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Effects of Category Labels on Induction and Visual Processing: Support or Interference?

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Abstract

Linguistic labels have been demonstrated to promote inductive generalizations even early in development, however, the mechanism by which labels contribute to induction remains unknown. According to one theoretical position, even young children, realize that labels denote categories. Therefore, labels enable categorization of presented entities, and thus contribute to category-based induction. According to the alternative proposal, early in development labels are features of objects that promote induction through their contribution to the overall similarity of compared entities. The goal of the experiments presented below was to distinguish between these positions.

Keywords: Induction, Categorization, Cognitive Development, Language.

Introduction

The ability to make inductive generalizations is crucial for acquiring new knowledge. For instance, upon learning that a particular cat uses serotonin for neural transmission, one can generalize this knowledge to other felines and possibly other mammals. The ability to perform inductive generalizations appears very early in development (Gelman & Markman, 1986; Sloutsky & Fisher, 2004a, 2004b; Welder & Graham, 2001), however the mechanisms underlying early induction remain unknown.

Two theoretical positions emerged in the course of study of early induction: a similarity-based and a knowledge-based approach. Proponents of the knowledge-based position argue that even early in development induction is driven by "theory-like" knowledge, implemented as a set of conceptual assumptions. These assumptions include among others the *category* and the *linguistic* assumptions. The category assumption is the belief that individual entities belong to more general categories and that members of the same category share many important properties. The linguistic assumption is the belief that linguistic labels presented as count nouns denote categories (for review of these assumptions see Gelman, 2003; Keil, et al 1998; Murphy, 2002). Therefore, according to the knowledge-based approach, when presented with entities that share the same name (i.e., both are called *Cats*), people, including young children, first infer (by the linguistic assumption) that the entities belong to the same category. Then (by the category assumption) they infer that things that belong to the same category share important properties, thus performing category-based induction.

Proponents of the alternative similarity-based approach argue that early in development generalizations are performed on the basis of multiple commonalities among presented entities (French, et al. 2004; Mareschal, Quinn, & French, 2002; McClelland & Rogers, 2003; Sloutsky, 2003; Sloutsky & Fisher, 2004a, 2004b). Members of a category often happen to be perceptually similar to each other, and different from the non-members; therefore, young children are more likely to generalize properties to members of a category, than to the non-members. Under this view, conceptual knowledge (i.e., knowledge that members of the same category share many important properties) is a product rather than a prerequisite of learning.

The similarity-based approach to early induction is exemplified by a model SINC (abbreviated for Similarity-Induction-Categorization), proposed recently by Sloutsky and colleagues (Sloutsky et al., 2001; Sloutsky & Fisher, 2004a). Unlike the knowledge-based approach, assuming that linguistic labels denote categories, SINC assumes that for young children labels are features of objects contributing to the overall similarity of compared entities. Support for this assumption comes from the finding that when two entities share the same name, young children but not adults, perceive these entities as *looking* more similar (Sloutsky & Fisher, 2004a). Furthermore, attentional weights of linguistic attributes are assumed to be greater than weights of other attributes early in development. In particular, it has been demonstrated that auditory input often overshadows (or attenuates processing of) the visual input for infants and young children, however this effect disappears by adulthood (Sloutsky & Napolitano, 2003; Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004).

In sum, according to the knowledge-based approach, even early in development people realize that labels denote

categories; therefore, it is the conceptual meaning behind labels that influences induction. On the other hand, according to SINC, effects of labels on induction early in development stem from the privileged processing of the auditory information, rather than from conceptual assumptions.

Traditionally, inductive generalization in children has been studied directly, by asking participants to perform generalizations, and inducing the mechanism of generalization from provided responses. However, this approach has generated evidence that does not allow distinguishing between the proposed theoretical positions (Gelman, 1988; Gelman & Markman, 1986; Sloutsky & Fisher, 2004a). An alternative approach allowing more direct examination of the mechanisms of induction has been recently developed (Fisher & Sloutsky, in press; Sloutsky & Fisher, 2004b). In this framework, memory traces formed during induction are examined, and generalization mechanisms are inferred from the patterns of memory accuracy. Predictions are based on the following reasoning. There is a well-known finding, known as the "level-of-processing effect", indicating that deep semantic processing facilitates correct recognition of presented items, increasing the proportion of "hits" (Craik & Lockhart, 1972; Craik & Tulving, 1975). At the same time, recent studies indicate that semantic processing (i.e., categorization) results not only in higher hit rates, but also in the elevated levels of memory intrusions – false recognition of non-presented semantically associated items, or "critical lures" (e.g., Koutstaal & Schacter, 1997; Rhodes & Anastasi, 2000; Thapar & McDermott, 2001). Therefore, if recognition accuracy is measured as the difference between hits and false alarms, the net result of semantic processing is an overall decrease in accuracy. At the same time, focusing participants on perceptual details of pictorially presented information leads to a relatively low rate of false alarms, and thus to accurate recognition (Marks, 1991).

