Relational Similarity in Identity Relation: The Role of Language

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Abstract

The development of the ability to perceive relational similarity was investigated. Experiment 1 was a similarity judgment task wherein relational similarity was pitted against object similarity. 4.5-, 8.5-year-olds, and adults chose whether the relational match (identity relation, e.g. two triangles) or the object match (e.g. a square and a circle, one shape in common with the standard) was more similar to the standard (e.g. two squares). 4.5-year-olds found the object match very compelling even with a basic relation (identity), whereas adults preferred the relational match. In Experiment 2, we asked whether language serves as a cognitive tool promoting relational insight. Same stimuli as in Experiment 1 were used, except that participants heard a novel word applied to the standard. Results provide evidence for a language benefit, as 4.5-, 8.5-year-olds and even adults showed significant increase in relational responding after hearing the novel label. With a view to a cross-species comparison, the relational matches employed in this study were identity relations, as has been widely used in research with nonhuman animals (Thompson & Oden, 2000）.

Introduction

Relational concepts are critical to higher-order cognition. The ability to perceive relational similarities underlies a number of fundamental cognitive processes such as analogy (Gentner, 1983, 2003; Kokinov & French, 2003), categorization (Ramscar and Pain, 1996), and inductive inferencing (Holland, Holyoak, Nisbett, and Thagard, 1986). One speculation is that humans' exceptional relational ability is the major contributor to our high intelligence as a species (Gentner, 2003).

What is the ontogeny of relational concepts? Studies of comparative cognition in humans and animals have found marked differences in relational ability across species. Much of this work has focused on whether animals can perceive *identity* between two elements—perhaps the simplest possible relation, and the one most likely to be perceived across species. Many animals can succeed in learning object identity in a sample-to-matching task as in figure. 1.1. But the ability to succeed in judgment of identity relations as in figure 1.2 is quite uncommon (Premack, 1983).

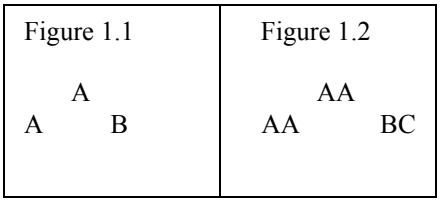

Figure 1. Matching-to-sample task and identity relational matching task.

Premack (1988) argued that a species' ability to do *same* versus *different* relational judgments is dependent upon its experience with symbolic communication systems—specifically, with the acquisition of labels for *same* and *different*. Only chimpanzees who had a symbolic, language-like training were successful in the task such as in Figure 1.2. Likewise, a study by Pepperberg and Brezinsky (1991) reported that an African gray parrot with significant amount of language training could indicate whether two objects were the same size and whether one object was larger or smaller than a comparison object. There is also evidence suggesting that a dolphin who received language training more readily generalized same/different concepts than a naïve dolphin (Herman, Kuczaj, & Holder, 1993). Most recently, Thompson, Oden and Boysen (1997) found that chimpanzees who were previously trained with *same* and *different* token training (e.g. given AA, then chose heart), were successful in relational matching tasks, whereas a naïve chimpanzee in the same experiment failed.

The results from animal studies suggest that relational concepts are non-obvious and elusive, and quite possibly, symbolic training or language enculturation is needed to make the relational concept more explicitly available. What is the status of relational knowledge in human development? Although relational concepts are used extensively in everyday cognition – from understanding the simple meaning of words like *mother* and *gifts* to understanding concepts such as limit in mathematics – relational concepts are not easily accessible among young children. Previous work has shown that children's appreciation of relational similarity in comprehension of

metaphor and analogy develops very gradually (Gentner, 1988; Vosniadou, 1987; Vosniadou 1995). Relatedly, young children initially think of a relational noun like "uncle" as a gift-giving, unrelated adult, and refuse to call their father's adolescent brother an uncle (Keil, 1989). Similarly, in a word naming study, Hall and Waxman (1993) found that 3.5-year-olds were unable to map a novel word meaning to its intended relational meaning like "passenger", even when they were explicitly told the relational meaning of the word (e.g. this is a 'murvil' because it's riding a car).

