*Research Article*

# When Development and Learning Decrease Memory

## Evidence Against Category-Based Induction in Children

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ABSTRACT—***Inductive inference is crucial for learning: If one learns that a cat has a particular biological property, one could expand this knowledge to other cats. We argue that young children perform induction on the basis of similarity of compared entities, whereas adults may induce on the basis of category information. If different processes underlie induction at different points in development, young children and adults would form different memory traces during induction, and would subsequently have different memory accuracy. Experiment 1 demonstrates that after performing an induction task, 5-year-olds exhibit more accurate memory than adults. Experiment 2 indicates that after 5-year-olds are trained to perform induction in an adultlike manner, their memory accuracy drops to the level of adults. These results, indicating that sometimes 5-year-olds exhibit better memory than adults, support the claim that, unlike adults, young children perform similarity-based rather than category-based induction.***

The ability to make inductive generalizations is crucial for learning: If one learns that a cat has a particular unobserved biological property, one could extend this knowledge to other cats, and possibly to other mammals. Furthermore, by some accounts, "inductive inference is the only process . . . by which new knowledge comes into the world" (Fisher, 1935/1951, p. 7).

There is much evidence that even infants and young children can perform simple inductions (Baldwin, Markman, & Melartin, 1993; Gelman & Markman, 1986; Sloutsky, Lo, & Fisher, 2001; Welder & Graham, 2001). However, the representations and processes underlying this ability remain unclear.

According to one view, people, including young children, hold several conceptual assumptions that drive their induction (see Keil, Smith, Simons, & Levin, 1998, and Murphy, 2002, for reviews of these assumptions). In particular, people hold a *category assumption*—they assume that each individual entity is a member of a class or category, that count nouns refer to categories, and that members of the same category share many unobserved properties. Conceptual assumptions are a priori—they are not learned, but are rather a precondition of learning, and are present early in development (Gelman & Hirschfeld, 1999; Keil et al., 1998). In the course of induction, people first identify presented entities as members of categories and then perform inductive inferences on the basis of categorization (Gelman, 1988; Gelman & Markman, 1986). Therefore, when presented with a rabbit and told that it has hollow bones inside its body, a child is more likely to generalize this property to another rabbit than to a dog because the child (presumably) understands that both rabbits belong to the same category, and members of the same category share many properties. It has been argued that this tendency to perform induction on the basis of categorization, or *category-based induction*, is especially pronounced when entities are members of familiar categories (Davidson & Gelman, 1990). In short, according to this view, induction is a function of categorization, whereas categorization is a function of a priori conceptual assumptions.

According to another view, young children perform induction (as well as categorization) by detecting multiple correspondences, or similarities, among presented entities (e.g., see Jones & Smith, 2002; McClelland & Rogers, 2003; Sloutsky, 2003; Sloutsky et al., 2001). Because members of a category often happen to be more similar to each other than they are to nonmembers, young children are more likely to induce unobserved properties to members of the category than to nonmembers. According to this view, induction and categorization in young children are variants of the same process, which is driven by the detection of multiple correspondences rather than by a priori conceptual assumptions. Furthermore, conceptual knowledge often found in adults (e.g., knowledge that entities are members of categories) is not a priori, but is a product of learning and cognitive development. Learning accounts of conceptual knowledge support this position, while weakening the claims that conceptual knowledge is a priori. For example, it has been claimed that young children's tendency to use similar shape as a reliable categorization cue is a product of a priori conceptual knowledge (Diesendruck & Bloom, 2003; Soja, Carey, & Spelke, 1991), whereas a convincing learning account of this shape bias (Smith, Jones, Landau, Gershkoff-Stowe, & Samuelson, 2002) has weakened the a priori claims by rendering them unnecessary.

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Overall, the two positions have several fundamental differences. According to the former position, when entities are members of familiar categories, induction is a function of categorization, and categorization is a function of conceptual knowledge. Therefore, induction is a function of conceptual knowledge. In addition, conceptual knowledge is a priori rather than learned. According to the latter position, early in development induction and categorization are a function of perceptual similarity among entities, whereas conceptual knowledge is a product of learning and development. Thus, the two positions assume different kinds of processing underlying induction and different developmental courses of induction and categorization.

