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Relational Language Helps Children Reason Analogically

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Abstract

This paper explores the role of relational language in the development of children's analogical reasoning ability. In two experiments, children were asked to make a relational mapping between two pictures while ignoring a competing object match. Three-and-a-half-year-olds, 5½-year-olds, and 7-year-olds were all more successful at this task when they heard relational language. Experiment 2 further demonstrated that children were as good at finding the relational match with an object match present if they heard relational language as they were when there was no compelling object match present at all. These results suggest that relational language may be important in instilling the ability to reason analogically.

Keywords: Analogy; analogical development; relational language; language and thought

Introduction

Humans are prolific learners, in part because of our ability to learn through analogy. Analogy involves aligning the shared relational structure between a base and target representation (Gentner, 1983). From this mapping, reasoners can draw inferences about a target that are suggested by the base. Analogies also promote the abstraction of relational schemas that can then be applied to new situations or domains, and making an analogy often leads to re-representation of either or both aligned structures (Gentner & Calhoun, in press; Gick & Holyoak, 1983; Loewenstein, Thompson, & Gentner, 1999).

Despite analogy's potential to facilitate learning, investigation into children's analogical abilities has received relatively little attention compared to adults'. This is perhaps due to a long-standing assumption that children could not reason analogically until about 13- or 14-years-old (Piaget, Montangero, & Billeter, 1977, as cited in Richland, Morrison, & Holyoak, 2006), an assumption based on the fact that younger children were unable to solve analogies of the form A:B::C:?. However, researchers have since found that young children are capable of reasoning about and learning from analogy. For example, Gentner (1977) showed that preschoolers could carry out spatial analogies from the human body to a mountain or a tree, even when when the matches were made difficult with surface distractors. Chen & Daehler (1989) found that 6-year-olds were able to transfer relational structure from a story to a real-world situation. Prior to completing a problem-solving task, children heard two stories. Some children heard neutral stories, and others heard stories illustrating abstract schemas for solving the task. Children who heard the abstract schemas were more likely to solve the task using the problem-solving technique exemplified by the stories than children who heard neutral stories.

Although young children are more capable at using analogy than originally thought, their abilities do not match those of adults. One of the most striking differences between adults' and children's performance on analogical tasks is children's focus on objects and object properties over relations (Blades & Cooke, 1994; Gentner & Toupin, 1986; Gentner & Rattermann, 1991). The transition from reliance on objects to relations has been termed the *relational shift* (Gentner, 1988). Although this shift is well-documented, researchers disagree on what drives the change. The various explanations are closely tied to general theories of analogical development, specifically *domain knowledge* accounts and *maturational constraints* accounts.

Domain knowledge theories of analogical development suggest that children's ability to reason analogically grows as they accrue knowledge about a particular domain and its relations (Gentner, 1988; Gentner & Rattermann, 1998; Goswami, 1992; Goswami & Brown, 1989). Thus, children may successfully reason analogically in a familiar domain (e.g. family relationships), but fail in an unfamiliar domain (e.g. scientific concepts). With limited knowledge of the relations, children depend instead on the information they do have about the objects and their properties. In contrast, *maturational constraints* theories view analogical development as driven primarily by increases in children's basic cognitive capacity, especially in components of executive function like working memory (Halford, 1993) and inhibitory control (Richland, Morrison, & Holyoak, 2006). In these accounts, children are unable to represent complex relations due to working memory limitations and

they lack the inhibitory control to carry out relational matches when compelling object distractors are present.

Of course, it may be the case that maturational gains and knowledge gains interact in the development of analogical reasoning, but it is important to determine the relative contribution of each. Using a paradigm adapted from Markman and Gentner's (1993) "one-shot mapping task", Richland, Morrison, and Holyoak (2006) investigated the roles of working memory and inhibitory control when knowledge of the relations was held constant. They showed children pairs of pictures depicting familiar relations (e.g. *chasing*) and asked children to find a corresponding object in the second picture that went with an object in the first picture. If children are reasoning analogically, they should select the second object based on its role in the relational structure. Richland et al. varied the complexity of the relations and the presence of a distracting object match[1] and found that 3- to 4-year-olds and 6- to 7-year-olds had difficulty with the task both when the relational structure was more complex and when a distracting object match was present. For the 3- to 4-year-olds, the effect of the distracting object was such that performance was extremely poor with a distractor present, regardless of the complexity of the relation. Richland et al. (2006) argued from these results that knowledge accretion alone is not enough to account for the development of analogical ability. Rather, they suggest that children must also have sufficient inhibitory control to successfully reason analogically.

