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When Induction Meets Memory: Evidence for Gradual Transition From Similarity-Based to Category-Based Induction

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The ability to perform induction appears early; however, underlying mechanisms remain unclear. Some argue that early induction is category based, whereas others suggest that early induction is similarity based. Category- and similarity-based induction should result in different memory traces and thus in different memory accuracy. Performing induction resulted in low memory accuracy in adults and 11-year-olds, whereas 5-, and 7-year-olds were highly accurate (Experiment 1). After training to perform category-based induction, 5- and 7-year-olds exhibited patterns of accuracy similar to those of adults (Experiment 2). Furthermore, 7-year-olds, but not 5-year-olds, retained this training over time (Experiment 3). With novel categories, even adults performed similarity-based induction, exhibiting high memory accuracy (Experiment 4). These results suggest a gradual transition from similarity- to category-based induction with familiar categories.

The ability to generalize from the known to the unknown is crucial for learning new information: On learning that polar bears use dopamine as a neurotransmitter, one could generalize this information to brown bears, black bears, giant pandas, and possibly to other mammals. Although it has been amply demonstrated that even infants and very young children are capable of simple inductive generalizations (Baldwin, Markman, & Melartin, 1993; Gelman & Markman, 1986; Sloutsky, Lo, & Fisher, 2001; Welder & Graham, 2001), mechanisms underlying early induction are hotly debated. Several theoretical accounts of early induction have been proposed. According to the naive theory approach, even young children perform induction by relying on a set of conceptual assumptions about the language and the world (Gelman & Coley, 1991; see also Murphy, 2002, for a review of these assumptions). Under this view, induction is a two-step process: Children first identify encountered entities as members of categories, and if entities belong to the same category (say, the same natural kind), children infer that these entities share many properties. The inference is licensed by children's assumptions that members of some categories (e.g., natural kinds) share many properties.

According to the alternative position (i.e., the similarity view), induction is a generalization process, and young children generalize on the basis of multiple commonalities, or similarities, among presented entities (e.g., Jones & Smith, 2002; McClelland & Rogers, 2003; Sloutsky, 2003, Sloutsky & Fisher, 2004a, 2004b; Sloutsky et al., 2001). This view does not attribute conceptual assumptions to young children. In the next section we present an overview of these positions.

Theoretical Accounts of Early Induction

Category-Based Induction

According to this position, induction is driven by children's knowledge about the language and the world. When "trying to determine whether to draw an inference from object A to object B, a child would not simply calculate the similarity between the two objects. Rather the child would determine whether A and B belong to members of the same natural kind category that encompasses both A and B" (Gelman & Coley, 1991, p. 185). Although children may rely on similarity in the absence of category information, when category information is present it overrides similarity information. This is especially true when induction is performed with familiar categories (Davidson & Gelman, 1990). Therefore, according to this position, categorization is a necessary step in

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induction, and induction in young children is category based (e.g., Gelman, 1988).

This knowledge about the world and the language comes in a form of conceptual assumptions, two of which are especially important for induction. The *category assumption* is the belief that individual entities are members of more general categories and that members of the same category share many unobserved properties. The *linguistic assumption* is the belief that linguistic labels presented as count nouns denote categories rather than individuals. When performing induction, people rely on these assumptions to conclude that entities sharing a label belong to the same kind and therefore share many unobservable properties. For instance, when shown a picture of a yellow fish and told that this fish needs branchia to breathe, children are more likely to generalize this property to a red fish than to a turtle or a couch (Gelman, 1988). Presumably, children apply the two assumptions to infer that because the entities have a matching label (i.e., both are referred to as a fish), these entities belong to the same kind, and therefore they share many important properties.

There is evidence supporting these assumptions. First, there is evidence supporting the linguistic assumption—children's belief that words presented as count nouns refer to categories. In a series of studies, Markman and Hutchinson (1984) demonstrated that in the absence of a label, children group things thematically (e.g., a police car and a policeman), whereas when the police car was named "a dax" and children were asked to select another "dax," they selected passenger car, thus grouping the cars together. More recently, Gelman and Heyman (1999) demonstrated that young children were more willing to generalize properties from one person to another when both persons were referred to by a noun (i.e., "carrot-eaters") than when both were referred to by a descriptive sentence (e.g., "both like to eat carrots"). Furthermore, similar to children, infants may also expect words to denote categories, although, unlike young children, infants hold this expectation not only for count nouns but also for other speech sounds (e.g., Balaban & Waxman, 1997; Booth & Waxman, 2003).

In addition, there is evidence supporting the idea that induction is category based. For example, Gelman and Markman (1986) presented young children with a target item and two test items, with one test item looking more like the target and another test item sharing the label with the target. Participants were also told that one test item had a hidden property (e.g., "This one has hollow bones") whereas another test item had a different hidden property (e.g., "This one has solid bones"), and they were asked to induce a hidden property to the target. Results indicate that young children tend to induce properties from the identically labeled, but not from the similarly looking, item. Similar findings were reported with infants (Welder & Graham, 2001).

This evidence, however, does not lend unequivocal support to the idea that children's induction is category based. In particular, it could be argued that labels do not have to be category markers to support induction. For example, some researchers have suggested that contribution of labels is driven by attentional rather than conceptual factors (Napolitano & Sloutsky, 2004; Sloutsky & Napolitano 2003). These researchers demonstrated that under many conditions auditory (including linguistic) information automatically captures young children's attention, thus overshadowing (or attenuating processing of) corresponding visual information.

There is also evidence that (possibly because of overshadowing effects) labels contribute to the overall similarity of compared entities and thus to both categorization and induction (Sloutsky & Fisher, 2004a). Sloutsky and Fisher (2004a) also demonstrated that similarity computed over labels and appearances can accurately predict young children's responses with the Gelman and Markman (1986) task and that these predictions were accurate for individual stimulus triads used by Gelman and Markman. These findings suggest that reliance on labels does not constitute evidence for category-based induction; therefore, there are reasons to believe that induction could be label based without being category based. Although these arguments do not eliminate the possibility that young children's induction is category based, they point to alternatives to category-based induction.

Similarity-Based Induction

According to this view, young children generalize on the basis of multiple commonalities, or similarities, among presented entities. Because members of the same category often happen to be more perceptually similar to each other than they are to nonmembers (i.e., a yellow fish is more similar to a red fish than it is to a turtle or a couch), children are more likely to generalize properties to members of a category than to nonmembers. Furthermore, common labels could be features directly contributing to perceptual similarity rather than denoting a common category (Sloutsky & Fisher, 2004a; Sloutsky & Lo, 1999). Proponents of this view challenge the position that young children hold conceptual assumptions, and they argue that induction with both familiar and novel categories is similarity based.

