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Relational Language Facilitates Analogy in Children

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Abstract

One important function of language is to name relations. Preschool children performed a simple mapping task with and without hearing spatial prepositions calling attention to key relations. Children at 44 months were successful only if they were in the language condition. By 49 months, children were competent on the task regardless of condition, although there were still benefits of language. These results suggests that relational language can therefore be an important tool for highlighting relational commonalities children may otherwise fail to use.

Introduction

Understanding relational similarities across examples is one of the achievements of development. Adults can see the similarity between letters of the alphabet and legos, or between the atom and the solar system. The former can both be considered kinds of building blocks, and the latter as central force systems. Children have more trouble understanding similarities on the basis of common relations. For instance, young children are likely to interpret the metaphor "a cloud is like a sponge" as meaning they are both soft and fluffy. Older children and adults, however, are more likely to comment on the relational commonality that both can hold and release water (Gentner, 1988). Developmental progressions in understanding metaphors and analogies that require relational understanding have been widely demonstrated (e.g., Brown, 1989; Chen & Daehler, 1989; Gentner & Toupin, 1986).

There is considerable evidence that knowledge of relational similarities develops in part as a result of domain-specific experience (e.g., Brown, 1989; Carey, 1985; Chen & Daehler, 1989; Chi, Feltovitch & Glaser, 1981; Gentner, 1988; Gentner & Rattermann, 1991; Goswami, 1991; Vosniadou, 1989). For example, learning causal laws of reasoning (Brown, 1989) or social-moral principles (Gentner & Toupin, 1986). Recently, Gentner & Rattermann (1991) have suggested that learning relational language may be a prominent factor in this development (Gentner, 1988; Gentner & Rattermann, 1991; Gentner, Rattermann, Markman & Kotovsky, 1995; Kotovsky & Gentner, 1996). Language has been argued to facilitate relational responding in a variety of tasks in the history of psychology, including transposition tasks (e.g., Kuenne, 1946) and reversal shift tasks (e.g., Kendler & Kendler, 1968). More recent evidence suggests that language learning - in particular learning relational terms - may play a role in similarity and analogy (e.g., Gentner & Rattermann, 1991).

For example, Kotovsky & Gentner (1996) gave four-year-olds a similarity matching task using simple patterns, e.g., small and large circles in a symmetric pattern (i.e., oOo). They had to choose which of two other triads this pattern was more similar to. Both of these had the same objects, but only one of them matched the original in terms of the relations among the objects; the other didn't. When the matches were across dimensions (e.g., small-large-small to light-dark-light), four-year-old children were at chance. However, when children this age were given labels for higher order relations among the three objects (e.g., "even" for symmetry, or "more and more" for monotonic increase) they were better able to make cross-dimensional matches on the basis of common relations.

An important domain that requires an understanding of relational similarities is spatial mapping. The key to understanding maps and models is understanding that they preserve the spatial relations among representations of objects in the world. There is abundant evidence that young children find understanding maps and models to be challenging (e.g., DeLoache, 1987; Blades & Spencer, 1994; Liben & Downs, 1989; Uttal, 1996; Uttal & Wellman, 1989). Young children can make mappings on the basis of object matches; for instance, at 38 months they can match a chair in a model room to a chair in a normal-size room. But if there are two like chairs in a model room, then they won't know which of the two chairs in the real room is the best match. Knowing which chair to choose hinges on understanding the relation between the chair and the other items in the room. It isn't until at least the end of the third year that children choose correctly on this task (Blades & Cook, 1994; Loewenstein, 1997).

Rattermann & Gentner (in preparation; Gentner & Rattermann, 1991) explored the role of relational language in a spatial task. They used two triads of like objects that varied in size, the first set containing objects of sizes 1, 2, and 3, and the second set containing objects of sizes 2, 3, and 4. The children had to do a search task, in which the experi-

menter hid a sticker in one triad, and the child had to find a sticker in the same place in the other triad. The finding rule was always relational: the sticker was under the object of the same relative size and position as in the experimenter's set. In Rattermann & Gentner's task, two of the three objects were identical in the two sets, but importantly they were playing different relational roles in each set. In the first set, size 2 is the middle sized one, while in the second set, size 3 is the middle sized one. Thus, in order to search under the object of the same relative size and position, children had to overcome the lure of an exact object match. Rattermann & Gentner found a strong improvement in three-year-olds' ability to find the sticker with the introduction of language labels naming the relational roles of the objects (e.g., *big*, *little*, *tiny*, or *Daddy*, *Mommy*, *Baby*).

