, or from ability to ignore primed responses, remains to be determined. The results remind us that although sensitivity to verbal cues begins before 2 years of age (Naigles, 1990), it is several years before children can reliably use verbal cues to guide inferences under increased cognitive demands.

Second, flexibility across changing predicate cues increases between 3 and 6 years of age. Only 3-year-olds showed a significant decline in predicate-appropriate inferences from the first block to later blocks. Also, the age difference in appropriate responses in later blocks was significant, even with first-block responses controlled (as a covariate). Finally, the distribution of individual children's response patterns changed significantly across age groups, with fewer perseverative and indiscriminate patterns among older children. Why does flexibility increase?

Inflexibility is often equated with perseveration, and it is attributed to inhibitory failure. A common idea is that inhibitory capacity increases with the maturation of basic, cortical cognitive mechanisms (Bjorkland & Harnishfeger, 1990; Dempster, 1992; Guttentag & Ornstein, 1990; Passler, Isaac, & Hynd, 1985). Although there is probably truth to this claim, it leaves many questions. For example, what is the nature of these inhibitory mechanisms? In what way do they mature? Is perseveration always caused by inhibitory failure? Empirically, there is compelling evidence that perseveration sometimes stems not from inhibitory failure but from failure to update representation of the current rule (e.g., Zelazo et al., 1996). For example, Jacques, Zelazo, Kirkham, and Semcesen (1999) showed 3-year-olds a puppet performing the DCCS task and perseverating in the postswitch block. Most 3-year-olds judged the puppet to be correct. Yet when the puppet switched correctly, many 3-year-olds said the puppet was mistaken! It is difficult to explain this in terms of inhibition because children did not have to inhibit a response. Rather, they seemed to consult their representation of the sorting rule—an outdated rule, in many cases—to evaluate the puppet's sorting behavior.

The findings here also do not support the idea that perseveration is necessarily caused by immature inhibitory mechanisms. For example, inhibitory failure should cause more perseveration at the beginning of a block (when interference from the previous predicate is greatest) than at the end, but this was not found.

Also, only a minority of children (14%) made appropriate responses in the first block, then continued making those responses. Finally, 3-year-olds were as likely to produce indiscriminate as perseverative responses. Although inconclusive, these results suggest that limited inhibitory capacity cannot fully account for preschoolers' inflexibility in an inductive task with changing problems and verbal cues. Experiment 3 addresses this issue more directly.

Another way to explain these findings is to assume that children's understanding or construal of a task governs their inferences from problem to problem. Children can view a task as a series of repetitive problems or a series of unique problems. In the former case, it is most efficient to analyze the first occurrence of the problem, then repeat the response whenever the problem recurs. This strategy will appear perseverative if, in fact, subsequent problems differ. In the latter case (i.e., viewing problems as unique) children should analyze each problem separately. If their analysis focuses on the current verbal cue, they will make conventionally appropriate inferences. If they are unsure which cue to select, they might shift responses haphazardly (perhaps seeking feedback; Speer, 1984). Alternately, they might use a default strategy of choosing the most perceptually compelling response, a pattern that also will appear perseverative. The General Discussion section describes factors that might cause children to adopt one or another of these strategies.

Implications for Word Learning

The data presented in this article extend previous reports that children as young as 2 years of age use predicate cues to make inferences about word meanings (Goodman et al., 1998). Even with interference from previous, perceptually compelling choices, 4-year-olds flexibly utilized changing predicate cues to infer word meanings. This suggests that when 4- to 6-year-olds hear several novel words, they can use each word's immediate verbal context to infer its meaning.

The data also extend accounts of preschoolers' tendency to generalize novel count nouns to same-shape objects (Smith, 1995). Three- and 4-year-olds did not generalize count nouns preceded by "looks like a" to same-body-shape objects. This was not because they made another syntax-consistent response (i.e., same part). Rather, the predicate did not seem to strongly imply any interpretation to preschoolers, so they relied on perceptually compelling or primed responses. The predicate "looks like a" *does* conventionally imply body shape, however, as shown by 6-year-olds' responses. Preschoolers' association between object shape and count nouns is very context sensitive, however. The association is contingent on children's age and native language, the salience of different perceptual attributes, and objects' ontological kind (Imai & Gentner, 1997; Jones, Smith, & Landau, 1991; Landau et al., 1992; Smith et al., 1996). These variables cannot, however, explain why children did not generalize nouns according to body shape. What can?

