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## The Effect of Language on Similarity: The Use of Relational Labels Improves Young Children's Performance in a Mapping Task

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### INTRODUCTION

The ability to use relational similarity is considered a hallmark of sophisticated thinking; it plays a role in theories of categorization, inference, transfer of learning and generalization (Gentner & Markman, 1997; Halford, 1993; Holyoak & Thagard, 1995; Novick, 1988; Ross, 1989). However, young children often fail to notice or use relational similarity (Gentner, 1988; Gentner & Rattermann, 1991; Goswami, 1993; Halford, 1993). For example, when given the metaphor "plant stems are like drinking straws" 5-year-old children focus on the common object similarities, commenting that "They are both long and thin," whereas 9-year-olds focus on the relational commonality that "They both carry water" (Gentner, 1988).

This relational shift in children's use of similarity—a shift from early attention to common object properties to later attention to common relational structure—has been noted across many different tasks and domains (Gentner & Rattermann, 1991; Halford, 1993). For instance, Gentner and Toupin (1986) presented children with a story mapping task in which object similarity and relational similarity were *cross-mapped*: that is, similar objects were placed in different relational roles in the two scenarios, so that the plot-preserving relational correspondences were incompatible with obvious object-based correspondences. Under these conflict conditions, 6-year-old children

were unable to preserve the plot structure in their mapping, although they could transfer the story plot accurately when given similar characters in similar roles. Older children (9-years-old) could maintain a focus on the relational structure and transfer the plot accurately despite competing object matches. There is evidence that this shift from objects to relations is based on gains in knowledge (Brown, 1989; Goswami, 1993; Kotovsky & Gentner, 1996; Rattermann & Gentner, in press), although maturational changes may also play a role (Halford, Wilson, Guo, Gayler, Wiles & Stewart, 1995).

Children's ability to carry out purely relational comparisons improves markedly across development. Yet even very young children can reason analogically under some circumstances (Crisafi & Brown, 1986; Kotovsky and Gentner, 1996). For example, Gentner (1977) demonstrated that preschool children can perform a spatial analogy between the familiar base domain of the human body and simple pictured objects, such as trees and mountains. When asked, "If the tree had a knee, where would it be?" even 4-year-olds (as well as 6- and 8-year-olds) were as accurate as adults in performing the mapping of the human body to a pictured object, even when the orientation of the tree was changed or when confusing surface attributes were added to the pictures.

What factors impede or promote the perception of common relational structure? According to structure-mapping theory (Gentner,

1983, 1989; Gentner & Markman, 1997), analogy is the mapping of know domain (the base) to another (the target) in which the system of relations among the base objects also holds among the target objects. When adults in psychology, the correspondences between target objects are based on commonality, the matching relational structure between corresponding objects in the base and target have to resemble each other. However, though the final interpretation of the analogy is determined by relational similarity rather than by object similarity, we have seen in the actual process of computing an analogy both object similarity and relational similarity are at work (Falkenhainer, Forthofer, 1990; Halford, Wilson, Wiles & Stewart, 1995; Holyoak & Thagard, 1989; Hummel & Holyoak, 1997; Brayshaw, 1988).

A natural consequence of this view is that knowledge of relational structure plays a crucial role in the mapping process. A child (or adult) has not represented the world within the domain then the mapping will be based upon common object similarity rather than common relational structure. As domain knowledge increases, the likelihood that the child's comparison is based on common relational structure increases.

In summary, the ability to use relational similarity is sensitive to change in the knowledge base. With increasing knowledge of the relationships in a domain, children become more able to understand and use common relational matches. This brings us to the question of interactions between language and relational structure.

