How to Go from *Nest* to *Home*: Children's Learning of Relational Categories

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Abstract

How do children learn relational categories such as *gift*, *barrier*, or *dwelling-of*? In this research we explore two means of promoting relational abstraction: comparison processes and relational labels. In Experiment 1, 6-, 4-, and 3-year-old children compared pairs of cards depicting analogous situations. We either *labeled* the relations underlying the analogies (Relational Word condition) or simply provided the analogous pairs without labeling the relation (Analogy Only condition). Four- and six-year-olds in both conditions were able to learn the relations, but performed better if relational labels were added. Three-year-olds were unsuccessful both with and without relational words. In Experiment 2 we used a *progressive alignment* training method with three-year-olds. We first gave them closely similar pairs, and then progressed to analogous pairs similar to those used in Experiment 1. Three-year-olds who received a combination of progressive alignment and relational labels during training were able to successfully learn the relation. Implications for the acquisition of relational concepts are discussed.

Introduction

Relational categories are categories whose membership is determined by a specific relation (either temporary or enduring) that category members have with another entity or category. For example, all *barriers* conform to the relationship: BLOCKS (X, Y). Members of a relational category can differ widely in their intrinsic properties. For example, the *barrier* category can include a fence, a river, a canyon, and even poverty and lack of education (Kurtz & Gentner, 2001; Gentner & Kurtz, in press). In this respect, relational categories resemble analogies. Relational categories are prominent in mathematics and science (e.g., *denominator, result, carnivore, pressure, magnetic attraction*). They are also frequent in everyday life (*pet, parent, winner, accident*). Indeed, Asmuth and Gentner (in preparation) found that relational nouns made up about half the nouns in a representative corpus of adult vocabulary.

Although much of the research on categories has focused on object categories (e.g., horse, mammal, animal), there is some prior work on relational categories. Barr and Caplan (1987) distinguished between intrinsically represented and extrinsically represented categories. They defined an *intrinsic feature* as one that is true of an entity considered in isolation (such as "has wings" for a bird) and an *extrinsic feature* as one expressing the relationship between two or more entities (for example, "used to work with" for a hammer). Rehder and Ross (2001) investigated the related notion of *abstract coherent categories* in which membership depends on relations rather than on specific attributes. Markman and Stilwell (2001) distinguished categories that name common relations or relational roles from those defined by common feature sets. Kurtz and Gentner (2001) contrasted relational categories with entity categories (defined by intrinsic features), goal-derived categories, and thematic clusters. Kloos and Sloutsky (2004) made a related contrast between *nominal kinds* (primarily relational categories) and *natural kinds* (primarily entity categories). Another relevant line of research is Barsalou's (1983) investigation of *goal-derived categories*, such as "things to take out of the house in case of fire"; such categories can often be characterized as relational categories.

As noted above, relational categories play a key role in abstract thought. Therefore it is important to know how such categories are learned by children. There is considerable evidence that children find relational categories difficult to learn. First, names for relational categories are acquired later than names for object categories. Second, when novel words are introduced, children appear to take them as names for objects (Gentner, 1982; Gentner & Boroditsky, 2001; Goldin-Meadow, Seligman, & Gelman, 1976; Landau, Smith, & Jones, 1998; Markman, 1989, 1990; Waxman, 1991), even as early as 13 months of age (Waxman & Markow, 1995). Names for entities—especially names for animate beings—are learned early in many languages, as evidenced by findings from English, Italian, Korean, Mandarin, Navajo, and Tzeltal (Gentner & Boroditsky, 2001; in preparation). For example, the MacArthur Communicative Developmental Inventory for 8-16-month-olds has 296 nouns, of which 93% are entity nouns (objects, animals and people) and 7% are mixed entity-relational nouns (there are no purely relational nouns). The MCDI for 17-30-month-olds has 411 nouns, of which 79% are entity nouns, 13% are mixed, and 8% are relational nouns.

