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Effects of multiple sources of information on induction in young children

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Abstract

This report considers differences in induction of biological properties between children and preadolescents based on differences in stimuli processing in these two groups. Two studies test predictions that young children, but not preadolescents, base their inductive inference on aggregating information from different sources rather than relying on a single source of information. In both experiments 4-5 year-olds, 7-8 year-olds, and 10-11 year-olds were presented with an inductive task. In Experiment 1, linguistic labels were fully crossed with relationship information, whereas in Experiment 2 perceptual similarity information was fully crossed with relationship and labeling information. While 10-11 year-olds relied exclusively on inheritance across experiments, 4-5 year-olds relied on an aggregate of multiple sources of information, and 7-8 year-olds fell between these two extremes. In addition, while the relative weight of inheritance on inferences increased with age, the weights of other information sources decreased. These results support the hypotheses suggesting that between 8 and 10 years of age children undergo a developmental shift from a holistic feature-integration induction to knowledge-based induction based on a single most predictive source.

Introduction

Inductive inference, or extending knowledge from known to novel instances, is ubiquitous in human cognition. For example, if one learned that a particular cat uses acid-based enzymes for digestion, one would expect other cats also to use acid-based enzymes for digestion, without having factual knowledge of digestion in cats.

The simplest case of inductive inference is induction over individuals, when attributes or relations are generalized from a single entity to another single entity, with both entities beings members of the same category (e.g., *This Bird has biological property X*, *therefore that Bird has biological property X*). There is a large body of research demonstrating the ability of young children to perform specific induction of biological properties (e.g., Gelman, 1988; Gelman & Markman, 1986, 1987; Gutheil, Vera, & Keil, 1998; Johnson & Solomon, 1997; Rosengren, Gelman, Kalish, & McCormick, 1991; Sloutsky & Lo, 2000; Sloutsky, Lo, & Fisher, in press; Solomon, Johnson, Zaitchik, & Carey, 1996; Springer, 1996; Springer & Keil, 1989). In addition, several lines of research have emerged in an attempt to determine what aspects, or what information cues, of compared entities children rely on when performing such induction.

One important aspect of previous research is that the majority of tasks pitted one information cue (or source of information) against another (e.g., appearance versus label, or appearance versus inheritance). This was necessary to establish the predictive value of each cue relative to a competing cue. At the same time, people typically face stimuli comprising multiple sources of information bundled together, with several sources supporting induction, but each having different predictive value. In particular, while the Target may comprise a bundle of cues $C_{i-1}C_{j-1}C_{k-1}$ (a particular appearance, inheritance, and category label), one entity may comprise another bundle $C_{i-1}C_{j-1}C_{k-2}$ (e.g., sharing appearance and category label with the Target), whereas another entity may comprise $C_{i-2}C_{j-2}C_{k-1}$ (e.g., sharing only inheritance with the Target). For example, a baby boy shares inheritance with his mother, whereas he shares appearance (at least in terms of his size and outfit), gender, and linguistic label "baby boy" with his neighbor baby boy. Would people induce from one baby boy to another or would they induce from a baby boy to his mother? It is reasonable to expect that when performing induction, adults would rely on a single most predictive cue: age to predict sleeping patterns, sex to predict gender development, and inheritance to predict blood type. However, it remains unclear how children perform induction across entities sharing multiple sources of information. Do they perform induction by relying on a single cue or do they aggregate information from different cues? In addition, if they rely on a single source of information, does the importance of this source change in the course of development? Or if they rely on multiple sources of information, does the relative importance of each source change in the course of development?

