Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 26(26)

ISSN
1069-7977

Authors
Fisher, Anna V.
Sloutsky, Valdimir M.

Publication Date
2004

Peer reviewed

The Development of Induction: From Similarity-Based to Category-Based

Anna V. Fisher (fisher.449@osu.edu)
Department of Psychology & Center for Cognitive Science
The Ohio State University
208B Ohio Stadium East, 1961 Tuttle Park Place
Columbus, OH 43210 USA

Vladimir M. Sloutsky (sloutsky.1@osu.edu)
Center for Cognitive Science
The Ohio State University
208C Ohio Stadium East, 1961 Tuttle Park Place
Columbus, OH 43210 USA

Abstract

The ability to perform inductive generalizations has been demonstrated to develop very early in life. We argue that while adults use their conceptual knowledge when performing induction, young children perform induction by computing the similarity among presented entities. We further argue that this differential processing underlying children's and adults' induction results in different memory traces, and affects accuracy on a subsequent memory test. Experiment 1 demonstrates that while performing induction decreases memory accuracy of adults and 12-year-olds, it does not affect memory accuracy of 5-, and 7-year-olds. In Experiment 2, 5- and 7-year-olds were trained to perform category-based induction, which resulted in a decrease of their memory accuracy. In Experiment 3, a delayed transfer task was used to examine whether 5- and 7-year-olds could retain their learning over time. Overall, results of the reported experiments point to a developmental trend from similarity-based to category-based induction.

Introduction

The ability to make inductive generalizations is undoubtedly crucial for humans, for not only does it facilitate acquisition of new knowledge and skills, but also aids survival: "our knowledge that leopards can be dangerous leads us to keep a safe distance from jaguars" (Sloman, 1993, p.321).

It has been demonstrated that infants and very young children can perform simple induction tasks (Gelman & Markman, 1986; Sloutsky, Lo, & Fisher, 2001, Welder & Graham, 2001). The process underlying this basic ability is, however, still open to debate.

According to one view, children's inductive generalizations are driven by *a priori* conceptual assumptions (Keil, Smith, Simons, & Levin, 1998, Gelman & Hirschfeld, 1999). Under this view, which has traditionally been referred to as a *naïve theory* position, even early in development, induction is driven by the category assumption – a belief that entities are members of categories, and members of the same category have much in common. Thus, in the course of induction, children first identify presented entities as members of categories, and then perform inductive inferences on the basis of this categorization, because they presumably believe that members of the same categories share many unobservable properties.

According to another position, 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 & Fisher, in press-a; Sloutsky, 2003). 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. One such similarity-based model, SINC (abbreviated for Similarity, Induction, and Categorization) was proposed recently by Sloutsky and colleagues (Sloutsky et al., 2001; Sloutsky, 2003, Sloutsky & Fisher, in press-a). Under this view, conceptual knowledge (i.e., knowledge that that members of the same category share many unobservable properties) is a product of learning and development rather than an *a priori* assumption.

In short, under the former view, induction is category-based (i.e., it is a product of categorization), whereas under the latter view, induction is a product of computation of similarity. One of the goals of this research is to distinguish between these positions.

Traditionally, inductive inference in children has been studied directly, by asking participants to perform inductive generalizations and assessing their performance. However, this approach may not be an optimal way of examining representations underlying performance on induction tasks. An alternative framework has been recently suggested (Sloutsky & Fisher, in press-b). In this framework, representations underlying induction performance are studied by examining memory traces formed in the course of Induction. Participants are first presented with sets of pictures of familiar animals, and are asked to make inductive inferences about these animals. Later participants are given a surprise recognition memory test, in which they are presented with some old pictures (i.e., pictures they had previously reasoned about in the induction task), and some Critical Lures (i.e., "new" pictures that belong to the same category as "old" pictures). If participants perform induction in a similarity-based manner, they should form item-specific representations, and exhibit high accuracy on a recognition test. At the same time, if participants form category-level representations (which might be the case if induction is category-based), they should poorly distinguish between Old Targets and Critical Lures.