One way of contrasting these theoretical positions is to compare predictions derived from them. For example, there is evidence in memory research that spontaneous categorization of items may lead to memory distortions, such as false recognition of *critical lures*, or nonpresented items that belong to the same category as previously presented items (Koutstaal & Schacter, 1997). These distortions may occur because participants form category-level or gist representations, whereas details of each individual item are not encoded or are encoded poorly (Brainerd, Reyna, & Forrest, 2002; Koutstaal & Schacter, 1997). When participants are required to focus on perceptual properties of items, they amply encode individual items, thus exhibiting accurate memory (Marks, 1991; McDaniel, Friedman, & Bourne, 1978).

Thus, similarity-based induction and category-based induction may result in differential remembering of information presented during an induction task: Whereas similarity-based induction may lead to accurate memories for perceptually distinct individual items, category-based induction may result in memory distortions, such as poor discrimination of presented items and critical lures. Therefore, if an induction task precedes a memory test, the memory test would reveal processing underlying induction. If people perform category-based induction and form category-level memory traces, their ability to discriminate items seen during the induction task from critical lures should be poor (compared with their performance on a baseline no-induction task). However, if they perform similarity-based induction, they should amply encode perceptual information, forming item-specific memory traces, and their discrimination should be as high as the baseline level.

It has been argued that when entities are members of familiar categories, adults may perform induction in a category-based manner (Osherson, Smith, Wilkie, Lopez, & Shafir, 1990), in which case an induction task should attenuate their recognition memory compared with the baseline. In contrast, if young children perform induction in a similarity-based manner, they should exhibit high accuracy in both baseline and induction conditions. Thus, following an induction task, young children may exhibit greater memory accuracy than adults. The prediction is nontrivial because typically adults' memory is markedly more accurate than that of young children (see Schneider & Bjorklund, 1998, for a review).

If adults' induction with familiar categories is indeed category based, whereas young children's induction is similarity based, how does this category-based induction develop? The category-based position argues that conceptual knowledge (e.g., the category assumption) is a priori rather than learned (Gelman & Hirschfeld, 1999; Keil et al., 1998). However, providing a learning account of category-based induction weakens this position by rendering the a priori nature of conceptual knowledge unnecessary.

To test the target prediction, we conducted Experiment 1, in which we compared the effects of an induction task on recognition memory of 5-year-olds and adults. In Experiment 2, we trained 5-year-olds to perform category-based induction and examined the effects of training on their recognition memory.

## EXPERIMENT 1

### Method

#### *Participants*

Participants were 77 young children ($M$ age = 5.43 years, $SD$ = 0.28 years) and 71 introductory psychology students ($M$ age = 19.3 years, $SD$ = 1.33).

#### *Materials, Design, and Procedure*

Materials were 44 color photographs of animals presented against a white background (see Fig. 1 for examples of the stimuli). During the study phase, participants were presented with 30 pictures, 1 picture at a time, from three categories (10 cats, 10 bears, and 10 birds). During the recognition phase, they were presented with 28 pictures, 1 picture at a time, and were asked whether they had seen each exact picture during the study phase. Half of the recognition pictures had been presented during the study phase, and the other half were new pictures. These recognition pictures also represented three categories: cats (7 old and 7 new), bears (all 7 old), and squirrels (all 7 new). To ascertain that all of these animals were well familiar to children, we pretested them with 5-year-olds in an earlier naming study. Only those pictures that were consistently named by a basic-level name (i.e., "cat," "bear," "bird," or "squirrel") by more than 85% of the children were selected for the present study.

The experiment included three between-subjects conditions: baseline, induction, and blocked categorization, with each condition consisting of a study phase and a recognition phase. The recognition phase was identical in all three conditions, whereas the study phase differed across the conditions. Participants were randomly assigned to

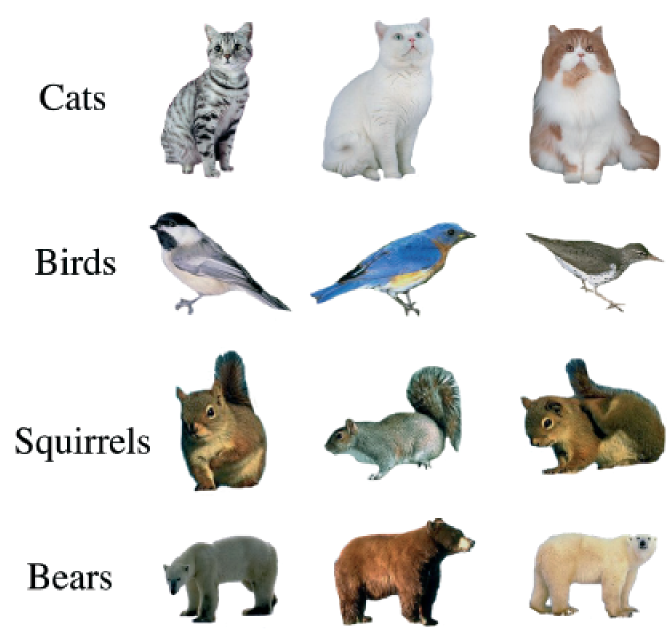


**Fig. 1. Examples of stimuli used in the study and recognition phases (copied from the Corel Draw database).**

one of the three conditions. There were 27 children and 29 adults in the induction condition, 24 children and 23 adults in the blocked-categorization condition, and 26 children and 19 adults in the baseline condition.

