The Primacy of One-to-One Generalization in Young Children's Induction

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Abstract

The paper compares predictions derived from the similarity-based and the theory-based accounts of young children's induction. The former predicts the primacy of induction from one single entity to another single entity (one-to-one induction), whereas the latter does not predict such primacy. Predictions were tested in three experiments where 4-5 year-olds and 11-12 year-olds were asked to perform inductive generalization of biological properties. Participants could generalize properties either from a single animal to another single animal (one-to-one induction) or from a group of animals to a single animal (many-to-one induction). Experiments 1 and 2 revealed that under various stimuli presentation conditions, young children exhibited a strong preference of one-to-one induction, performing generalizations in a similarity-based manner. At the same time, preadolescents exhibited a strong preference of many-to-one induction, performing generalizations in a theory-based manner. In Experiment 3, an alternative explanation that one-to-one induction stems from a tendency to match quantifiers or label endings was tested and eliminated. Results are discussed in relation to cognitive and developmental aspects of inductive inference.

Introduction

Inductive generalization is prominently present both in low-level processes, such as sensation and perception, and in high-level processes, such as learning and transfer, categorization, analogy, rule discovery, and inductive inference (see Shepard, 1987, for a discussion). Inductive generalization involves at least two stimuli (or stimuli sets): the source and the target of generalization.

One issue that has been hotly debated is what aspects of the source and the target support inductive inference. One possibility that has been extensively discussed in the literature is that inductive generalizations are driven by similarity construed as featural overlap between the source and the target (see Estes, 1994; Medin, 1975; Nosofsky, 1986; Shepard, 1987; Tversky, 1977, for specific models of computing similarity). In this case, the more similar the source and the target, the more likely there will be generalization from the source to the target (see Medin & Smith, 1984; E. Smith, 1995; L. Smith, 1989 for discussions).

However, it has been counter argued that similarity construed this way does not sufficiently constrain generalization processes (see Carey, 1985; Keil, 1989; 1994; Medin et al., 1993, for discussions). For example, there are many more overlapping features between a live monkey and a mechanical monkey than between the live monkey and a worm. However, people deem it more appropriate to generalize biological properties from a live monkey to a worm than to generalize biological properties from the live monkey to a mechanical monkey (Carey, 1985). Therefore, not all featural overlaps are equally important. Somehow people intuitively realize that it is appropriate to generalize certain biological properties from Elephant to Hippopotamus (as they both are mammals) and it is inappropriate to generalize these properties from Elephant to Paris (as they both are smaller than China). Hence, it has been argued that generalization must be constrained by some deep "theoretical" beliefs that could not be reduced to simple featural similarity. Proponents of this view have suggested that generalization processes are constrained by a set of core beliefs about the "essence" of a category. Those entities that have common “essential” properties (e.g., the same biological origins) should be also considered as members of a common group. Those biological properties that stem from the essence (and therefore from the common membership) could be legitimately generalized from one entity onto the whole group and subsequently to each member of this group (Murphy & Medin, 1985; Gelman & Coley, 1991; Gelman & Wellman, 1991; Keil, 1994).

In this paper we attempt to derive predictions from these positions and to empirically test these predictions. Inductive generalizations can be performed over individual entities (e.g., This dog has property X, therefore that dog has property X) or over classes (e.g., Dogs have property X, therefore cats have property X). Quantification of the source and the target define several types of induction. The current research focuses on two of these types of induction over individual entities, one-to-one induction and many-to-one induction. In the case of one-to-one induction, attributes or relations could be generalized from one single entity to another single entity (e.g., This sparrow has biological property X, therefore that sparrow has biological property X). In the case of many-to-one induction, attributes or relations could be generalized from a group of entities to a single entity (e.g., Sparrows have biological property X, therefore this sparrow has biological property X). Note that induction could be also performed strictly over classes (see

Osherson, Smith, Wilkie, Lopez, & Shafir, 1990, for a discussion of induction over classes).