Early on, not only do children learn more entity terms than relational terms, but when they do learn relational terms, they often initially treat them as entity terms (Gentner & Rattermann, 1991). For example, kinship terms are often understood initially in terms of entity characteristics, and only later in terms of relational roles (E. Clark, 1993). A brother may be described as "a boy about 12 years old",

rather than as any male co-sibling, or an uncle as "a nice man with a pipe" rather than any male in a sibling relationship with one's mother or father (Keil & Batterman, 1984). Likewise, Keil and Batterman found that 4-year-olds conceive of an island as "a place with sand and palms." Only later do they learn the relational meaning of "land surrounded by water." In a training study, Hall and Waxman (1993) found that 3 ½ -year-olds had difficulty learning novel nouns denoting concepts like *passenger* ("situation-specific nouns"). Even when they were explicitly told (for example) "This one is a *blicket* BECAUSE IT IS RIDING IN A CAR," children asked to find another *blicket* chose a similar-looking doll, rather than another doll also riding in a car. In other words, they did not interpret the new word in terms of the intended relational concept (*passenger)* but rather as referring to a concrete object category (Hall & Waxman, 1993).

This pattern is consistent with prior developmental research indicating a *relational shift* from a focus on concrete objects to a focus on relations in the interpretation of analogy and metaphor. For example, when asked to interpret the metaphor *A tape recorder is like a camera*, 6-year-olds produced object-based interpretations (e.g., *Both are black*), whereas 9-year-olds and adults produced chiefly relational interpretations (e.g., *Both can record something for later*) (Gentner, 1988). Similarly, Billow (1975) reported that metaphors based on object similarity could be correctly interpreted by children of about 5 or 6 years of age, but that relational metaphors were not correctly interpreted until around 10 to 13 years of age.

Given all the difficulties outlined above, one might wonder how relational categories are acquired at all. Gentner (2003) hypothesized two mechanisms that promote the acquisition of relational categories: *comparison* and *relational language*.

Comparison. There is abundant evidence that comparison across instances can facilitate noticing and encoding common relational structure (e.g., Catrambone & Holyoak, 1989; Gentner & Namy, 1999; Loewenstein & Gentner, 2001; Kotovsky & Gentner, 1996). Comparison is not a low-level feature-matching mechanism, but a process of structural alignment and mapping that is powerful enough to acquire structured knowledge and rules (Gentner & Medina, 1998; Gentner & Wolff, 2000). The act of carrying out a comparison promotes alignment relations and renders the common structure more salient (Gentner & Namy, 1999; Gick & Holyoak, 1983; Markman & Gentner, 1993; Wolff & Gentner, 2000). There is considerable evidence that mutual alignment promotes learning and transfer. That is, when a learner is induced to compare two things — for whatever reason, be it common labels, perceptual similarity, or similar roles in pretend play — the alignment process tends to render the common relational structure more salient and prompt its re-representation at a more abstract level.

Relational language. The second candidate for promoting the learning of relational categories is relational labels. In this research we ask whether hearing a label for a relation helps children to abstract the relation and transfer it to new situations. This kind of facilitation occurs with object categories: labeling a disparate set of objects with a common name invites children to form a category based on their commonalities.

At first glance, it seems implausible that this facilitative effect will hold for relational labels. Compared to the acquisition of names for object categories, the acquisition of relational labels poses a significant challenge, as noted above. This is in part because relations are often non-salient in the environment, and, more pervasively, because it is often not obvious *which* relation is relevant to the meaning of the word (Gentner, 1982; Gentner & Boroditsky, 2001). One strong reason to doubt that relational nouns can readily alert children to relational concepts is children's strong tendency to take words as names of objects, as reviewed above (Gentner, 1982; Markman, 1989; Waxman, 1999).

However, there is research indicating that under some circumstances, relational labels *can* help invite relational abstractions. We hypothesize that this is especially likely to occur when learners are able to compare situations and abstract the common relation (Gentner & Namy, 1999; Kotovsky & Gentner, 1996). In such cases, the relational label may serve to consolidate the common relations derived from the comparison process (Gentner, 2003; Gentner & Medina, 1998).

In the studies that follow, we investigated these questions by using cards that illustrate two analogous situations and asking children to transfer the analogy to a third situation. More specifically, each of the two situations modeled involved a relational category, and in the third situation the child was asked to determine the appropriate member of the relational category for that situation. Half the children heard a novel word that labeled the relational category in each set of analogous situations, and half received the analogous situations alone. In this way we aimed to examine children's ability to make use of a combination of comparison *and* relational labels to extract relational categories and transfer them to novel situations.

Experiment 1a

Participants Twenty-four 6-year-olds (range = 6;0 to 6;6, *M* = 6;2) participated. Children were randomly assigned to the Relational Word condition or the Analogy Only control.

