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Brief article

Causal relations drive young children's induction, naming, and categorization ☆

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Abstract

A number of recent models and experiments have suggested that evidence of early category-based induction is an artifact of perceptual cues provided by experimenters. We tested these accounts against the prediction that different relations (causal versus non-causal) determine the types of perceptual similarity by which children generalize. Young children were asked to label, to infer novel properties, and to project future appearances of a novel animal that varied in two opposite respects: (1) how much it looked like another animal whose name and properties were known, and (2) how much its parents looked like parents of another animal whose name and properties were known. When exemplar origins were known, children generalized to exemplars with similar origins rather than with similar appearances; when origins were unknown, children generalized to exemplars with similar appearances. Results indicate even young children possess the cognitive control to choose the similarities that best predict accurate generalizations.

Keywords: Conceptual development; Concepts; Categorization; Induction; Word learning; Causal reasoning

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1. Introduction

A basic function of categorization is generalization. By categorizing a novel bug as a mosquito rather than a mayfly, one can generalize information about other mosquitoes to the novel bug and guide one's actions toward it according to one's goals. A basic problem for cognitive psychology concerns the information that is processed when making generalizations.

Adults' generalization from familiar to novel exemplars is typically influenced by two types of similarities – relational similarity, the degree of overlap in common *roles* (e.g., a mosquito and a leech each playing a *parasitical role with respect to people*) (Medin, Goldstone, & Gentner, 1993) and perceptual similarity, the degree of overlap in *perceptual attributes* (e.g., two mosquitoes each *possessing six legs*) (Shepard, 1987; Tversky, 1977). Although generalization by either type of similarity alone has been found in animals and human infants, there is a lively debate in the field of cognitive development about whether a "relational shift" allows older children (around 8 years old) to ignore perceptual similarities and generalize over opposing relational similarities (Gelman, 2003; Gentner & Toupin, 1986; Goswami, 1991; Sloutsky & Fisher, 2004).

One reason to doubt the "relational shift" hypothesis is that young children's analogies and categories often map onto shared taxonomic, functional, and social relations more closely than onto holistic perceptual similarity (Brown & Kane, 1988; Goswami, 1995; Opfer & Siegler, 2004; Springer, 1992). In a seminal study demonstrating this principle, Gelman and Markman (1986) found 5-year-old generalizing properties to a bat-like bird from a flamingo (same taxonomic relation, dissimilar appearance) rather than from a bat (different taxonomic relation, similar appearance).

On the other hand, these reports of children ignoring perceptual similarities have also been challenged. Findings in which preschoolers appear to use taxonomic relations could be explained using a model of perceptual similarity that is relative rather than absolute (Medin et al., 1993), that has a differential weighting of exemplar features driven by attentional biases (Jones & Smith, 1993; Rakison, 2000) or by feature–feature correlations (McClelland & Rogers, 2003; Rakison & Hahn, 2004), or that treats labels as perceptual features of exemplars rather than category markers (Sloutsky & Fisher, 2004). For example, when young children generalize from a flamingo to a blackbird, common labels (like 'bird') and even non-linguistic sounds (e.g., a beep) may simply increase the two birds' perceptual similarity (Sloutsky & Fisher, 2004; Sloutsky & Lo, 1999; Sloutsky & Napolitano, 2003).

In this paper, we offer a third alternative. Rather than children inflexibly generalizing over similar appearances, labels, or relations, children could increase their overall accuracy by using different relations to determine which perceptual similarities indicate category-membership and thus license generalization. An interesting test of this hypothesis comes from the biological domain. Among living things, the correlation between appearance and kind is never perfect; cases of homologies, camouflage, mimicry, sexual dimorphism, injuries, surgery, and aging are but a few of many exceptions to the rule, "Same looks, same kind" (Gelman, 2003). Nor is the correlation between label and kind perfect either; cases of homonyms, homophones, synonyms, and parent/teacher mislabeling are but a few of many exceptions to the rule, "Same label, same kind" (Sloutsky & Fisher, 2004). In contrast, there is a high correlation between causes and effects; so following the rule, "Same causes, same kind" would likely generate more accurate generalizations of novel properties than use of either appearances or labels. This difference in predictive accuracy, in turn, may lead children to weight similarity of causal relations over similarity of non-causal relations and similarity of appearances (see also Rakison & Hahn, 2004, for a similar perspective on children's use of non-obvious properties).