### Language and Relational Structure

We propose that language plays a crucial role with the development of analogical reasoning by serving as an invitation to children to make comparisons. The results of the studies of Markman, Waxman, & Spelke have shown that when children are introduced to a new object term they assume that the word applies to things of like

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1983, 1989; Gentner & Markman, 1997) an analogy is the mapping of knowledge from one domain (the base) to another domain (the target) in which the system of relations that holds among the base objects also holds among the target objects. When adults interpret an analogy, the correspondences between base and target objects are based on common roles in the matching relational structures; the corresponding objects in the base and target do not have to resemble each other. However, although the final interpretation of an analogy is determined by relational similarity rather than by object similarity, we hypothesize that in the actual process of computing an analogy both object similarity and relational similarity are at work (Falkenhainer, Forbus, & Gentner, 1990; Halford, Wilson, Guo, Gayler, Wiles & Stewart, 1995; Holyoak & Thagard, 1989; Hummel & Holyoak, 1997; Keane & Brayshaw, 1988).

A natural consequence of the structure-mapping view is that knowledge of relations plays a crucial role in the mapping process; if the child (or adult) has not represented the relations that hold within the domain then the matches formed will be based upon common object similarity rather than common relational similarity. Thus as domain knowledge increases, so does the likelihood that the child's comparisons will be based on common relational structure.

In summary, the ability to use relational similarity is sensitive to changes in the child's knowledge base. With increasing knowledge of the relationships in a domain, children become more able to understand and produce purely relational matches. This brings us to the issue of interactions between language and thought.

*Language and Relational Similarity*

We propose that language may interact with the development of analogical ability by serving as an invitation to seek likeness—to make comparisons. The word-learning studies of Markman, Waxman, and others have shown that when children are taught a new object term they assume very that the word applies to things of like kind (Imai,

Gentner & Uchida, 1994; Markman, 1989; Waxman & Gelman, 1986). However, this work has focused on noun learning. We propose that the acquisition of relational language promotes the development of analogy by inviting children to notice and represent higher-order relational structure (Gentner & Medina, 1997). So far, the evidence on this issue is rather scant, although Kotovsky and Gentner (1996) found that 4-year-olds were better able to perceive cross-dimensional perceptual matches—e.g., symmetry of size compared to symmetry of shading—when they had previously been taught a relational label—"even"—to identify the relation of symmetry.

*The Present Studies*

In these experiments we tested whether children's relational performance can be improved by the introduction of relational labels. The basic task used in these experiments was a *cross-mapping* search task in which object similarity and relational similarity were in conflict so that a response based on one type of similarity precluded a response based on the other. We chose the higher-order relation of *monotonic change in size across position*. This relation has the advantage that it can be understood on the basis of perceptual information available to the child (in contrast to some causal or social higher-order relations that may require abstract knowledge). This cross-mapping task is used in Experiment 1, whose results of serve as a baseline level of performance. In Experiment 2, we gave children the relational labels "Daddy/Mommy/Baby" and found a predicted gain in performance. In Experiment 3 we tested other sets of relational labels, and further, tested for long-term effects of labeling.

EXPERIMENT 1

*Participants*

The participants were 24 3-year-olds, 24 4-year-olds, and 16 5-year-olds.

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**Procedure**

Children were asked to map monotonic change in size between a triad of objects belonging to the experimenter and a triad of objects belonging to the child. A cross-mapping was created by staggering the sizes of the objects, as illustrated in the following diagram in which the objects, represented by numbers, form monotonic change in size from left to right.

E	3	2	1
C	4	3	2

The experimenter and the child sat across from each other with the stimulus sets in two arrays separated by about 6 inches, forming an arc in front of the child. The child closed his eyes and the experimenter hid a sticker underneath one of his toys, as she explained, "I'm going to hide my sticker underneath one of my toys while you watch me. If you watch me carefully, and think about where I hid my sticker, you'll be able to find your sticker underneath one of your toys." She then placed her sticker under a toy in her set and said "If I put my sticker under this toy, where do you think yours is?". The child was then allowed to guess, but kept the sticker only if he found it on his first guess.