One possibility is the structure of the stimuli. A nonmatching part might make preschoolers question whether the standard and same-body-shape objects belong to the same category. However, another possible explanation must be considered. Attention to body shape might have been attenuated by subtle semantic implications of "looks like a …." The predicate can imply subjective apperception (e.g., "That ink blot *looks like* a cat") or hedging (e.g., "It *looks like* a fish, but it's really a mammal"; see Lakoff, 1973). These implications might have licensed children to select any (subjectively) compelling match. This possibility, although inconsistent with 6-year-olds' responses, was tested in a follow-up study of twelve 3-year-olds (5 boys, 7 girls; M = 3;4) and twelve 4-year-olds (8 boys, 4 girls; M = 4;6). These children completed a variant of the novel word task. The predicate "looks like a" was replaced with the copula "is a," and all children heard "is a" in the first block. Their mean number of first block, same-body-shape choices was compared to the number of same-body-shape choice by 3- and 4-year-olds who heard "looks like a" in the first block ($n = 24$). Preschoolers who heard "is a" made a mean of 1.7 same-body-shape choices ($SD = 1.5$). Those who heard "looks like a" first made a mean of 2.8 same-body-shape choices ($SD = 1.7$). The effect of predicate ("is a" vs. "looks like a") was reliable, $t(46) = 2.2$, $p < .04$, but contrary to the hypothesis, children made fewer same-body-shape generalizations of words following "is a." The subtle semantic implications of "looks like" did not prevent preschoolers from generalizing count nouns according to body shape.

EXPERIMENT 2

In Experiment 1, 3-year-olds showed initial utilization of predicate cues. This increased substantially with age. On later problems, 4- and 6-year-olds, but not 3-year-olds, flexibly shifted their inferences about novel words. Because these results have implications for our understanding of children's problems solving and word learning (see General Discussion), the study was replicated to rule out the possibility that the results are due to stochastic variance or sampling error.

Another goal was to test the robustness of the results by eliminating the familiarization phase used in Experiment 1. Familiarization was meant to ensure that children knew the implications of the predicates. It also, however, provided support that is not typically available in naturalistic situations. Older children, who are more accustomed to following instructions in highly verbal, formal tasks, might have benefitted more from familiarization. The procedure might therefore have exaggerated the age differences obtained in Experiment 1. It is important to verify that children make similar inferences without the benefit of familiarization.

Method

Participants

Eighteen 3-year-olds (8 boys, 10 girls; *M* = 3;8, range = 3;1–3;11), eighteen 4-year-olds (7 boys, 11 girls; *M* = 4;6, range = 4;3–4;10), and eight 6-year-olds (4 boys, 4 girls; *M* = 6;0, range = 5;6–6;6) participated. Preschoolers were recruited from a database maintained at the University of Minnesota and from preschools in Nashville, Tennessee. Six-year-olds were recruited from a public after-school program in Nashville. Children were predominantly middle class and White.

Materials

The objects and words from the test phase of Experiment 1 were used.

Procedure

The procedure from Experiment 1 was replicated without the familiarization phase.

Results

The mean number of predicate-appropriate choices (and standard deviations) in the first block, and in the second and third blocks (averaged), is shown in Table 1 (bottom section). The age effect in the first block was marginally significant, $F(2, 41) = 2.5$, $p < .10$. The age effect in the last blocks was significant, $F(2, 41) = 8.5$, $p < .001$. Post hoc Scheffé tests showed that 6-year-olds made significantly more predicate-appropriate inferences than 3-year-olds. The mean difference between the first block and the average of the last two blocks was 1.9, 1.7, and –0.4 for 3-, 4-, and 6-year-olds, respectively. The age difference was reliable, $F(2, 41) = 4.2$, $p < .03$. Post hoc tests showed that the difference was larger for 3- and 4-year-olds than for 6-year-olds. The replication therefore shows a striking age-related increase in flexibility: Preschoolers utilized predicate cues less reliably after the first inference about a set.

Separate one-way ANOVAs compared appropriate responses to each predicate block, with age between-subjects. There was a reliable increase with age in same-material generalization of words following “is made of … ,” $F(2, 41) = 6.8$, $p < .005$. There was also a significant increase in same-part generalizations of words following “has a … ,” $F(2, 41) = 3.5$, $p < .05$. There was a trend toward more body shape generalization of words following “looks like a … ,” $F(2, 41) = 2.3$, $p < .11$. As in Experiment 1, developmental changes in flexibility accompany increasing attention to predicate cues.

The qualitative nature of the age differences is apparent in children's response patterns. Among 3-year-olds, 7 (39%) were flexible, 5 (28%) perseverated, and 6 (33%) were indiscriminate. This distribution does not differ from Experiment 1 (31%, 36%, and 33%, respectively), $\chi^2(2, N = 44) < 1$, *ns*. Twelve 4-year-olds (67%) were flexible, 4 (22%) perseverated, and 2 (11%) were indiscriminate. This does not differ from Experiment 1 (61%, 28%, and 11%), $\chi^2(2, N = 44) < 1$, *ns*.

Between-Experiment Comparison

To test whether predicate familiarization increased appropriate responses, particularly in 6-year-olds, total predicate-appropriate responses were entered in a 3 (age: 3-, 4-, and 6-year-olds) × 2 (Experiments: 1 and 2) ANOVA ($N = 134$). The age effect was significant, $F(2, 128) = 28.5$, $p < .001$, but the experiment effect, $F(1, 128) < 1$, and the interaction, $F(2, 128) < 1$, were not. Tests of other variables (e.g., responses to each predicate, to the first block, and to the second–third blocks) showed no reliable between-experiment differences. Therefore, predicate familiarization had no measureable effect.