Thus, a memory test administered after an induction task should reveal differential encoding of information during induction: If participants perform category-based induction, they should be engaged in semantic processing, and therefore exhibit low discrimination of studied items from critical lures during a memory test (compared to a no-induction baseline condition), due to an elevated level of false alarms. On the other hand, if participants perform similarity-based induction, they should be engaged in perceptual processing, and as a result exhibit accurate recognition, due to a high level of hits and a relatively low level of false alarms.

Because SINC assumes that induction is similarity-based early in development, it makes a nontrivial prediction that under certain conditions (i.e., after performing induction) young children should exhibit more accurate recognition than adults. These predictions received empirical support (Fisher & Sloutsky, in press; Sloutsky & Fisher, 2004b), and aggregated findings of the previous research that used Induction-then-Recognition paradigm are presented in Figure 1. The figure represents memory sensitivity A-prime

scores. A-prime is a non-parametric analogue of the signal-detection d-prime statistic (Snodgrass & Corwin, 1988). An A-prime score of .5 indicates that participants do not discriminate studied items from critical lures, and as discrimination accuracy increases, A-prime scores approach 1. As shown in the Figure, after performing induction about members of familiar animal categories (i.e., cats, bears, and birds), adults' memory accuracy attenuated markedly compared to the no-induction baseline, whereas 5 year-olds remained accurate. However, after a short training to perform induction by relying on category information, memory accuracy of 5-year-olds decreased to the level of adults in the induction but not in the baseline condition. Therefore, decrease in memory accuracy observed in the induction condition is attributable to specific effects of training in category-based induction, rather than to general factors, such as fatigue. This finding suggests that young children perform similarity-based induction, and that development of category-based induction requires learning.

Furthermore, it has also been demonstrated that category-based induction develops gradually, such that adults are more likely to perform category-based induction that 11 year-olds, and 11 year-olds are more likely to perform category-based induction that 5- and 7-year-olds (Fisher & Sloutsky, in press). Additionally, both 5- and 7-year-olds can successfully learn to perform category-based induction, however retention of this learning is a function of age, with 7 year-olds being able to retain learning for longer periods of time than 5 year-olds (Fisher & Sloutsky, in press). These results demonstrate that unlike adults, young children spontaneously perform similarity-based induction, and that category-based induction is a product of learning and development.
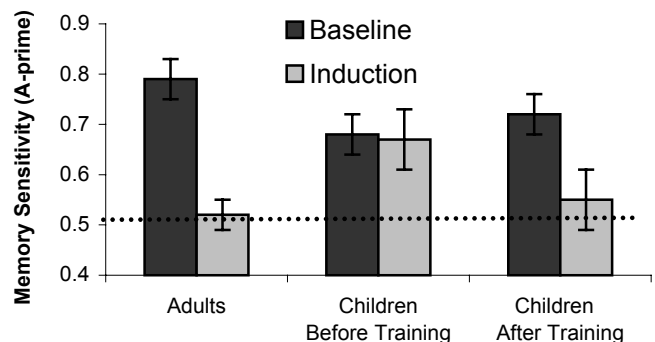

Figure 1: Recognition Accuracy in 5 year-olds and adults (aggregated findings from Sloutsky & Fisher, 2004b). The dashed line represents the point of no sensitivity.

In all of the experiments that used the Induction-then-Recognition paradigm, study items were drawn from familiar animal categories, and Sloutsky & Fisher (2004b) established that even the youngest participants could easily label the pictures that were used in research. However, category labels never accompanied these pictures, and it could be argued that the presence of labels is critical for the

ability to perform category-based induction. According to this argument, young children might have exhibited evidence for category-based induction, had the category labels been provided. At the same time, according to SINC, for young children labels are features of entities, with labels affecting induction by contributing to similarity. Furthermore, there are reasons to believe that effects of auditorily presented labels stem from auditory information overshadowing, (i.e., attenuated processing of) corresponding visual information early in development (e.g., Napolitano & Sloutsky, 2004; Sloutsky & Napolitano, 2003). The goal of this research is to distinguish between these theoretical alternatives.