Using a relative size rule, if the experimenter chose object 2 in her set the correct choice is the child's object 3 (Notice that the child must resist an object match between the experimenter's object 2 and his object 2.). Thus, object similarity was put in conflict with relational similarity (in the form of monotonic increase) forming a task in which a response based on either similarity type is possible, but only a response based on relational similarity is correct. The children performed 14 cross-mapped trials.

**Materials**

We designed rich stimulus sets that contained interesting, rich objects that varied along all dimensions, including size, within the two sets (e.g., a red flower in a pot, a wooden house, a green mug, and a race car) and sparse stimulus sets that contained very simple, sparse objects that were identical in all respects but size within the two sets (e.g., clay flower pots). (See Figure 1.)

Based on structure-mapping theory, we predicted that the rich object matches would compete strongly with the relational mapping rule. In contrast, the sparse object matches would be relatively easy to overcome—children would be able to perform the relational mapping despite a common object identity choice. A related prediction was that the children would make significantly more object-identity responses when object richness was high than when object richness was low.

**Results and Discussion**

The children's correct relational responses revealed both the predicted effect of object richness and the relational shift in analogical performance. The richness effect led the children to produce significantly more relational responses with the sparse stimulus objects (54% for the 3-year-olds, 62% for the 4-year-olds, and 95% for the 5-year-olds) than with the rich stimulus objects (32% for the 3-year-olds, 38% for the 4-year-olds, and 68% for the 5-year-olds), suggesting that the presence of rich, distinctive object matches created a salient alternative to the relational response (at least for young children). In contrast, when sparse objects were used, the object similarity matches were less compelling and therefore less likely to act as a competitive alternative to the relational response. As further evidence for the effect of object richness, the number of object identity errors significantly increased with the use of the rich stimuli (33% for the rich versus 17% for the sparse, collapsed across all three age groups). The relational shift was found in the children's overall performance, with the 5-year-olds performing significantly better than 3- and

4-year olds, who achieved a performance only with the sparse

In Experiment 2 we tested relational labels that provide explicit relational structure. We carried out a relational comparison task. We introduced a group of 3-year-olds with the labels "Daddy/Mommy" and then presented them with a matching task of Experiment 1. We hypothesized that these labels would provide an explicit framework for the relational use of *monotonic change in size*. Children's ability to perform a relational response with both the rich and the sparse objects improved with the use of these labels to the maximal effect of labeling. We used different lengths to ensure that the children were familiar with the relational use of the labels. We trained participants with the "Daddy/Mommy" labels prior to presenting the cross-mapping task. We also recorded the proportion of these labels on each course of the experiment.

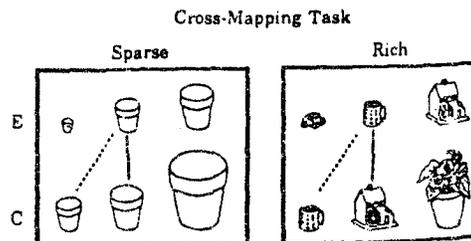
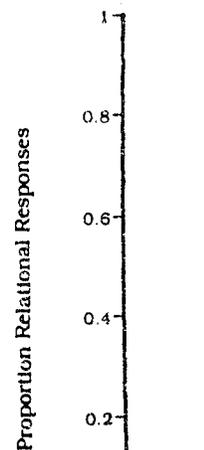


Figure 1.



structure-mapping theory, we predict that the rich object matches would be more likely to be chosen than the relational mapping. In Experiment 1, the sparse object matches were generally easy to overcome—children were able to perform the relational mapping more often than the common object identity choice. The main finding was that the children would choose the object-identity more often than the relational mapping when object richness was high than when object richness was low.

