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Dissociation between Categorization and Induction Early in Development: Evidence for Similarity-Based Induction

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Abstract

The goal of the current research is to examine mechanisms underlying induction early in development. Artificial categories were created in which the appearance of items could be pitted against category membership. Children between 4 and 5 years of age participated in two types of tasks: categorization and induction. Although participants readily classified items based on category membership, they ignored category membership during induction, and instead based their responses on the appearance of items. These results support the idea that early in development induction is similarity-based.

Keywords: Cognitive Science; Psychology; Cognitive development, Learning, Reasoning, Developmental experimentation.

Introduction

Inductive generalization is a critical aspect of human cognition because it enables people to generate new knowledge. For example, seeing claws on a cat allows us to generalize that other cats have claws too. It is well established that induction appears early in development (Gelman & Markman, 1986; Mandler & McDonough, 1996; Welder & Graham, 2001; Sloutsky & Fisher, 2004a, 2004b), however, mechanisms of early induction remain unclear. In an attempt to explain early induction, two theoretical proposals have been formulated, the knowledge-based and the similarity-based.

Knowledge-Based Approach

According to the “knowledge-based” approach (often referred to as a “naïve theory” position), even early in development, induction is driven by conceptual knowledge. This knowledge is implemented as a set of conceptual assumptions, such as the *category assumption* and the *linguistic assumption*. The category assumption is the belief that entities belong to categories, and that category members

share many important properties. The linguistic assumption is the belief that labels presented as count nouns denote categories (for review of these assumptions see Gelman, 2003; Keil, et al, 1998; Murphy, 2002). When performing inductive generalizations, people, including young children, are believed to first identify entities that belong to the same categories and then to generalize properties to the members of common categories. In sum, the knowledge-based approach argues that even early in development induction is based on prior categorization of presented entities.

The main support for the category and the linguistic assumptions came from the innovative research by Gelman and Markman (1986, 1987). In a series of experiments they presented young children with a triad task, in which stimuli consisted of one target and two test items. The triad task was designed to pit perceptual similarity against category membership, with test item 1 looking more similar to the target, and test item 2 sharing the category membership with the target. Note that category membership was communicated by the common label. Participants were informed that test item 1 had a hidden property (e.g., “hollow bones”), whereas test item 2 had a different hidden property (e.g., “solid bones”). Participants were then asked to generalize one of these hidden properties to the target. Results indicated that children tended to generalize properties from the identically labeled, but not from the similarly looking items, which was interpreted as evidence for category-based induction.

Similarity-Based Approach

According to the alternative approach, conceptual knowledge (i.e., knowledge that members of the same category have many important properties in common) is a product rather than a precondition of learning. This approach argues that early in development cognitive processes are grounded not in conceptual knowledge, but rather in powerful learning mechanisms, such as statistical

and attentional learning (Smith, 1989; Smith, et al., 1996; French, et al. 2004; Mareschal, Quinn, & French, 2002; McClelland & Rogers, 2003; Sloutsky, 2003; Sloutsky & Fisher, 2004a, 2004b). Within this approach, Sloutsky and colleagues have recently proposed a similarity-based model of early generalization – SINC, abbreviated for Similarity-Induction-Categorization (Sloutsky et al., 2001; Sloutsky & Fisher, 2004a).

SINC argues that early in development both induction and categorization are based on the overall similarity of compared entities. One of the major assumptions of SINC is the assumption that for young children labels are features of objects contributing to the overall similarity, rather than conceptual markers denoting category membership. Support for this assumption comes from the finding that young children, but not adults, perceive identically labeled entities as *looking* more similar (Sloutsky & Fisher, 2004a) than entities that do not share the same label.

SINC also assumes that (1) early in development, attentional weights of labels are greater than attentional weights of other perceptual attributes, and (2) that attentional weights of labels decrease in the course of development (Sloutsky & Fisher, 2004a). These assumptions are driven by theoretical considerations about allocation of attention in the course of cross-modal processing, and there is empirical evidence supporting these considerations. In particular, there is evidence that auditory input overshadows (or attenuates processing of) the visual input for infants and young children, but not for adults (Sloutsky & Napolitano, 2003; Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004).

Finally, SINC can successfully account for children's performance on the Triad Tasks involving novel as well as previously used stimuli (Sloutsky & Fisher, 2004a), thus challenging the idea that early induction is category-based.

Induction: Category-Based, Label-Based, or Similarity-Based?