However, reliance on similarity in the course of induction does not constitute unequivocal evidence against reliance on conceptual knowledge—both positions agree that under some conditions children rely on similarity. For example, it has been argued that categorization and induction ''reflect an interaction of perceptual knowledge, language, and conceptual knowledge'' (Gelman & Medin, 1993, p. 159). Therefore, one of the goals of this research was to focus on an important difference between the two positions: whether young children's induction is driven by the category and linguistic assumptions.

In the next section, we review several recent findings challenging the contention that young children's induction is category based. We then summarize unanswered questions and formulate the goals of present research.

Induction and Memory: Evidence for Similarity-Based Induction in Children

One way of deciding whether induction is category based or similarity based is to examine memory traces formed during an induction task (Sloutsky & Fisher, 2004b; see also Hayes & Heit, 2004, for a review). The idea is based on the following reasoning. There is a well-known level-of-processing effect—deeper semantic processing facilitates correct recognition of presented items, increasing the proportion of ''hits'' (Craik & Lockhart, 1972; Craik & Tulving, 1975). At the same time, several recent studies indicate that deeper processing results not only in higher hit rates but also in higher levels of memory intrusions—false recognition of nonpresented critical lures, or semantically associated items (e.g., Rhodes & Anastasi, 2000; Thapar & McDermott, 2001). It has been also demonstrated that when to-be-remembered items are related categorically, participants often false alarm on critical lures that are nonpresented members of studied categories (Koutstaal & Schacter, 1997). Because of elevated levels of false alarms, the net result of deep semantic processing on recognition accuracy (i.e., hits – false alarms) is negative. At the same time, it is known that focusing on perceptual details of pictorially presented information leads to more accurate recognition (Marks, 1991)—although hits might be slightly lower, false alarms are significantly lower than under deep semantic processing. Therefore, these memory findings suggest that categorization (which is a variant of deeper semantic processing) would result in a higher level of memory intrusions and thus in lower recognition accuracy than shallow perceptual processing (see also Brainerd, Reyna, & Forrest, 2002, for related arguments).

Thus, a memory test administered after an induction task may reveal differential encoding of information during induction: If participants perform category-based induction, they should be engaged in deep semantic processing and therefore exhibit low discrimination of studied items from critical lures during a memory test (compared with a no-induction baseline condition). On the other hand, if participants perform similarity-based induction, they should be engaged in shallow perceptual processing, and as a result their memory accuracy should not decrease compared with the baseline. Because, unlike adults, young children were expected to perform similarity-based induction, this reasoning led to a nontrivial prediction that after performing induction, young children may exhibit greater memory accuracy (i.e., have fewer false alarms) than adults.

These predictions have received empirical support: The pattern of results reported by Sloutsky and Fisher (2004a, 2004b) indicates that whereas adults perform category-based induction, young children perform similarity-based induction. In particular, after performing inductive generalizations about members of familiar animal categories (i.e., cats, bears, and birds), adults' memory accuracy attenuated markedly compared with the no-induction baseline, and these effects of induction were robust across a wide range of animal categories (Fisher & Sloutsky, 2004). At the same time, young children were accurate in both the baseline and induction conditions, exhibiting greater accuracy in the induction condition than did adults. However, after a short training to perform category-based induction (i.e., participants were taught that things that have the same name belong to the same kind and have much in common—information that they were supposed to have in the form of conceptual assumptions), memory accuracy of 5-year-olds decreased to the level of adults in the induction condition. At the same time, training did not attenuate children's accuracy in the baseline condition; even after training, 5-year-olds exhibited high recognition memory accuracy. Therefore, decrease in memory accuracy observed in the induction condition is attributable to specific effects of training to perform category-based induction rather than to general factors, such as fatigue. These results clearly demonstrate that (a) young children (unlike adults) spontaneously perform induction in a similarity-based rather than category-based manner, and (b) they can learn to perform category-based induction. This research, however, left several questions unanswered, and the goal of the current research was to answer these questions by replicating and further extending Sloutsky and Fisher's (2004a, 2004b) findings.

Unanswered Questions and Goals of Present Research

First, it could be counterargued that because it was relatively easy to train 5-year-olds to perform category-based induction, children did not learn to perform induction in a category-based manner during training; rather, training simply activated their preexisting conceptual knowledge. If this is the case, 5-year-olds should be able to retain effects of training: It should not be hard to retain something that is supposed to be already known. At the same time, finding that even after short delays young children revert to similarity-based induction would indicate that the learned knowledge is fragile, thus undermining the possibility of priming of preexisting knowledge. One of the goals of this research was to examine this issue.

Another goal was to examine the developmental course of category-based induction. In particular, finding that recognition accuracy following an induction task decreases with age would strongly indicate that category-based induction develops gradually, which would further indicate that it is not a default but rather a product of learning and development. At the same time, this would be a novel and counterintuitive finding because memory is known to increase and not decrease from early childhood to young adulthood (see Schneider & Bjorklund, 1998, for a review). The third goal was to provide more direct evidence that similarity-based induction results in accurate recognition memory. Finding that when forced to perform similarity-based induction, adults exhibit high recognition accuracy would constitute such evidence.

The four reported experiments were designed to achieve these goals. To establish the developmental pattern of effects of performing induction on recognition memory accuracy, Experiment 1 presented participants from four different age groups (5-, 7-, and 11-year-olds, and adults) with the same induction-then-recognition memory paradigm used by Sloutsky and Fisher (2004a, 2004b). Based on previous research (e.g., Sloutsky & Fisher, 2004a, 2004b; Sloutsky et al., 2001), we expected that category-based induction would increase with age and thus that memory accuracy after an induction task would decrease with age.

In Experiments 2 and 3 younger children (5- and 7-year-olds) were trained to perform category-based induction, and effects of training on memory accuracy were examined, with the two experimental conditions (i.e., induction-then-recognition, or baseline-then-recognition) administered either immediately after training (Experiment 2) or after a delay (Experiment 3). Finally, in Experiment 4 we presented adults with members of novel artificial categories under either the induction-then-recognition condition or the baseline-then-recognition condition, thus forcing adults to perform similarity-based induction. We expected that unlike category-based induction, similarity-based induction in adults would result in high recognition accuracy.