**Results and Discussion**

The children's correct relational responses were significantly higher than the predicted effect of object richness. The predicted effect of object richness was that the children would choose the relational mapping more often than the object identity when the stimulus was sparse (54% for the 4-year-olds, and 62% for the 3-year-olds, and 68% for the 5-year-olds) than with the rich stimulus (38% for the 3-year-olds, 38% for the 4-year-olds, and 68% for the 5-year-olds). The presence of rich, distinctive objects created a salient alternative to the relational mapping (at least for young children). When sparse objects were used, the similarity matches were less likely to act as a distractor relative to the relational mapping. The evidence for the effect of object richness on the number of object identity choices increased with the use of the relational mapping (38% for the rich versus 17% for the sparse). A significant shift was found in the children's performance, with the 5-year-olds performing significantly better than 3- and 4-year-olds on the relational mapping task.

**Relational Mapping Task**

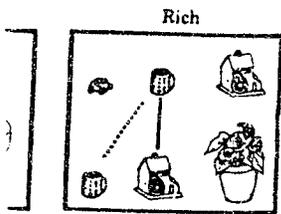


Figure 1.

4-year olds, who achieved above chance performance only with the sparse stimuli.

In Experiment 2 we tested whether a set of relational labels that provide children with an explicit relational structure could help them carry out a relational comparison and mapping. We introduced a group of 3-year-olds to the use of the labels "Daddy/Mommy/Baby" to describe the relationship of monotonic change, and then presented them with the cross-mapping task of Experiment 1. We hypothesized that these labels would provide the children with an explicit framework for the relational system of *monotonic change in size*. If so, then the children's ability to perform a relational mapping with both the rich and the sparse stimuli should improve with the use of these labels. To obtain the maximal effect of labeling, we went to great lengths to ensure that the children were familiar with the relational use of the family labels, training participants with the "Daddy/Mommy/Baby" labels prior to presenting them with the cross-mapping task. We also reminded the children of these labels on each trial during the course of the experiment.

**EXPERIMENT 2**

**Participants**

The participants were 24 3-year-olds.

**Procedure**

**Label-training.** The label training stimuli were a set of toy penguins and a set of teddy bears, each of four different sizes and with very different markings. Training consisted of two sets of four trials in which the cross-mapping between objects and relations did not hold (bears were mapped to penguins) and two sets of four cross-mapped trials (penguins were mapped to penguins). The following protocol was used for the first eight trials:

"These bears and these penguins are each a family. In your bear family, this is the Daddy (pointing to the larger bear) and this is the Mommy (pointing to the smaller bear). In my penguin family this is the Daddy and this is the Mommy (again pointing appropriately)." When the child successfully labeled the animals in

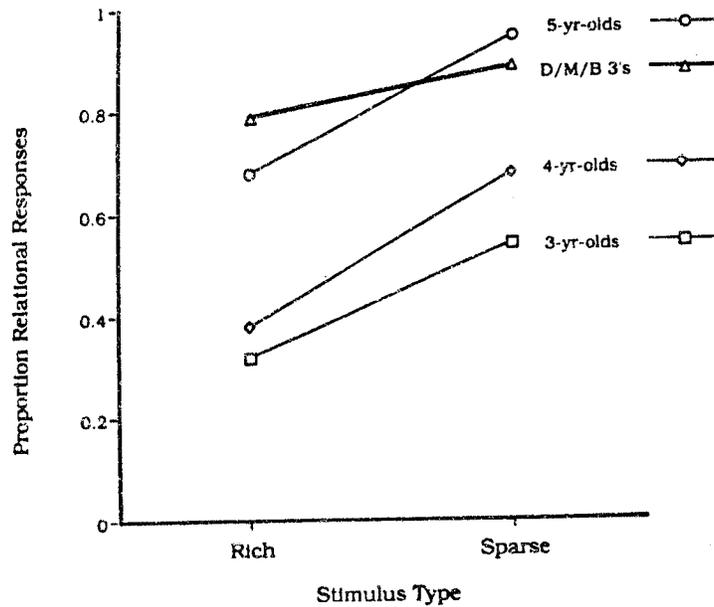


Figure 2.

both sets, the experimenter said "If I put my sticker under my Daddy penguin, your sticker is under your Daddy bear. Look, my sticker is under my Daddy. Where do you think your sticker is?" and the child was allowed to search for the sticker, again only keeping it if he found it on his first guess. After four trials a third, smaller, stuffed animal was added to each set and the labels "Daddy/Mommy/Baby" were applied in the manner described above. The same protocol was adapted for use in the cross-mapped penguin/penguin trials.