In the study phase of the baseline condition, participants were presented with 30 pictures of animals, and their task was to remember these pictures for a subsequent recognition test.

In the study phase of the induction condition, participants were first presented with a picture of a cat and informed that it had "beta cells inside its body." Participants were then presented with 30 pictures of animals (identical to those presented in the baseline condition) and were asked whether each of the presented animals also had beta cells. After responding, the participants were provided with yes/no feedback indicating that only cats, but not bears or birds, had beta cells. The fact that 5-year-olds do not know what beta cells are was of no concern because young children easily induce unfamiliar properties or blank predicates, and as we show in the Results and Discussion section, they had no difficulty inducing this property. The recognition test was not mentioned in the study phase of this condition.

In the study phase of the blocked-categorization condition, participants were first presented with a picture of a cat and informed that it was young. Participants then were presented with 30 pictures of animals (identical to those presented in the baseline and induction conditions) and asked whether each of the presented animals was young or mature. Participants were provided with random yes/no feedback. The purpose of this random feedback was to block inferences based on the animal-kind information and to force participants to focus on perceptual features of individual items. As in the induction condition, the recognition test was not mentioned in the study phase.

The recognition phase was presented immediately after the study phase. At recognition, participants were presented with 28 pictures and were asked to determine whether each was "old" (i.e., exactly the one presented during the study phase) or "new." No feedback was provided during the recognition phase. The young children were tested individually in their day-care centers by female experimenters blind to the hypotheses. The undergraduate students were tested individually in a laboratory on campus. For all participants, stimuli were presented on a computer screen in a self-paced manner, and stimulus presentation was controlled by SuperLab Pro 2 (1999) software.

### Results and Discussion

Recall that young children were expected to perform induction by comparing each animal with the target animal and thus to remember study-phase animals well, accurately accepting old animals and rejecting new ones. At the same time, it was expected that adults would spontaneously categorize animals as cats, bears, and birds when performing induction, and thus they would form gist or category-level memory traces. As a result, it was expected that they would remember category information, but not item-specific information, and thus fail to discriminate between old items and critical lures (i.e., new members of a studied category). Also, recall that the blocked-categorization condition was identical to the induction condition, except that the categorization of animals as cats, bears, and birds was blocked. Because categorization was blocked, it was expected that memory accuracy for both children and adults in this condition would be comparable to accuracy in the baseline condition.

After several trials, the majority of 5-year-olds and adults realized that the property of having beta cells should be induced to cats, but not to bears or birds, and they accurately performed this induction: The average rate of correct induction was over 75% of trials for both children and adults. Also, in the recognition phase, both children and adults exhibited above 92% accuracy across conditions in rejecting distractors from an unstudied category (i.e., squirrels). Therefore, participants took the task seriously and paid attention to stimuli during the study phase.

Recall that we were interested in participants' discrimination of old items and critical lures across conditions. Percentages of hits (i.e., correct recognitions) and false alarms on critical lures by age group and condition are presented in Table 1. Data in the table indicate that whereas children exhibited equivalent accuracy (i.e., hits − false alarms) across the baseline, induction, and blocked-categorization conditions, $F(2, 76) < 1$, adults' accuracy was dramatically lower in the induction condition than in the other two conditions, $F(2, 68) = 11.5$, $p < .0001$, $\eta_p^2 = .252$, both $p$s $< .01$ in post hoc Tukey tests.

To further examine the ability to discriminate old items from critical lures, we computed memory sensitivity $A'$ scores. $A'$ is a nonparametric analogue of the signal detection statistic $d'$ (Snodgrass & Corwin, 1988; Wickens, 2002). If participants do not discriminate old items from critical lures, $A'$ is at or below .5. The greater the discrimination accuracy, the closer $A'$ is to 1. $A'$ scores are presented in Figure 2. As predicted, 5-year-olds discriminated old items from critical lures well across the three conditions (in all conditions, $A'$s $> .5$, one-sample $t$s $> 3$, $p$s $< .005$). Adults were accurate in the baseline and blocked-categorization conditions (both $A'$s $> .5$, one sample $t$s $> 7$, $p$s $< .001$), whereas they were not accurate in the induction condition: Unlike the $A'$s of the young children, adults' $A'$s in this condition were not different from .5, $t < 1$, indicating the adults did not discriminate between old items and critical lures.