Note that proponents of both positions expect labels to affect induction, however the mechanisms that drive these effects differ radically across the positions. According to the knowledge-based approach, labels affect induction because they denote categories, whereas according to the similarity-based approach, labels affect induction because they contribute to similarity. Therefore, the analysis of label-based induction is insufficient for distinguishing between the two positions.

One way to distinguish between the two positions is to create a novel “natural-kind” type of category and to pit knowledge of the category-membership against appearance in an induction task. If category-based induction is a default, then young children should ignore appearances and rely on category membership. At the same time, if similarity-based induction is a default, then young children (even when they learn the category) should disregard their knowledge of category membership and rely on appearances.

The experiments presented here had the following overall structure. Participants were first trained to categorize artificial animal-like creatures into two categories. The two categories were rule-based, and hence,

participants had to ignore the appearance of items for successful categorization. Then participants were presented with a triad induction task. Each triad consisted of the target and two test stimuli, with test item 1 belonging to the same category as the target (i.e., sharing the rule) and test item 2 having the same appearance as the target. Participants were familiarized with a quasi-biological property of the target, and asked to generalize it to one of the test items. Finally, they were given a post-induction categorization task, which was identical to the pre-induction categorization task.

Predictions of both theoretical approaches are quite straightforward: If children perform category-based induction they should overlook conflicting appearances and induce properties from an item that they know belongs to the same category as the target. However, if early induction is similarity-based, children should induce on the basis of common appearances, despite their knowledge of what categories test items belong to. Notice that the final categorization task controls for the possibility that participants might simply forget the rule during the course of the induction task.

Experiment 1

The goal of this Experiment was to test the predictions outlined above.

Method

Participants Participants were 16 4- and 5-year-olds (8 girls and 8 boys), recruited from suburban middleclass preschools with a mean age of 61.2 months ($SD = 2.9$ months). Four more children were tested and omitted from the sample because they did not meet the learning criterion (see Procedure).

Stimuli The stimuli were colorful drawings of artificial bug-like entities, created by combining the following six attributes: a body, a tail, antennas, wings, buttons, and fingers. These six attributes varied on two out of three dimensions (i.e., size and color, color and shape, or shape and size). The resulting 12 features represented the ‘appearance’ of a stimulus. Features were manipulated to create two types of stimuli, those with appearance A_1 and those with appearance A_2 . Each of these features had three levels (e.g., for the size of the wing: short, medium, and long) referred to as levels 1, 2, or 3, respectively. For A_1 stimuli, 75% of stimulus features belonged to level 1, whereas for A_2 stimuli, 75% of features belonged to level 3. The rest of the features for both A_1 and A_2 stimuli belonged to level 2.

Additionally, the buttons and fingers attributes also differed in their number, ranging from 1 to 6. Category membership was assigned on the basis of the relation between these two features: Members of Category 1 (R_1 stimuli) had *more* fingers than buttons, while members of Category 2 (R_2 stimuli) had *fewer* fingers than buttons.

Overall, four types of items were created: A_1R_1 and A_2R_1 (i.e., stimuli that were members of Category 1, with either A_1 or A_2 appearance); as well as A_1R_2 and A_2R_2 (i.e., stimuli

that were members of Category 2, with either A_1 or A_2 appearance). Figure 1 shows an example of each type of item. Notice that A_1R_2 and A_2R_1 foils were critical items because appearance was directly pitted against category membership.

Procedure The experiment was administered on a computer and controlled by SuperLab Pro 2.0 software. Children were tested in a quiet room in their preschool by female hypothesis-blind experimenters.

The cover story involved a boy named Fritz who lives on planet Elbee and who would like to get a pet. Pets on planet Elbee are called Ziblets and come from a magical store that carries both pets and dangerous wild animals, called Flurps. Children’s task was to determine whether an animal from this magical store is a Ziblet or a Flurp.

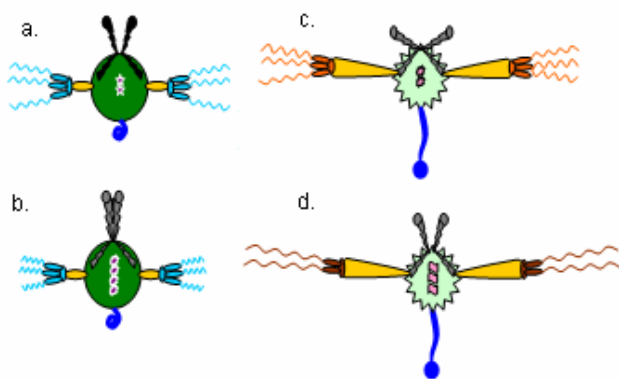


Figure 1: Examples of stimuli in Experiment 1.
(a.) A_1R_1 ; (b) A_1R_2 ; (c) A_2R_1 ; and (d) A_2R_2 .