The distinction between the two types of induction affords deriving specific and testable predictions from each of the above mentioned positions. If induction in young children is similarity-based, there should be primacy of one-to-one induction over many-to-one induction, whereas if induction is category-based, there should not be such primacy. As shown below, each prediction follows directly from the respective position.

Proponents of the similarity-based position have argued that induction in young children is not category-based, and that both induction and categorization are products of featural similarity between compared stimuli (Sloutsky & Lo, 1999). They have also suggested that (a) different attributes and attribute dimensions have different weights in the computation of similarity, (b) young children consider linguistic labels as attributes with greater weights than other attributes (Sloutsky & Lo, 1999). Finally, according to the similarity-based approach, when entities are novel, computation of similarity between two single novel entities should be simpler than computation of similarity between many novel entities and one novel entity. This is because it is possible to directly compute similarity between single entities, whereas computation of similarity between a group and a single entity is difficult. The later requires one first to construe a composite representation of the group and then to compute similarity between the single entity and the group. Note that the argument may not apply to familiar entities, for which a composite representation had been established (see Estes, 1994, for a discussion). Therefore, if induction is a function of overall similarity, one-to-one induction should be easier for young children than many-to-one induction.

Recall that according to the theory-based approach, young children have abstract representations of categories, such as biological kinds. When an entity is familiar, it is represented as a member of a familiar category, whereas when an entity is novel, it is represented as a member of a novel category. These novel categories are devoid of representational specifics; they rather exist as category "templates" or "placeholders" (see Gelman, Coley, & Gottfried, 1994; Gelman & Coley, 1991 for discussions), and linguistic labels point to this category placeholder. When a perceptual input indicates that compared novel entities are animals, a set of beliefs about "natural kinds" is activated. These include beliefs about growth, inheritance, reproduction, self-generated movement, and so forth (Gelman, Coley, & Gottfried, 1994). These beliefs in conjunction with the common category membership suggest that both entities belong to the same natural kind, and, therefore, they should share unobservable biological properties (Murphy & Medin, 1985; Gelman & Coley, 1991; Keil, 1994). Thus, according to the theory-based explanation, induction is category-based (i.e., it is a function of categorization) (Gelman & Coley, 1991), and the process underlying induction should be as follows. (1) The description of a single entity or multiple entities (e.g., This Gubla has biological property X or These Gublas have biological property X) activates the essence placeholder "GUBLA." (2) Other members of the category GUBLA (this membership is denoted by the linguistic label) should have biological property X. (3) As indicated by the common label, this GUBLA is a member of the category GUBLA (or these Gublas are members of the category GUBLA), and therefore, it (or they) should have biological property X. Therefore, because both one-to-one and many-to-one induction follows from the category membership, there should be no primacy of one-to-one induction over many-to-one induction.

To test predictions derived from both approaches, we developed the following task. Suppose that the child is presented with a set of realistically looking novel animals having novel labels (e.g., "Look, these are Gublas"). Then, one Gubla is presented as a Target, another Gubla is presented as Test 1 and the rest of Gublas are presented as Test 2. The child is also told that this Gubla (Test 1) has biological property X, whereas these Gublas (Test 2) have biological property Y. Does the Target Gubla have biological property X or Y?

The putative processes that, according to each model, underlie the child's inference are as follows. According to the theory-based approach, the encounter with a group of novel biological objects that have the same linguistic label (i.e. Gubla) should activate the category placeholder GUBLA. Once the category is activated, the child should be equally likely to generalize from Test 1 (one Gubla) or from Test 2 (many Gublas) to the Target. On the basis of the theory-based approach, it should be inferred that in the task like this, young children should be at chance, or have a slight preference for many-to-one over one-to-one induction. The slight preference might stem from the fact that many identically looking Gublas should be more representative of the category than a single Gubla. Furthermore, normatively it is more appropriate to generalize from many Gublas than from a single Gubla, because a single entity is more likely to be an exception than many entities. Of course, we should not expect many young children to take into account this consideration, therefore, if any, only a small many-to-one preference should be predicted.