$A'$ values were submitted to a two-way (Age × Experimental Condition) analysis of variance. The analysis confirmed a significant age-by-condition interaction, $F(2, 142) = 4.64$, $p = .001$, $\eta_p^2 = .06$. Whereas 5-year-olds exhibited no differences in accuracy across the conditions, all $p$s $> .87$, $A'$s in adults were markedly lower in the

**TABLE 1**

***Mean Proportions of Hits and False Alarms (FA) and Mean Accuracy in Experiment 1***

| | Children | | | Adults | | |
|---|---|---|---|---|---|---|
| Condition | Hits | FA | Accuracy (hits − FA) | Hits | FA | Accuracy (hits − FA) |
| Baseline | .77 (.19) | .50 (.32) | .27 | .89 (.10) | .47 (.31) | .42 |
| Induction | .72 (.24) | .41 (.34) | .31 | .83 (.20) | .76 (.25) | .07 |
| Blocked categorization | .78 (.13) | .51 (.20) | .27 | .80 (.18) | .50 (.24) | .30 |

**Note.** Standard deviations are in parentheses.

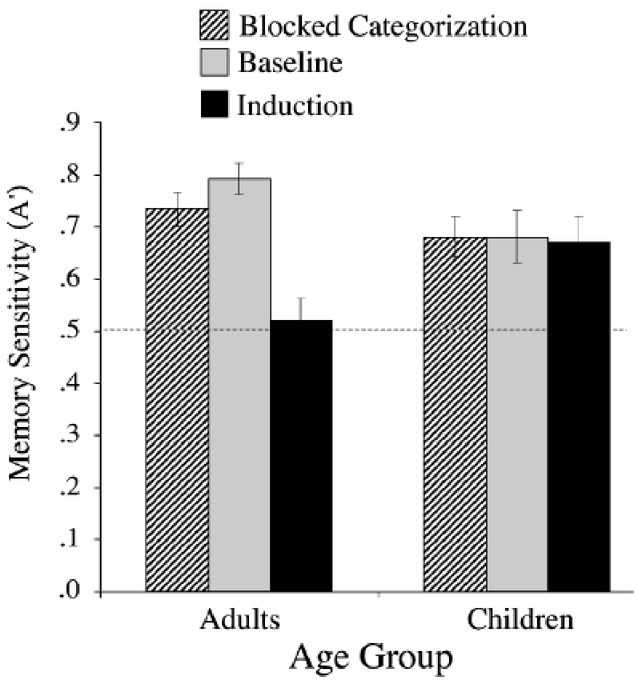


**Fig. 2.** Memory sensitivity scores ($A'$) of children and adults across the three experimental conditions in Experiment 1. The dashed line represents the point of no sensitivity. Error bars represent the standard errors of the mean.

induction condition than in the other two conditions, $F(2, 68) = 13.5$, $p < .001$, $\eta_p^2 = .29$, post hoc Tukey test $ps < .001$. Furthermore, as predicted, in the induction condition, 5-year-olds exhibited greater accuracy than adults, one-tailed $t(54) = 2.36$, $p = .011$.

In short, the induction task markedly attenuated adults' recognition accuracy, whereas young children remained accurate. These results suggest that whereas adults performed category-based induction, young children performed similarity-based induction.

It could be argued, however, that the children were accurate because of extraneous factors. For example, the children could have been more interested in the pictures than the adults, or the children could have forgotten gist information faster than item-specific information, whereas the adults could have forgotten item-specific information faster than gist information. The goal of Experiment 2 was to eliminate these explanations by training children to perform category-based induction. If our hypothesis is correct, such training should differentially affect young children's memory across conditions: Although their accuracy should drop in the induction condition (analogous to the drop for adults in Experiment 1), it should not drop in the baseline condition. In addition to providing controls, Experiment 2 (if successful) would provide a learning account of category-based induction found in adults, thus weakening the claim that category-based induction is based on a priori conceptual knowledge.

## EXPERIMENT 2

### Method

#### *Participants*

Participants were 42 young children ($M$ age = 5.25 years, $SD = 0.21$ years), with 26 participating in the baseline condition and 16 participating in the induction condition.