**Cross-mapping trials.** The cross-mapping task from Experiment 1 was used. The children were first asked to label both sets of objects using the family labels (this was repeated every second trial), and then the full-labeling procedure (e.g., "If I put my sticker under my daddy toy, your sticker is under your daddy toy. Look, my sticker is under my daddy, where do you think your sticker is?") was used. The participants each performed 14 sparse trials and 14 rich trials, counterbalanced, although only their performance from the first stimuli type presented was analyzed.

### *Results and Discussion*

The use of the "Daddy/Mommy/Baby" labels did improve young children's ability to make relational comparisons, even in the face of a tempting object choice. When trained to use these labels, 3-year-old children's ability to map relational similarity increased dramatically with both rich and sparse stimulus sets. As can be seen in Figure 2, when "Daddy/Mommy/Baby" was applied to the relation of monotonic increase, the number of relational responses produced by 3-year-olds increased from 54% with the rich stimuli and 32% with the sparse in Experiment 1 to 89% and 79%, respectively, bringing the performance of these participants to the level of performance found in the 5-year-olds. Note, however, that even when the relational labels were used, the effect of object richness was replicated; children produced significantly more relational mappings with sparse objects than with rich objects. Along with the increase in relational mappings, there was a

concomitant decrease in the number of object identity errors between Experiments 1 and 2 (from 23% to 8% with sparse and from 43% to 19% with rich).

We propose that "Daddy/Mommy/Baby" helped the young children notice the presence of a familiar higher-order relationship, namely monotonic change, that they may have already represented. Alternatively, the use of the relational labels may have led children to align the two relational systems (the E set and the C set) and derive the common monotonicity structure.

In Experiment 3, we address three further issues. First, we asked whether relational adjectives such as "big/little/tiny" would also enhance children's ability to perform a relational mapping. Second, we tested for long-term representational change brought about by our use of labels by retesting a sample of 3-year-olds 1-4 months after initial testing. And third, we addressed the possibility that our use of the "Daddy/Mommy/Baby" labels on every trial in Experiment 2 led the children to use the labels as an external crutch—perhaps following the rule "look under the object to which the same label has been applied" without grasping the relationship of monotonic increase in size. To be able to dismiss this possibility we presented children with a small number of full-label trials after which they were given new stimulus sets and asked to perform the cross-mapping without labels being overtly applied.

### EXPERIMENT 3

#### *Participants*

The participants were 51 3-year-olds, 28 who returned to the laboratory for session 2. The time period between Session 1 and Session 2 varied from 1 month to 4 months.

#### *Materials and Procedure*

**Session 1.** The children were randomly assigned to a labeling condition: no-labels, "Daddy/Mommy/Baby," or "big/little/tiny." Children were given the label-training task used in

Experiment 2, and then eight trials with the rich or the sparse stimulus label procedure of the previous experiment. After completing the labeled trials, children were shown a new set of stimuli of the opposite richness type and were given eight unlabeled trials.

**Session 2.** To ensure that children's ability to map monotonic change in this later session was as good as possible from the initial session, the following were made: (1) the children were given the opposite type of stimuli (i.e., rich or sparse) than was used in their initial session; (2) the children were tested in a different room; and (3) a different experimenter formed the experiment. The instructions to the children were minimal; they were told that they had played this game with a family member, you played a Daddy game last time. Lets see if you can do it better. The children were given eight trials, without labels, using the rich and bears. Each child was then given eight unlabeled cross-mapping trials. After the eight unlabeled cross-mapping trials, the full-label procedure was used, and then eight more unlabeled trials.