1.1. The present studies

To address whether young children are inflexibly biased toward relational or perceptual similarity, we systematically manipulated perceptual similarity, presenting children with two problems where use of relational and perceptual similarity would generate opposite generalization functions. In the first problem – "offspring problems" – similar-looking juveniles were the *effect of* (i.e., babies of) dissimilar-looking adults; in the second problem – "prey problems" – similar-looking juveniles were the *goal of* (i.e., prey of) dissimilar-looking adults.

In offspring problems (Fig. 1), two exemplars (a – "dax" and b – "fep") have known causal origins (XX and YY, respectively). The task was to label the target (t), which, in this example, looks much more like the fep (b) than the dax (a). If generalization were based on perceptual similarity of exemplar to target, the probability of labeling the target "dax" would be very low. The probability of choosing that the target is a "dax" can be estimated using Luce's choice rule – $P(a) = Sim(a,t)/Sim(a,t) + Sim(b,t)$. In this case, $P(a)$, the probability of generalizing from the dax (a), should be 0% because $Sim(a,t)$, the similarity of the target to the a-exemplar, is 0/6 features and $Sim(a,t) + Sim(b,t)$, the sum of its similarity to all exemplars, is 0/6 features plus 6/6 features. In contrast, if generalization were based on relational similarity (i.e., both a and t sharing the relation, *effect-of-Xs*), the probability of generalizing

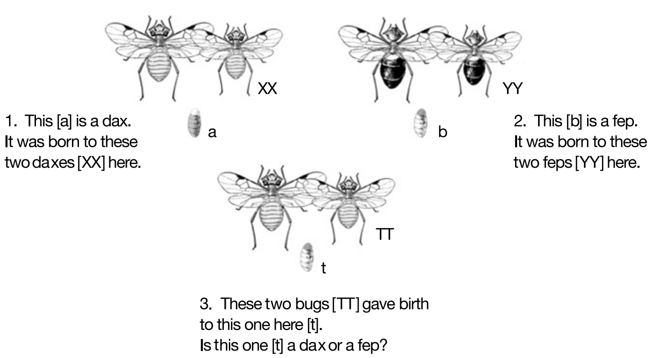

Fig. 1. Example of a problem presented in the offspring condition of Experiment 1. Similarity of X to T/similarity of X to T + similarity of Y to $T = 100\%$; similarity of a to t/similarity of a to t + similarity of b to $t = 0\%$.

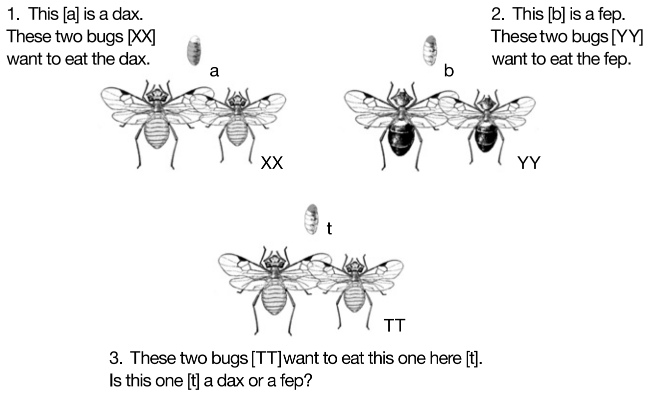

Fig. 2. Example of a problem presented in the prey condition of Experiment 1. Similarity of X to T/similarity of X to T + similarity of Y to T = 100%; similarity of a to t/similarity of a to t + similarity of b to t = 0%.

the label "dax" to the target should be very high and can be estimated by applying the same formula to the *causal origins of the two exemplars* and *causal origins of the target* – that is, $P(a) = Sim(XX, TT)/Sim(XX, TT) + Sim(YY, TT)$. The probability of labeling the target a "dax" should be 100%, because origins of the target are less similar in appearance to origins of the "fep" (0/6 identical parts) than to origins of the "dax" (6/6 identical parts). In prey problems (Fig. 2), the same logic applies.