Combined Results of Experiments 1 and 2

Because the results of Experiments 1 and 2 are so similar, the data were aggregated for a more powerful test of several effects. First, the mean number of predicate-appropriate responses in the second and third blocks (averaged) was subtracted from the mean in the first block (see Figure 5). The difference between the two was significantly greater than zero among 3-year-olds ($M = 1.2$), $t(53) = 3.5$, $p < .002$, and marginally greater among 4-year-olds ($M = 0.7$), $t(53) = 2.0$, $p < .06$. Among 6-year-olds, the difference ($M = 0.3$) was not greater than zero, $t(25) = 0.7$, *ns*. A one-way ANOVA confirms a significant decrease in difference scores with age, $F(2, 131) = 3.3$, $p < .04$. The aggregated sample of 3-year-olds made more appropriate responses than expected by chance in the first block ($M = 3.5$, $SD = 1.6$), $t(53) = 6.8$, $p < .001$, but not in the last blocks ($M = 2.3$, $SD = 1.4$), $t(53) = 1.4$. Four-year-olds made more appropriate responses than expected in the first block ($M = 4.3$, $SD = 1.8$), $t(53) = 9.1$, $p < .001$, and in the last blocks ($M = 3.6$, $SD = 1.7$), $t(53) = 6.7$, $p < .001$.[4]

Aggregating the samples also allows a more powerful test of preschoolers' tendency to generalize "looks like a [NOVEL WORD]" to same-body-shape objects.

[4]As in Experiment 1, this pattern of results is unchanged if same-part responses to "looks like a [NOVEL WORD]" also are considered appropriate.

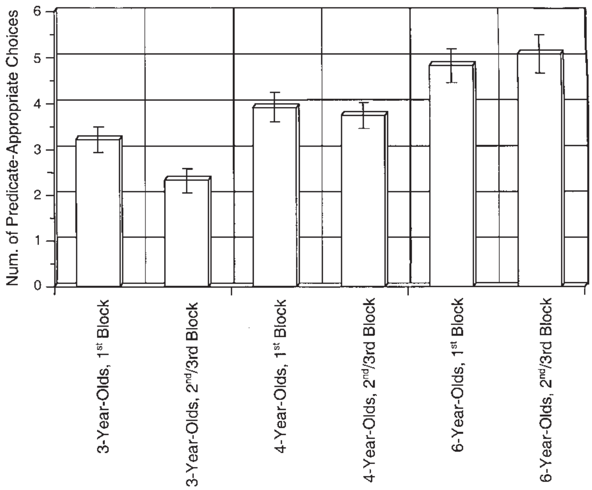

FIGURE 5 Number of predicate-appropriate inferences in the first block of problems, and in the second–third blocks (averaged), with standard deviations, by age group.

Among all 3- and 4-year-olds who heard the predicate "looks like a" in the first problem block, the number of same-body-shape choices (M = 3.2, SD = 1.7) was greater than the number expected by chance (2.0, or 33%), $t(35) = 4.1$, $p < .001$. In contrast, among all 3- and 4-year-olds who heard "looks like a" in the second or third block the number of same-body-shape choices (M = 2.0, SD = 2.0) did not exceed chance, $t(71) < 1$.

Discussion

The results of Experiment 1 are not spurious. They closely replicate across samples and across a procedural variation; specifically, whether children are familiarized with the predicate cues. The familiarization phase in Experiment 1 had no measurable effect on performance. Based on the combined results of these experiments, we can conclude that a minority of 3-year-olds reliably use predicate cues to make inferences about successive novel words. Many 3-year-olds shift their inferences without reference to predicate cues (i.e., an indiscriminate pattern). Others make the same inference about successive words for the same stimulus array (i.e., a perseverative pattern). Presumably, the latter group either fails to inhibit prepotent responses or believes that successive problems are fundamentally alike and therefore deserve the same response. Possible reasons for this are proposed in the General Discussion.

There is no evidence that familiarization taught 6-year-olds the predicates' implications or caused them to associate "looks like a …" with body shape. If it had, we could not assume that 6-year-olds' modal responses in Experiment 1 were based on mature understanding of the predicates. Six-year-olds in Experiments 1 and 2 generalized an average of 4.5 count nouns following "looks like a" to same-body-shape objects—over twice the number expected by chance. In contrast, they selected an average of 1.1 same-material objects and 0.3 same-part objects, suggesting that meronymic interpretations were not strong alternatives for words preceded by "looks like a."

The results suggest that, other things being equal, 6-year-olds tend to generalize words following "looks like a …" to artifacts with the same overall body shape (i.e., the largest unit of an object to which other parts are affixed). This presumably reflects a conventional, learned association that overrides other syntax-appropriate (e.g., same-part) responses. The tendency is emerging in 3- and 4-year-olds: When the first predicate block is "looks like a," so there is no interference from prior responses, 3- and 4-year-olds tend to generalize words according to body shape. Apparently they weakly associate count nouns with body shape, but the association does not reliably override competing factors (e.g., prior responses).