Answers to these questions depend on how young children process multiple information cues. If they process each cue separately, one cue at a time, then due to working memory limitations (see Hitch & Towse, 1995, for a review), they should invariably rely on one most salient cue. On the other hand, if they process complex information in a holistic manner without attending to specific dimensions of stimuli (Shepp, 1978; Smith, 1989a, 1989b), they should rely on an aggregate of multiple sources. These different processing mechanisms may result in different developmental scenarios. If young children process cues separately, and development is a function of increasing working memory, then both young children and adults should rely on a single cue, with adults exhibiting larger flexibility in cue selection. For example, in the baby boy example, adults, but not young children, should use different cues when inducing gender development versus inducing the blood type. On the other hand, if, unlike adults, young children process cues holistically, then young children and adults should exhibit more profound differences, with young children relying on multiple sources of information, while adults relying on a single, most predictive source. Therefore, answers to the posed questions are important for understanding of developmental mechanisms of knowledge generalization and inductive inference, as well as general principles of the development of stimuli processing.

The overall experimental approach is as follows. The task consisted of presenting participants with triads of pictures. Each triad included a Target (a Baby animal), Test Stimulus A (a neighbor animal "who played with the baby") and Test Stimulus B (an animal "who gave birth to the baby"). Within each triad, participants were asked to generalize an unobservable biological property from the Test stimuli to the Target (e.g., blood color). In Experiment 1 the Target and the Test stimuli received labels and inheritance information, while perceptual similarity was kept constant. For half of the triads the Target shared a linguistic label with Test A while on the other half it shared a label with Test B. In Experiment 2, in addition to relationship information and labels, participants were also presented with perceptual information (with one Test stimulus being perceptually similar to the Target, while the other one being dissimilar), with the three attributes fully crossed.

Experiment 1

Method

Participants Participants were 45 children and preadolescents recruited from one daycare center and one elementary school located in middle class suburbs of Columbus, Ohio. There were three age groups, with 15 participants in each: (1) 4-5 year-olds (5 boys and 10 girls; M = 4.5 years; SD = .66 years); (2) 7-8 year olds (7 boys and 8 girls; M = 7.7 years; SD = .51 years); and (3) 10-11 year-olds (7 boys and 8 girls; M = 10.4 years; SD = .68 years). These participants were selected on the basis of returned parental consent forms.

Design and Materials The experiment had a mixed design with age as a between-subject factor and the information condition as a within-subject variable. The information condition had two levels: (1) Inheritance only information (when the Target shared only inheritance information and not labeling information with the Mother) and (2) Inheritance + Label information (when the Target shared both inheritance information and the label with the Mother). Note that in the Inheritance only condition the Target shared the label with the Friend, whereas in the Inheritance + Label condition, the Target had a label that was different from that of the Friend.

The order of Inheritance only and Inheritance + Label trials was counterbalanced across participants. Each participant was presented with eight stories (four stories in the Inheritance only condition and four stories in the Inheritance + Label condition).

Materials consisted of triads of line-drawing pictures with a fully shown Target animal, and Test A and Test B stimuli hidden behind trees, stories, biological properties, and auditorily presented linguistic labels. Each triad of stimuli had two labels, so that either Test A or Test B shared the label with the Target, whereas the other Test stimulus had a different label. To avoid confounds with existing knowledge about specific animals, we used only artificial labels, each consisting of a short two-syllable word (e.g., Jiga, Gapo, etc.). The labels were presented as count nouns (e.g., "look, this is a Jiga"). After each label was introduced, children were asked to repeat the label.

Procedure

The experiment was conducted in a single 10-15 minute session, during which participants were read four short stories, one story at a time. Each story constituted a trial that included three phases: stimuli presentation, comprehension/memory check, and inductive inference. Each participant was asked a total of 16 inductive inference questions with four questions for each of the four stories. Participants were tested individually in a quiet room by a female experimenter.