Experiment 1

Method

Participants

Participants were 69 five-year-olds (29 girls, 40 boys; *M* age = 5.11 years, *SD* = 0.38), 49 seven-year-olds (26 girls, 23 boys; *M* age = 7.87 years, *SD* = 0.59 years), 66 eleven-year-olds (31 girls, 35 boys; *M* age = 11.87 years, *SD* = 0.59 years), and 60 introductory psychology students (25 women, 35 men, *M* age = 19.77 years, *SD* = 1.14). In this and all other experiments reported here, children participants were recruited from several day care centers and schools located in predominately White middle-class suburbs of Columbus, Ohio on the basis of returned consent forms, and adults were undergraduate students at The Ohio State University participating in the experiment in partial fulfillment of a course requirement.

Materials

Materials were identical to those used in Sloutsky and Fisher (2004b) and consisted of 44 color photographs of animals presented against white background (see Figure 1 for the full list of stimuli). During the study phase participants were presented with 30 study pictures from three categories (10 cats, 10 bears, and 10 birds), 1 picture at a time. During the recognition phase participants were presented with 28 recognition pictures, 1 picture at a time, and were asked whether they had seen this exact picture during the study phase. Half of the recognition pictures consisted of pictures presented during the study phase, and the other half were new pictures. Pictures presented during the recognition phase also represented three categories: cats (7 of which were

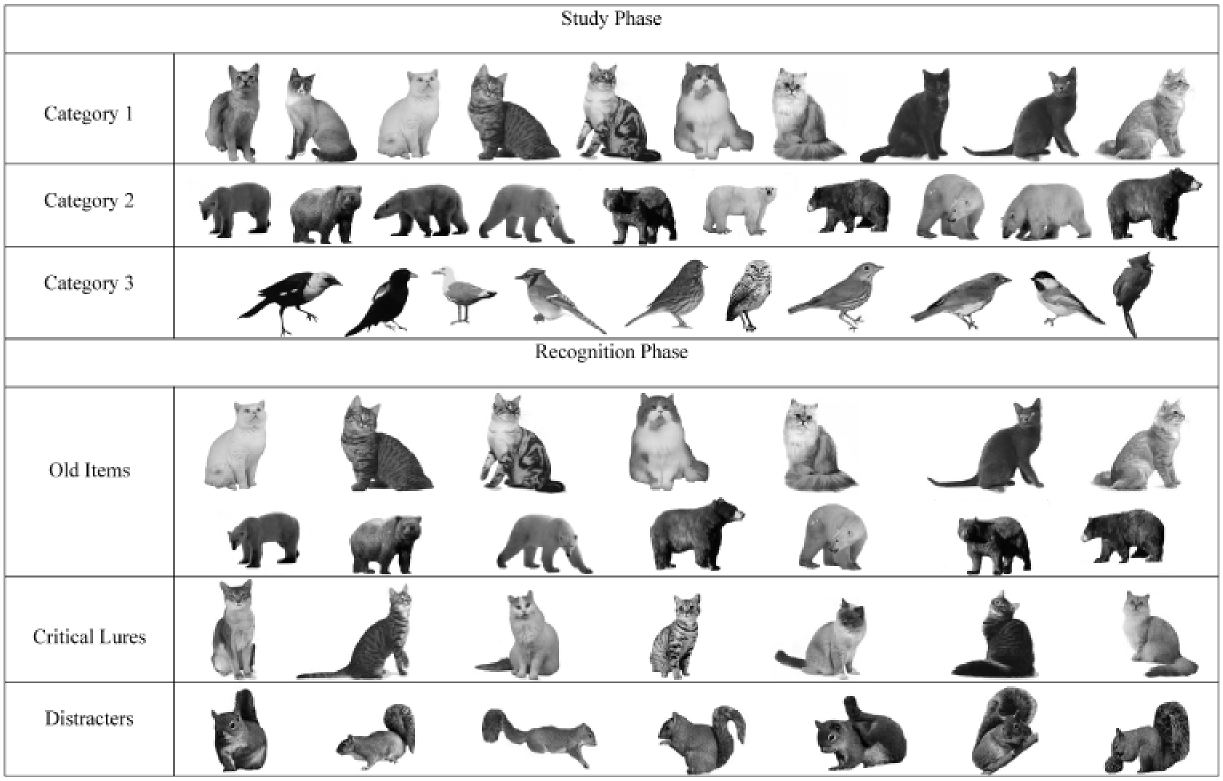

Figure 1. Examples of stimuli used in Experiments 1 to 3. In all experiments these stimuli were presented in color. The color version can be found on the following website: http://cogdev.cog.ohio-state.edu/FiguresforMemory.pdf.

old and 7 were new, thus serving as the critical lures), bears (all 7 of which were old), and squirrels (all 7 of which were new). The latter were distracters serving as overall controls for accuracy: In this and all other experiments reported here, data from participants who failed to reject correctly at least 5 of 7 catch items were excluded from further analyses.

Before the experiment all of the pictures were presented to a group of 5-year-olds, none of whom participated in this study, to ascertain that even the youngest children in our study were well familiar with the chosen animal categories. Only pictures that were consistently (i.e., across multiple presentations) labeled by a basic level name (i.e., ''cat,'' ''bear,'' ''bird,'' or ''squirrel'') by more than 85% of children were selected for this study.

Design and Procedure

The experiment had a 3 (condition: induction, baseline, and blocked categorization) × 4 (age group: 5-year-olds, 7-year-olds, 11-year-olds, and adults) between-subjects design. Participants were randomly assigned to a respective condition. Each condition consisted of a study phase, which differed across conditions, and a recognition phase, which was identical in all three conditions.

Study phase: Baseline. In this condition participants were presented (in a random order) with 30 study pictures of animals and asked to remember them for a subsequent recognition memory test.

Study phase: Induction. In this condition participants were first presented with a picture of a cat and were informed that it had ''beta cells inside its body.'' Participants were then presented (in a random order) with 30 study pictures of animals (identical to those in the baseline condition) and were asked whether each of the presented animals also had beta cells inside its body. Participants were provided with corrective yes – no feedback indicating that only cats, but not other animals, had beta cells inside their body. The recognition test was not mentioned in the study phase of this condition.