Results reported by Sloutsky and Fisher (in press-b) indicate that young children exhibit high recognition accuracy for Critical Lures (thus pointing to similarity-based induction), whereas adults exhibit low recognition accuracy for Critical Lures (thus suggesting category-based induction). It has also been demonstrated that adults' category-based induction results in a decrease in memory accuracy compared to the Baseline memory tasks, while young children's similarity-based induction does not.

The goal of the series of experiments presented below is to compare the two theoretical positions by examining the pattern of development of inductive inference. The similarity-based position assumes a gradual transition from similarity-based to category-based induction in the course of learning and development, whereas no such transition is predicted by the naïve theory position. According to this position, even young children perform category-based induction. Another goal is to provide a learning account of the transition from similarity-based to category-based induction.

Experiment 1

Method

Participants Participants were 45 5 year-olds (19 girls, 26 boys, *M* age= 5.2 years, *SD* = .32 years), 35 7 year-olds (21 girls, 14 boys, *M* age= 7.9 years, *SD* = .54 years), 39 12 year-olds, (18 girls, 21 boys, *M* age = 12.1 years, *SD* = .48), and 30 introductory psychology students at a large Midwestern university (12 women and 18 men, *M* age= 19.5 years, *SD* = .99 years).

Materials, Design and Procedure Materials were 44 color photographs of animals presented against the white background. All animals were highly familiar to both children and adults, with familiarity established in a separate experiment (Sloutsky & Fisher, in press-b). Examples of the photographs used are presented in Figure 1. During the study phase, participants were presented with 30 pictures, one picture at a time, from three different categories (10 cats, 10 bears, and 10 birds). During the recognition phase, they were presented with 28 pictures, one picture at a time, and were asked whether they had seen each picture during the study phase. Half of the recognition pictures were previously presented during the study phase, and the other half were new pictures. The recognition pictures represented animals from three different categories: cats (7 of which were old and 7 were new), bears (all 7 of which were old), and squirrels (all 7 of which were new).

The experiment included two between-subject conditions: Baseline and Induction. The recognition phase was identical in both conditions, whereas the study phase differed across conditions.

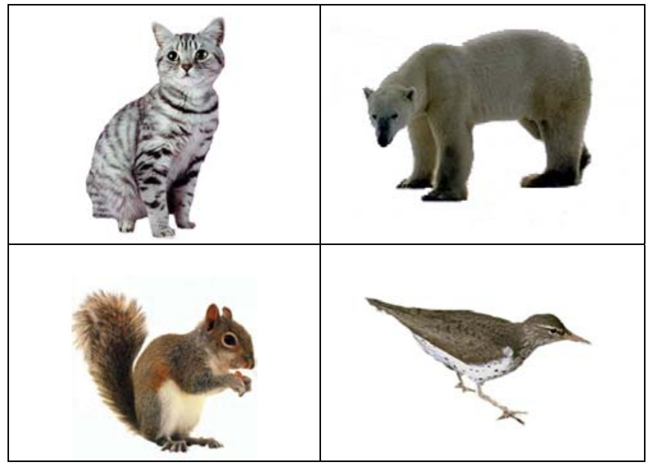

Figure 1: Examples of stimuli in Experiment 1.

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 asked whether each of the animals also had beta-cells inside. After responding, participants were provided with "yes/no" feedback, indicating that only cats, but not bears or birds, had beta-cells. The recognition test was not mentioned in the study phase of this condition.

During the recognition phase, which immediately followed the study phase, 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

Children were tested individually in their 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, and stimuli presentation was controlled by Super Lab Pro 2 software (Cedrus Corporation, 1999).

Results and Discussion

Although participants in every age group were very accurate in the study phase of the Induction condition, adults and 12 year-olds were somewhat more accurate (averaging 91% and 94% of correct inductions respectively) than 5- and 7-year-olds (74% and 84% of correct inductions respectively), $F(3, 78) = 5.9$, $p < .01$, post-hoc Tukey test, *p*s < .05 for all differences.

In the recognition phase of the experiment all participants were highly accurate in rejecting non-target distracters (i.e., squirrels), averaging over 91% of correct responses across conditions.