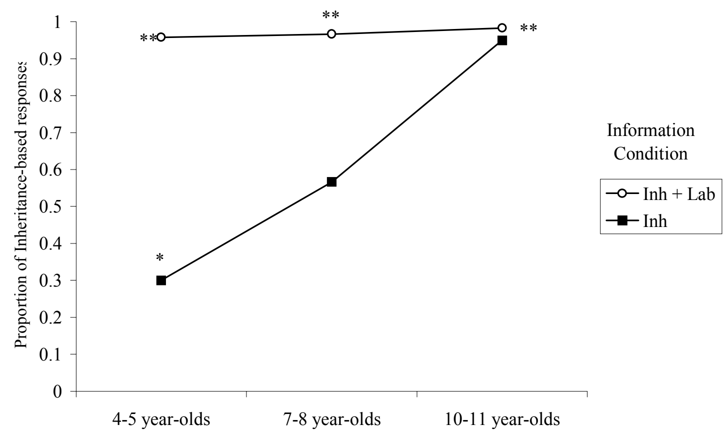
First, participants were read a cover story describing a baby animal who saw two adult animals playing in the forest. One of these animals was introduced as the one "who used to play with the baby," while the other was introduced as the one "who gave birth to the baby." The order of presentation of the Test stimuli was counterbalanced across the stories, and the order of introduction of attribute pairs was randomized across trials and across participants. Then participants were told that each of the Test stimuli (i.e., Mother vs. Friend) has a particular biological property (e.g., thick blood vs. thin blood) and asked which of these properties are likely to be shared by the Target (i.e., Baby).

Results and Discussion

Proportions of Inheritance-Based induction broken down by age group and information condition are presented in Figure 1. As shown in Figure 1, in the Inheritance only condition (Inh), the proportion of Inheritance-Based generalizations differed across the age groups. In the group of 4-5 year-olds this proportion was at 30% (below chance, Confidence Interval from 17.3% to 40%, $p < .01$) and in the group of 7-8 year-olds this proportion was at 57% (not statistically different from chance). At the same time, in the group of 10-11 year-olds the proportion of Inheritance-Based induction was at 95% (Confidence Interval from 86% to 99%, ps < .001). As opposed to Inheritance only condition, in the Inheritance + Label condition (Inh + Lab), the majority of participants of all age groups (over 95% in each group) responded in an Inheritance-Based manner.

Proportions of Inheritance-Based induction were subjected to a two-way (age group by information condition) repeated measures ANOVA. The analysis revealed significant main effects of age group, $F(2, 42) = 10.7$, $p < .0001$, and information conditions, $F(1, 42) = 42.3$, $p < .0001$, and a significant age group by information condition interaction, $F(2, 42) = 10.5$, $MSE = 4.5$, $p < .0001$. Post-hoc Bonferroni tests of the main effect of age indicated that children in the two youngest groups performed Inheritance-Based induction significantly less frequently than did children in the oldest group, all ps < .05. The second main effect (indicating that in the Inheritance + Label condition participants performed Inheritance-Based induction more frequently than in the Inheritance only condition) was largely driven by the interaction. To analyze the interaction, t-tests with Bonferroni adjustments for multiple comparisons were performed within each age group. The analysis pointed to significant differences between the Inheritance + Label and the Inheritance only conditions in the group of 4-5 year-olds and 7-8 year-olds, both ts > 5, ps < .01. At the same time, there were no such differences in the group of 10-11 year-olds, $t < 1$. Therefore, younger children were more likely to perform Inheritance-Based induction when both Inheritance and Label information supported such induction than when induction was supported by Inheritance information alone. At the same time, older children relied solely on inheritance information, while ignoring labeling information altogether.

Figure 1. Proportion of Inheritance-Based induction by age group and labeling condition



Note: ** Above chance, $p < .01$; * below chance, $p < .01$

However, Experiment 1, while presenting suggestive evidence, does not rule out an alternative explanation that 4-5 yea-olds perform induction across similarly labeled entities, while ignoring inheritance information altogether. To test this alternative, we conducted Experiment 2, where additional information cues were added to the design. If young children rely on multiple sources of information when performing induction, their induction should be a function of the number of information sources shared by compared entities. Another goal of Experiment 2 was to examine whether or not the relative importance of each source change in the course of development?