Study phase: Blocked categorization. The goal of this condition was to control for different task demands in the baseline condition (which had neither induction task nor feedback) and induction condition (which had both induction task and feedback). Participants were first presented with a picture of a cat and were informed that the animal was young. Participants were then presented (in a random order) with 30 study pictures of animals (identical to those in the baseline and induction conditions) and were asked whether each of the animals was young or mature. Participants were provided with random yes–no feedback intended to block inferences based on the animal kind information and to force all participants to concentrate on perceptual features of individual items. Similar to the induction condition, the recognition test was not mentioned during the study phase.

Recognition phase. The recognition test was administered immediately after the study phase. Participants were presented with 28 recognition pictures of animals and were asked to determine whether each picture was old (i.e., exactly the one presented during the study phase) or new. No feedback was provided during the recognition phase.

In this and all other experiments reported here, children were tested individually in their schools or day care centers by female hypothesis-blind experimenters. 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 stimuli presentation was controlled by Super Lab Pro 2 software (Cedrus Corporation, 1999). Adult participants responded by pressing a keyboard button, and children responded verbally, with their responses recorded by experimenters.

Results and Discussion

Seven 5-year-olds (1 in the induction condition, 2 in the baseline condition, and 3 in the blocked categorization condition), one 7-year-old (in the baseline condition), and 12 adults (all in the blocked categorization condition) did not reliably reject control items, and their data were eliminated from further analysis. The rest of participants were highly accurate in rejecting control items, averaging 96%, 97%, 99%, and 97% of correct responses across conditions for 5-, 7-, and 11-year-olds, and adults, respectively.

In the induction condition participants promptly realized that the target property should be extended to cats but not to other animals. The rate of correct inductions in 5-, 7-, and 11-year-olds, and adults was 75%, 85%, 94%, and 91%, respectively, all above chance, one-sample $t\text{s} > 5.7$, $p\text{s} < .0001$.

Across conditions participants were also accurate in correctly recognizing old items; however, their recognition accuracy on the critical lures (i.e., novel pictures of cats) differed across conditions and age groups. Proportions of hits (i.e., correct recognitions) and false alarms on critical lures by age group and

Table 1
Mean Proportions of Hits and False Alarms (FA) in Experiment 1 by Age Group and Experimental Condition

Condition	Hits	FA
	5-year-olds	
Baseline	.82	.59
Blocked categorization	.62	.38
Induction	.70	.41
	7-year-olds	
Baseline	.79	.40
Blocked categorization	.77	.25
Induction	.77	.45
	11-year-olds	
Baseline	.79	.39
Blocked categorization	.77	.31
Induction	.79	.59
	Adults	
Baseline	.88	.40
Blocked categorization	.86	.49
Induction	.81	.74

condition are presented in Table 1. Measures of memory sensitivity (i.e., A-prime scores) by age group and condition are presented in Figure 2. A-prime is a nonparametric analogue of the signal-detection d-prime statistic (Snodgrass & Corwin, 1988; Wickens, 2002). An A-prime score of .5 indicates that participants do not discriminate old items from critical lures, and as discrimination accuracy increases, A-prime scores approach 1.

Data in Table 1 and Figure 2 indicate that 5- and 7-year-olds experienced no decrease in memory accuracy in the induction condition compared with baseline, whereas memory accuracy of 11-year-olds and adults in the induction condition decreased dramatically compared with baseline.

To examine the significance of these tendencies, A-prime scores were subjected to a two-way Age ×

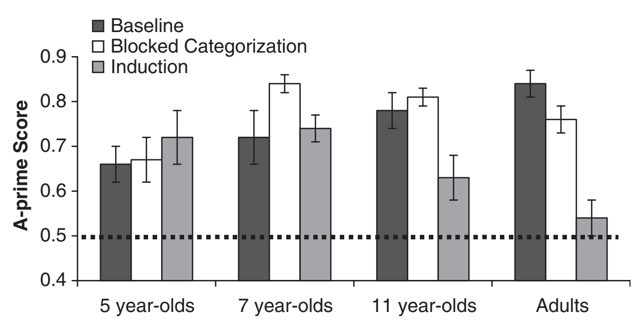

Figure 2. Memory sensitivity scores (A-prime) across four age groups and three experimental conditions in Experiment 1. The dashed line represents the point of no sensitivity. Error bars represent standard errors of the mean.

Condition between-subjects analysis of variance (ANOVA). The analysis indicated that there was no significant main effect of age, $F(3, 215) < 2.6$, $p > .05$, whereas there was a significant main effect of condition, $F(2, 215) = 9.2$, $p < .0001$, with accuracy in the induction condition being significantly lower than accuracy in the baseline and blocked categorization conditions, post hoc Tukey test, all ps < .05. This main effect, however, was driven by a significant Age × Condition interaction, $F(6, 215) = 4.1$, $p < .001$.

Follow-up analyses indicated that 5- and 7-year-olds discriminated old items from critical lures well in all three conditions, and there were no significant differences in their levels of discrimination across the task conditions, as indicated by the one-way ANOVAs performed on the A-prime scores, both Fs < 2.3, ps > .1. At the same time, adults and 11-year-olds discriminated old items from critical lures well in the baseline and blocked categorization conditions, whereas their discrimination in the induction condition was dramatically lower than in the other two conditions, both Fs > 8.8, ps < .001, post hoc Tukey test ps < .05 for all significant differences.

To examine further this developmental trend, we analyzed the differential effects of induction on recognition accuracy as a function of age. Figure 3 presents average differences in A-prime scores in the induction condition compared with the baseline condition across different age groups. Data in Figure 3 suggest that whereas induction in 5- and 7-year-olds did not result in any appreciable change in memory accuracy, it resulted in marked changes in accuracy of 11-year-olds and adults. This contention was supported by statistical analyses: One-way ANOVA with age as a factor revealed a significant main effect of age, $F(3, 73) = 15.49$, $p < .0001$. Post hoc Tukey tests indicated that after performing induction, 11-year-olds and adults exhibited a greater drop in accuracy (compared with the baseline condition) than did younger participants (all ps < .05).

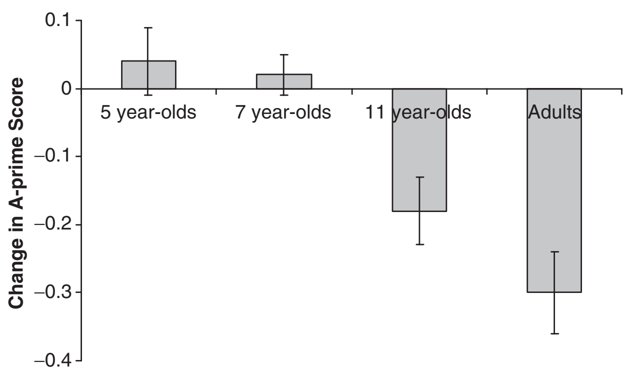

Figure 3. Change in the A-prime scores in induction compared with the baseline across age groups in Experiment 1. Error bars represent standard errors of the mean.