The similarity-based approach yields different predictions. As described above, all other things being equal, the computation of similarity between two entities should be simpler than computation of similarity between many entities and one entity. In addition, because similarity between two identical entities is the unity (Estes, 1994; Medin, 1975; Sloutsky & Lo, 1999), this similarity could not be less than similarity between several entities and one entity. Therefore, similarity between the Test Gubla and the Target Gubla should be no less than similarity between Test Gublas and the Target Gubla, and the former should be more easily computed. Based on these considerations, the similarity-based approach predicts a large preference of one-to-one induction over many-to-one induction.

These considerations led us to formulation of the following specific predictions. If young children base their induction on similarity between compared entities, they should generalize from a single Gubla to another single Gubla more often than chance. At the same time, according to the theory-based account, young children should perform at chance (or with a slight preference of many-to-one induction).

Experiment 1

Method

Participants Participants were 31 children aged 4 to 12 years. The first group consisted of 16 four-to-five-year-old children enrolled in two daycare centers in an upper middle class suburb of Columbus, Ohio (*M* = 4.5 years, *SD* = 0.6 years, 11 boys and 5 girls). The second group consisted of 15 eleven-to-twelve year-olds selected from a public middle school located in an upper middle class suburb of Columbus, Ohio (*M* = 11.7 years, *SD* = .31 years, 8 girls and 7 boys).

Materials Eight sets of line-drawing pictures were used in the present experiment. Each set consisted of two single pictures and a stack of pictures (see Figure 1), with each picture measuring approximately 3" by 5". Both single pictures depicted realistically looking animals, whereas the stack was turned faced down such that pictures in the stack were not visible. The Target (a single picture) looked identical to Test 1. Materials also included artificial labels and a set of biological properties. The animals presented in each set of pictures were given the same artificial label (e.g., a Gubla). Children were taught that each of the Test stimuli had a particular biological property (e.g., has salt inside the body or has sugar inside the body). The task consisted of generalization of biological properties from one of the Test stimuli to the Target. The experiment had a between-subject design with age as a factor. The dependent variable of interest was the proportion of inductive generalizations from each of the Test stimuli, either one-to-one induction (choosing Test 1) or many-to-one induction (choosing Test 2). Each participant received eight trials.

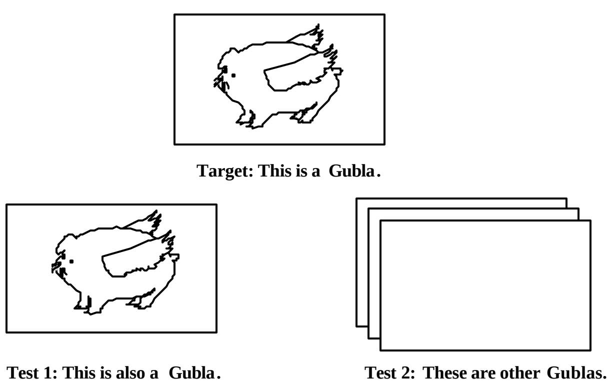

Figure 1: Layout of stimuli in Experiment 1.

Design and Procedure The experiment was conducted in a single 15-20 minute session that included three phases: stimuli presentation, comprehension/memory check, and inductive inference. Each participant was tested individually in a separate room at their daycare center or school.