There is considerable evidence that objects are more cognitively and perceptually salient than relations in the structure of the perceived world (Gentner, 1982; Gentner & Boroditsky, 2001). Thus a key question in the development of relational thinking concerns when children become able to perceive relational similarity in the presence of a competing object similarity. Many researchers found that when relational similarity is pitted against object similarity, younger children are more influenced by object matches, and less able to attend to relational matches (Gentner & Toupin, 1986; Gentner & Rattermann, 1991; Rattermann & Gentner, 1998a; Rattermann & Gentner, 1998b, Richland, Morrison, & Holyoak, 2006). The term *relational shift* (Gentner, 1988; Halford, 1993) has been used to capture this phenomenon: there is a shift from focus on object similarity to focus on relational similarity. This shift seems to appear at different ages in different domains (e.g., Brown, Kane, & Echols,1986; Gentner & Toupin, 1986; Goswami, 1989; Smith, 1984; Uttal, Schreiber, & DeLoache, 1995).

How do young children develop from strongly preferring object similarity to being able to appreciate relational similarity? We aim to investigate this question in two ways. First, we ask whether there is a basic context allowing young children to spontaneously perceive relational similarity. Second, we ask whether there is a factor in development that strongly supports the development of relational thinking. We propose that language is one such candidate factor. In Experiment 1, by measuring relational performance with a basic relation and simple objects, we gain insight to the initial state of relational knowledge. We then compare this initial performance with performance with linguistic label (Experiment 2) in order to determine the role of language in the development of relational thinking.

We created a basic context in two ways: 1) we used a simple, arguably basic, relation—that of *identity between two things*, and 2) we used very simple objects—namely, geometric shapes (see Figure 2). The identity relation is chosen as it has been attested as one conceptual relation that is available among varieties of (symbolically trained) species, as discussed previously. By using the identity relation in our research with humans, we aimed to partly equate the difficulty level of the relational matching task, making the results more comparable to the results from animal research. We also used simple objects to create an easy environment, motivated by prior evidence that rich object matches competes strongly with relational matches, whereas simple object matches will be relatively easy to overcome (Gentner & Rattermann, 1991, Paik and Mix, 2005).

The second question that we investigate is whether the use of linguistic symbols aids the ability to think relationally. As discussed above, symbolic training has been shown to improve relational performance in animal research. According to Vygotsky (1962), language provides a form of cultural scaffolding that contributes to children's learning. This support is likely to be especially important in learning abstract relational concepts. Therefore, in our second study, we tested the hypothesis that language promotes the ability to perceive relational commonalities

A number of studies have found a beneficial effect of relational labels in children's performance of relational mapping. Rattermann and Gentner (1998a) gave children relational labels that conveyed the relational system of *monotonic change in size* (e.g. Daddy/Mommy/Baby). They found that the use of relational labels improved young children's ability to carry out relational mapping, despite the lure of common objects. Likewise, Hermer-Vasquez, Moffet, & Munkholm (2001) found that children's performance in a retrieval task was correlated with their ability to use the spatial language relevant to the task. The use of spatial relational language can also improve children's performance in spatial mapping tasks (Loewenstein and Gentner, 2005).

In all these cases, the relational labels were familiar to the children. Thus the labels could have operated in two different ways: (1) by conveying a specific known relation; and (2) by inviting children to compare the two configurations that had the same labels. This second possibility stems from prior evidence suggesting that hearing a common label invites children to compare the two things, and this in turn highlights relational commonalities (Gentner and Namy, 1999; Namy and Gentner, 2002).

Evaluating the second possibility requires testing whether labels are helpful even without a prior associated meaning. Therefore, we used novel labels instead of familiar relational labels. In prior studies with similar stimuli, we have found that giving children an informative label (such as "double" for the standard with its identity relation) can improve children's performance (Christie & Gentner, 2005). The question is whether a *novel* label will promote relational responding.