In this paper, we focus on an additional factor that may be important in children's ability to reason about relations: relational language. In fact, we suggest that relational language can help children overcome the challenge of competing object matches to succeed on analogical tasks.

Relational language is a representational tool that can help children focus on common relations and align two structures (Gentner & Rattermann, 1991). Loewenstein and Gentner (2005) found, for example, that aligning two three-tiered boxes in order to find a hidden object was difficult for young children. The task was even more challenging when distinct objects were placed at each location in the two boxes in such a way that corresponding objects were not in corresponding locations (the objects were *cross-mapped*). However, when the locations of the boxes were described with spatial language (e.g. *on*, *in*, *under* or *top*, *middle*, *bottom*), children were able to successfully align the two boxes and find the hidden toy.

As in Markman and Gentner's and Richland et al.'s studies, the present studies asked children to view pairs of scenes with familiar relations and to select an object from a target picture that corresponded with a particular object from the base picture. However, in our task the key variable was whether children heard relational language to describe the pictures. Given previous research suggesting that relational language enhances children's analogical abilities, we expected that children who heard relational language would outperform children who heard neutral language.

[1] In Richland et al.'s studies, the distracting object was present in the second picture but was not part of the main relational structure, in contrast to Markman and Gentner's method.

Experiment 1

Method

Participants Seventy 5½- and 7-year-olds participated in this experiment. Six children were excluded, either due to parental interference (N = 1) or answering incorrectly on at least one filler trial (N = 5), leaving 32 5½-year-olds (ages 61-71 months, M = 65.4 months old) and 32 7-year-olds (ages 78-89 months, M = 83.3 months) in the final analyses. Half of the children in each age group participated in the Relational language condition, and half in the Neutral Language condition. All participants were native English speakers.

Materials and design Children viewed pairs of scenes depicting familiar relations (e.g. *chasing*) and were asked to select an object from the target picture that corresponded with the actor (the "doer" of the action) in the base picture. Importantly, on experimental trials, the picture pairs were *cross-mapped* (Gentner & Toupin, 1986): that is, the actor in the base picture also appeared in the target picture but played a different role in the relation (see Figure 1). Thus, children could select an object in the target picture by matching objects (e.g. *cat*) or by matching relational roles (e.g. *chaser*).

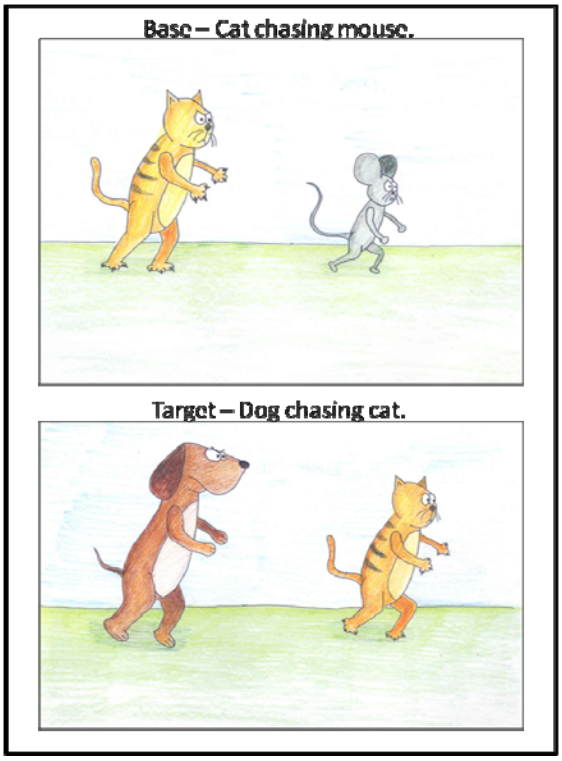

Figure 1: Sample stimuli pictures from Experiment 1.

Children saw a total of 15 picture pairs. Three literally similar pairs served as practice trials and depicted scenes in which the objects and the roles they filled were highly similar (e.g. a giraffe eating from a tree in the base and a slightly taller giraffe eating from a different tree in the target). Two literally similar trial pairs were also interspersed among the ten experimental trials to serve as fillers. The practice trials were designed to introduce children to the task. We used literally similar practice pairs in order to avoid biasing children towards either relational or object matches. The literally similar filler trials were designed to check whether children remained engaged throughout the testing session. Children who failed to answer both filler trials correctly were excluded from further analyses.

Children in each age group were assigned to either the Relational Language condition or the Neutral Language condition, resulting in a 2 x 2 between-subjects design.