To apply Luce's choice rule on proportion of *a*-choices, we first determined levels of similarity among juvenile or adult insects, by manipulating insect-segments according to Tversky's (1977) contrast rule. Juvenile insects had six segments colored dark or light; adult insects had six segments (antennae, head, thorax, wings, legs, and abdomen) with five possible forms. Adult similarity ($Sim[XX, TT]/Sim[XX, TT] + Sim[YY, TT]$) was never equal to juvenile similarity ($Sim[a, t]/Sim[a, t] + Sim[b, t]$) so we could determine whether children used adult or juvenile insect similarity in their *a*-choices.

By controlling perceptual similarity in this way, we could determine whether children generalized using relational or perceptual similarities. If children generalized using perceptual similarities of exemplar to target, the probability of *a*-choices would increase with the perceptual similarity of the *a*-exemplar to the target. In contrast, if children generalized using relational similarities (e.g., both *a* and *t* sharing the relation *goal-of-Xs*), the probability of *a*-choices would increase with the relative similarity of the *XX*-exemplars to the *TT*-exemplars.

2. Experiment 1

2.1. Method

2.1.1. Participants

Sixty-four kindergartners and first graders (mean age = 6.7 years, range 5.6–7.9 years; 31 males and 33 females) participated.

2.1.2. Stimuli and procedure

A computer presented children with illustrations of juvenile and adult insects and with questions about the juvenile insects (offspring problem, Fig. 1; prey problem, Fig. 2). For every question, juvenile-*a* appeared first with accompanying auditory stimuli (e.g., a voice saying "This is a dax."), followed by adults-*XX* ("It was born to these two daxes here"/"These two bugs want to eat the dax"), juvenile-*b* ("This is a fep."), adults-*YY* ("It was born to these two feps here"/"These two bugs want to eat the fep"), adults-*TT* ("These two bugs gave birth to…"/"These two bugs want to eat…"), and juvenile-*t* ("…this one here. Is this one a dax or a fep?"). Children were instructed to answer by pointing to either the left or right side of the computer screen; no feedback was given. Children were asked four questions – whether the target shared a category label with *a* or *b*, whether it would look like *a* or *b* in the future, and whether it had a property inside its blood like that of *a* or *b*, and the similarity of parents of *a* or *b*. Similarities were varied within-subjects and counter-balanced over trials using a Latin-square design. Trial-to-trial, differences between adult and juvenile similarity varied from 67- to 100-points but for a child always summed to 0% to control for perseveration.

2.2. Results and discussion

We first examined proportion of *a*-choices for each of the four questions independently. Across all conditions and experiments, number of *a*-choices did not differ by question ($ps > .1$); we collapsed the four questions into one measure of *a*-choices (0–100%). The summary of results is shown in Fig. 3, which depicts results for the strongest test of hypotheses, where adult and juvenile similarities were perfectly and negatively correlated.

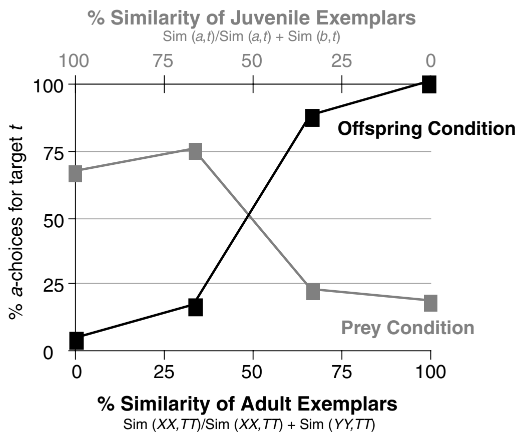

Fig. 3. In Experiment 1, the same exemplars elicited very different generalization functions depending on how they were related to one another. Presenting juvenile insects as prey resulted in generalization on basis of juvenile similarity, whereas presenting the juveniles as offspring led to generalization based on adult similarity.

We next examined effect of juvenile similarity by conducting a 2 (condition: prey, offspring) × 4 (juvenile similarity: 0%, 33%, 66%, and 100%) ANOVA on proportion of *a*-choices. Results indicated that effects of juvenile similarity were strongly affected by experimental condition, $F(3,127) = 36.90$, $p < .001$.