Materials 72 colored line drawings of objects (nine sets of eight cards each) were used as stimuli. Each set included four example cards and four test cards. The example cards were divided into two pairs; each consisting of a base card (e.g., a man; a bird) and a same-relation card (e.g., a house; a nest). The test cards consisted of a base card (e.g., a dog) and three choice cards: a same-relation choice (e.g., a doghouse), a taxonomic choice (e.g., a different dog), and a thematic choice (e.g., a bone).

Procedure In the Relational Word condition, the child was told that we would play a game about figuring out what words mean. The experimenter presented the two sets of example cards and said, "The first word is *blick*. The house is the *blick* for the man, and the nest is the *blick* for the bird." Then, putting down the test trial base card she said, "Now it's your turn. What would be the *blick* for the dog?" After the child responded verbally, she put down the three choice cards, and said, "Can you pick which of these cards would be the *blick* for the dog?". In the Analogy-Only condition, children heard instead, "The house goes with the man, and the nest goes with the bird *the same way*. Now it's your turn. What would go with the dog the same way?" As in the Relational word condition, after the verbal response children were asked to choose among the three cards.

Results

The results suggest that having a novel word label a relation across different situations helps children to focus on the relevant relation and recognize it in other contexts. Participants in the Relational Word condition (M = .82, SD = .13) chose the same-relation cards significantly more often than those in the Analogy Only condition (M = .65, SD = .15), t (12) = 3.09, p < .01. Further, in both conditions, children chose the same-relation cards at above-chance (.33) rates, and at a significantly higher rate than that for either the thematic or the taxonomic cards, all p's < .0001. See Figure 1. Thus, structural alignment supports abstracting a common relation, but hearing a label strengthens the effect.

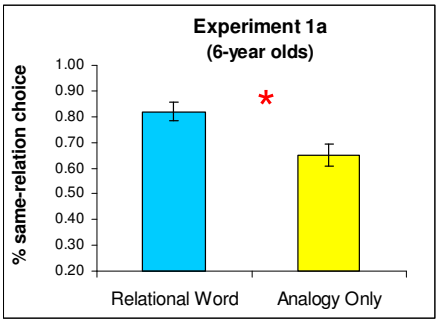

Figure 1: Results from Experiment 1a.

Discussion

The results of Experiment 1a suggest that children can form analogies across situations and transfer them to new situations. Further, that performance was higher in the Relational Word condition than in the Analogy-Only condition suggests that hearing a novel relational noun that labels a common relation serves to boost this ability.

These results demonstrate that relational categories are accessible to 6-year-olds. This led us to ask whether younger children would also be able to form relational analogies, and whether novel relational language would facilitate this process.

Experiment 1b

Participants Thirty-two 4-year-olds (range = 4,6-5,3, M = 4,10) and thirty-two 3-year-olds (range = 3,0-3,6, M = 3,2) participated. At each age, children were randomly assigned to the Relational Word condition or the Analogy Only control.

Materials and Procedure The materials and procedure were identical to those used in Experiment 1a.

Results

The results suggest that the benefit derived from a combination of making comparisons and hearing a novel relational word helps 4-year-olds to focus on the relevant relation and recognize it in other contexts, as it did for 6-year-olds in Experiment 1a.

Proportion of trials on which children chose the same-relation card were submitted to an ANOVA with Condition (2: Relational Word, Analogy Only) and Age (2: 4 years, 3 years) as between-subject factors. A main effect of Age, F(1, 60) = 27.356, p < .001, revealed that 4-year-olds (M = .57, SD = .24) chose the same-relation cards more often than did 3-year-olds (M = .30, SD = .19). A main effect of Condition, F (1, 60) = 4.434, p < .05, reflected that participants in the Relational Word condition (M = .49, SD = .28) chose the same-relation cards significantly more often than those in the Analogy Only condition (M = .38, SD = .21). There was also a marginally significant Age x Condition interaction, F (1, 60) = 3.364, p = .07, demonstrating that whereas 4-year-olds in the Relational Word condition (M = .67, SD = .24) chose the same-relation cards more often than 4-year-olds in the Analogy-Only condition (M = .47, SD = .19), 3-year-olds' performance did not differ from chance in either condition. See Figure 2.