EXPERIMENT 3

The findings so far do not explain why most 4-year-olds but few 3-year-olds are flexible in a novel word learning task. In a gross sense this resembles the age-related pattern found in tasks such as the DCCS (Zelazo et al., 1996). Yet the task in this experiment is quite different from previous ones. Those tasks asked children to follow explicit, unambiguous, and repetitive rules such as "This is the color game …. All the red ones go in this box, and all the blue ones go in that box" (Zelazo et al., 1996) or "When you see this card, I want you to say 'day' …. When you see this [other] card, I want you to say 'night' " (Gerstadt et al., 1994, p. 134; see also Diamond & Taylor, 1996; Luria, 1959).

At least two general features of this novel word task differ from previous flexibility tasks. Because there is a gross resemblance in the age-related results of this task and previous tasks, these general features might at first glance be taken as irrelevant. Yet these factors may in fact impact flexibility in profound ways. First, this task is more variable than previous tasks. Children must choose from a greater number of possible responses on every trial. The stimuli—complex novel objects—embody more (and more distracting) information than pictorial stimuli used in most studies (Deák & Bauer, 1996). Also, the problems within the task vary considerably. Every trial incorporates a unique combination of novel word, novel objects, and predicate cue. At least two of these variables change on every trial.

The effect of task variability on flexibility is unknown. If cognitive resources are limited, and variable tasks require more information-processing resources, children might fail to inhibit prepotent responses and perform less flexibly. On the other hand, greater variability between problems might alert children that every problem is unique and therefore requires an independent analysis.

The novel word task also differs from previous tasks because rather than following explicit, determinate rules, it demands utilization of probabilistic cues to solve indeterminate problems. By nature, predicate cues are probabilistic, and novel words are indeterminate (Quine, 1960). No explicit instruction to use predicate cues is given. Rather, the task demands implicit linguistic knowledge that predicate cues constrain the words that they modify. Again, the effect of this characteristic is unknown. On one hand, it might be difficult to separate predicate cues from a dynamic milieu of objects and utterances in order to infer novel word meanings. The fact that 3-year-olds did not always utilize predicate cues in the first block indicates that this indeed is difficult.

The effect of these features (variability and determinacy) on flexible problem solving was explored in Experiment 3. A control task was designed with the variety and variability of the novel word task, but with unambiguous, determinate questions akin to the DCCS or the day–night Stroop task. Children were asked to find an object matching the standard on some familiar, named attribute. In one problem, for example, children were told that the standard (e.g., a paper square with an affixed button) "looks like a square" and then were asked to find another one that looks like a square. Among the choices were an object with the same shape (i.e., square), one made of the same material (e.g., paper), and one with the same affixed part (e.g., a button). Across trials there were three problems about each of six object sets, just as in the novel word task.

By holding between-problem and variability constant across tasks, we can test whether children's flexibility is influenced by indeterminate (novel words and attributes) versus determinate (familiar words and attributes) problems. The control task problems are determinate because children need not select and utilize predicate cues to resolve uncertainty. They can simply look for another exemplar of the attribute label. The task still tests flexibility, however, because across trials children must select different objects. If utilization of indeterminate cues is difficult for 3-year-olds, they should perform significantly better in the first block of the control task than in the first block of the novel word task.

The control task tests the alternative hypothesis that flexibility in Experiments 1 and 2 increased with age because preschoolers are more susceptible to fatigue, distraction, or boredom. (The task lasted about 30 min.) To rule out this rather mundane albeit plausible explanation, the control task was designed to be identical in length and structure to the novel word task (Experiment 1).

Method

Participants

Twelve 3-year-olds (6 boys, 6 girls; *M* = 3;6, range = 3;3–3;9) and twelve 4-year-olds (5 boys, 7 girls; *M* = 4;7, range = 4;2–4;11) participated. Children were recruited as in Experiment 2.

Materials

Six new sets of novel objects were created. Each included a standard and four comparison objects, three of which matched the standard on body shape, material, or an affixed part. Matching attributes were ostensibly familiar to children. Body shapes were square, circle, triangle, ovoid, star, and heart. Materials were wood, glass, paper, sponge, (fake) fur, and Play-Doh™. Parts were bells, small teddy bears, butterflies, dinosaurs, sea shells, and "googly-eyes." Attributes were labeled with familiar words: *square, circle, triangle, egg, star, heart, wood, glass, paper, sponge, fur, Play-Doh, bell, bear, butterfly, dinosaur, shell,* and *eye.*

To equate the length and structure of this task with Experiment 1, six pairs of objects were used in a familiarization phase. Two pairs had the same shape (rectangles and cones), two were of the same material (plastic and metal), and two had the same parts (lion and car).

Procedure

The familiarization and test procedures, and design, were analogous to Experiment 1. However, children generalized familiar words for attributes of a standard (e.g., "This one looks like a *star*.") to one of the four comparison objects (e.g., "Which of these also looks like a *star*?"). Children matched 18 familiar words to matching attributes, including 3 words for each standard.