In the offspring condition (where juveniles were introduced as offspring), juvenile similarity *decreased* *a*-choices, $F(3,63) = 26.32$, $p < .001$, suggesting that children ignored countervailing similarity of the targets to other exemplars in favor of the similarity of their parents. Consistent with this hypothesis, a one-way ANOVA (adult similarity: 0%, 33%, 66%, and 100%) on proportion of *a*-choices indicated that similarity of adult-*XX* to adult-*TT* *increased* *a*-choices, $F(3,63) = 19.98$, $p < .001$. This finding is interesting because it reflects "essentialist" generalization, one in which generalization almost perfectly follows the attributes of the *causal origin* of a target ($r = .95$) rather than the target itself. Could this generalization pattern have resulted from the salience of adults? Evidence from the prey condition, in which adults and juveniles were identical to the offspring condition, allowed us to test this hypothesis.

In the prey condition (where juveniles were introduced as prey), relative similarity of juvenile-*a* to juvenile-*t* had the opposite effect and *increased* *a*-choices, $F(3,63) = 12.38$, $p < .001$, as would be expected if children generalized to targets based on their perceptual similarity to exemplars. This finding is important for both broad and narrow reasons. Broadly, it indicates that having a target share a relation with an exemplar (i.e., both being the prey of a similar predator) was not itself sufficient to affect generalization, at least not when targets looked more like another exemplar. More narrowly, it demonstrates that adult similarity was not sufficient to distract children from juvenile similarity, which children were apparently able to follow.

When information about causal origins was removed (see Figs. 4 and 5), similarity of prey-*a* to prey-*t* increased *a*-choices, $F(3,63) = 16.96$, $p < .001$, and similarity of offspring-*a* to offspring-*t* increased a-choices, $F(3,63) = 42.59$, $p < .001$ (see Fig. 6). These results are consistent with the prediction that generalization follows exemplar-to-target similarity in absence of data about the causal origins of the target, which were present in the offspring condition when *TT* were present but absent in the offspring condition when *TT* were absent. The overall effect of juvenile similarity on

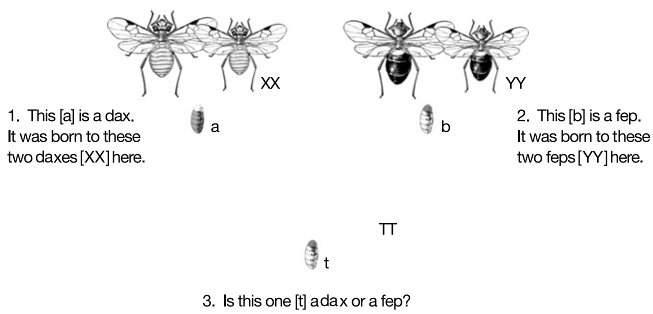

Fig. 4. Example of a problem in the offspring condition of Experiment 1, where causal origins of target were absent. Similarity of *a* to *t*/similarity of *a* to *t* + similarity of *b* to *t* = 0%.

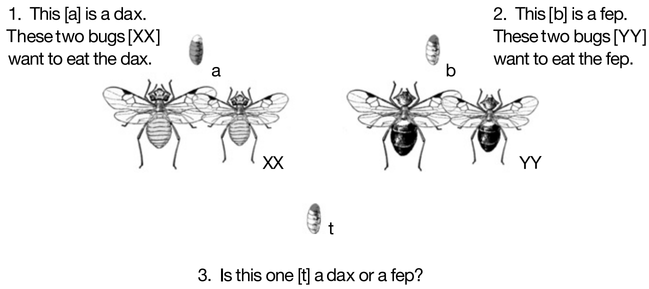

Fig. 5. Example of a problem in the prey condition of Experiment 1, where predators of target were absent. Similarity of a to t/similarity of a to t + similarity of b to $t = 0\%$.