Experiment 1

Experiment 1 examined the effect of category labels on induction and recognition accuracy in young children. According to the knowledge-based position, providing category labels should promote category-based induction and therefore, increase induction accuracy. At the same time, category-based induction should lead to an increase in the level of false alarms, and therefore to a decreased recognition accuracy. However, SINC predicts that labels often overshadow visual input early in development; therefore labels may disrupt young children's encoding of visual information, thus having negative effects on their recognition accuracy. These effects however, should differ from negative effects exerted by semantic processing: While the latter should result in an elevated level of false alarms, the former (due to disrupted encoding of visual information) should result in a decreased level of hits.

Method

Participant Participants were 83 5 year-olds (44 girls, 39 boys, *M* age= 5.17 years, *SD* = .35 years).

Materials, Design and Procedure Materials were 44 color photographs of familiar animals used in our previous research (Fisher & Sloutsky, in press; Sloutsky & Fisher, 2004a, 2004b). Materials also included a set of category labels – cat, bear, and bird.

Experiment 1 consisted of two phases, a Study Phase and a Recognition Phase. During the Study Phase, participants were presented with 30 pictures representing three different categories (10 cats, 10 bears, and 10 birds), one picture at a time. During the Recognition Phase, participants were presented with 28 pictures, half of which were previously presented during the Study Phase, and the other half were new pictures. The recognition pictures consisted of (1) previously presented pictures (7 cats and 7 bears), (2) novel pictures from the studied category (7 cats, which served as critical lures), and (3) novel pictures from a non-studied category (7 squirrels, which served as catch items).

There were two between-subject task conditions: Baseline and Induction. 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. Note, that different instructions regarding the upcoming memory test and differential task demands during the Study Phase in the Induction and Baseline conditions were not a concern, because we repeatedly demonstrated that these factors do not affect the pattern of results in this paradigm (Fisher & Sloutsky, in press; Sloutsky & Fisher, 2004a, 2004b). In particular, all previous studies included an additional condition controlling for different instructions and task demands; results of this control condition were statistically equivalent to the Baseline condition.

Additionally, there were two between-subject labeling conditions: (1) No Labels and (2) Category Labels. In the Study Phase of the Category Labels condition, each picture was accompanied by a basic category label (i.e., cat, bird, or bear), whereas no labels were presented in Study Phase of the No Labels condition.

The Recognition Phase, which was identical for all study task and labeling conditions, immediately followed the Study Phase. Participants were presented with 28 recognition pictures, and were asked to determine whether each picture was "old" (i.e., exactly the one presented during the Study Phase) or "new." None of the pictures were labeled, and no feedback was provided during the Recognition Phase.

Children were tested individually in their day care centers by female hypothesis-blind experimenters. All stimuli were presented on a computer screen, and stimuli presentation was controlled by Super Lab Pro 2 software (Cedrus Corporation, 1999).

Results and Discussion

Catch Trials Accuracy. Data from participants who failed to correctly reject at least 5 out of 7 catch items in the Recognition Phase were excluded from further analysis. Based on this criterion, 5 participants in the Baseline condition (3 in the No Labels and 2 in the Category Labels condition) and 4 participants in the Induction condition (1 in the No Labels, and 3 in the Category Labels condition) were excluded. The rest of the participants were highly accurate in rejecting catch items, averaging over 96% of correct responses across all experimental conditions.

Induction Accuracy. Similar to the previous reports (Fisher & Sloutsky, in press; Sloutsky & Fisher, 2004a, 2004b), when no labels were presented, participants performed accurate inductive generalizations, averaging 75% of correct responses. The rate of correct generalizations was somewhat

lower when category labels were introduced (67% of correct inductions), however the difference did not reach significance. Although the difference did not reach significance, it was clearly in the direction opposite from that predicted by the knowledge-based approach: while the knowledge-based approach predicts facilitative effects of category labels on induction, current results do not support this prediction.

Recognition Accuracy. Memory sensitivity A-prime scores, computed for each participant and averaged across participants in each between-subject condition, are presented in Figure 2. Data in the Figure indicate that when no labels were presented during the Study Phase, participants demonstrated accurate recognition memory in both, Induction and Baseline conditions (average A-prime scores were .63 and .66 respectively, both above chance, $ts > 2.5$, $ps < .05$). However, when category labels were introduced during the Study Phase, participants' memory accuracy in the Induction condition decreased to chance, $p > .3$, whereas participants remained accurate in the Baseline condition, $t(15) > 4$, $p < .001$.
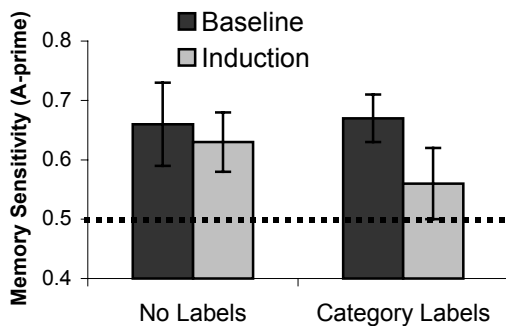
Figure 2: Memory sensitivity A-prime scores across conditions in Experiment 1. The dashed line represents the point of no sensitivity.