Results

Mean appropriate responses in the first block, and in the last two blocks (averaged), are shown in Table 1. Three- and 4-year-olds' means were compared in a multivariate analysis of variance with experiment (1: novel words vs. 3: familiar words) and age between-subjects. The age effect was significant, $F(2, 91) = 6.4$, $p < .005$. The experiment effect also was significant, $F(2, 91) = 44.5$, $p < .001$. Univariate tests showed the effect in both the first block, $F(1, 92) = 21.9$, $p < .001$, and the last blocks, $F(1, 92) = 53.7$, $p < .001$. The Age × Experiment interaction was not reliable, $F(2, 91) < 1$.

TABLE 3
Mean Number of Predicate-Appropriate Responses to Each Predicate and Total Appropriate Responses, in Experiments 1 and 2 (Novel Words and Attributes) and Experiment 3 (i.e., Familiar Attributes and Words)

	Predicate Block							
	"looks like a"		*"is made of"*		*"has a"*		*Total*	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Experiments 1–2								
3-year-olds	2.3	1.7	3.0	2.1	2.8	1.8	8.1	2.6
4-year-olds	2.5	2.2	4.9	1.6	4.1	1.9	11.5	3.9
6-year-olds	4.5	1.8	5.5	1.3	4.7	1.7	14.8	3.8
Experiment 3								
3-year-olds	5.1	1.3	4.8	1.1	5.7	0.6	15.7	2.2
4-year-olds	5.6	0.8	5.7	0.5	6.0	—	17.3	1.0

Note. *N*s = twelve 3-year-olds and twelve 4-year-olds. Designated appropriate choices are same body shape objects for "looks like a," same-material objects for "made of," and same-part objects for "has a." Maximum was 6 per block or 18 total.

Three-year-olds made a mean of 88% appropriate responses in the second and third blocks of the familiar word control task. Three-year-olds' difference scores (first block – [second + third blocks]/2) did not differ from zero ($M = 0.2$), $t(11) < 1$; and neither did the 4-year-olds' ($M = 0$). Flexibility is reflected in individual data: Every 3- and 4-year-old produced a flexible response pattern (as defined in Experiment 1).

To ascertain that the familiar word task enhances flexibility by reducing reliance on predicate cues, separate *t* tests compared preschoolers' appropriate responses to each predicate cue in Experiments 1 and 2 (combined) and Experiment 3. Means (and standard deviations) are shown in Table 3. The difference between experiments was significant for "looks like a," $t(94) = 7.7$, $p < .001$.[5] It was also significant for "is made of," $t(94) = 3.2$, $p < .005$, and "has a," $t(94) = 5.8$, $p < .001$.

Discussion

The data suggest that age differences in flexibility are not due to fatigue, distraction, or boredom: Three-year-olds in Experiment 3 made more appropriate choices than 6-year-olds in Experiment 1.

[5]This finding is unchanged if same-part responses to "looks like a [NOVEL WORD]" (in Experiments 1 and 2) also are considered appropriate.

Preschoolers were substantially more flexible than their agemates in Experiments 1 and 2. Three-year-olds made as many appropriate responses in later blocks as in the first block. This suggests that preschoolers' flexibility in generalizing novel words is limited by the demands of utilizing variable predicate cues. That demand was reduced in this task because children could match familiar words (e.g., "square") to exemplars (e.g., square objects).

The experiment also addresses another central issue, albeit indirectly. Children can match the familiar attributes and labels in the DCCS (Zelazo et al., 1996), yet in that task, most 3-year-olds perseverate after the rule shift. No child perseverated in our control task. Why does this task reveal flexibility that other tasks do not? Perhaps in addition to the determinacy of task cues, the variability of the task is important. Variable tasks might prevent children from representing successive problems as repetitions of a single problem. This might compel children to search for information (e.g., predicates or labels) to resolve each problem. In the control task, finding that information (i.e., familiar words) is trivially easy.

GENERAL DISCUSSION

Flexible induction is the ability to make different generalizations or groupings in response to different problems. This requires sensitivity to task context and task demands. Flexible induction is necessary for word learning as well as for scientific thought, analogical reasoning, and creative problem solving. In general, it is needed to solve any unfamiliar or unexpected problem.

Many questions about the development of flexible cognition remain unresolved. We know little about how the sequence and timing of successive problems impacts children's reasoning. We know little about how flexibility changes as children's cognitive capacities (e.g., inhibition) mature, how children generate ad hoc inferences, or how children's understanding of a task impacts their analysis of the problems within the task. This investigation speaks to some of these questions.

The data show that 3-year-olds can use predicate cues to interpret a novel word. They fail to do so, however, when there is interference from distracting matching stimuli, some of which are primed by previous responses. Three-year-olds tend to make appropriate inferences about the first word for an object set, but not about subsequent words. By comparison, 4-year-olds made many predicate-appropriate inferences about the first *and* subsequent words. Note, however, that one third of 3-year-olds made a critical number of predicate-appropriate inferences (i.e., 10 or more out of 18 at p = .33 per inference), and two fifths of 4-year-olds did *not*. Individual differences in early problem-solving flexibility have not been rigorously investigated.