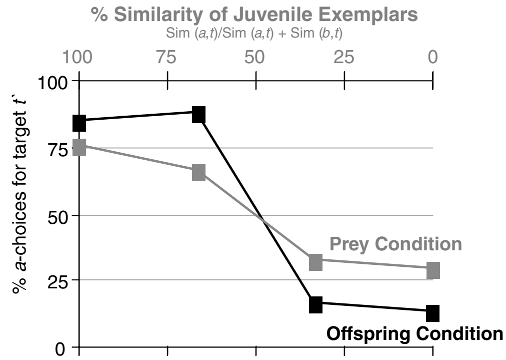

Fig. 6. In Experiment 1, the same exemplars elicited very similar generalization functions when information about target–exemplar relations was removed. In both conditions, children used juvenile similarity to generalize novel information, as in the prey condition of Experiment 1.

exemplar-to-target generalization was only marginally affected by experimental condition, $F(3,127) = 2.62$, $p = .06$. Interestingly, the tendency toward an interaction reflected the stronger effect of juvenile similarity in the *offspring condition*, suggesting that the manipulation of spatial characteristics cannot explain children's use of adult similarity in the offspring condition. Rather, children's generalization using adult similarity when *TT* was present likely reflected their interpretation of the adults as causal origins, and lacking that, they generalized strongly on bases of exemplar-to-target feature overlap.

3. Experiment 2

Experiment 2 aimed to replicate Experiment 1 results under conditions in which children were not given category labels. The theoretical motivation for this test is provided by Sloutsky and Fisher (2004) SINC (similarity-based induction, naming, and categorization) model, in which shared category labels increase similarities between different sets of perceptual features. For example, the model predicts that by using category labels such as "dax" and "fep", we may have increased the discriminability of exemplars, leading to greater attention to adult insects in the offspring condition (where adults were labeled) than to adults in the prey condition (where adults were unlabeled).

3.1. Method

3.1.1. Participants

Thirty-two kindergartners (mean age = 5.7 years, range 4.7–7.3 years; 20 males and 12 females) participated.

3.1.2. Stimuli and procedure

Tasks were identical to those in Experiment 1, except we replaced novel category labels (e.g., "dax") with a general descriptive term (e.g., "this bug"). Additionally, rather than asking children to choose between two *category labels* for a target (e.g., "is this a dax or a fep?"), we asked them to choose between two *categories* for the target (e.g., "is this one the same kind?").

3.2. Results and discussion

We examined the effect of juvenile similarity by conducting a 2 (condition: prey, offspring) × 4 (juvenile similarity: 0%, 33%, 66%, and 100%) ANOVA on proportion of *a*-choices. Results indicated that effects of juvenile similarity were strongly affected by experimental condition, $F(3,127) = 27.81$, $p < .001$ (see Fig. 7).

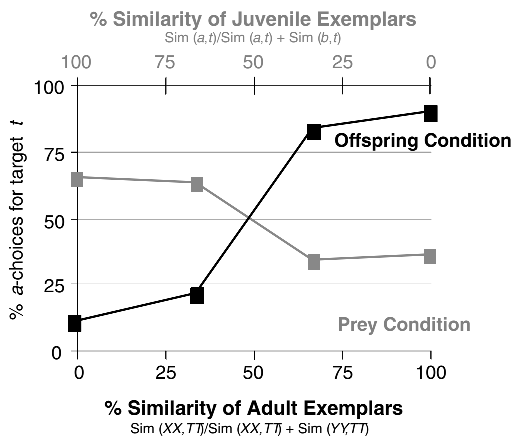

Fig. 7. In Experiment 2, category labels were not presented to children, and the same exemplars continued to elicit very different generalization functions depending on whether exemplars were related to one another casually.

In the prey condition, similarity of juvenile-*a* to juvenile-*t* *increased* *a*-choices, $F(3,63) = 4.54$, $p < .01$, indicating that adult similarity was not sufficient to distract children from the perceptual similarity of the juveniles even when the juveniles did not receive distinct category labels. In the offspring condition, juvenile similarity *decreased* *a*-choices, $F(3,63) = 32.08$, $p < .001$, suggesting that children ignored the countervailing similarity of targets to other exemplars in favor of similarity of parents even when adults did not receive distinct category labels.