Stimuli presentation. Each participant was presented with eight stimuli triads, one triad at a time. Each triad was referred to using a two-syllable artificial linguistic label and was introduced as a group of animals (e.g., I will show you several Famos). The experimenter then presented participants with three stimulus items: (a) a single card depicting a single animal (the Target), (b) another single card depicting another single animal (Test stimulus 1), and (c) a stack of cards that were face down (Test stimulus 2). At this point, participants were asked to repeat the label. After presenting the stimuli items, the experimenter introduced two biological properties, one characterizing Test 1, and another characterizing Test 2 (e.g., This Famo has a lot of sugar inside the body. These Famos have a lot of salt inside their bodies). The order of presentation of the Test stimuli, their positions relative to the Target, and the order of introduction of biological properties were counterbalanced across trials. Stimuli items were randomly paired with biological properties.

Comprehension/memory check and inductive inference phases. After the stimuli items were presented, participants were asked to repeat the labels and biological properties. The labels and biological properties were reintroduced when participants failed to answer correctly. All participants successfully completed this comprehension/memory check phase. After repeating the labels and biological properties, children moved to the inductive inference phase, in which participants were asked which of the two biological properties was likely to be shared by the Target.

Results and Discussion

In this section, we present proportions of generalizing from each of the Test stimuli across the two age groups. Results of this experiment are presented in Figure 2.

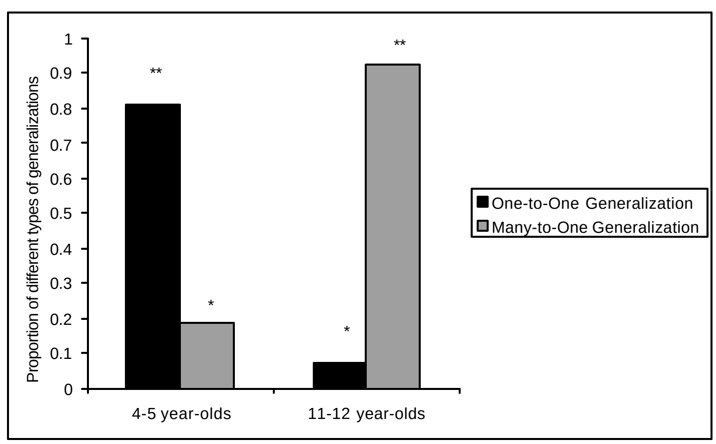

Figure 2: Proportions of one-to-one and many-to-one generalizations by age. Note: ** above chance, p < .0001; * below chance, p < .0001.

To determine the difference from chance, these results were subjected to one-sample t-tests. The analysis indicates that while 4-5 year-olds generalized from Test 1 (one animal) to the Target significantly above chance (81% of all responses), $t(15) = 11.2$, $p < .0001$, 11-12 year olds generalized from Test 2 (many animals) to the Target, significantly above chance (93% of all responses), $t(14) = 9.4$, $p < .0001$. Percentages of one-one choices and percentages of many-one choices (both aggregated across the 8 trials) were subjected to a one-way ANOVA with age as a factor. The analyses indicate that 4-5 year-olds were significantly more likely to generalize from Test 1 (one animal) to the Target than 11-12 year-olds, whereas 11-12 year-olds were significantly more likely to generalize from Test 2 (many animals) to the Target than 4-5 year-olds, *F*s(1, 29) > 97.1, *p*s < .0001. In addition, 10 out of 14 preadolescents explicitly pointed that the Target is more likely to share properties with a larger group of animals than with a single animal.

These results support our predictions describing inductive generalizations of young children and point to important differences in inductive generalizations of 4-5 year-olds and 11-12 year olds. While preadolescents' inductive generalizations conform to what should be expected when induction is category-based (they did in fact generalized in a category-based manner, thus both supporting predictions and validating the task), young children's inductive generalizations conform to what should be expected when induction is similarity-based. This experiment, however, constitutes a rigorous test of whether participants performed category-based induction, and a not so rigorous test of whether participants performed similarity-based induction. This is because one-to-one induction was supported by a picture, whereas many-to-one was not (see Figure 1).