#### *Materials, Design, and Procedure*

Materials in both conditions were identical to those in Experiment 1. There were two between-subjects conditions, induction and baseline, and participants were randomly assigned to one of the two conditions.

The procedure of Experiment 2 differed from that of Experiment 1 in that prior to the recognition phase, the 5-year-olds were presented with training in which they were taught to perform category-based induction. They were first taught that animals that have the same name belong to the same category—"they are the same kind of animal." They were then given three boxes, with each box identified by a black outline of a lion, a rabbit, or a dog, and were presented with pictures of lions, rabbits, and dogs (none of these categories was presented during the main experiment). They were told that animals that have the same name are the same kind of animal and could be placed in the same box. The children were asked to place the pictures in the boxes face down. All presented pictures had been pretested in a prior naming study that revealed that each of the depicted animals could be reliably named by 5-year-olds. The children were presented with six categorization trials, and yes/no feedback was given after each trial. Both types of feedback were accompanied by an explanation that animals that have the same name belong to the same kind and should be placed in the same box.

The categorization training was followed by induction training. Participants were first reminded that animals that have the same name are the same kind of animal. They were then told that animals of the same kind have "the same stuff inside." Then participants were given six induction trials, each accompanied with yes/no feedback. On each trial, they were shown a picture and told that the animal had a particular biological property (e.g., "this dog has thick blood inside its body"), and asked to place the picture in an appropriate box. Feedback was followed by an explanation that animals of the same kind have the same name and same stuff inside. All children completed training successfully, giving either five correct answers out of six or four correct answers in a row in the induction training task. At the conclusion of the training session, they were reminded that "animals that have the same name are the same kind of animal, and these animals have the same stuff inside." They were then presented with the main experiment, which was identical to Experiment 1.

### Results and Discussion

Hits, false alarms, and recognition accuracy (hits − false alarms) across the conditions are presented in Table 2. Data in the table point to a marked difference between 5-year-olds' high accuracy in the baseline condition and low accuracy in the induction condition, $F(1, 40) = 12.18$, $p < .005$, $\eta_p^2 = .24$. Although accuracy in the baseline condition remained as high as in Experiment 1, accuracy in the induction condition dropped dramatically to the level of adults in the induction condition of Experiment 1.

Children's $A'$ scores across the two experiments are presented in Figure 3. As shown in the figure, children's accuracy in the induction condition of Experiment 2 dropped compared with their accuracy in the baseline condition of Experiment 2, one-tailed independent-samples $t(40) = 3.4$, $p < .005$, as well as compared with their accuracy in the induction condition of Experiment 1, one-tailed independent-samples $t(41) = 1.7$, $p < .05$. Furthermore, after training, their accuracy in the induction condition did not differ significantly from .5, or from that of adults in Experiment 1, both $ps > .28$, thus

**TABLE 2**
*Mean Proportions of Hits and False Alarms (FA) and Mean Accuracy in Experiment 2*

| Condition | Hits | FA | Accuracy (hits − FA) |
|---|---|---|---|
| Baseline | .74 (.16) | .42 (.28) | .32 |
| Induction | .85 (.21) | .77 (.29) | .08 |

**Note.** Standard deviations are in parentheses.

indicating that like adults in Experiment 1, 5-year-olds who had received training in category-based induction failed to discriminate between old items and critical lures. At the same time, their accuracy remained high in the baseline condition ($A' > .5$), one-sample $t(25) = 7.7$, $p < .0001$.

In short, training to perform category-based induction attenuated memory accuracy of 5-year-olds in the induction, but not the baseline, condition. These findings suggest that the high recognition accuracy exhibited by 5-year-olds in Experiment 1 did not stem from extraneous factors, but rather stemmed from similarity-based induction leading to accurate representation of item-specific information. These findings also provide a learning account of category-based induction.

## GENERAL DISCUSSION

In the present study, (a) the induction task decreased recognition accuracy of adults, whereas young children exhibited high recognition accuracy, and (b) training to perform category-based induction decreased recognition accuracy of young children in the induction, but not in the baseline, condition.