This finding complements previous research on children's ability to utilize predicate cues to learn words. There is evidence that 2-year-olds can use syntactic cues (Naigles, 1990) and semantic cues (Goodman et al., 1998) to infer word meanings. However, despite detailed investigations of 3-year-olds' inflexibility in rule use tasks (e.g., Jacques et al., 1999; Zelazo et al., 1996), there has been almost no systematic study of the development of flexibility of inductive inferences.

These data suggest that most 4-year-olds can overcome multiple sources of interference (e.g., previous responses) to make successive appropriate inductive inferences. In contrast, few 3-year-olds overcome this interference. Yet 3-year-olds are uniformly flexible in a control task (Experiment 3) analogous to the novel word task. Thus, 3-year-olds *can* flexibly shift inferences about words for objects (see also Ebeling & Gelman, 1989). For some reason the novel word task prevents this. Curiously, though, tasks that are less variable than the control task (e.g., the DCCS) also elicit perseveration from 3-year-olds. How can we reconcile this apparent inconsistency?

One explanation for early perseveration is immaturity of inhibitory functions controlled by the frontal cortex (Dempster, 1992; Passler et al., 1985). This is consistent with the theory that cognitive skills mature as a function of endogenous information-processing capacities (Bjorkland & Harnishfeger, 1990; Guttentag & Ornstein, 1990). Although this is no doubt true in some respects, it cannot easily account for data on flexible problem solving. For example, perseveration in the DCCS seems to stem from failure to update representations of the current rule within a rule system, not inability to inhibit a prepotent response (Jacques et al., 1999; Zelazo et al., 1996). Also, when children have more than two choices, some of their errors are not perseverative (Zelazo, Reznick, & Spinazzola, 1998). In Experiments 1 and 2, similar proportions of 3-year-olds produced indiscriminate and perseverative response patterns. Even among children who perseverated, the role of inhibition was not clear. A total of 37 children (28%) perseverated in Experiments 1 and 2. Of these, 16 (12% of the total) continued to make responses that were appropriate in the first block (e.g., if the first predicate block was "is made of," they persistently chose same-material objects). Apparently only a minority of children failed to inhibit responses primed by early problems. Most children who perseverated (n = 21) did *not* consistently select a particular attribute; rather, across sets they chose objects that matched the standard on different attributes. This could reflect ignorance that predicate cues govern word meanings, a hypothesis explored next. Children might reselect the same object on successive trials, not because they fail to inhibit a prepotent response but because they adopt a "stick with the winner" strategy.

Available evidence does not support a simple maturation-of-inhibition account of the development of flexible problem solving. A more elaborate account, involving several factors (perhaps including inhibition), could accommodate the evidence. Any account must explain the following findings:

1. Most 3-year-olds are inflexible in repetitive tasks consisting of unambiguous, determinate questions (e.g., DCCS; day–night Stroop). Most 4-year-olds also are flexible.
2. Most 3-year-olds are inflexible in a variable task consisting of indeterminate problems with probabilistic cues (Experiments 1 and 2). Most 4-year-olds are flexible.
3. Three- and 4-year-olds are uniformly, consistently flexible in a variable task consisting of determinate problems with unambiguous cues (Experiment 3).

This pattern of results is depicted in Figure 6. Note that 3-year-olds respond flexibly only when the task is variable *and* the cues to each problem are determinate. Most 4-year-olds are flexible when *either* supportive factor is present.

This pattern of results suggests that two interrelated skills or sensitivities develop between 3 and 5 years of age. First, children pragmatically learn how to interpret certain speech acts (Donaldson, 1978; Siegal, 1991). In a series of questions, each question is defined by its specific verbal content. Preschool children must learn to *decontextualize* such utterances, considering only the meaning contained in the specific speech act (Olson, 1977). For example, excepting certain idioms, the direct object of a sentence must be semantically and syntactically consistent with its predicate; otherwise, the utterance is anomalous, ungrammatical, or both. If a content word is unfamiliar, listeners can at least assume that its meaning is consistent with the predicate context. Two- to 3-year-olds do not seem to recognize this. They interpret speech acts using a combination of imported beliefs, broad context (e.g., previous utterances), and idiosyncratic associations. Predicate content is "blended" with these other sources. For example, when asked bizarre

AGE	TASK: Novel Words and Attributes	Familiar Words and Attributes	DCCS
	Variable	*Variable*	*Repetitive*
	Predicate Cues	*Determinate (Words)*	*Determinate (Rules)*
3-Year-Olds	Inflexible	Flexible+	Inflexible
4-Year-olds	Flexible	Flexible+	Flexible

FIGURE 6 Summary of results from the novel word inference task (Experiments 1 and 2), the familiar word control task (Experiment 3), and Zelazo, Frye, and Rapus's (1996) Dimensional Change Card Sort (DCCS) task. Tasks are categorized by variability and by cue ambiguity. Inflexible = modal perseverative/indiscriminate response patterns; Flexible = modal flexible patterns; Flexible+ = uniformly flexible response patterns.

questions such as “Is red heavier than yellow?” preschoolers not only accept the anomaly but import idiosyncratic content into their replies (e.g., “Yes … because there’s water in it”; Hughes & Grieve, 1983). Such data suggest that young children do not know *which* speech acts to interpret strictly in terms of the specific linguistic content.