Therefore, reported findings are indicative of the category-based induction of 11-12 year-olds, whereas they are ambiguous with respect to induction of 4-5 year-olds. Indeed, generalization in the latter group could point either to the primacy of one-to-one induction or to the preference of young children of depicted stimuli over non-depicted stimuli. Although such preference in itself might be indicative of similarity-based induction (indeed, category placeholders are not accompanied by pictures), we deemed it necessary to conduct a more rigorous testing of predictions generated by the similarity-based model. To this end, we conducted Experiment 2, where both Test 1 and Test 2 were both accompanied by pictures (Condition 1) or both were presented without pictures (Condition 2).

Experiment 2

Method

Participants A group of 30 children aged 4 to 5 years participated in the two conditions. These children were selected from daycare centers in an upper middle class suburb of Columbus, Ohio on the basis of permission slips returned by parents. The No-Picture condition group of 15 children consisted of 7 boys and 8 girls ($M = 4.4$ years, $SD = 0.48$ years). The Picture condition group of 15 children consisted of 9 boys and 6 girls ($M = 4.4$ years, $SD = 0.39$ years).

Materials, design, and procedure Materials, design, and procedure were identical to those in Experiment 1. The only differences were that the design included an additional between-subject factor, the picture presentation condition that had two levels, Picture and No-Picture conditions, and that pictures were presented differently from those in Experiment 1. In the Picture condition, both Test stimuli were accompanied by pictures, whereas in the No-Picture condition neither of the Test stimuli was accompanied by a picture.

Results and Discussion

Results of this experiment indicate that in both Picture and No-Picture conditions young children reliably generalized in a one-to-one manner. In the No-Picture condition in 78% of responses children generalized from Test 1, whereas in the Picture condition 77% of responses children generalized from Test 1, both above chance, *t*s(14) > 6.2, *p*s < .0001. The response patterns in the Picture and No-Picture conditions were practically identical, $t < 0.5$.

These findings replicate those of Experiment 1 for young children, ruling out the possibility that young children's responses in Experiment stemmed from the fact that Test 1 (single animal) was accompanied by a picture, whereas Test 2 (many animals) was presented without a picture. Results of Experiments 1 and 2 also point to a difference in inductive generalization of young children and preadolescents: while the later perform inductive generalizations in a manner compatible with the category-based model, the former perform in a manner compatible with the similarity-based model.

The fact that young children equally frequently generalized from a single animal in both Picture and No-Picture conditions deserves special consideration. This finding could be indicative of several factors. First, it is possible that young children generalize from Test 1 (single animal) rather than from Test 2 (many animals) because they merely match quantifiers (e.g., one and one vs. one and many) or linguistic labels (e.g., Gubla and Gubla vs. Gubla and Gublas). Another possibility is that because computation of similarity is easier between single objects, young children are biased to compute similarity between single objects prior to computing similarity between a single object and multiple objects. Experiment 3 was conducted to distinguish between these possibilities.

Experiment 3

Method

Participants A group of 16 children aged 4 to 5 years ($M = 4.1$ years, $SD = 0.4$ years, 10 girls and 6 boys) participated in this experiment. These children were selected from daycare centers in an upper middle class suburb of Columbus, Ohio on the basis of permission slips returned by parents.

Materials, design, and procedure Materials, design, and procedure were identical to those in Experiment 1. The only difference was that the Target was presented as many entities, Test 1 as a single entity, and Test 2 as many entities. All stimuli were presented face up.

Results and Discussion

Results of this experiment indicate that in 52% of responses young children generalized from Test 2, whereas in 48% of responses they generalized from Test 1; both types of generalization were indistinguishable from chance, t (15) < 0.3. Furthermore, the analysis of patterns of individual responses indicates that the chance-level performance does not stem from a bi-modal distribution where a part of the sample consistently generalized from Test 1, whereas the other part consistently generalized from Test 2. This performance rather stemmed from inconsistency within-participants. In particular, 2 out 16 participants consistently (on 6 or more out of 8 trials) generalized from Test 2 (many entities), and another 2 out of 16 participants consistently (on 6 or more out of 8 trials) generalized from Test 1 (single entity), while 12 out 16 participants were inconsistent in their choices of the two test items.