However, participants exhibited differential accuracy for the Targets (items previously presented during the study phase, i.e. old cats and bears) and Critical Lures (new items from the same category as the Targets, i.e., new cats) in the Induction and the Baseline. To examine the ability of participants to discriminate previously presented Targets from Critical Lures, memory sensitivity A-prime scores were computed. A-prime is a non-parametric analogue of the signal-detection statistics d-prime (Snodgrass & Corwin, 1988). If participants do not discriminate old Targets from Critical Lures, A-prime is at or below 0.5. The greater the discrimination accuracy, the closer A-prime scores are to 1. Proportions of hits (i.e., correct recognitions), false alarms on Critical Lures (FA), and A-prime scores by age group and condition are presented in Table 1.

Data in the table indicate that 5-, 7- and 12-year-olds well discriminated old items from Critical Lures in the Induction as well as the Baseline condition (A-primes > 0.5, one-sample *t*s > 2.8, *p*s < .01). At the same time, adults were accurate in the Baseline condition (A-primes > .5, one-sample t (14) 16.1, p < .001), whereas they were not accurate in the Induction condition: unlike children, adults' A-primes in this condition were not different from 0.5, one-sample $t < 1$, indicating no discrimination between old items and Critical Lures. Furthermore, adults' accuracy was lower than that of 5-year-olds or 7-year-olds, both independent sample *t*s > 2, *p*s <.05.

Table 1: Proportions of Hits, False Alarms (FA) and A-prime scores by age group and condition.

Age group	Baseline			Induction		
	Hits	FA	A-prime	Hits	FA	A-prime
5 year-olds	.82	.59	.66	.71	.56	.69
7 year-olds	.75	.40	.72	.77	.45	.74
12 year-olds	.79	.39	.78	.79	.59	.63
Adults	.88	.40	.84	.81	.74	.54

These findings are summarized in Figure 2, which presents a change in the A-prime scores in the Induction condition compared to the Baseline. Data in the figure indicate that in the Induction condition recognition memory was somewhat reduced in 12 year-olds and dramatically attenuated in adults, while Induction had virtually no effect on the recognition accuracy of 5- and 7-year-olds. The significant age by condition interaction was confirmed by the two-way (age by experimental condition) ANOVA performed on the A-prime scores, F (3, 141) = 5.7, p < .001.

We argue that high recognition accuracy of younger participants of Experiment 1 was due to the fact that they were engaged in item-specific processing regardless of the experimental condition. Adult participants, on the contrary, demonstrated high memory accuracy only in the task that forced them to perform item-based processing, the Baseline condition. In the Induction condition, however, adults demonstrated low memory accuracy, due to engagement in category-level processing. Results of Experiment 1 therefore point to a developmental trend from similarity-based to category-based induction: memory sensitivity of younger children does not decrease at all in the Induction compared to the Baseline, while sensitivity of 12 year-olds decreases somewhat, and sensitivity of adults reduces dramatically.

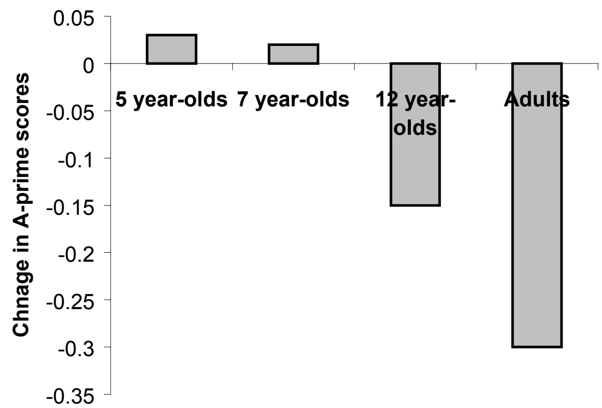

Figure 2: Change in the A-prime scores in the Induction condition compared to the Baseline across age groups.

Experiment 2 was designed to provide a learning account of the category-based induction found in adults, by training 5- and 7-year-olds to perform induction in the category-based manner. If training is successful, that is if memory accuracy of younger children can be reduced to the level of adults, this would further undermine the claim that reasoning in young children is *a priori* conceptually constrained.