Procedure On all trials, the experimenter began by placing a pair of pictures in front of the child, with the base picture above the target picture. Then, the experimenter pointed to the base picture and asked the child, "What's in this picture?" Regardless of the child's answer, the experimenter agreed and described the picture, mentioning both the relation and the objects (e.g. "That's right, the cat is chasing the mouse."). Following the description, the experimenter pointed to an object in the base picture and asked the child to find the one that "went with" that object in the target picture. On experimental trials, children in the Relational Language condition heard, "Do you see this one *that's chasing*? What does this one go with in this [pointing to target] picture?" Children in the Neutral Language condition heard, "Do you see this one? What does this one go with in this [pointing to target] picture?" In both conditions, children heard neutral phrasing for all practice and filler trials.

If children had trouble during the practice trials, the experimenter showed them the correct answer and explained. Once the child understood the format of the task after the three practice trials and was able to respond correctly on his or her own on the last two practice trials, the experimenter moved on to the experimental trials.[2] No feedback was given on the experimental and filler trials.

Results and Discussion

Each child's proportion of relational responses was entered into a 2(Age) x 2(Language Type) univariate ANOVA (Figure 2). Seven-year-olds made more relational choices than 5½-year-olds, although this effect was only marginally significant, $F(1,60) = 3.12$, $p = .08$. However, a main effect of Language Type was significant, $F(1,60) = 6.52$, $p < .05$. Children who heard relational language chose the relational match more often than children who heard neutral language.

[2] These practice procedures differ from those used by Richland et al.'s (2006), which more closely resemble those used in Experiment 2.

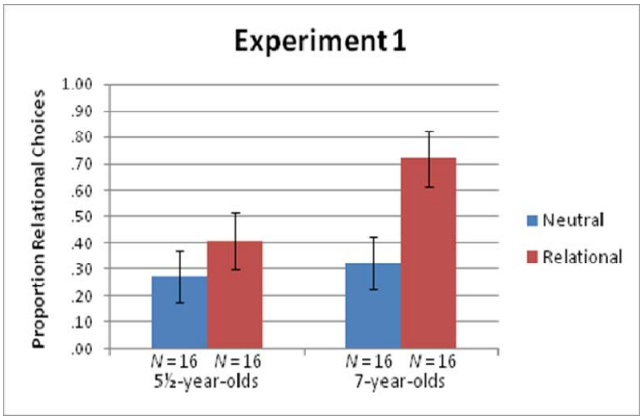

Figure 2: Mean proportion of relational choices in Experiment 1.

Although the Age x Language interaction was not significant, when the two age groups were analyzed separately, the relational language advantage was found only for the 7-year-olds, $F(1,60) = 7.33$, $p < .01$.

As predicted, hearing relational language helped children make an appropriate relational match, despite a compelling object match. However, compared to the performance of the 7-year-olds in Richland et al.'s (2006) studies (Richland et al. did not test 5½-year-olds), the performance of the 7-year-olds who heard neutral language in this experiment was fairly low (32% versus 64% relational). To better understand the factors contributing to this difference, in Experiment 2 we used instructions and practice procedures similar to those used by Richland et al., and in anticipation of improved performance, replaced the 7-year-olds with a younger group of 3½-year-olds. The key differences between the studies were that Richland et al. (1) used fuller instructions; (2) gave analogical practice pairs, with feedback supporting the relational match (in contrast to our less informative literal similarity matches); and (3) used object distractors that did not participate in the target relation, but were instead extraneous to the main action (in contrast to the design of Experiment 1, in which the object distractors were always participants in the target relation but were cross-mapped so that they filled another role). In Experiment 2, in addition to adopting Richland et al.'s instructions and practice procedures, we added a within-subjects factor of distractor type to investigate any differences that may exist between external and cross-mapped distractors. A model of children's analogical ability that proposes competition between relational and object matches predicts a difference in performance for cross-mapped and external distracters, since the relation should exert differential sway when the object participates in the relation versus when it is outside the relational structure.

Experiment 2

Methods

Participants Twenty-four 3½-year-olds (ages 40-47, *M* = 43.89 months) and 21 5½-year-olds (ages 62-66, *M* = 64.18) participated in this study. Two additional 3½-year-olds refused to participate. All but four children participated in the lab at Northwestern University. The other four children (all 5½-year-olds) were tested individually at a local preschool. Children received a book or T-shirt for their participation.