However, it could be argued that because induction accuracy related inversely to subsequent memory accuracy (e.g., 5-year-olds had the lowest level of induction accuracy and the highest level of recognition performance), this could be an alternative explanation of age differences in memory performance; that is, in the younger age groups there may have been more children who did not fully understand the induction instructions during training and perhaps treated the task as one of assessing object similarity. To examine this possibility, we calculated correlation between accuracy during induction training and A-prime scores in the subsequent recognition test. Except for 11-year-olds, the average correlation between induction accuracy and A-prime scores did not surpass ± 0.02. For 11-year-olds the correlation, although higher ($r = -.24$), was still very small and did not approach statistical significance ($p > .29$).

Taken together, results of Experiment 1 replicate and extend findings reported by Sloutsky and Fisher (2004a, 2004b): Eleven-year-olds and adults spontaneously performed category-based induction, whereas 5- and 7-year-olds spontaneously performed similarity-based induction. These findings suggest that the ability to perform category-based induction develops gradually between 7 years of age and adulthood rather than being a default present early in development.

The experiment, however, left several questions unanswered. First, it could be argued that even if younger participants do perform category-based induction, their greater memory accuracy could be driven by their elevated interest in pictures. Although this argument was undermined in previous research (Sloutsky & Fisher, 2004b), we deemed it necessary to replicate these findings. Second, although results suggest different ways of performing induction in younger and older participants, cross-sectional data alone do not provide an insight into how and why this transition takes place. To address these issues, we conducted Experiment 2.

Experiment 2

The goals of Experiment 2 were (a) to provide a learning account of category-based induction found in older participants in Experiment 1 and (b) to undermine the possibility that results of Experiment 1 stemmed from younger participants' having greater interest in pictures than older participants. In Experiment 2, 5- and 7-year-olds were trained to perform induction in a category-based manner. If, as a result of training, children start performing category-based induction, their memory accuracy in the induction condition (but not in the baseline condition) should decrease.

Method

Participants

Participants were 46 five-year-olds (27 girls, 19 boys; *M* age = 5.30 years, *SD* = 0.15 years) and 30 seven-year-olds (22 girls, 8 boys; *M* age = 7.39 years, *SD* = 0.59 years).

Materials, Design, and Procedure

Materials were identical to those in Experiment 1. The experiment had a 2 (condition: induction and baseline) $\times$ 2 (age group: 5-year-olds and 7-year-olds) between-subjects design, with participants being randomly assigned to either the induction or the baseline condition. The procedure of Experiment 2 was similar to that of Experiment 1, with one important exception: Before the experiment proper, 5- and 7-year-olds were presented with training in which they were taught to perform category-based induction.

Training was focused on three pieces of information: (a) animals that have the same name belong to the same kind, (b) animals that belong to the same kind have similar insides, and (c) animals that have the same name have similar insides. Training materials included three boxes, with each box identified by a black outline of a lion, a rabbit, or a dog. The materials also included pictures of lions, rabbits, and dogs (none of these categories was used in the experiment proper, and a separate naming study revealed that these animal categories were familiar to 5-year-olds).

Children were first told that "animals that have the same name are the same kind of animal," and these animals should be placed in the same box. Children were then presented with six categorization trials in which their task was placing pictures in appropriate boxes face down. After each trial children were provided with corrective yes–no feedback.

This categorization training was followed by induction training. First, participants were 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" and were given six induction trials, each accompanied by yes–no feedback. On each trial, children were shown a picture and were told that the animal had a particular biological property (i.e. "this dog has thick blood inside its body"). Children were then asked which animals this property could be generalized to. Feedback was followed by an explanation that same kinds of animals have the same name and same stuff inside.

At the conclusion of training participants were reminded that "animals that have the same name are the same kind of animal, and have the same stuff inside." All participants completed training successfully (i.e., gave either five of six, or four correct answers in a row in the categorization and induction training tasks) and were then presented with either the induction or the baseline condition of the experiment proper (identical to those in Experiment 1).

Results and Discussion

Data from five 5-year-olds (2 in the induction condition and 3 in the baseline condition) that did not reliably reject control items were eliminated from further analysis. As in Experiment 1, the rest of participants were highly accurate in rejecting control items, averaging 96% and 100% of correct responses across conditions for 5- and 7-year-olds, respectively. Participants were also highly accurate in the induction task, averaging 91% and 94% of correct inductions for 5- and 7-year-olds, respectively.

Proportions of hits, false alarms on critical lures, and A-prime scores by age and condition are presented in Table 2. Data in the table indicate that the pattern of recognition accuracy changed dramatically compared with that observed in Experiment 1. Unlike Experiment 1, in the induction condition, memory sensitivity of participants in both age groups, as indicated by the A-primes scores, dropped to chance, both one-sample $ts < 1.7$, $ps > .1$.

Table 2

Mean Proportions of Hits, False Alarms on Critical Lures (FA), and A-Prime Scores by Age and Condition in Experiment 2

Condition	Hits	FA	A-prime scores
		5-year-olds	
Training+baseline	.70	.39	.69†
Training+induction	.82	.66	.58
		7-year-olds	
Training+baseline	.89	.44	.78†
Training+induction	.73	.59	.57

†Above chance recognition accuracy, $p < .005$.

Furthermore, after training, memory accuracy of 5- and 7-year-olds (A-prime scores = .58 and .57, respectively) dropped to the adult level in Experiment 1 (A-prime score = .54).

At the same time, participants exhibited above-chance memory accuracy in the baseline condition, both one-sample $ts > 3.4$, $p < .005$. In fact, there was no drop in memory accuracy for either age group as a result of training in the baseline condition (A-prime scores in the training+baseline in Experiment 2 were .69 and .78 for 5- and 7-year-olds, respectively, whereas A-prime scores in the baseline condition of Experiment 1 were .66 and .72 for 5- and 7-year-olds, respectively). Therefore, it is unlikely that memory decrease in the training+induction condition stemmed from extraneous factors.