The effect of decontextualization is difficult to isolate because it is correlated with increases in verbal comprehension that would impact utilization of predicate cues. In these studies, development of verbal comprehension is indicated by an increase with age in appropriate inferences in the first block (Experiments 1 and 2). Development of decontextualization is seen in 3-year-olds’ less reliable use of predicate cues in later blocks (when prior responses conflict) than in the first block, compared to 6-year-olds’ reliable use of predicate cues in all blocks. Taken alone, 3-year-olds’ decline in appropriate responses might be explained as inhibitory failure. Experiment 3, however, shows that when reliance on predicate cues is reduced, 3-year-olds perform quite well after the first block. So 3-year-olds’ performance is best explained not as a general inhibitory failure but as failure to decontextualize sentential information to make lexical inferences.

This does not explain why 3-year-olds are flexible in the familiar word control task but not in tasks such as the DCCS. Perhaps this is because preschoolers are poor at recognizing when each problem in a series is unique. When asked multiple questions about a stimulus array, preschoolers give odd sequences of responses (Rose & Blank, 1974; Siegal, 1991). They often “homogenize” questions, treating different successive questions as identical. For example, Green and Flavell (1986) showed children a deceptive object like an apple-shaped candle, and they asked questions about its appearance (i.e., “What does this look like?”) and function (i.e., “What is it really and truly?”). Many 3-year-olds perseverated, giving the same answer to each question. Deák, Ray, and Brenneman (1998) showed that children who perseverate in this task also perseverate across two distinct questions about nondeceptive objects. This suggests a general tendency to homogenize distinct questions about a stimulus. Deák and Maratsos (1998) made questions about deceptive objects’ function and appearance more distinctive by providing contrasting category labels and function demonstrations. In this task, 3-year-olds consistently produced different words for objects’ appearance and function. It seems that making the questions more distinct helped children realize that different responses (i.e., productions) were expected.

Deàk and Maratsos (1998) finding implies that variable tasks might facilitate flexibility by highlighting changes between problems. In tasks like the DCCS (Zelazo et al., 1996), children might not recognize when a problem has changed and, therefore, do not reanalyze the new problem. Across trials, children see similar items (e.g., red or blue cars or flowers) and make similar responses (i.e., put each item in the left or right box). The experimenter asks similar questions in which only one or two familiar words (e.g., *red* and *blue, car* and *flower*) alternate.

The task is very simple for 3-year-olds, as shown by their preswitch performance. Perhaps during the first trials, 3-year-olds are "lulled" into thinking that they understand the task and need not reanalyze any subsequent problems. The initial ease of the task, which makes 3-year-olds' perseveration so striking, might actually work against them! Traditional information-processing capacity accounts would predict that more variable tasks are more demanding. However, with respect to flexibility, tasks that *seem* simple and repetitive, but actually require periodic response shifts, might be more difficult for preschoolers. As evidence, the control task (Experiment 3) posed problems that were simple and determinate yet more variable than DCCS problems.[6] Yet 3-year-olds consistently analyzed each new problem and performed flexibly.

Anecdotal evidence suggests that preschoolers who perseverated tended to interpret the novel word task as a series of repetitive questions. Some seemed to believe that later problems about a set tested their memory of the first response. One 3-year-old, for example, said "I have a good memory for that!" after selecting the same object for the second time. Others seemed overly confident in their performance, stating decisively, "I got them all right!" after completing the task. Although such evidence must be interpreted cautiously, it implies that at least some children who perseverated believed they performed the task correctly. This is reminiscent of the findings reported by Jacques et al. (1999) on 3-year-olds' evaluation of puppet DCCS performance. As in that study, perseveration seems to stem from children's construal of the task, not inability to inhibit primed responses.

The hypothesis is that decontextualization of verbal cues, and discerning whether problems must be solved independently, are both necessary for flexible induction. These skills are interdependent. Decontextualizing current verbal context probably helps children construe successive problems as unique, and construing a task as variable probably compels children to search for critical verbal cues. Some findings imply this interdependency. For example, recognizing that a word is novel should trigger an analysis of the most recent verbal contextual cues. Preschoolers do not always recognize that a word is unfamiliar (Merriman & Bowman, 1989), however. In this case they would not encode the novel word as a uniquely indeterminate problem. In addition, preschoolers generally have trouble detecting whether a problem is indeterminate—that is, whether available evidence is sufficient to solve a problem. In problems with several possible answers, pre-