Materials and Design Like Experiment 1, Experiment 2 employed Age and Language Type as between-subjects factors. Additionally, a within-subjects factor of Distractor Type was added to the design, resulting in a 2 x 2 x 3 mixed design. In Experiment 1, the object match, or distractor, was always cross-mapped from the base to the target picture. Experiment 2 also used cross-mapped distractors, in addition to external distractors and no distractor (Figure 3). On cross-mapped trials, the object distractor participated in the same relation in the target picture as in the base picture (e.g. *towing*), but in a different role (e.g. *towee* versus *tower*) (Figure 3c). On external distractor trials, the distractor did not participate in the target relation, but was present in the target picture (Figure 3b). On no-distractor trials, no object distractor was present in the target picture (Figure 3a). Children saw a total of nine experimental picture pairs (three of each distractor type), each exemplifying a different relation (e.g. *towing*). The type of distractor seen with each relation was counterbalanced across participants.

In addition to the nine experimental trials, children also saw three practice trials, one of each distractor type, for a total of twelve picture pairs. No fillers were used in Experiment 2.

Procedure The general format of Experiment 2 roughly follows that of Experiment 1, but the wording of the instructions and questions were modified to resemble those used by Richland et al. (2006). The experimenter began by laying down the first pair of practice pictures, with the base above the target, and saying:

> "There is a certain pattern in the top picture, and the same pattern happens in the bottom picture, but it looks different. Let me show you what I mean on this page. See, up in the top picture, there is a boy holding a dog. This is the boy, and this is the dog. Now in the bottom picture, there is an elephant holding a cat. See, the same pattern happens in both, but it looks different. Now, in this game, first you have to figure out what the pattern is that happens in both pictures. Okay? Then I am going to point to one thing in the top picture, and your job is to tell me what is in the same part of the pattern in the bottom picture. So, on these pictures, if we have a boy holding a dog, if I point to the boy, which one is like this one in the bottom picture? Which one is in the same part of the pattern in the bottom picture?"

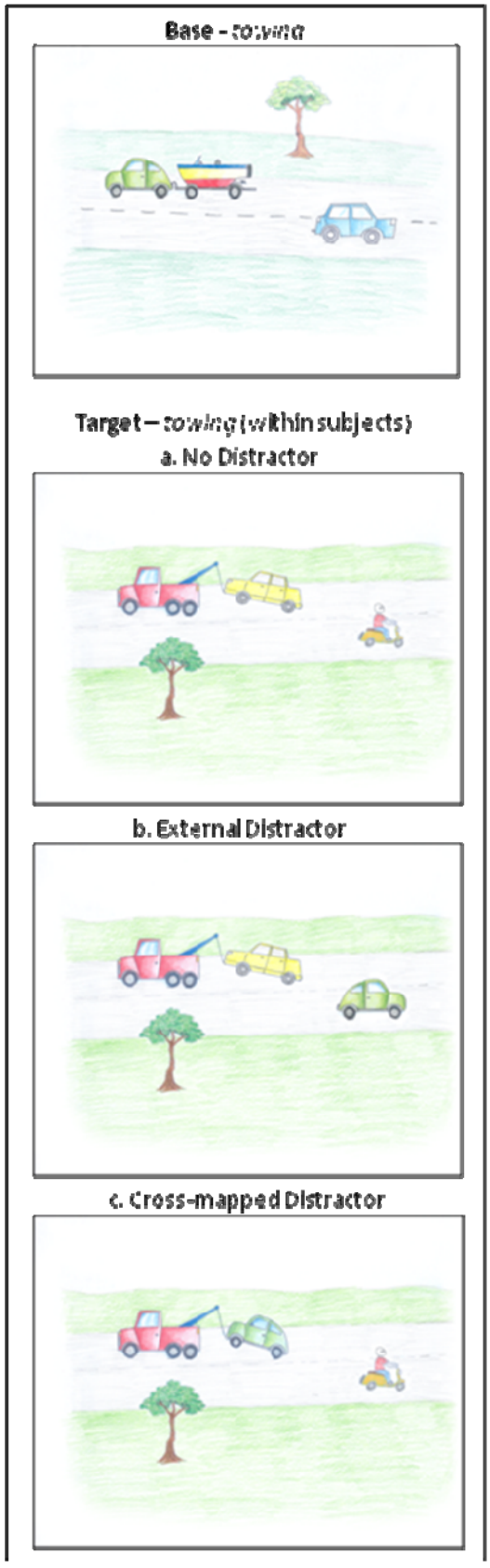

Figure 3: Sample stimuli pictures from Experiment 2.

On practice trials, children were given feedback about the correct (i.e. relational) answer, and incorrect practice trials were repeated. All children first saw the no distractor practice trial, followed by the external distractor practice trial, followed by the cross-mapped distractor practice trial.