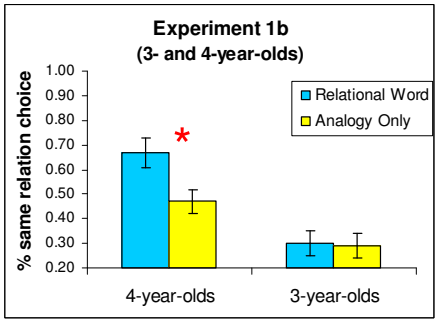

Figure 2: Results from Experiment 1b.

Discussion

The results suggest that 4-year-olds, like the 6-year-olds in Experiment 1, can form analogies between situations and transfer them to new situations. Further, as with the older children, hearing a novel word that labels the relation helped 4-year-olds focus on the relation and recognize it in other contexts. However, we saw no evidence that 3-year-olds could learn the relation in either condition.

The failure of the 3-year-old group could result from a maturational limitation, such as insufficient processing capacity to carry out the mapping. However, another possibility is that what the 3-year-olds lack is a sufficiently firm knowledge of the domain relations to be able to align the common relational structure and profit from the analogy. Gentner and Rattermann (1991) showed that young children's poor performance on analogies can result from a lack of sufficient relational knowledge.

One way to bootstrap analogical comparison in a domain is to begin with concrete literal similarity comparisons (Gentner & Namy, 1999). The idea is that in a literal similarity comparison, the close object matches--which are easy for the child to grasp—can help the child to notice the relational correspondences. For example, a child who cannot see the match between *watermelon/knife* and *log/ax* may easily match *watermelon/knife* with *orange/knife*. Carrying out this concrete alignment can help the child see the common relation of *cutting*. If the child is then given the more distant match with *log/ax*, she may then be able to perceive the common *cutting* relation (Of course, she may have to perform a further re-representation to align the specific kind of cutting done by a knife with that done by an ax.)

In the next study we tested whether progressive alignment can help 3-year-olds to grasp relational categories. Specifically, we enriched the comparison element of the task used in Experiment 1: we began with two high-similarity pairs, and then progressed to two low-similarity pairs much like those used in Experiment 1. Based on the Gentner and Namy results, we predicted that making concrete (literal similarity) comparisons will help highlight relational commonalities. We also predicted, based on the results of Experiment 1, that receiving the relational label will help children extract and retain the common relation.

Experiment 2

Participants 40 3-year-olds (*range* = 3;0 - 3;8, *M* = 3;2) participated. They were randomly assigned to the Relational Word condition or the Analogy Only control.

Materials 72 colored line drawings of objects (6 sets of 12 cards each) were used as stimuli. Each drawing was displayed on a laminated card. Each set included eight example cards and four test cards. The example cards were divided into four pairs; each pair consisted of a base card and a same-relation card. The base cards in the first two pairs (close-pair) are closer in similarity (e.g., a watermelon and an orange), than the base cards in the second two pairs (far-pair; e.g, a log and a tree). The test cards consisted of a base card and three choice cards: a same-relation choice, a taxonomic choice, and a thematic choice. See Figure 3.

Procedure As in Experiment 1, in the Relational Word condition, the experimenter said, "In this game we are going to teach Sammy (a puppet sitting on the table) the word *blick*. We're going to teach him what *blick* means." Then she showed the child the first close-pair base card and said, "Here's a watermelon. See?" As she showed the child the relational match (e.g., a knife for *cutting* relation), she said, "Here is the *blick* for the watermelon." Then she picked up the second close-pair base card and said, "You know what this is? Yes, an orange.", and as she pointed to the relational match (e.g., a knife), she said, "Here is the *blick* for the orange." Then she made a sweeping gesture across these two close-pair base cards and their matches and said, "You see how these *[across the base cards]* are *blicks* for these *[across the matches]*?" Then the experimenter continued to the far-pairs (tree/saw; log/ax), and used the same instructions as those for the close-pairs. Finally, the experimenter concluded the examples section by showing all cards on the table and said, "Now let's look at all of them. You see how these *[sweeping gesture across all four base cards]* are all *blicks* for these *[sweeping gesture across all four matches]*?"

In the Analogy Only condition, the procedure was similar to that in the Relational Word condition, except for the language used when the experimenter pointed to the relational matches of the base cards. On the first pair, she said, "This *[pointing to the knife]* goes with the watermelon." On subsequent pairs she said, "This *[pointing to the knife/saw/ax]* goes with the (orange/log/tree) *in the same way*."

At Test, the child saw the test base card (e.g., paper) and the three choice pictures (e.g., pencil, scissors, paper) and was asked, "Can you teach Sammy which one of these is the *blick* for the paper?" (Relational Word condition) or "Can you teach Sammy which one of these goes with the paper in the same way?" (Analogy Only condition).