Experiment 2

Method

Participants Participants were 96 children recruited from two daycare centers, two elementary schools, and one middle school located in middle class suburbs of Columbus, Ohio. These participants represented three age groups each consisting of 32 children: (1) 4-5 year-olds (15 boys and 17 girls, $M = 4.8$ years; $SD = 0.63$ years); 7-8 year-olds (14 boys and 18 girls, $M = 7.6$ years; $SD = 0.74$ years); and 10-11 year-olds (15 boys and 17 girls, $M = 11.2$ years; $SD = 0.54$ years).

Design and Materials This experiment had a mixed design with age as a between-subject factor, perceptual similarity (i.e. Target perceptually similar to Test A vs. Target perceptually similar to Test B) as a between-subject variable, and information condition as a within-subject variable. The crossing of perceptual similarity and information conditions resulted in four cells. (1) Inheritance only (Inh) where the Target shared only inheritance information with the Mother. (2) Inheritance + Label (Inh + Lab) where the Target shared inheritance and the label with the Mother. (3) Inheritance + Perceptual Similarity (Inh + PS) where the Target shared inheritance and appearance with the Mother. And (4) Inheritance + Label + Perceptual Similarity (Inh + Lab + PS) where the Target shared inheritance, the label, and appearance with the Mother. All materials were identical to those used in Experiment 1, except that stimuli in the present experiment showed the Target, Test A, and Test B fully.

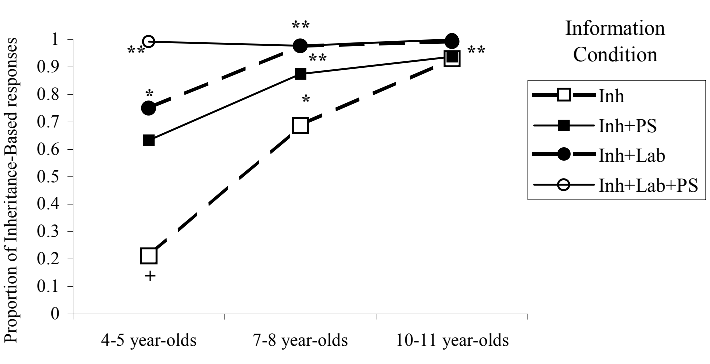
Similarities among stimuli were estimated in a calibrating experiment with 10 adult participants judging similarity between each pair of stimuli. Similarity scales ranged from 5 (very similar) to 0 (very dissimilar). The mean similarity rating for those pairs that we deemed dissimilar was .63 (*SD* = .43), while for those that we deemed similar it was 4.45 (*SD* = .23), $t(18) = 24.86$, $p < .0001$.

Procedure The procedure was identical to that in Experiment 1.

Results and Discussion

Proportions of Inheritance-Based responses, broken down by age group, similarity, and information conditions, are presented in Figure 2.

Figure 2. Proportion of Inheritance-Based induction by age group and information condition



Note: * Above chance $p < .05$; ** above chance $p < .005$; + below chance, $p < .005$.

As shown in Figure 2, participants of different age groups differed in their reliance on various information sources in the course of induction. In the group of 4-5 year-olds, the proportion of Inheritance-Based induction increased with the number of available information sources ranging from 20% in the Inh condition to 65-75% in the Inh + Lab and Inh + PS conditions, and to 99% in the Inh + Lab + PS condition. At the same time, in the group of 10-11 year-olds no such differences were observed: in this group proportions of Inheritance-Based induction were at ceiling across the information conditions. The group of 7-8 year-olds was between these extremes with differences among the conditions being larger than in the group of 10-11 year-olds, but smaller than in the group of 4-5 year-olds.

In short, data in Figure 2 suggest that preadolescents relied only on inheritance information, while ignoring other sources of information. At the same time, participants of the two younger groups relied on multiple sources of information. Another aspect of the findings, as indicated in Figure 2, is a sharp developmental increase in the importance of inheritance information.