The procedure consisted of four phases: training, initial categorization, induction, and final categorization. During training, children were given information about Ziblets. In particular, they were told: “To tell if an animal is a Ziblet or a Flurp, you have to count the buttons and the fingers. Ziblets always have more fingers than buttons.” Two examples followed, each consisting of the correct combination of the number of fingers and buttons (with no other features present). After that, children were presented with 8 feedback trials (two trials per each of the four item types), in which they were asked to determine whether each presented animal was a Ziblet or a Flurp. After responding, participants received corrective feedback and were reminded of the rule for assigning category membership.

During the initial categorization task, a new set of 8 trials was presented to children (again two trials for each type of item), and they were asked to determine whether an item was a Ziblet or a Flurp. No feedback was given during this part, and the rule was not repeated. To be included in the sample, children had to perform correctly in at least six of these eight trials. Note that during training and initial categorization task, appearance was not correlated with category membership.

After the initial categorization task, children were presented with an induction task. They were told: “The pet store owner has a few questions for those who want to buy a pet. Can you help Fritz get those questions right?” In each trial, children were shown a target stimulus and, underneath the target, two testing stimuli. For a subset of children the target was an A_1R_1 item (i.e., a Ziblet), and for the rest of the children, the target was an A_2R_2 item (i.e., a Flurp). The two testing stimuli were critical items (A_1R_2 and A_2R_1 ; counterbalanced for position on the screen), identical for all children. On each trial, children were told about a hidden property of the target. For example, they were told “Here are three animals from the pet store. The store owner says that this one (pointing to the target item) has thick blood. Which one of these (pointing to the testing items) has thick blood too?” Children completed 12 induction trials presented in random order, with each hidden property being used twice.

After the induction task, participants were presented with a final categorization task, in which their memory of the rule for assigning category membership was tested. The testing items used in the final categorization task were a subset of the testing items used during induction (6 A_1R_2 foils, and 6 A_2R_1 foils), intermixed with four catch stimuli (the catch stimuli were cartoon-like drawings of new animals). Half of the children were asked to determine whether or not a stimulus was a Ziblet, and the rest of the children were asked to determine whether a stimulus was a Flurp. Children who failed to correctly reject catch items or to respond “yes” to at least one trial during the final categorization task (i.e., participants with an obvious “yes”- or “no”-bias) were excluded from the sample.

Results and Discussion

Children performed very well during the initial categorization task. The mean proportion of correct responses across all trials was $M = 0.95$ ($SE = .02$), with 9 children (out of 16) performing correctly on each trial.

Figure 2 shows the mean proportion of rule-based responses during induction, as well as pre- and post-induction categorization (initial and final categorization task). Despite understanding the relevant categorization rule (pre-induction categorization was above chance rule-based, $p < .001$), children did not base their induction on knowledge about the rule. The mean proportion of trials in which children extended the hidden property to the test item with the same rule was only 0.27 ($SE = .05$), below chance, one-sample $t(15) = -2.78$, $p < .02$. Therefore, children based their induction on a match in appearance between test and target and not on the common category.

It could be argued that children’s reliance on appearance during induction could be explained by children simply forgetting the relevant rule. Results of the final categorization task rule out this explanation: when presented with the exact same test stimuli used during induction, children could readily distinguish between Ziblets and Flurps. Their mean proportion of correct responses was 0.82

($SE = .04$), significantly above chance, one-sample $t(15) = 7.46, p < .001$.

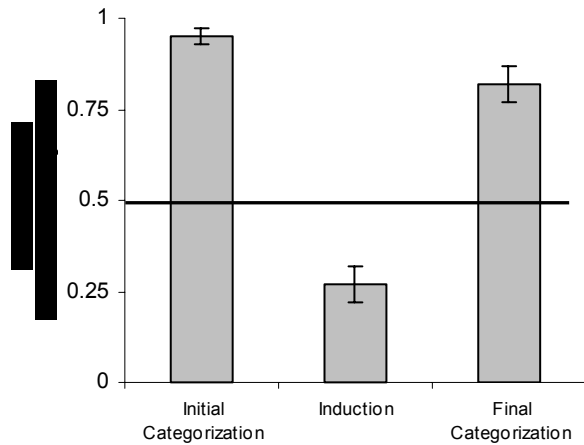


Figure 2: Proportion of Rule-Based Responses during Categorization and Induction. For the initial categorization task, only performance on critical lures is included. Error bars represent standard errors. The line represents chance responding