The aim of the current study is to ask whether children's ability to carry out spatial analogies is enhanced by the use of spatial relational terms. We focused on a set of spatial terms that children learn early - the spatial prepositions *in*, *on*, and *under*. Children comprehend these prepositions and have some facility at using them by the time they are three years old (Johnston, 1988). The logic of this study is first to demonstrate that a spatial task based on disambiguating spatial relations will be difficult for preschool children, and second to investigate whether introducing relational language in the form of spatial prepositions can facilitate performance.

For the present study, we devised a spatial mapping task. As in other search tasks, children were shown the location of a hidden object in one situation, and had to find the hidden object in a corresponding location in a second nearly identical situation (see Figure 1).

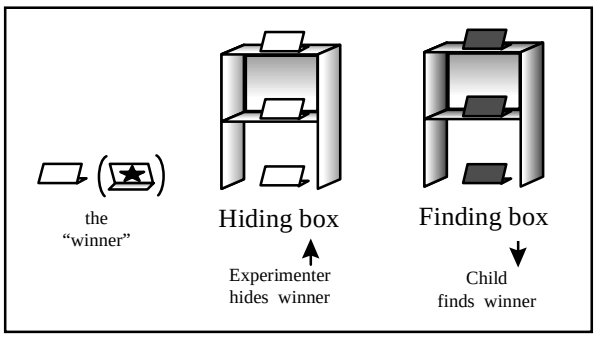

Figure 1: The experimental set-up

In some respects the task is a relatively easy version of the search task used in model room studies. The Hiding and Finding models are nearly identical and they are placed close together so that they can be simultaneously viewed. However, in other fundamental respects, the task is predicted to be far more difficult than the standard search tasks. Our task uses only one reference object - the box. All objects are placed with respect to it. Thus to solve the task the child must attend to the specific spatial relation between the hiding place and the box. Simple object correspondences are not enough.

The child watched as the experimenter took a card marked with a star, called the "winner," and placed it at the Hiding box along with two unmarked cards at the other locations. The child was then asked to find the winner at the Finding box "in the same place." The only difference between our baseline and language conditions was that the language group heard the experimenter use the spatial prepositions to describe the location of the winner when hiding the toy. The question is whether even this subtle a manipulation will be sufficient to enable preschool children to use the spatial relation as the basis for their mapping from one space to another.

Method

Participants

Participants were 40 children from the northern Chicago area. The younger children ranged in age from 42-46 months, and for both conditions the mean age was 44 months. The older children ranged in age from 47-52 months, and for both conditions the mean age was 49 months. Half of the participants in each age and condition were male and half were female.

Design

There were two age groups (44 months or 49 months). Half the children at each age were randomly assigned to the language condition, and half to the baseline condition. The dependent measures were the number of correct responses on the six search trials, and the six retrieval trials (two for each location, on, in and under). Thus the experiment was a 2 X 2 (Age X Condition) repeated measures design.

Materials

Our reference objects were much like Wilcox & Palermo's (1980) neutral object, used because it seemed to have roughly equivalent saliencies for the three possible placement locations. The boxes were roughly a foot and a half high and a foot wide. One was painted white, the other blue, and they were placed about three feet apart. Each box had four accompanying cards made from picture frames with colored paper inserts. One of the four cards for each box had a star on the back, making it the "winner." At all times there was a card placed on, in and under each box, only one of which was the winner.

Procedure

Orientation to the task Each child was first shown the hiding box and the four accompanying cards, front and back, so the child would understand that only one was the winner. Three of the cards were placed on, in and under the box, respectively. The fourth (the winner) was placed in front of the box. The child was shown each card in turn. The experimenter said for each card: "Let's look at this one. Does it have anything on the back?" This was repeated with the finding box and its cards.

The experimenter then explained the finding game. The child was told that the winners were always put in the same

place in the two boxes. The experimenter then placed the winner to the right of the hiding box saying: "I'm putting this winner right here." The experimenter put the winner for the finding box in the corresponding place, saying: "And this winner goes right here, in the very same place." The child was asked to find the winner for the finding box, and then the hiding box. This was done to show the children what was meant by the locution "the same place" and give them an easy warm up trial to get them involved in the game.

Search trials As the child watched, the experimenter placed the winner on/in/under the hiding box, saying: "I'm putting the winner right here." While the child closed his eyes, the experimenter hid the other winner at the finding box. The child was then asked to open his eyes, and come find the winner "in the very same place" at the finding box. Children were scored correct on a trial only if they looked in the correct location first, although they were allowed to look for the winner until they found it. Individual children were considered to have performed above criterion if they exceeded what was expected from the binomial as chance performance - at least five of the six trials correct. Two random orderings of placements were used. Half way through the search trials, there was one catch trial designed to be easy and keep the children motivated. More importantly, this served as a check in children's understanding of the basic search task. The winners were placed to the right of the boxes, just as in the orientation phase. The *in*/*on*/*under* search trials tested the children's ability to map correspondences between the cards in the two locations on the basis of their relations to the boxes.