[6]Although we have no metric to precisely quantify and compare variability, the tasks differ on a number of dimensions including number of different stimulus items presented on each trial, number of different response options on each trial, dimensional complexity of the stimulus items, proportion of trials in which stimulus items changed, number and type of distinct questions, and number of sentence elements (i.e., predicates, novel words, or both) changing across questions. On all of these dimensions, the control task is more variable

schoolers tend to “settle” on the most apparent response to the first problem, then reproduce that response (after a cursory analysis or no analysis) for subsequent problems (Speer, 1984; Vurpillot, 1968). Detection of indeterminacy improves somewhat around 5 or 6 years of age (Fabricius, Sophian, & Wellman, 1987; Patterson, Cosgrove, & O’Brien, 1980; Revelle, Wellman, & Karabenick, 1985), around the time children become consistently flexible in the novel word task. Thus, ability to detect indeterminacy might contribute to age differences in flexibility in the novel word induction task (Experiments 1 and 2)

Although the two-factor hypothesis requires further investigation, several other findings are generally consistent. Ebeling and Gelman (1989) reported modest flexibility in 3-year-olds’ judgments of which object is “big” or “little” across contextual changes (e.g., a small hat with a medium hat and then with a tiny hat). All questions had to be interpreted by physical contextual cues, however, and not decontextualized predicate cues. From one trial to the next, one of two objects was switched or an object was added, and different object pairs were presented on different trials. This variability apparently was sufficient to signal a new problem. Future investigations should examine how different aspects of between-problem variability contribute to children’s realization that each problem must be solved independently. Kalish and Gelman (1992) found that 4- but not 3-year-olds were flexible in making inferences about novel properties of novel objects (e.g., wooden pillows). This study featured indeterminate problems that required decontextualization of verbal cues, similar to the novel word task in Experiment 1 and 2. All of this evidence is suggestive, but we now require more precise tests of the relations among problem indeterminacy, problem variability, and related cognitive variables.

Implications for Word Learning

Preschool children use semantic (Goodman et al., 1998), syntactic (Naigles, 1990), and pragmatic (Akhtar, Carpenter, & Tomasello, 1996) cues to constrain their inferences about word meanings. Together, proximal syntactic and semantic cues constitute the predicate context of open-class words (e.g., nouns). This study suggests that between 3 and 6 years of age, children gradually increase their reliance on predicate cues to infer word meanings. In some situations, predicate context is repetitive and predictable. For example, when reading an alphabet picture book, each page might depict a discrete item, which the parent labels using the same predicate (e.g., “A *is for* apple … B *is for* bat …,” etc.). In many situations, however, predicates are unpredictable and variable across utterances and speakers. In situations in which children hear several novel words, they should inhibit previous contextual cues to infer the most recent word meaning.

There is unfortunately a dearth of evidence pertaining to temporal and sequential effects in preschoolers' word learning and lexical inferences. The magnitude and range of effects of prior lexical and sentential inferences on children's subsequent word learning remains to be established. The effect is likely a function of variables including interval between inferences, the nature of the communicative interaction, and the structure and significance of the stimulus array.

Preschoolers in Experiments 1 and 2 systematically generalized words following "is made of" to same-material objects and words following "has a" to same-part objects. However, they had only a weak bias to generalize count nouns preceded by "looks like a" to artifacts with the same main-body shape, and this bias was readily disrupted by interference from primed responses. This extends accounts of preschoolers' inferences about the meanings of count nouns (Smith, 1995). The absence of the bias was not because body shape matches were not compelling; the preliminary study showed that they were the most compelling match. The association between count nouns and body shape was not ameliorated by the semantic connotations of "looks like a …" (e.g., hedging). This was shown in the Experiment 1 posttest using the copula (i.e., "is a"). A likely explanation is that nonmatching parts cause confusion about whether objects are members of the same category. A word after "looks like a …" is a category label. Some objects are categorized by overall body shape and by affixed parts. For example, affixing a handle to a vessel changes its category from "glass" to "mug." Preschoolers attend to parts when generalizing category labels (Smith et al., 1996), so they might have been confused by nonmatching parts. Note, however, that a matching part is not a viable alternative for defining an object category: Preschoolers did not generalize words following "looks like a" to same-part objects, and 6-year-olds consistently generalized words following "looks like a" to same-body-shape objects. Thus, nonmatching parts seemed to engender confusion resulting in more variable responses, but single matching parts did not pose a viable response alternative.

CONCLUSIONS

These data permit several conclusions. First, 4-year-olds, but not 3-year-olds, shift attention among different aspects of a stimulus array to make different inductive inferences, and they do so in the face of competing alternative responses, including those primed by previous inferences. Three-year-olds use predicate cues less reliably and show little flexibility across problems, although they are consistently flexible in a familiar word control task. These findings speak to the relation between problem solving and word learning. The data are not easily explained by maturation of a simple inhibitory mechanism. They are better explained in terms of children's construal of the task in which they are engaged and their ability to appropriately utilize linguistic information. For preschoolers, flexibility rests on viewing a task as a series of independent problems that require unique responses and on decontextualizing the verbal information (e.g., predicate cues) that specifies each individual problem.

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