Results of Experiment 2 indicate that training to perform category-based induction significantly reduced memory accuracy of both 5- and 7-year-olds in the induction condition, bringing their recognition performance to chance and making it comparable to the performance of older participants in Experiment 1. Results also demonstrate that training did not have a general adverse effect on participants' accuracy (e.g., such as overall fatigue) because training did not result in reduced memory accuracy in the baseline condition. Thus, Experiment 2 replicated earlier findings demonstrating that 5-year-olds can learn to perform category-based induction and extended these findings to 7-year-olds.

However, it could be argued that children did not learn to perform induction in a category-based manner during training; rather, training merely activated their preexisting ability to perform category-based induction. If this is the case, both 5- and 7-year-olds should be able to retain effects of training. At the same time, finding that even after short delays children revert to similarity-based induction would undermine this preexisting knowledge possibility. Experiment 3 was designed to address this issue by investigating the ability of 5- and 7-year-olds to retain the effect of training over a relatively short delay.

Experiment 3

Method

Participants

Participants were 29 five-year-olds (17 girls, 12 boys; M age = 5.05 years, $SD = 0.35$ years) and 20 seven-year-olds (5 girls, 15 boys; M age = 7.62 years, $SD = 0.45$ years).

Materials, Design, and Procedure

Materials and procedure were similar to those of Experiment 2 with one important difference: There was a delay between training to perform category-based induction and the experiment proper (which included the induction and recognition phases). The delay was on average 14.6 days ($SD = 1.5$ days, range = 14–18 days). Participants were presented with the induction condition only, with both the training procedure and the induction condition being identical to those in Experiment 2.

Results and Discussion

Seven 5-year-olds and one 7-year-old did not reliably reject control items, and their data were eliminated from further analysis. As in the previous experiments, the majority of participants were highly accurate in rejecting control items (averaging more than 97% of correct rejections) and making correct inductions during the study phase (averaging 84% and 86% of correct inductions for 5- and 7-year-olds, respectively).

Proportions of hits, false alarms on critical lures, and A-prime scores across the two age groups are presented in Table 3. As can be seen in the table, in contrast to Experiment 2, memory accuracy differed across the age groups: Whereas 7-year-olds retained a high level of false alarms and hence low accuracy (A-prime scores were not different from chance), one-sample $t(18) = 1.9$, $p > .07$, 5-year-olds recovered their high pretraining accuracy (A-prime scores reliably above chance), one-sample $t(16) = 4.9$, $p < .0001$.

These results indicate that retention of the learned ability to perform category-based induction was a function of age: Whereas 5-year-olds were unable to retain the trained ability to perform category-based induction even over a short 2-week delay, 7-year-olds were able to do so. Therefore, it seems unlikely

Table 3
Mean Proportions of Hits, False Alarms on Critical Lures (FA), and A-Prime Scores by Age in Experiment 3

	Training – delay – induction condition		
Age group	Hits	FA	A-prime scores
5-year-olds	.83	.61	.68*
7-year-olds	.91	.76	.58

*Above chance recognition accuracy, $p < .05$.

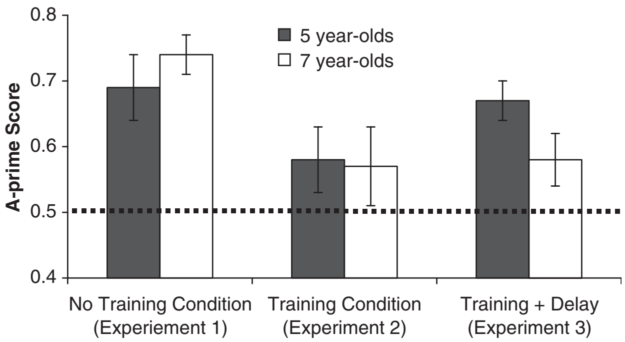

Figure 4. A-prime scores in the induction condition of Experiments 1 to 3 for 5- and 7-year-olds. The dashed line represents the point of no sensitivity. Error bars represent standard errors of the mean.

that training merely activated the preexisting ability of 5-year-olds to perform category-based induction. Given how fragile this ability is, it seems more likely that young children learned de novo how to perform category-based induction.

A-prime scores of 5- and 7-year-olds in the induction condition across the three reported experiments are presented in Figure 4. Data in the figure point to an interesting developmental pattern that suggests that both 5- and 7-year-olds do not perform category-based induction spontaneously (i.e., their memory sensitivity scores are high in the no-training condition of Experiment 1), but children in both age groups can be successfully trained to perform category-based induction (as demonstrated by reduced memory sensitivity scores in the induction condition of Experiment 2). Furthermore, only 7-year-olds are able to retain the results of training over several weeks (i.e., their memory sensitivity scores remained low in Experiment 3), whereas 5-year-olds reverted to performing similarity-based induction (i.e., after the delay in Experiment 3, their memory accuracy returned to high pretraining levels).

Experiments 1 to 3 demonstrated that young children spontaneously perform similarity-based induction and that category-based induction develops gradually between 7 years of age and adulthood. However, in these experiments similarity-based induction was inferred from patterns of correct recognition memory. The goal of Experiment 4 was to present converging evidence that similarity-based induction results in accurate recognition memory. To achieve this goal, we forced adults to perform similarity-based induction by presenting them with artificial (and thus novel) categories of animal-like creatures.

Experiment 4

Method

Participants

Participants were 48 introductory psychology students (27 women, 21 men; M age = 22.51 years, SD = 6.70 years).

Material, Design, and Procedure

Design and procedure were identical to those of the induction and baseline conditions of Experiments 1 to 3; however, materials consisted of a set of artificial animal-like stimuli created by combining seven features: body, upper wings, lower wings, buttons, antennas, tails, and spirals. Each feature varied on several dimensions (i.e., shape, size, color, or number). Four categories were created: Category 1, Category 2, Category 3, and distracters. Stimuli were created such that Category 1 creatures all had round bodies, long upper wings, and lower wings; Category 2 creatures had round bodies, short upper wings, and lower wings; and Category 3 creatures had long bodies, long upper wings, and no lower wings, and the rest of the features varied. Distracters were created to be perceptually different from the rest of the creatures: They were blue and had spirals attached to the upper wings (neither of these features was used for the other animal categories). These stimuli partitioned by categories are presented in Figure 5. Note that there was greater within-category similarity than similarity across categories, which was confirmed empirically in a separate experiment with 11 undergraduate students (none of whom participated in the experiment proper). These participants were not informed about the structure of these artificial categories, and yet they accurately classified items into the four groups (the overall accuracy was 94%). In the experiment proper, participants were tested individually in a laboratory on campus, and all instructions were presented to them on a computer screen. During the induction phase, corrective yes–no feedback was provided to indicate that only Category 1 creatures, but not members of other categories, had beta cells inside them.