Experiment 2

Method

Participants Participants were 27 5 year-olds (16 girls, 11 boys, *M* age= 5.2 years, *SD* = .26 years), and 15 7 year-olds (11 girls, 4 boys, *M* age= 7.6 years, *SD* = .44 years).

Materials, Design and Procedure Materials were identical to those of Experiment 1, however, participants were tested in the Induction condition only. The procedure of Experiment 2 was different from Experiment 1 in that prior to the study phase, participants were trained to perform category-based induction. Children were taught that animals that have the same names belong to the same category, and that animals that belong to the same category share unobservable properties. Picture cards representing rabbits, dogs, and lions were used for the training procedure; none of these categories of animals were used in the experiment proper.

Upon completing the training, participants were presented with the experimental task, which was identical to the Induction condition of Experiment 1. Hypothesis-blind female experimenters tested children individually in their schools and child care centers.

Results and Discussion

Overall participants were highly accurate during the study phase of Experiment 2, averaging over 92% of correct inductions. Similar to Experiment 1, participants were also very accurate in rejecting non-target distracters (i.e. squirrels), giving on average 98% of correct responses.

However, unlike Experiment 1, memory sensitivity of participants in both age groups, as indicated by the A-primes scores, did not differ from chance, both one-sample *ts* < 1.7, *ps* > .1. Proportions of hits, false alarms on Critical Lures, and A-prime scores are presented in Table 2.

Results of Experiment 2 indicate that training to perform category-based induction significantly reduced memory accuracy of both 5- and 7-year-olds, bringing their recognition performance to chance and making it comparable to the performance of adult participants in Experiment 1.

Could it be that training had a non-specific effect on memory accuracy, such that, regardless of the experimental task, children participating in the training experiment exhibited reduced memory accuracy? This issue was addressed by Sloutsky and Fisher (in press-b), who demonstrated that training had no adverse effects on children's memory in the Baseline condition.

Table 2: Proportions of Hits, False Alarms (FA) and A-prime scores by age group in Experiment 2.

Age group	Training Condition		
	Hits	FA	A-prime
5 year-olds	.82	.65	.58
7 year-olds	.73	.59	.57

While demonstrating that both 5- and 7-year-olds were successful in learning to perform category-based induction, the experiments left an important question unanswered. In particular, it remained unclear whether effects of this training would be retained over time. Results of Experiment 2 together with the developmental trend found in Experiment 1 suggest that older children should be better able to retain what they learned during training over a time delay. Experiment 3 was designed to investigate the ability of 5- and 7-year-olds to retain this new knowledge over a time delay.

Experiment 3

Method

Participants Participants were 17 5 year-olds (11 girls, 7 boys, *M* age= 5.3 years, *SD* = .17 years), and 19 7 year-olds (4 girls, 15 boys, *M* age= 7.6 years, *SD* = .44 years).

Materials, Design and Procedure Materials and procedure were identical to those of Experiment 2 with one important difference: there was a delay between training to perform category-based induction and the experiment proper. The delay was on average 14.6 days (SD = 1.5 days, range 14 – 18 days). As in the previous experiments hypothesis-blind female experimenters tested children individually in their schools and child care centers.

Results and Discussion

Similar to previous experiments participants were highly accurate both in rejecting non-target distracters (averaging over 96% of correct rejections), and making correct inductions during the study phase (84% and 86 % of correct inductions in the groups of 5- and 7-year-olds respectively). However, in contrast to Experiment 2, participants demonstrated differential memory accuracy for Critical Lures. Proportions of hits, false alarms on Critical Lures, and A-prime scores are presented in Table 3. Memory accuracy of 7 year-olds indexed by the A-prime scores was close to chance (which was similar to their accuracy in Experiment 2), one-sample *t* (18) = 1.9, *p* > .07. On the other hand, recognition memory of 5 year-olds was clearly above chance, one-sample *t* (16) = 4.9, *p* < .0001.