Recall, that when labels are present, both similarity-based induction and category-based induction should result in lower recognition accuracy. However, patterns of hits and false alarms generating attenuated recognition should be different. If labels facilitate category-based induction (as predicted by the knowledge-based approach), the drop in accuracy should occur because of an increased level of false alarms (due to semantic processing). At the same time, if labels overshadow visual information, thus disrupting encoding of visual details (as predicted by SINC), attenuated recognition accuracy should stem from a decreased level of hits.

To distinguish between these possibilities follow-up analyses of hits and false alarms were conducted. The results of these analyses are presented in Figures 3-4. Data in Figure 3 indicate that in the No Labels condition, the level of hits was significantly above chance ($t(20) > 3.8$, $p < .001$) and statistically different from the level of false alarms (paired-samples $t(20) > 3.6$, $p < .005$); however in the Category Labels condition the rates of hits and false alarms were indistinguishable (paired-sample $t(22) = 1$, $p > .3$) and equivalent to chance (both $ps > .06$).
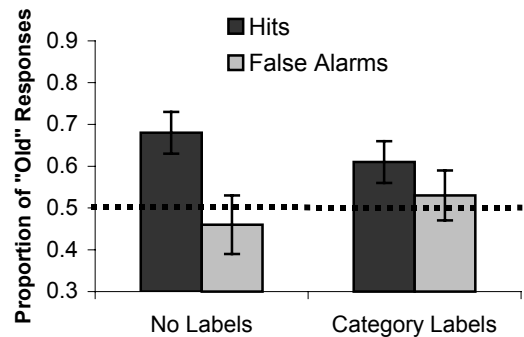
Figure 3: Proportions of Hits and False Alarms in the Induction condition of Experiment 1. The dashed line represents chance level.

Data presented in Figure 4 demonstrate, that recognition accuracy in the Baseline condition was generated by a pattern of high hits (.74 and .79 in the No Labels and Category Labels conditions respectively, both above chance, $ts > 5.7$, $ps < .0001$) and relatively low false alarms (.58 and .45 in the No Labels and Category Labels conditions respectively, both at chance, $ps > .3$). Furthermore, the difference in the level of hits and false alarms in both labeling conditions was statistically significant, both paired-samples $ts > 3.6$, $ps < .005$.
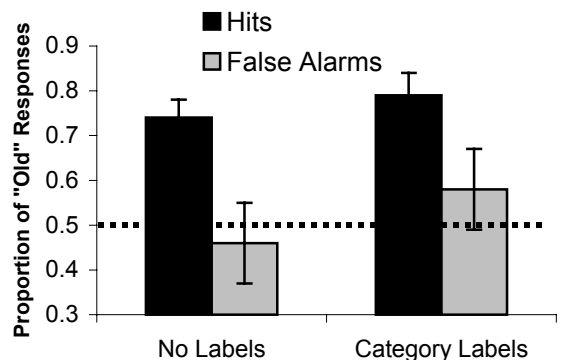
Figure 4: Proportions of Hits and False Alarms in the Baseline condition of Experiment 1. The dashed line represents chance level.

Thus, results of Experiment 1 indicate that providing category labels did not promote category-based induction in 5 year-old children: The rate of correct inductions in the Category Labels condition did not increase compared to the No Labels condition, and analysis of the hits and false alarms patterns pointed to disrupted perceptual processing rather than to conceptual processing.

However, it could be argued that low hits and low false alarms observed in the Induction-with-Labels condition (see Figure 3) stem from extraneous factors rather than interrupted perceptual encoding. To eliminate this possibility, we conducted Experiment 2, in which young children were trained to perform category-based induction. Our previous results (Sloutsky & Fisher, 2004a, 2004b) indicate that such training results in the pattern of recognition accuracy indicative of category-based induction (i.e., high hits and high false alarms). Therefore, if results of Experiment 1 stemmed from interrupted similarity-based induction, training to perform category-based induction should result in low accuracy stemming from high hits and high false alarms.