Practice trials were followed by the nine experimental trials. On experimental trials, the experimenter did not ask for or give descriptions of the base and target pictures. Rather, the experimenter only asked what was "like this one" in the target picture. Children in the Relational Language condition heard a relational description of the actor in the base (e.g. "Do you see this one *that's towing*? What is like this one in the bottom picture?"). Children in the Neutral Language condition heard a neutral description of the actor (e.g. "Do you see this one? What is like this one in the bottom picture?"). Children were given no feedback on experimental trials.

Results and Discussion

As predicted, children who heard relational language chose the relational match more often than those who did not. This was confirmed by a 2(Age) x 2(Language Type) x 3(Distractor Type) repeated measures ANOVA over children's relational responses, where Age and Language Type were between-subjects factors (Figure 4). Main effects of Age, $F(1,43) = 11.79$, $p < .01$, and Language Type, $F(1,43) = 13.06$, $p < .01$, were significant. The 5½-year-olds chose the relational match significantly more often than the 3½-year-olds, and children who heard relational language chose the relational match significantly more often than those who did not. A main effect of Distractor Type was also significant, $F(2,86) = 3.92$, $p < .05$.

The main effects of Distractor Type and Language Type are best understood in light of their interaction, $F(2,86) = 5.22$, $p < .01$. Children who heard relational language chose the relational match as frequently on trials with a distractor (external or cross-mapped) as on those with no distractor. In contrast, children who heard neutral language chose the relational match significantly more frequently when there was no distractor than with either external or cross-mapped distractors (both Bonferronis, $p < .01$). Performance on the external and cross-mapped trials did not differ significantly. The three-way interaction with Age was not significant, suggesting that a similar pattern was found for both age groups.

In Experiment 2, as predicted, relational language helped children to select the appropriate relational match and ignore tempting object matches. In fact, children were just as accurate on distractor trials as on no-distractor trials when they heard relational language, suggesting that relational language helped children focus on the relational matches rather than on the competing object matches. It is also interesting that external distractors and cross-mapped distractors were equally disruptive to children's performance in the neutral language condition. The fact that children showed similar performance whether or not the object match participated in the relevant relation suggests

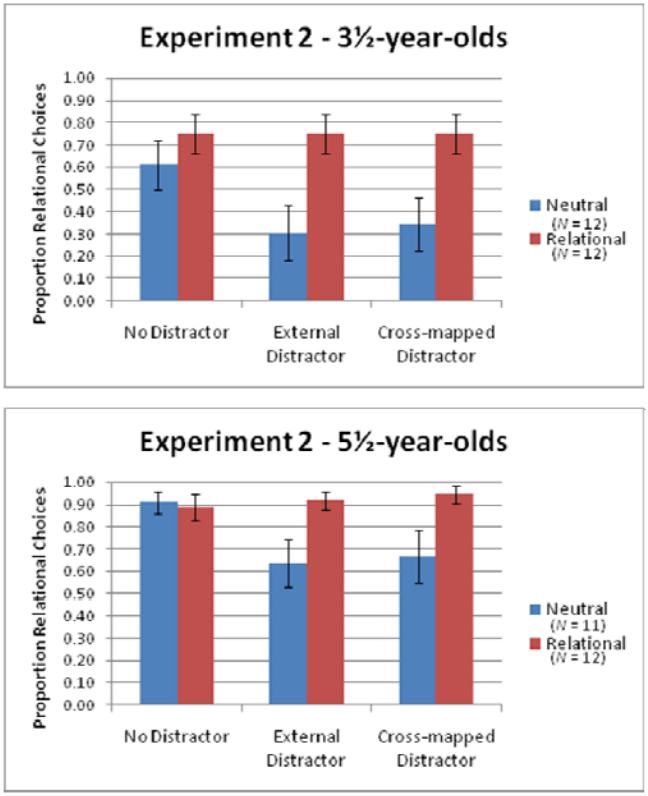

Figure 4: Mean proportion of relational choices in Experiment 2.

that children may not be attending to the relation at all when an object match is present. This is counter to a view of the relational shift in which there is competition between the relational match and the object match.

General Discussion

Together, these studies demonstrate that in addition to gains in domain knowledge and processing capacity, relational language should be considered a fundamental aspect of children's analogical development. When children were provided with relational descriptions, they were able to completely overcome their focus on objects to make a correct relational match.

Although it is clear that relational language is helpful to children when reasoning analogically, much more work is needed to determine precisely how language is helping. One way that relational language might aid the mapping process is by selecting among several possible conceptualizations; another is by highlighting the common relations, so that the child is better able to attend to the common structure (Gentner, 2003; Gentner & Clement, 1988). Thus, rather than representing an object as a *cat*, hearing a relational label *chaser* might suggest focusing on the chasing relation and on the role of the cat within that structure. Further studies may reveal how relational language interacts with relational reasoning.

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