Results presented in Figure 2 were subjected to a 3-way (age group * similarity condition * information condition) ANOVA with age group and similarity condition as between-subjects factors and labeling condition as a repeated measure. All main effects were significant. First, there was a significant main effect of age group, $F(2, 90) = 26.1$, $MSE = 4.3$, $p < .0001$, with 4-5 year-olds generalizing biological properties from the Mother significantly less frequently than children in the two older groups (63% vs. 88% vs. 96%), post-hoc Bonferroni tests, *p*s < .0001. Second, there was a significant effect of perceptual similarity condition, $F(1,90) = 15.1$, $MSE = 4.3$, $p < .0001$, with a tendency to perform an Inheritance-Based induction more frequently when the Mother looked similar to the Target (90% vs. 76%). Third, there was a main effect of Information condition, $F(1,90) = 57.4$, $MSE = 4.3$, $p < .0001$, with the overall tendency to perform Inheritance-Based induction more often in the Inheritance + Label than in the Inheritance only condition (95% vs. 71%).

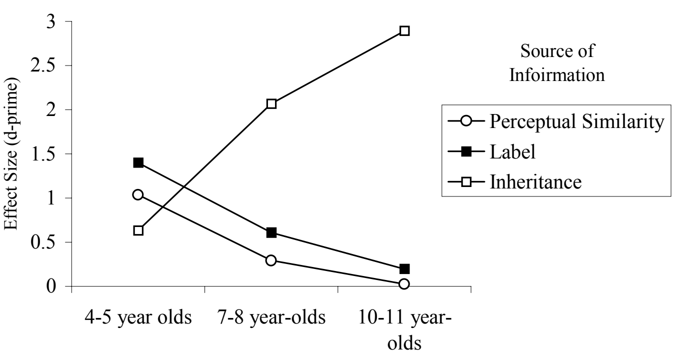
The two latter main effects, however, were largely driven by the two significant interactions. First, there was a significant age group by perceptual similarity interaction, $F(2, 90) = 6.8$, $MSE = 4.3$, $p < .003$, with significant effects of perceptual similarity on induction in the youngest group, both *t*s for both within-subject conditions > 3, *p*s < .01, but no such effects in the older groups (all ps > .27). Second, there was a significant age group by information condition interaction, $F(2, 90) = 3.3$, $MSE = 3.0$, $p < .0001$, with large (i.e., 54%) differences between the Inheritance + Label and the

Inheritance only conditions in the youngest group, $t(31) = 6.8$, $p < .0001$, and smaller (i.e., 29% and 6%, respectively) differences in the older groups, both *t*s > 2.3, *p*s < .05. No other interactions were significant.

To analyze interactions, t-tests, comparing means for each condition, were conducted within each age group. In the group of 4-5 year-olds, the proportion of Inheritance-Based generalizations exhibited the following differences (1) Inh (21%) < Inh + PS (64%) = Inh + Lab (75%) < Inh + PS + Lab (99%), all *t*s > 3, *p*s < .01, for differences. In the group of 7-8 year-olds, the proportion of Inheritance-Based generalizations exhibited the following differences: Inh (69%) < Inh + PS (88%) = Inh + Lab (98%) = Inh + PS + Lab (98%), all ts > 2.8, ps < .05, for differences. At the same time, in the group of 10-11 year-olds no significant differences among the conditions were found, all proportions ranging between 99% to 100%, all *p*s > .1.

Data presented in Figure 2 allowed us to estimate the relative contribution of inheritance information, shared label, and perceptual similarity to generalizing biological properties from the Mother. To do so, we calculated effect sizes for each of these sources of information, by dividing differences between marginal means for each of the sources (e.g., M perceptual similarity – M no perceptual similarity) by pooled standard deviations (Cohen, 1988). These estimated contributions of inheritance information, perceptual similarity and labeling broken down by age group are presented in Figure 3.