Results and Discussion

Eight participants did not reliably reject distracters during the recognition test (1 in the induction condition and 7 in the baseline condition), and their data were excluded from further analyses. The rest of participants were accurate in rejecting distracters

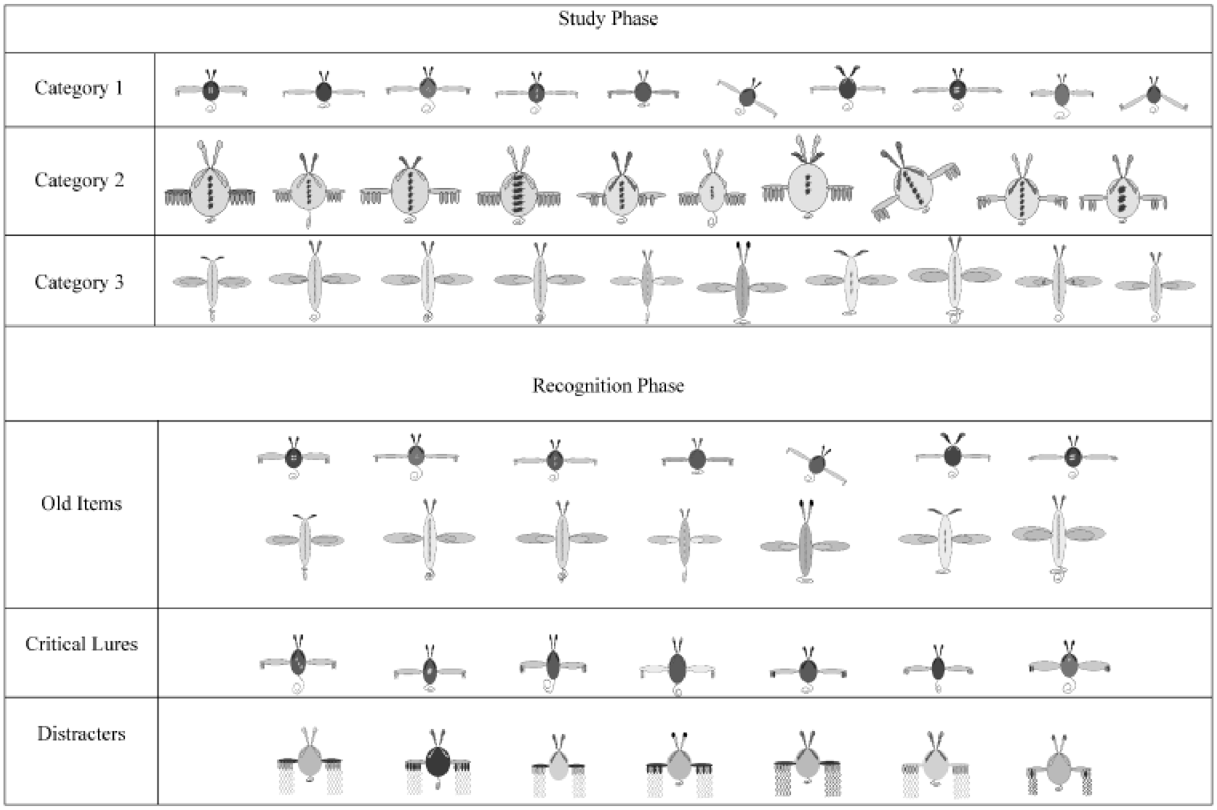

Figure 5. Examples of stimuli used in Experiment 4. These stimuli were presented in color. The color version can be found on the following website: http://cogdev.cog.ohio-state.edu/FiguresforMemory.pdf.

(95% correct) and, most important, in restricting their inductions only to the members of Category 1 (74% correct). As predicted, participants exhibited accurate recognition memory in both the baseline condition (hits = .74, false alarm = .50, A-prime = .64) and the induction condition (hits = .74, false alarm = .57, A-prime = .64), with both A-prime measures being above chance, both one-sample ts > 2.99, ps < .01. Furthermore, unlike Experiment 1, accuracy scores were not statistically different in the induction and baseline conditions, $t(38) = .84$, $p > .40$. The fact that participants exhibited above-chance accuracy when performing induction with completely new categories is remarkable: Participants were more accurate with these novel stimuli than they were with pictures of highly familiar categories used in Experiment 1, in which A-prime scores did not differ from chance.

Recall that in this condition adult participants were forced to perform similarity-based induction, and as a result they exhibited the same pattern of high recognition accuracy as did young children in Experiments 1 and 3. These findings present direct evidence that similarity-based induction results in higher memory accuracy.

General Discussion

Summary of Findings

Results of the four experiments point to several important regularities. First, in Experiment 1 recognition accuracy decreased with age in the induction condition but not in the baseline or blocked categorization conditions. In Experiment 2, 5- and 7-year-olds were successfully trained to perform category-based induction, and training attenuated their recognition memory accuracy in the induction condition but not in the baseline condition. These findings replicated and extended the findings of Sloutsky and Fisher (2004a, 2004b) suggesting that (a) induction attenuated memory accuracy in older but not in younger participants, and (b) when younger participants were trained to perform category-based induction, their memory accuracy dropped to the adult level. In addition, Experiment 1 yielded a novel finding, revealing a clear developmental trend: After performing induction, 5- and 7-year-olds were more likely to exhibit accurate recognition than were 11-year-olds and adults. These findings are remarkable because under regular conditions memory is known to increase rather than decrease from early childhood to young adulthood (see Schneider & Bjorklund, 1998, for a review). These results (a) support the hypothesis that early induction is similarity based and (b) point to a gradual development of category-based induction from early childhood to adulthood.

In Experiment 3, when a delay was introduced between induction training and the experiment proper, recognition memory accuracy of 5-year-olds increased to the pretraining level, whereas accuracy of 7-year-olds remained low. Finally, Experiment 4 demonstrated that when adults were forced to perform similarity-based induction, they exhibited patterns of accurate recognition in both the baseline and induction conditions. Although results of Experiments 1 and 2 replicate and extend previous research, results of Experiment 3 and 4 represent novel findings.

Taken together, reported findings suggest that category-based induction is not a default but rather a product of development and learning. These results elucidate the development of induction, and they have theoretical implications for the study of categorization and induction, as well as broader implications for the study of memory and its development.