Retrieval trials After children searched and found the winner, they retrieved the winner from the hiding box as a check on their memory for the location of the winner they saw being hidden. The retrieval trials weren't a pure check of memory, because the children were allowed to look until they found the toy in the search trials. Still, they were at least a partial measure of the encoding children had for the original placement of the winner.

Language condition The procedure for the language condition differed minimally, but importantly, from the baseline condition. When manipulating the cards at the hiding box during the orientation phase and search trials, the experimenter used spatial prepositions for the locations of the card being manipulated. During the orientation, the instruction was: "Let's look at the card on [in/under/in front of] the box. Does it have anything on the back?" During the search trials, the instruction was: "I'm putting the winner on [in/under/next to] the box." The introduction of spatial prepositions was done to emphasize the relations crucial for success on the task.

Results

Baseline condition

The children in the baseline condition found this task quite difficult (see Table 1). Our predictions regarding the difficulty of a mapping task requiring the use of spatial relations were confirmed. The 44-month-old children didn't perform significantly better than a chance level of 33% correct (actual performance of 42% correct) on the search trials for *on*, *in* and *under*. Looking individually at the children, only one of the ten children met the criterion for above chance performance, five out of six trials correct. These children did, however, perform well (70%) on the catch trial, indicating that they understood the basic search task. This suggests that their difficulties lay specifically with disambiguating the spatial relations with respect to the box. Turning to the retrieval trials, these children showed better than chance performance (62% correct) although this is far from perfect performance. We can infer from this above-chance retrieval that the poor performance on the finding task wasn't simply a matter of forgetting where they had seen the winner placed. Consistent with this claim, all the children correctly retrieved the winner on the catch trial.

Although the evidence suggests that children had some relational encoding specificity for the box-hiding place relations, their encoding appears insufficiently firm to support their mapping behavior. They seem to presume only roughly the distinction between *at* the box, and *not at* the box. This would be consistent with an object-based mapping process.

Table 1: Baseline condition mean percent correct

	Results for *on*, *in*, *under*		Results for the catch trial (*next to*)	
	Search trials	Retrieval trials	Search trials	Retrieval trials
44 mo.	42%	62%	70%	100%
49 mo.	63%	85%	80%	100%

The 49-month-old children performed above chance on the search trials (63% correct), although they weren't entirely successful. Only three of the ten children met criterion. The 49-month-olds also performed well on the catch trial (80%), confirming they understood the basic task. These children performed very well on the retrieval trials (85% correct; seven out of the ten children met criterion) Performance on the catch trial retrieval was perfect. These children were more finely encoding the relations involved in the task than the younger children in the baseline condition.

The results from the baseline condition provide a measure of the difficulty of the task for preschool children. The young children don't spontaneously use their full knowledge of spatial relations in this task, and even the older children had some difficulties at this. Overall performance on the retrieval trials is better than performance on the search trials, as might be expected due to the fact that the retrievals are trials on which children actually saw the toys being hidden.

Language condition

The children in the language condition performed well on this task, particularly compared with the baseline condition (see Figure 2). Using spatial prepositions highlighted the relations in the task, enabling the children to keep them distinct from one another.