#### *Results and Discussion*

**Session 1.** Children trained to use relational labels ("Daddy/Mommy/Baby") produced significantly more relational mappings than children in the control condition (58% for relational labels versus 32% for no-label, collapsed across stimulus set and trial type). The effect of richness was replicated; children produced significantly more relational mappings with the sparse stimuli (67% versus 37% for rich stimuli) across label types and trial type. This replicates previous experiments the children produced significantly more object identity mappings with the rich than the sparse (37% versus 23% for rich stimuli).

**Session 2.** We first examined children's ability to map monotonic change in this later session. Eight, non-labeled, cross-mapping trials data reflects children's ability to map the relation of monotonicity. Children's ability to map the relation of monotonicity was significantly better than the sparse (37% versus 23% for rich stimuli).



& Gentner, 1993). In each of our experiments, the presence of a rich object conflict was more detrimental to the ability to perform a relational mapping than the presence of a sparse object conflict. It is worth noting that a similar effect has been found in the performance of adults presented with a cross-mapping task. Markman and Gentner (1993) found that adults will also respond based on object similarity when the number of matching object attributes of the cross-mapped objects is increased.

In the present work young children's susceptibility to rich object matches was due to their incomplete knowledge of monotonic change. We propose that simply using the labels "Daddy/Mommy/Baby," invited children to represent the higher-order relation of monotonic change. We further claim that the addition of this relational knowledge led to a striking improvement—equivalent to that of a 2-year-age gain—in the children's ability to perform relational mappings.

Finally, these experiments show quite forcefully that language, and in particular relational language, can facilitate relational representation. We found that both "Daddy/Mommy/Baby" and "big/little/tiny" led to increased relational responding in our three-year-olds, and that this ability remained several weeks after the initial exposure to these relational labels. The role of language, we suggest, is to provide an invitation to form comparisons and further, to provide an index for stable memory encoding of the newly represented relational structure.

### IMPLICATIONS FOR THEORIES OF ANALOGY

The research of Halford and his colleagues (Halford, 1993; Halford, Smith, Dickson, Maybery, Kelly, Bain, & Stewart, 1995) has also found the shift from objects to relations. They propose that an important driver of this shift is changes in cognitive capacity. That is, children show a developmental increase in cognitive capacity that allows them to represent and map increasingly more complex matches. Thus, for example, not until three years should children

be able to carry out complex system matches. In contrast, in our account it is domain knowledge that leads to increases in children's analogical abilities.

Neither view of analogy is meant to be exclusive; we acknowledge the role of maturational change in children's cognitive abilities and Halford has consistently noted the role of knowledge. However, our results demonstrate that striking changes in ability can occur over the course of one experimental session, and further that these gains persist after the experimental session is over. It appears that the limits on performance are not in children's capacity to represent and use complex relations, but rather in whether they have as yet represented a given complex relation. These results underscore the point that an increase in relational responding is not evidence, in itself, of maturational gain.

Another prominent theory of analogical reasoning is Goswami's (1993) relational primacy view. Goswami proposes that very young children (3-years-old) can perform an analogy when they have represented the requisite relational structure. While we agree with Goswami that domain knowledge plays a crucial role, we differ in the hypothesized role of object similarity. Goswami has stated that "As long as the relations that the child must map can be represented... then performing the mapping should present little difficulty, and this should hold true whether the objects to be mapped are similar or different in appearance." (Goswami, 1995, p. 891). However, in our studies there is still a robust effect of object similarity, even when labels have been applied and the children's relational performance is overall very good.