Experiment 2

In Experiment 2 participants were first trained to perform category-based induction relying on common category labels. After training participants were presented with the experiment proper, which was identical to the Induction task of the Category Labels condition of Experiment 1. It was expected that after training participants should perform category-based induction. Therefore, participants' (1) induction accuracy was predicted to increase (compared to that in Experiment 1), and (2) participants' recognition accuracy was expected to be low, due to an increase in the level of false alarms.

Method

Participants Participants were 22 5 year-olds (10 girls, 12 boys, *M* age= 4.9 years, *SD* = .39 years).

Materials, Design and Procedure Materials, design, and procedure of Experiment 2 were identical to those of the Induction task of the Category Labels condition of Experiment 1, with one important difference. Prior to the experiment proper, participants were given training in category-based induction. The training procedure was identical to the one used in our previous research (Fisher & Sloutsky, in press; Sloutsky & Fisher, 2004a, 2004b). In the course of training children were taught that (1) animals that have the same names belong to the same category, (2) animals that belong to the same category share many important properties, and (3) therefore, animals that have the same name share many important properties. Participants were presented with six categorization and six induction trials, and their responses during training were accompanied by explanatory feedback. Materials used in training were cards representing pictures of rabbits, dogs, and lions – the categories of animals that were not used in the experiment proper.

Upon completing training, participants were randomly assigned to an Induction or a Baseline task, in which presentation of animals during the Study Phase was accompanied by category labels. Hypothesis-blind female experimenters tested children individually in their schools and child care centers.

Results and Discussion

Catch Trials Accuracy. Data from participants who failed to correctly reject at least 5 out of 7 catch items in the Recognition Phase were excluded from further analysis. Based on this criterion, data from 4 participants were excluded. The rest of the participants were highly accurate in rejecting catch items, averaging over 96% of correct rejections.

Induction Accuracy. As predicted, after training participants demonstrated high induction accuracy: accuracy = 88%, above chance, one-sample t (16) > 10.6, $p < .0001$. Furthermore, their induction accuracy in Experiment 2 (i.e., 88%) exceeded that in Experiment 1 (i.e., 67%), independent samples t (38) > 3.3, $p < .001$.

Recognition Accuracy. Similar to Experiment 1, recognition accuracy in the Induction condition of Experiment 2 was quite low, with an average A-prime score of .52 (not different from chance, $p > .7$). However, the pattern of hits and false alarms changed dramatically compared to Experiment 1: As predicted, after training in category-based induction, participants exhibited a pattern of high hits (.77) and high false alarms (.71), both above chance, ts > 2.4, $p < .05$. Furthermore, the rate of hits was statistically equivalent to the level of false alarms, paired-samples t (16) < 1, p > .4. Recall, that post-training decrease in recognition accuracy can be attributed to specific effects of training, rather than to general factors, such as fatigue, because our previous findings (Fisher & Sloutsky, in press; Sloutsky & Fisher, 2004a, 2004b) indicate that post-training decrease in recognition memory does not occur in the Baseline condition.

Experiment 2 demonstrated that after training in category-based induction, children started relying on labels when performing inductive generalizations, which resulted in a marked increase in the level of false alarms. Notice, that the pattern of results observed in the Induction condition of Experiment 2 (high hits/high false alarms) is indicative of semantic processing, and is different from the (1) pattern observed the Baseline condition of Experiment 1 (high hits/low false alarms), a pattern indicative of perceptual processing, and (2) from the pattern observed in the Induction condition of Experiment 1 (low hits/low false alarms), a pattern that suggests interrupted perceptual processing.

General Discussion

Several important findings stem from the experiments reported above. First, as demonstrated in Experiment 1, introduction of category labels does not automatically promote category-based induction: Category labels seem to interrupt perceptual processing, rather than promote conceptual processing in the Induction tasks - as evidenced by slightly decreased induction accuracy and dramatically decreased level of correct recognition. At the same time, no

evidence for auditory overshadowing was found in the Baseline tasks. One potential explanation for this finding is a possibility that overshadowing effects are, at least in part, moderated by the task complexity that interacts with stimulus familiarity and age of participants (both of the latter variables have been implicated in overshadowing effects, see Napolitano & Sloutsky, 2004 and Robinson & Sloutsky, 2004 for a discussion). However, this possibility requires further investigation.

Experiment 2 demonstrated that training young children to rely on common category labels increases their induction accuracy, and also leads to a pattern of recognition accuracy (high hits – high false alarms) indicative of semantic processing. At the same time, recognition accuracy in the Baseline condition was unaffected by training.

Taken together, the reported findings suggest, even in the presence of labels, young children perform similarity-based induction; however they can be trained to perform category-based induction. These findings support predictions of the SINC model, while challenging the idea of the knowledge-based approach that early induction is driven by the category and linguistic assumptions.

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