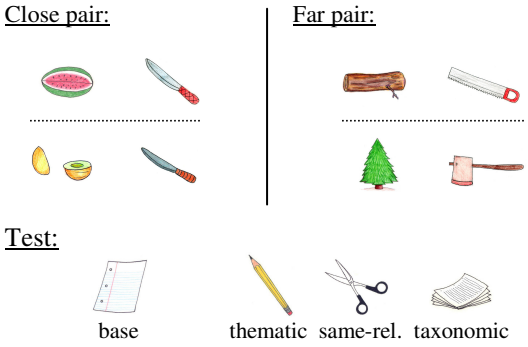

Figure 3: Sample set depicting a *cutting* relation.

Results

As predicted, the proportion of same-relation choices in the Relational Word condition (*M* = .54, *SD* = .22) was greater than chance ($p < .001$), and also greater that in the Analogy Only condition (*M* = .41, *SD* = .26), $t(38) = 1.76$, $p = .04$, one-tailed. (See Figure 4.) Thus, having a novel relational word applied across progressively alignable situations can help 3-year-olds focus on the relevant relation and recognize it in other contexts.

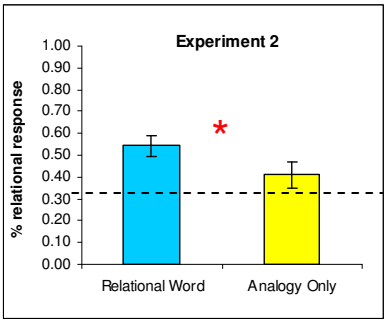

Figure 4: Results from Experiment 2.

Discussion

Results from Experiment 2 suggest that 3-year-olds can make use of the combination of relational language and progressive alignment to pick up common relations and transfer them to new situations. It may be the case that close alignments in the form of object similarity help them pick up the relation by an initial noticing of a more specific version of the relation.

General Discussion

Taken together, the results of these studies demonstrate that both comparison and relational language can help children to see relational commonalities among analogical situations. Older children—four- and six-year-olds—were able to notice these common relations and transfer them to new situations readily, with or without relational language. However, both age groups performed significantly better when relational labels were present. These findings suggest that the relational abstraction process can be promoted by relational labels. That is, the capacity to see consistent mappings between structures across different surface contexts is promoted both by direct experiential comparisons and by hearing relational language.

We suggest two reasons that relational labels may contribute to relational learning. First, when a comparison has already taken place, the label may provide a kind of consolidating effect that helps the learner retain the relational structure for later use. Second, a common label may itself *invite* comparison among the things so labeled; Gentner and Loewenstein (2002) termed this "symbolic juxtaposition." Applying a common label across two situations is a signal that there are important commonalities to be discovered. By giving two things the same name, we invite children to compare them regardless of their surface similarity—an important requirement for learning relational categories, whose members are superficially unlike.

For the younger children, the combination of analogical comparison and relational labels in Experiment 1 was insufficient to achieve relational insight. However, when we made the basis for comparison more clear by beginning with close literal alignments, 3-year-olds were able to reap the benefits of comparison and relational language.

These results invite further exploration. Future work should investigate the potential facilitative role of relational labels using unknown categories. It would also be useful to investigate children's construal of what they are supposed to learn. For example, we could test the range of extension of a given relational category across several new contexts that represent different possible interpretations of the novel word.

Children's initial representations are often described as highly conservative. Their knowledge is described as "concrete," "situated" or "contextually embedded." We suggest that progressive alignment processes allow learners to see that the same relational patterns may apply across specific situations. In this way comparison promotes the abstraction or disembedding of relations from their initial concrete contexts. This gradual abstraction of initially conservative, context-specific representations can give rise to more abstract relational representations (Forbus & Gentner, 1986; Medin & Ross, 1989).

Learning relational terms may have benefits for later learning (Loewenstein & Gentner, in press). Possessing relational language may increase the likelihood that the learner will be reminded of the prior situation when a new instance of the relation occurs (Clement et al, 1994; Son & Goldstone, 2005). This in turn will increase the likelihood of encoding relations in the same way across different situations (Forbus, Gentner, & Law, 1995). When relational concepts become part of our mental store, they may facilitate the application of the concepts they embody to new experiences.

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