Although the final categorization task generated highly accurate responses, children’s accuracy in the final categorization task ($M = 0.82, SE = .05$) dropped compared to the initial categorization task ($M = 0.95, SE = .02$), paired-sample, $t(15) = 2.05, p < .03$. This decrease in performance could be either due to fatigue or it could be a carryover from the induction task – having performed induction in the similarity-based manner, participants could be slightly more likely to perform categorization in the similarity-based manner as well. The goal of Experiment 2 was to distinguish between these possibilities.

Experiment 2

Children were tested with the same procedure that was used in Experiment 1, with the only difference being that the induction task was replaced with an irrelevant task. In this task, participants were presented with the same triads of stimuli (a target and two test stimuli) as in the induction task, but instead of extending a hidden property, they had to simply pick the test stimulus that they liked best. Such a like-best task is likely to put the same processing demands on children as an induction task, however it is unlikely to lead to similarity-based processing. Therefore, if children’s lower performance during the final categorization task in Experiment 1 was a result of fatigue, children’s performance in the final categorization task of Experiment 2 should be similar to their performance in Experiment 1.

Method

Participants Participants were 15 4- and 5-year-olds (5 girls and 10 boys), with a mean age of 60.2 months ($SD =$

3.1 months). Five more children were tested and omitted from the sample because they did not meet the learning criterion (see Procedure).

Stimuli and Procedure Stimuli were identical to those used in Experiment 1. The procedure was similar to the one used in Experiment 1 (training, initial categorization, ‘induction’, and final categorization), with one important difference during part 3: instead of inducing hidden properties, children were asked to pick the test stimulus they like best. For each trial, they heard: “A friend of mine likes this top one (the Target item). Which one of these bottom ones do you like best?”

Results and Discussion

As was found in Experiment 1, children performed very well during the initial categorization task. The mean proportion of correct responses was $M = 0.93 (SE = .03)$, with 8 children (out of 15) performing correctly on every trial.

The main result pertains to children’s performance during the final categorization task. The proportion of correct responses in Experiment 2 ($M = 0.86$) was not different from the proportion of correct responses in Experiment 1 ($M = .82, p > 0.6$).

Given that participants exhibited comparable drop in the final categorization performance compared to the initial categorization performance in both experiments, it is unlikely that the drop in Experiment 1 stemmed from carryover from induction to post-induction categorization. It appears more likely that this drop was due to less important factors, such as fatigue.

General Discussion

The main finding of the two reported experiments is that when category membership is pitted against appearance, young children’s induction is driven by appearance and not by category-membership. These findings are important for two reasons.

First, the results question the claim that young children’s induction with natural kinds is driven by the common category. Instead we found that children’s induction is driven by the similarity of the items. While not tested directly, it is likely that the same findings would hold for artifacts. This is because artifact categories might be bound by similarity (e.g., by similarity of shape) even more than natural kinds are (e.g., Gentner, 1978; Keil, 1989). Future experiments will test this hypothesis.

Second, the reported research tests a novel paradigm that couples category learning with the triad task, which has been extensively used in previous research (e.g., Gelman & Markman, 1986; Sloutsky & Fisher, 2004). The advantage of the paradigm presented here enables to distinguish category-based and label-based induction. Indeed in Experiment 1, young children were trained to categorize entities into Category 1 and Category 2, and yet this categorization played little or no role in their induction.

These findings, in conjunction with previous research on induction (e.g. Sloutsky & Fisher, 2004) seem to support a distinction between label-based and category-based induction. While there is little evidence for category-based induction in young children (see also Fisher & Sloutsky, in press; Sloutsky & Fisher, 2004b, for further evidence against category-based induction in young children), there is much evidence that common labels do contribute to young children's induction (Gelman & Markman, 1986; Sloutsky & Fisher, 2004a; Welder & Graham, 2001).

Therefore, findings presented here seem to support prediction of the SINC model that labels contribute to induction by contributing to the overall similarity of compared entities (Sloutsky & Fisher, 2004a) rather than by denoting a category. Overall, the reported findings support the idea that early in development similarity-based induction, rather than category-based induction, is the default.

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