Table 3: Proportions of Hits, False Alarms (FA) and A-prime scores by age group in Experiment 3.

Age group	Delayed Transfer Condition		
	Hits	FA	A-prime
5 year-olds	.82	.59	.67
7 year-olds	.91	.75	.59

Thus, results of Experiment 3 indicate that while 7 year-olds retained what they had learned during training over a two-week delay, 5 year-olds were unable to do so. Therefore, retaining of the learned ability to perform induction in a category-based manner seems to be a function of age.

Memory accuracy of 5- and 7-year-olds across three reported experiments is presented in Figure 3. Results presented in Figure 3 point to an interesting developmental pattern: while both 5- and 7-year-olds do not perform category-based induction spontaneously (i.e., under the no-training condition of Experiment 1, their accuracy is high), children in both age groups can be successfully trained to perform category-based induction (as evidenced by their reduced accuracy in the training condition of Experiment 2). However, only 7 year-olds are able to retain the results of training over longer periods of time (i.e., after the delayed condition in Experiment 3, their accuracy remained low). At the same time, 5-year-olds reverted back to similarity-based induction (i.e., after the delayed condition in Experiment 3, their memory accuracy returned to the high pre-training level).

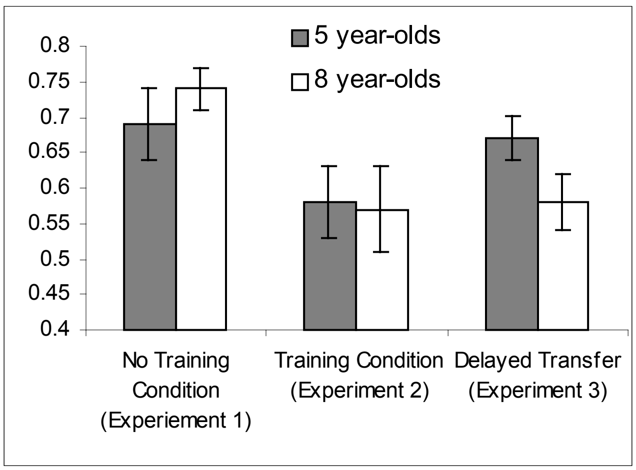

Figure 3: A-prime scores for 5- and 7-year-olds in the Induction task across Experiments 1 – 3.

General Discussion

Several important findings stem from the three reported experiments. First, there is a clear trend in the development of induction: induction task attenuates memory accuracy for individual items of 12-year-olds and adults, whereas 5- and 7-year-olds exhibit accurate memory for individual items. Furthermore, in the Induction (but not in the Baseline) condition younger participants exhibit greater memory accuracy than older participants or adults. Second, training to perform category-based induction leads to a decrease in memory accuracy of 5- and 7-year-olds to the level of adults. And third, 7-year-olds retain training over longer periods of time than 5-year-olds: 5-year-olds sooner than 7-year-olds exhibit high levels of memory accuracy for individual items, returning to their pre-training high accuracy.

These results indicate that: (1) while 12-year-olds and adults perform category-based induction (which results in mostly category-level representations), 5- and 7-year-olds perform similarity-based induction (which results in item-level representations); (2) there is a gradual developmental transition from similarity-based to category-based induction; and (3) category-based induction does not have to be *a priori*, it can be learned and retained over time (although the length of retention is a function of age). These results support predictions of the similarity-based account of induction, while presenting challenges to the naïve theory approach. In what follows, we consider theoretical implication of these results.

Induction and Memory Accuracy Across Development

The results support the contention of the similarity-based approach that early in development children perform induction by computing similarity among compared entities. As a result, these participants form item-specific representations, and accurately remember individual items encountered in the course of induction. At the same time, older children and adults perform category-based induction (i.e., they first categorize entities, and then generalize properties to members of the same category), and as a result they form category-level, but not item-specific representation, thus exhibiting poor memory for individual items encountered in the course of induction. Note that older children and adults have no difficulty remembering individual items, in the Baseline condition, in which they are not required to perform induction. Furthermore, there is additional evidence that category-based induction affects memory accuracy for individual items: when younger participants were trained to perform category-based induction, their memory accuracy in the Induction (but not in the Baseline) condition dropped to the level of adults.