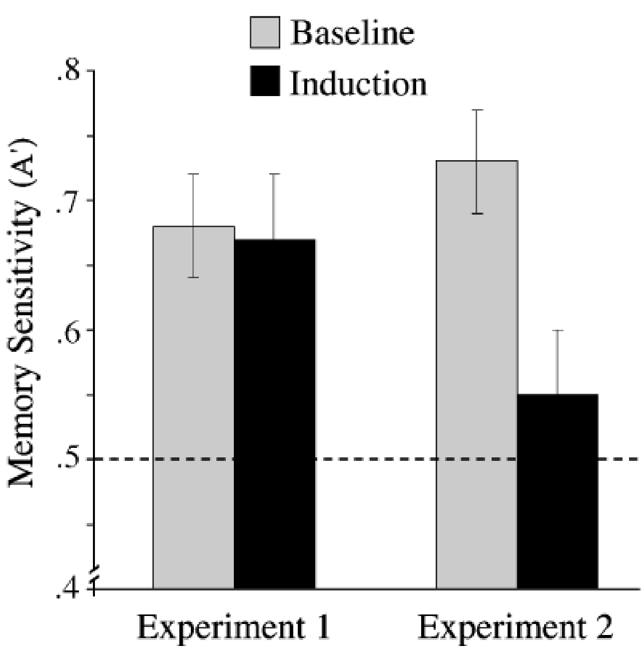


**Fig. 3.** Young children's memory sensitivity scores ($A'$) in the induction and baseline conditions in Experiments 1 and 2. The dashed line represents the point of no sensitivity. Error bars represent the standard errors of the mean.

Recall that similarity-based induction is expected to result in item-specific representations, whereas category-based induction is expected to result in category-level representations. Therefore, category-based, but not similarity-based, induction may lead to errors in recognition memory. Hence, finding that young children (unlike adults) exhibit high recognition accuracy after an induction task suggests that young children do not spontaneously perform category-based induction, but rather perform similarity-based induction. This finding is new evidence challenging the idea that when categories are familiar, induction in young children is driven by the category assumption.

There is mounting evidence challenging the claim that young children hold a priori conceptual assumptions; however, much of this evidence challenges the *centrality assumption*—the idea that young children assume rather than learn differential importance of different properties. It was shown that participation in a learning task in which allegedly central features (i.e., matching labels) were poor predictors of biological properties, whereas allegedly peripheral features (i.e., similar appearances) were good predictors, resulted in young children's ignoring labels in favor of appearances in an induction task presented 3 months later in a different context by a different experimenter (Sloutsky & Spino, in press). In addition, children's reliance on linguistic labels (which are allegedly more central than perceptual similarities) in an induction task is more pronounced for line-drawing pictures than for real three-dimensional objects (Deak & Bauer, 1996). Furthermore, perceptual similarity could be more important for induction than are matching labels: Young children are more likely to rely on similarity of motion than on a matching linguistic label (Mak & Vera, 1999). This evidence seriously undermines the idea of an a priori centrality assumption because properties of "peripheral" information should not affect the centrality of "essential" information. Unlike previous research, the current research challenges the category assumption: There is little evidence that young children spontaneously perform induction in a category-based manner.

Finding that training to perform induction in a category-based manner reduced memory accuracy of young children to the level of adults supports a learning account of category-based induction, suggesting that it is unnecessary to posit that conceptual knowledge is a priori. Recall that in Experiment 2, participants were taught that (a) animals that have the same name belong to the same kind, (b) animals that belong to the same kind have the same stuff inside, and (c) animals that have the same name have the same stuff inside. It is possible that the first two points are taught in school, whereas the third is a direct consequence of the first two. Therefore, the results of Experiment 2 may explain the transition from the similarity-based induction exhibited by children to the category-based induction exhibited by adults, suggesting that category-based induction and requisite conceptual knowledge could be a product of feedback-based learning. These findings are consistent with previous research indicating that smart behaviors do not have to be a priori—they can develop from simpler representations and processes (e.g., Jones & Smith, 2002; Smith, Jones, & Landau, 1996; Smith et al., 2002).

Could the reported results stem from extraneous factors, such as differential forgetting of gist and item-specific information or differential interest in pictures in children and adults? Although these factors could account for the results of Experiment 1, it is unclear how they can account for the results of both experiments. Recall that training to perform category-based induction attenuated recognition memory of 5-year-olds in the induction but not the baseline condition.

It seems very difficult to come up with a plausible differential-forgetting or differential-interest account that would explain why learning to perform category-based induction would differentially affect recognition in the two conditions.

The reported results reflect effects of induction on encoding of information: Whereas categorization-based induction results in category-level representations leading to memory distortions, similarity-based induction results in item-specific representations leading to accurate recognition. These results suggest that young children perform induction in a similarity-based manner, thus challenging the position that young children's induction is category based.

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