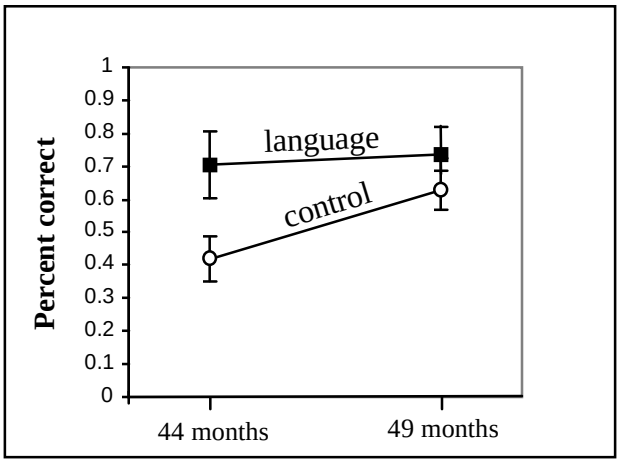

Figure 2: Search trials results

The children in the language condition performed nearly equivalently regardless of age. At 44-months, the spatial prepositions group was dramatically better than the baeline group (70% correct versus 42% chance performance). Six children in the language condition met criterion, while only one child in the baseline condition at this age did so. The language advantage for the older children was less pronounced - 73% correct versus 63%, a non-significant difference. However, some gain was apparent in the subject analysis: 7 out of 10 children in the language condition met criterion, while only 3 out of 10 children did so in the baseline condition. At both ages, children did well on the catch trial (85% correct). They also did well on retrieval, performing nearly at ceiling (92%; eighteen of the twenty children met criterion, and all were perfect on the catch trial retrieval). Thus we infer that the language condition children's initial encoding was more articulated in terms of spatial relations within the box than the encoding of the baseline group.

Condition and age comparisons

The data for search trials were analyzed in a 2 X 2 (Age X Condition) repeated measures ANOVA. In support of the above analyses, there was a significant effect of language, with children in the language condition (72% correct) doing better than children in the control condition (53%), $F(1,36) = 5.530$, $p < .05$. The key contrast was between the baseline and language condition 44-month-old children, and the difference between these two groups was significant, $t(18) = 2.279$, $p < .05$. There was no significant effect of age, but there was a tendency for the older children (68%) to do better than the younger children (56%), $F(1,36) = 2.352$, $p > .05$. There was no effect of type of hiding place. All the children did about as well at finding the toy in, on and under the box.

The data for retrieval trials were also analyzed in a 2 X 2 (Age X Condition) repeated measures ANOVA. There was a significant effect of language, with children in the language condition (92% correct) doing better than children in the control condition (73%), $F(1,36) = 10.371$, $p < .05$. There was a significant effect of age, as the older children (88%) did somewhat better than the younger children (77%), %), $F(1,36) = 4.200$, $p < .05$. Finally, there was an age by condition interaction, suggesting that it was only the younger control condition children who showed a deficit (63% correct, as opposed to a combined average for the other three groups of 90%), $F(1,36) = 4.200$, $p < .05$. There was no significant effect of type of hiding place for the retrieval trials. Overall, children did about as well at remembering where they had seen the winner placed when it was in, on and under the box. This result is modified by a marginal place by age interaction, and a significant place by age by condition interaction, although there were so few errors made by children in the language condition and the older children in the baseline condition that these results are suspect.

Discussion

These results bear out the hypothesis that performance in a relational mapping task is facilitated by language labels that highlight the common relations. Hearing spatial prepositions enabled preschool children to perform successfully on a spatial mapping task at which their age mates were unsuccessful. By using a task that only had one object placed in relation to one reference object, we were able to isolate the key problem area of mapping on the basis of correspondences between relations. The 44-month-old children in the baseline condition seemed to encode only AT(card, box) and NOT-AT(card, box), which was insufficient for searching correctly on all but the catch trial. Hearing the spatial prepositions, however, helped the children in the language condition make a more articulated encoding of the toy's location. They seemed to have the fuller representation of the correspondences, encoding something much closer to ON(card, box), IN(card, box), and UNDER(card, box). This representation was sufficient to succeed on the task. The effects of language weren't limited to finding the hidden toy correctly; they also affected the children's retrieval of the original toy they actually saw being hidden. That is, the young children in the language condition were considerably better at retrieving the original toy than those in the baseline condition. Relational language, therefore, may be a powerful support for children noticing, using, and maintaining memories of relational similarities.

There are two possible developmental limits on the benefits of explicit relational language. First, if children haven't mastered the meanings of the relational terms, then the terms may not pick out the relevant relations. In this case no benefit will be seen. In pilot studies, children just turning three years old were unsuccessful on this mapping task even in the language condition. At the other end of the continuum, when children achieve a level at which the relations are very well understood and entrenched, then explicitly marking

them will be of no benefit. We suspect that five-year-old children would do well on this mapping task regardless of condition. Thus there may be a transitional period in a child's domain learning at which relational language will be most important in supporting fledgling relational understanding.

Extrapolating from these results, we speculate that learning relational language may foster the development of relational thought (Gentner, 1998). If this is true then we should find that different languages - often with very different semantic systems of relational terms - might facilitate different cognitive insights. Cross-linguistic investigations (e.g., Levinson, 1996) will be important in revealing linguistic differences in spatial semantics that could engender differences in which relations young children attend to (Bowerman & Choi, to appear).

In our study, children's ability to make similarity comparisons on the basis of relational commonalities was facilitated by the presence of relational language. Learning relational language may facilitate the development of relational thought.

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