Experiment 1

Method

Participants. Eighteen 4.5-year-olds (M = 55 months, range = 52-60 months); Sixteen 8.5-year-olds (M = 99 months, range = 96-102 months); and 28 adults (college students) participated in the experiment.

Materials There were eight triads of simple geometric shapes. Each triad consisted of a standard, and a pair of

choices: object similarity choice (object match), and relational similarity choice (relational match) (Figure 2). Standards, object matches and relational matches were always composed of two geometric shapes. All eight standards were composed of two identical shapes (e.g. two circles) – hence depicting identity relation. Within a triad, the object match was composed of one identical shape to the standard and another shape (e.g. a circle and a triangle). The relational match was composed of two identical shapes, not shared by either the standard or the object match (e.g. two squares). Hence, the relational match also depicted an identity relation as in the standard, but did not share object similarity with the standard. Left and right placement of the object match and the relational match was counterbalanced.

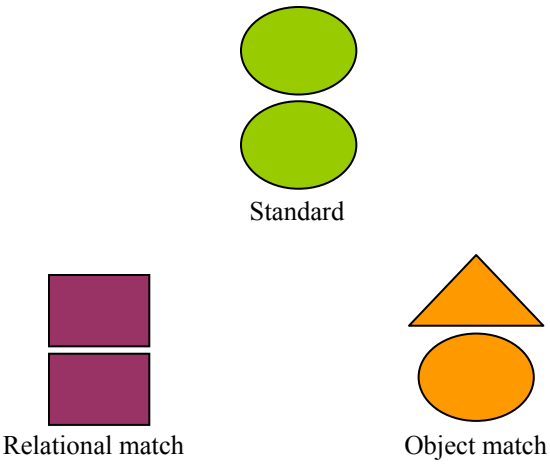

Figure 1. Sample triad: standard, relational match, and object match

Procedure Children were seated across the experimenter. For each trial, the experimenter showed the standard while saying, "I am going to show you one picture, see this one?!" The child was given a few seconds to observe the standard. With the standard still at view, the experimenter next showed both the relational match and the object match. The child was given a few seconds to observe the pictures, and then was asked to make a similarity judgment, "which one of these two pictures is more like the top picture?" The child indicated his or her choice by pointing one of the two matches. No feedback was given, though children were given general encouragement that they were doing well in the game. There were 8 trials in total, with different configurations of geometric shapes, but only one relation tested (identity relation). The procedure for adults was identical except that they wrote down their choices on an answer sheet instead of directly pointing to the picture. The two choices were labeled as right and left, and participant wrote down R or L on their answer sheet. We adopted this procedure so that the experimenter could not know participant's answer during the testing session.

Results

T-test against chance showed that 4.5-year-olds strongly preferred the object match (M_{object} =.83, *SD* =. 38), t (17) = 3.68, $p < 0.005$). In contrast, adults significantly preferred the relational matches ($M_{relational}$ = .69, *SD* = .33), t (27) = 3.03, $p < 0.05$. 8.5-year olds did not have any significant preference for either the object match or the relational match (M_{object} = .66, *SD* =. 42; $M_{relational}$ = .34, *SD* =. 42). One-way ANOVA revealed significant differences of proportion of relational choices among the three age groups, F (2, 61) = 11.81, $p < 0.001$. Setting the criteria for choosing 7 out of 8 trials (p *binomial* = *.013*); 15 out 18 (83%) 4.5-year-olds chose the object match, whereas 8 out of 16 (50%) 8.5-year-olds did so, and only 3 out of 28 adults (10%) chose the object match.

Discussion

Even with a very simple relational match, young children failed to show a preference for relational similarity. With object similarity pitted against relational similarity, 4.5-year-olds strongly preferred the object match, even though the relation tested was the identity relation and the competing object match was extremely simple. Although we did not find the 8.5-year-olds to prefer the object match significantly above chance, the results suggest a trend towards preference for object similarity. Overall, the results suggest that object similarity is very salient among young children, and that the attraction towards object similarity may persist for a rather extensive period in development.