Taken together, these findings do not support the contention of the naïve theory position that induction in young children is category-based, but they rather support the contention of SINC that induction in young children is similarity-based.

The Development and Learning of Category-Based Induction

The reported results also present developmental and learning accounts of category-based induction. First, category-based induction gradually emerges in the course of development: there is little evidence that 5- or 7-year-olds spontaneously perform category-based induction, whereas 12-year-olds are more likely to perform it than younger children, and adults are more likely to perform it than 12-year-olds. Second, people do not need *a priori* category assumption – young children can be trained to perform category-based induction. However, the retention of this training is a function of age – 7-year-olds are more likely to retain training over time than younger children. Therefore, it seems reasonable to conclude that (a) there is a transition from similarity-based to category-based induction, and this transition is gradual; (b) category-based induction can be successfully learned; and (c) the retention of learning is a function of age. These findings provide 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) similar things that have the same name belong to the same kind, (b) things that belong to the same kind share many non-observable properties, and (c) things that have the same name share many non-observable properties. It is possible that (a) and (b) are taught in school, whereas (c) is a direct consequence of (a) and (b). Therefore, results of Experiment 2 may explain the transition from the similarity-based induction exhibited by children to category-based induction exhibited by adults, suggesting that category-based induction and requisite conceptual knowledge could be a product of feedback-based learning. While presenting a learning account of category-based induction, these findings seriously challenge the contention of the naïve theory position that category-based induction has to be based on *a priori* assumptions.

Conclusion

Overall, results of the three reported experiments represent novel findings indicating that (a) early in development people spontaneously perform similarity-based rather than category-based induction; (b) there is a gradual transition from similarity-based to category-based induction; and (c) category-based induction is a product of learning. These results support the similarity-based account of young children's induction, while presenting challenges to the naïve theory approach.

Acknowledgments

This research is supported by grants from the National Science Foundation (BCS # 0078945 and REC # 0208103) to Vladimir M. Sloutsky.

References

Gelman, S. A., & Markman, E. (1986). Categories and induction in young children. *Cognition*, *23*, 183-209.

Gelman, S. A. & Hirschfeld, L. A. (1999). How biological is essentialism? In S. Atran & D. Medin (Eds.). *Folkbiology*, Cambridge, MA: MIT Press.

Jones, S. S., & Smith, L. B. (2002). How children know the relevant properties for generalizing object names. *Developmental Science*, *5*, 219-232.

Keil, F. C., Smith, W. C., Simons, D. J., & Levin, D. T. (1998). Two dogmas of conceptual empiricism: Implications for hybrid models of the structure of knowledge. *Cognition*, *65*, 103-135.

McClelland, J. L., & Rogers, T. T. (2003). The parallel distributed processing approach to semantic cognition. *Nature Reviews Neuroscience*, *4*, 310-322.

Sloman, S. A. (1993). Feature-based induction. *Cognitive psychology, 25,* 231 – 280.

Sloutsky, V. M., Lo, Y.-F., & Fisher, A. V. (2001). How much does a shared name make things similar? Linguistic labels and the development of inductive inference. *Child Development*, *72*, 1695-1709.

Sloutsky, V. M. (2003). The role of similarity in the development of categorization. *Trends in Cognitive Sciences*, *7*, 246-251.

Sloutsky, V. M., & Fisher, A. V. (In press-a). Induction and categorization in young children: A similarity-based model. *Journal of Experimental Psychology: General.*

Sloutsky, V. M., & Fisher, A. V. (In press-b). When development and learning decrease memory: Evidence against category-based induction in children. *Psychological Science.*

Snodgrass, J. G., & Corwin, J. (1988). Pragmatics of measuring recognition memory: Applications to dementia and amnesia. *Journal of Experimental Psychology: General*, *117*, 34-50.

Welder, A. N., & Graham, S. A. (2001). The influences of shape similarity and shared labels on infants' inductive inferences about nonobvious object properties. *Child Development*, 72, 1653-1673.