### *Language and Relations*

We have presented the view that labels, and in particular relational labels, invite children to notice and retain patterns of elements; language encourage them to *modify* thought. When applied across a set of cases (or a pair of cases, as here), labels provide children with an invitation to make comparisons, and then provide a system of meanings upon which to base these com-

parisons (Gentner & Medina, of these labeling studies sup- year-olds trained with the label my/Baby" and "big/little/tin- nificant increase in relational a relatively simple linguistic

The results of these exp that young children can per- mapping, even in the presen object similarity, when famili to highlight the appropriate ture. The impressive gains ir use of relational labels suppo language provides an invita to modify their thought. Lang ever, the only path to relatio Other manipulations, such *alignment* in which children a easy *literal similarity* match cult analogical matches will provement (Kotovsky & Gent with primates has also show labels need not be embedde tic system to improve relatio (Thompson, Oden & Boysen.

Thus we conclude that o development of the ability to u- ilarity is the acquisition and language. Relational language catalyst for comparison and a jects and relations, which can a mechanism for the progres dren's naive thought to the s- tract thought of adults.

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out complex system matches. Our account it is domain knowledge that increases in children's analogical reasoning.

of analogy is meant to be extended to show the role of matured children's cognitive abilities. We consistently noted the role of language. However, our results demonstrate that changes in ability can occur over time in an experimental session, and these gains persist after the experiment is over. It appears that the limitations are not in children's capacity to use complex relations, but that they have as yet not represented the relation. These results underwrite the claim that an increase in relational reasoning is evidence, in itself, of maturation.

The dominant theory of analogical reasoning is Gentner's (1993) relational primacy theory. She proposes that very young children (3-year-old) can perform an analogy. We presented the requisite relational structure. While we agree with Goswami (1995) that knowledge plays a crucial role, we hypothesized that the role of object similarity is as stated that "As long as the child must map can be representing the mapping should be able to do so, and this should hold true for all objects to be mapped are similar in appearance." (Goswami, 1995, p. 10). In our studies there is still a lack of object similarity, even when the structure is applied and the children's reasoning is overall very good.

#### Language and Relations

We extended the view that labels, and relational labels, invite children to think in terms of elements; language does not modify thought. When we presented cases (or a pair of cases), we invited children with an invitation to think, and then provide a system in which to base these com-

parisons (Gentner & Medina, 1997). The results of these labeling studies support this view; 3-year-olds trained with the labels "Daddy/Mommy/Baby" and "big/little/tiny" showed a significant increase in relational responding with a relatively simple linguistic intervention.

The results of these experiments suggest that young children can perform a relational mapping, even in the presence of conflicting object similarity, when familiar labels are used to highlight the appropriate relational structure. The impressive gains in ability after the use of relational labels supports our claim that language provides an invitation for children to modify their thought. Language is not, however, the only path to relational competence. Other manipulations, such as *progressive alignment* in which children are presented with *easy literal similarity* matches prior to difficult analogical matches will also lead to improvement (Kotovsky & Gentner, 1997). Work with primates has also shown that relational labels need not be embedded in a full linguistic system to improve relational responding (Thompson, Oden & Boysen, 1997).

Thus we conclude that one factor in the development of the ability to use relational similarity is the acquisition and use of relational language. Relational language can serve as a catalyst for comparison and alignment of objects and relations, which can, in turn, provide a mechanism for the progression from children's naive thought to the sophisticated, abstract thought of adults.

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## ANALOGICA

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## INTRODUCT

Analogical reasoning is a theme of the psychology of development. It's probably because it's a developmental mechanism subject to construct and modify in a flexible and adaptive way. Our goal is to analyse the cognitive analogical problem-solving in children.

Historically, studies on analogical reasoning were first devoted to problems (a:b::c:d) then to solving (target problems) which require relations (source problems). In this view, the ability to reason by analogy emerges when the child reaches the preschool age. Recently, researchers showed that children did not fail because they cannot reason by analogy but because they lack knowledge about objects or causal relations (Gentner & Brown, 1989; 1990 and Rattermann, 1991). However, more complex analogies proposed to the children are often solved by a high phase process. Other situations require to retrieve the relations to solve the target problem.

In problem solving situations, children's resources can contribute to improve