If easy context alone does not support learning beyond surface similarity, how do children eventually acquire relational knowledge? In Experiment 2, we investigated the hypothesis that for the same age groups where we saw strong preference for object similarity, hearing a novel linguistic label would reduce salience of object matches, and increase preference for relational similarity.

Experiment 2

Method

Participants. Same age groups as in Experiment 1 were tested: sixteen 4.5-year-olds (M = 55 months, range = 52-60 months); sixteen 8.5-year-olds (M = 98 months, range = 96-102 months); and 28 adults (college students).

Material and Procedure. Same stimuli and procedure as in Experiment 1 was used, with the additional use of a novel label. The experimenter labeled the standards with a novel word, "Look, this is a truffet," and asked, "which one of these is also a truffet?" As in Experiment 1,

children notified their choices by pointing, and adults wrote their answer in an answer sheet**.**

Results

4.5-year-olds' preference for relational match approached significance ($M_{relational}$ = .68, *SD* = .38), t (15) = 1.9, $p = 0.07$. Adults, just like in Experiment 1, significantly preferred relational match ($M_{relational}$ = .91, *SD* = .29), t(27) = 7.34, $p < 0.001$; similarly, 8.5-year olds also significantly preferred relational match ($M_{relational}$ = .84, *SD* = .33, t(15) = 4.1, $p < 0.05$. One-way ANOVA revealed no significant differences relational choices across age groups, F (2, 59) = 2. 39, *ns*.

We compared the proportions of relational choices in Experiment 1 and 2 for each age group. 4.5-year-olds in Experiment 2 chose relational matches significantly more than those in Experiment 1, F (1,33) = 15.33, $p < 0.001$. Similarly, significant increase of relational choices after hearing a novel label was also observed among 8.5-year-olds, F (1,31) = 14.33, $p < 0.005$. Moreover, adults in Experiment 2 also responded more relationally than those in Experiment 1, F (1, 55) = 6.74, $p < 0.05$.

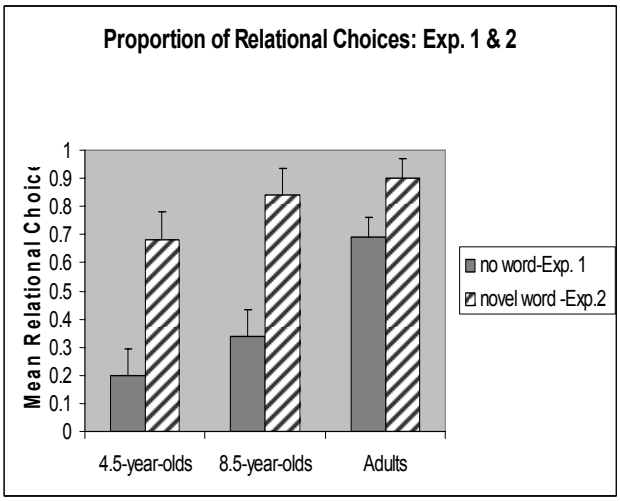

Figure 3. Results of Experiments 1 and 2.

Discussion

Results from Experiment 2 suggest that the presence of linguistic labels strongly supports children's perception of relational similarity. Upon hearing a novel label applied to the standards, 4.5-, and 8.5-year-olds were more likely to choose the relational match, as compared to when they were given the same task without a label in Experiment 1. Quite surprisingly, even adults' preference for relational similarity was aided by the presence of a novel label.

General Discussion

The studies presented here were designed to explore the development of relational commonalities. In particular we asked whether young children would respond to relational similarity in a highly simplified choice task, using the identity relation depicted by simple objects. Even under these circumstances, 4.5-year-olds strongly preferred object matches over relational matches. However, performance shifts dramatically when the standard is given a novel label. These findings both underline the difficulty of focusing on relational similarity when competing object matches are present and suggest that learning language may exert a powerful effect on relational thinking.