Figure 3. Relative contribution (effect sizes) of different sources of information to inductive inference by age group



Effect sizes exhibited the following patterns: while relative contributions of labels and perceptual similarity tend to decrease with age, the contribution of inheritance increased dramatically with age. In particular, effect sizes due to labels and perceptual similarity decreased from 1.4 and 1, respectively, in the youngest group to 0.2 and 0.02, respectively, in the oldest group. At the same time, effect sizes due to inheritance increased from 0.65 in the youngest group to 2.9 in the oldest group. In short, while for children of the youngest group all sources of information made sizable contributions to induction (all d-primes 0.65), participants of the oldest group (i.e., preadolescents) relied almost exclusively on inheritance information. At the same time, 7-8 year-olds were between these two extremes. In particular, for this group, inheritance information made a greater contribution than either perceptual similarity or labeling information, while the effect size due to labeling was still quite sizable (d-prime = 0.61).

In short, 4-5 year-olds exhibited maximal proportions of Inheritance-Based induction when all three sources of information supported this induction, 7-8 year-olds were at the maximum when at least two sources supported Inheritance-Based induction, and 10-11 year-olds were at the maximum even when only inheritance information was available.

General Discussion

The reported findings fit predictions well, supporting our contention that young children rely on multiple sources of information when performing induction. The larger the informational overlap between the Target and the Test stimuli, the more likely that a biological property would be generalized from the Test to the Target. For example, Inheritance alone contributed less than Inheritance + Perceptual Similarity or Inheritance + Label, which, in turn, contributed less than Inheritance + Label + Perceptual Similarity.

Findings of the reported experiments point to two important developmental changes: (1) increasing reliance on a single source of information and (2) increasing salience of inheritance information accompanied by decreasing salience of labeling and perceptual similarity.

The first change supports the developmental scenario in which processing develops from holistic to specific. As predicted by this scenario, young children tended to perform induction relying on multiple sources of information, whereas preadolescents, regardless of the number of sources of information, performed induction relying on a single source. Of course, it could be argued that the observed pattern of responses could stem solely from the second change – the increasing importance of inheritance information. However, previous research suggested that preadolescents do not focus on inheritance per se when performing induction, but they rather focus on a single attribute that they deem most predictive (Sloutsky & Lo, 2000; Sloutsky, Lo, & Fisher, in press), they consistently relied on the label information, considering it more reliable predictor than appearance information. Hence, it seems that the tendency to rely on a single source increases with age, independently of the increasing salience of inheritance information.

The second change points to a decrease in the importance of less predictive sources of information (i.e., appearance and labels) and an increase in the importance of a more predictive source (i.e., inheritance). Both developmental changes suggest that between 8 and 10 years of age children undergo a developmental shift from a feature-integration induction to a single-feature, knowledge-based induction.

Current experiments also raise questions about the nature of young children's induction. If children's induction is driven by their intuitive theories, they should be able to attend separately to each predictor, and then to integrate information from different predictors. On the other hand, if the reliance on multiple features stem from their inability to selectively attend to each of the source and the inability to separate sources, this would be indicative that induction is not based on intuitive theories. This is because intuitive theories are beliefs about the world, and, therefore, they could not be products of low-level pre-attentive mechanisms. Current results cannot conclusively distinguish between these possibilities. This issue, however, could be addressed in future research directly examining separability of inheritance, labeling, and perceptual information in children and preadolescents.

In sum, this research suggests that when compared stimuli comprise multiple sources of information, 4-5 year-olds tended to rely on several sources when performing induction, 7-8 year olds relied mostly, but not exclusively on inheritance information, whereas 10-11 year-olds relied solely on inheritance information. Therefore, in the course of development, children undergo a transition from performing induction relying on multiple sources of information to performing induction relying on a single, most predictive source.

Acknowledgments

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