Development of Induction

Theoretical approaches assuming reliance on conceptual knowledge in the course of induction have been influential in the past decade; however, recent findings pose a challenge to this assumption (e.g., Jones & Smith, 2002; Sloutsky & Fisher, 2004a, 2004b; Sloutsky & Spino, 2004; Smith, Jones, & Landau, 1996; see also Sloutsky, 2003, for a review). Results presented here challenge the idea that early in development induction is category based: The reported findings are inconsistent with the idea that children first identify presented entities as members of the known categories and then generalize properties to other members of the same categories. These findings suggest that it is unnecessary to posit conceptual assumptions to account for inductive generalizations in young children, thus supporting the recently proposed similarity, induction, and categorization (SINC) model (Sloutsky & Fisher, 2004a), which argues that for young children, both induction and categorization are similarity-based processes.

Experiment 1 presented evidence that category-based induction emerges gradually in the course of development rather than being present early in development. However, the results did not indicate what it is in development that may underlie the transition from category-based to similarity-based induction. Experiments 2 and 3 provided a learning account of this transition, thus challenging the notion that category-based induction is an early ability. Recall that in Experiments 2 and 3 participants were taught that (a) entities that look similar belong to the same kind, (b) entities that belong to the same kind share many properties, and (c) entities that share the same name belong to the same kind and share many properties. It is possible that children implicitly learn through observation and interaction with objects that things that look alike are likely to share many properties. At the same time it is possible that they learn at school that (a) there are kinds that consist of similar entities and (b) entities that share the name belong to the same kind. Therefore, based on this learning of (a) and (b), as well as the acquired knowledge of categories, people gradually develop the ability to infer that entities belonging to the same kind are likely to share many properties. Taken together, results of Experiments 1 to 3 suggest that category-based induction is a product of learning appearing relatively late in development.

Note that the claim that there is a gradual transition from similarity-based to category-based induction does not imply that adults perform induction only in the category-based manner. When categories are novel (as in Experiment 4), adults perform similarity-based induction, whereas when categories are familiar (as in Experiment 1), adults perform category-based induction. Therefore, although mature induction can be (depending on conditions) either similarity based or category based, early induction is likely to be similarity based. Thus, it seems reasonable to conclude that similarity-based induction is a default, whereas category-based induction is a product of learning and development.

Results of reported experiments also point to a potentially important distinction between perceptual (or bottom-up) categorization and conceptual (or top-down categorization). In particular, perceptual categorization is less likely to result in memory distortions (i.e., adults in Experiment 4) than in conceptual categorization (i.e., adults in Experiment 1). There is ample evidence that perceptual categorization appears very early in development: Even 3- to 4-month-old infants are capable of perceptual categorization that is driven by perceptual learning (e.g., French, Mareschal, Mermillod, & Quinn, 2004; Quinn, Eimas, & Rosenkrantz, 1993). Current results suggest that even in preschoolers familiar categories are represented perceptually: Young children's performance with familiar categories was similar to that of adults' performance with novel categories. Therefore, current research indicates that perceptual and conceptual categorizations result in different memory accuracy, thus suggesting that the two types of categorization are cognitively distinct (see French et al., 2004, for related arguments).

It could be counterargued, however, that there are findings that may challenge current conclusions that early induction is similarity based. In particular, there is evidence that even in 5-year-olds induction could be affected by typicality information (Lopez, Gelman, Gutheil, & Smith, 1992). In particular, children judged inferences from more typical animals to all animals (e.g., ''Dogs have X; therefore, all animals have X'') stronger than inferences from less typical animals (e.g., ''Bats have X; therefore, all animals have X''). However, it is also possible that these putative typicality effects stemmed from the fact that the less typical animal was referred to by a less familiar word. For example, the MRC Psycholinguistic database (Wilson, 1987) suggests the following familiarity ratings for the items in question: animal = 620, dog = 598, bat = 514. Note that according to the database, familiarity values range from 100 to 700, with $M = 488$ and $SD = 99$. Therefore, it is possible that results reported by Lopez et al. (1992) stemmed from a lower familiarity of the word *bat* rather than from a lower typicality of the category *bat*.

There is also evidence that knowledge about the world may be an important part of categorization and induction: This knowledge was found to assist categorization and category learning of children (Carmichael & Hayes, 2001; Krascum & Andrews, 1998). This evidence, however, is indirect. Although demonstrating that having prior knowledge (including conceptual assumptions) could be beneficial, it does not constitute direct evidence for the presence of conceptual assumptions in young children.

Overall, the fact that these findings are either indirect or open to alternative interpretations weakens the ability of these findings to challenge the conclusions of current research.

Implications for the Study of Memory

Reported results may have broader implications for the study of memory and its development. First, the present research indicates that deeper levels of processing do in fact reduce recognition accuracy. Across all experiments, category-based induction (which is associated with deeper semantic processing) resulted in less accurate recognition than did similarity-based induction (which is associated with less deep perceptual processing).

Second, current results indicate that young children are less prone to the levels-of-processing manipulations: Without training, even with familiar categories, young children exhibit evidence of perceptual rather than semantic processing. These results suggest that the ability to encode the semantic level, or category information, is a product of development. As a result, although adults can form both category-level (or ''gist'') representations and item-specific representations, young children tend to form mostly item-specific representations. These considerations are consistent with the fuzzy trace theory of memory (Brainerd et al., 2002).

Third, the reported findings point to interesting interrelations between categorization and recognition. Although recognition has been typically thought of as a process closely correlated with categorization, current results suggest that the relationships could be inverse: Greater categorization may result in lower recognition accuracy for individual items, and high recognition accuracy for individual items may indicate lower categorization of these items. However, more research is needed to examine this issue.

Finally, the present results suggest that under some conditions, greater stimulus familiarity may lead to higher levels of memory intrusions and thus to less accurate recognition memory. These results suggest that induction with familiar and novel categories is a useful levels-of-processing manipulation that could be employed for studying memory and its development, as well as for contrasting single- and dual-process approaches to recognition memory (see Rotello & Heit, 1999, for a review of these approaches).

Conclusion

Results of the four experiments indicate that (a) young children spontaneously perform similarity-based induction, (b) there is a gradual transition from similarity-based to category-based induction, and (c) category-based induction is likely to be a product of learning. These results support the similarity-based account of young children's induction and present a challenge to the naive theory approach, which assumes that young children's induction is category based as a function of preexisting conceptual knowledge.

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