To test this interpretation, we examined effect of adult similarity by conducting a 2 (condition: prey, offspring) × 4 (adult similarity: 0%, 33%, 66%, and 100%) ANOVA on proportion of *a*-choices. Results indicated that effects of adult similarity on *a*-choices were also strongly affected by experimental condition, $F(3,127) = 33.56$, $p < .001$. When adults were introduced as predators, similarity of adult-*XX* to adult-*TT* *decreased* *a*-choices, $F(3,63) = 4.56$, $p < .01$; however, when adults were introduced as parents, similarity of adult-*XX* to adult-*TT* *increased* *a*-choices, $F(3,63) = 47.87$, $p < .001$.

4. General discussion

We examined whether young children would generalize from exemplars to targets on the basis of perceptual or relational similarity (e.g., *effect-of-X*, *goal-of-X*). We hypothesized that the greater predictive accuracy of causal origins would lead young children to ignore target-to-exemplar perceptual similarity when the countervailing relational similarity was causal but to rely on target-to-exemplar perceptual similarity when the countervailing relational similarity was non-causal. The results of Experiments 1 and 2 confirmed this prediction.

Rather than children generalizing by perceptual similarities until a general "relational shift" occurred (Gentner & Toupin, 1986; Halford, 1992; Inhelder & Piaget, 1958), no child in these experiments generalized using only similar appearances or relations. Instead, young children appeared to process two kinds of similarity, perceptual and relational, and to generalize using the more predictive one. Thus, children likely assumed a causal explanation for a perceptual match between exemplars and targets, motivating them to generalize using feature overlap. Consistent with this interpretation, children who were given no information about target origins (i.e., children in the prey conditions) reported that similar-looking targets had similar parents. More direct evidence for this account came from offspring conditions, where children had access to both perceptual and relational similarities, and reliably chose the latter for generalizing.

The finding that children use different relations to select the perceptual features by which to categorize suggests an interesting perspective on Gelman and Markman's (1986) findings and on Sloutsky and Fisher's (2004) failure to replicate them. Here, we provided a conceptual replication of Gelman and Markman's work; children ignored perceptual similarity and used relational information to infer category membership. Further, in Experiment 2, labels did not enhance category-based induction compared to Experiment 1, suggesting that young children's bias to attend to auditory information (Napolitano & Sloutsky, 2004; Robinson & Sloutsky, 2004; Sloutsky & Lo, 1999; Sloutsky, Lo, & Fisher, 2001) cannot explain their category-based induction, as it might have in Gelman and Markman (1986). Most generally, these results are consistent with claims that children's category-based induction relies on use of causally central information (Ahn, Gelman, Amsterlaw, Hohenstein, & Kalish, 2000; Springer, 2001), which is a central tenet of Gelman's (2003) theory of early categorization.

How widely do children use causal origins to generalize in their everyday lives? Without detailed information about the frequencies that children even encounter origin information, any answer to this question is admittedly speculative, and sharply different answers have been aired (Gelman & Wellman, 1991; Oakes & Madole, 2003; Rakison, 2003). Our view is that both direct and indirect information about origins may be present to some degree. First, children have direct experience with offspring that are not clones of their parents and thus could learn that parent/offspring relations are more predictive of category-membership than appearances. For instance, two seeds may look similar, but since they come from different fruit their properties differ substantially; two chicks may look similar, but since they are hatched from eggs laid by different birds, their properties also differ; and so on. These contexts of direct origin information could provide indirect information about origins. Thus, that kin tend to cohabitate (Lieberman, Tooby, & Cosmides, 2003), engage in nepotism (Agrawal, 2001; Hamilton, 1964), and avoid engaging in incest (Lieberman et al., 2003), infanticide (Struhsaker & Leland, 1987; Watts, 1989; Watts & Mitani, 2000) and cannibalism (Bilde & Lubin, 2001; Watts & Mitani, 2000) potentially provides a rich source of indirect information about origins and thus its importance in category-judgments.

The importance of causal relations is not limited to biology. Evidence of origin-based generalization is reported in literature from social psychology (Rothbart & Taylor, 1992) and cognitive anthropology (Gil-White, 2001), where descent affects generalizations within social groups. An effect of origins has also been observed in judgments about the value of various non-living kinds, such as the value of chewed-up gum that came from Britney Spears versus another person (Frazier & Gelman, 2005). These findings suggest that generalizing over origins may cause children's essentialist reasoning across many domains beyond biology.

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