It is rather surprising that even with simple objects and basic identity relations, 4.5-year-olds still found object similarity to be extremely compelling, and virtually ignored the relational matches. Even 8.5 year-olds responded relationally only about a third of the time. Would children show more relational responding if they were given richer objects? This is probably unlikely considering Rattermann & Gentner's (1998a) results: children in the rich object condition gave significantly fewer correct relational responses than those who were in the simple object condition.

Our finding that relational responding is low even with basic identity relations and simple objects highlights the elusiveness of relational concepts. This echoes the findings that perception of relational similarity is slow to develop. We are not suggesting that children lack the cognitive capacity to perceive relational similarities. However, the current result poses a question as to how children eventually arrive at spontaneous perception of relational commonality.

The role of language

How do children acquire the ability to focus on relational commonalities? Although there may be a number of factors that aid the mind in arriving at relational perception, we suggest that language may be one powerful tool by which humans gain relational insight. Our results from Experiment 2 show that hearing novel labels benefits 4.5- and 8.5-year-olds' relational responding. An analogous increase was even observed in adults when the standard is labeled.

These findings are consistent with prior findings that novel word learning facilitates acquisition of deep conceptual categories (Gelman & Markman, 1986; Golinkoff et al., 1992; Markman, 1989; Waxman & Gelman, 1986; Waxman & Kosowski, 1990). Evidence that common labels can highlight relational commonalities comes from studies by Namy and Gentner (2002), who found that the use of labels is important in encouraging children to compare and attend to relational categories. They presented children with two perceptually similar exemplars (e.g. a bicycle and a tricycle) that were either given a unifying label or contrasting labels. Children then had to choose between a relational category match (a skateboard) and a perceptual match (a pair of glasses). Children in the unifying word condition chose

the relational category match more often than when the those in the contrasting label condition.

What is the mechanism whereby labels can change relational thinking? As discussed above, we suggest that one path lies through comparison; that is common labels invite comparison (Gentner & Namy, 1999) and comparison tends to highlight relational commonalities (Gentner & Markman, 1997). On this account, in our study, when children heard the question "which one of these two is a *truffet*?" they were likely to compare the standard *truffet* with each of the alternatives, thus highlighting common relations (identity) shared between the standard and the relational choice.

A second possible way in which the labels may have improved children's performance is that they may have helped in binding the two components (shapes) of the standard into a unified whole. That is, it is possible that without the label, children simply compared one part of the standard with various parts of the alternatives. When the label was applied, children may have been more likely to consider the two parts of the standard as belonging to coherent whole. (However, the fact that adults also showed more relational responding when novel labels were used perhaps argues against this explanation, as it seems unlikely that adults would fail to understand that the standard was meant to be considered as a whole.)

One remarkable feature of these results is that the effects of language were immediate in children: we found no difference between performance on the first three trials and performance on the last three trials. This is all the more striking given that participants never received training on the novel word; after hearing it applied to the standard for the first time, they were immediately asked to extend the novel word.

Further Questions

To return to the theme of comparative cognition, we can compare these results with the findings from animal studies. Our findings suggest that the perception of relational similarity is difficult for human children, as for nonhuman animals. However, we note that the children in our study faced a harder task than that given to chimpanzees and other nonhuman animals. In the animal studies, the question is whether relational similarity can be perceived against an unrelated alternative; whereas our subjects had to choose relational similarity from a strongly competing alternative (the object match).

Thus, another important cross-species comparison would involve presenting human children with triads in which there is no competing object match. We are currently carrying out such studies. Our preliminary results suggest that even without a competing object match, 4- and 5-year-olds still do not perform above chance levels in choosing the relational match (Christie & Gentner, in preparation).

Another difference between our studies and the typical animal study is that our children did not receive any prior training on the relation of identity. In future studies, we will investigate this factor as well.

Summary

Our results suggest that even with a highly simplified task, the perception of relational similarity is not immediate in children. However, our results also suggest that language may provide an important route by which children can acquire relational insight. In this way, language appears to be an important contributor to human intelligence.

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