These findings allow us to rule out the matching hypothesis. Indeed, if participants were exhibiting matching, they should have generalized from Test 2 (many entities) to the Target (many entities) most often, which was not the case. Therefore, it seems plausible that patterns of responses observed in Experiments 1 and 2 (i.e., the tendency to generalize from a single entity to another single entity) stem from the fact that it is easier to compute similarity between several single entities than it is to compute similarity between a group of entities and a single entity.

General Discussion

Results of the three reported experiments are as follows. Young children more readily generalize biological properties from one single entity to another single entity, whereas older children more readily generalize biological properties from many entities to a single entity. At the same time young children performed at chance when asked to generalize from many entities either to a single entity or to many entities. The latter finding undermines the possibility that young children's preference for generalization from one single entity to another single entity stems from their tendency to match quantifiers or label endings.

Taken together, these findings support predictions of the similarity-based approach. In particular, they indicate that when the computation of similarity is relatively simple (such as computation of similarity between single entities) young children more readily generalize biological properties than when computation of similarity is relatively complex (such as computation of similarity of many entities to a single entity). At the same time, when computation of similarity is comparably difficult (such as computation of similarity of many entities to many entities or a single entity to many entities), young children perform at chance.

These results point to the primacy of the one-to-one induction over the many-to-one induction in young children, an effect that has been predicted by the similarity-based position, but not by the theory-based position. Recall that in the case of category-based induction advocated by the theory-based position, there should be no primacy of the one-to-one induction, and preadolescents, who supposedly perform induction in a category-based manner, did not exhibit the primacy of one-to-one induction.

Results also point to important developmental differences between young children and preadolescents. While preadolescents' inductive generalizations conform to what should be expected when induction is category-based, young children's inductive generalizations conform to what should be expected when induction is similarity-based. Therefore, it seems reasonable to infer that there should be a developmental transition from similarity-based to category-based induction. Such transition could be due to developmental and educational factors that lead to understanding that common category membership is a better predictor of unobservable properties than similarity (e.g., a whale looks more similar to a fish, but has internal structure similar to other mammals). However, additional research is needed to discern and tease apart these contributing factors.

The reported findings afford the differentiation between the theory-based and the similarity-based approaches to young children's induction, undermining the former and supporting the latter. Recall that according to the theory-based position, linguistic labels activate "essence placeholders" that should be equally applicable to all members of the category, independent of the quantity of these members. Therefore, if induction had been performed in a category-based manner, young children should have equally often generalized from a single animal and from a group of animals, or have a slight preference for many-to-one over one-to-one induction. In addition, the theory-based position does not predict dramatic differences between young children and preadolescents: both groups should perform induction in the category-based manner. At the same time, the similarity-based position (e.g., Sloutsky & Lo, 1999) predicts that while young children should generalize in a similarity-based manner (generalizing from a single entity to another single entity), preadolescents should generalize in a category-based manner. The primacy of one-to-one induction in young children and major differences between young children's and preadolescents' induction fit predictions of the similarity-based position, while not fitting predictions of the theory-based position.

Of course, the current results could not conclusively rule out the possibility of young children having representations of category templates, and it is hard to imagine any empirical findings capable of conclusively ruling out this possibility. The results of current experiments, however, support a parsimonious account of young children's induction that is based on a set of a priori predictions. We believe that a priori predictions are favored over post hoc accounts by both inferential statistics and philosophy of science, and, therefore, they should weigh more than post hoc accounts (cf. Barsalou, 1999).

In short, while the similarity-based approach is not capable of conclusively ruling out the proposal that young children rely on categories when performing inductive inference, it is capable of undermining such a possibility. In particular, the similarity-based approach is capable of predicting phenomena (such as those reported above) that could not be predicted by the category-based position.

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