The Effects of Familiar Labels on Young Children's Performance in an Analogical Mapping Task*

Mary Jo Rattermann
University of Illinois
Dept. of Psychology

Dedre Gentner
University of Illinois
Dept. of Psychology

Judy DeLoache
University of Illinois
Dept. of Psychology

Abstract

This research investigates the role of language in children's ability to perform an analogical mapping task. We first describe the results of a simple mapping task in which preschool children performed poorly. In the current study, we taught the children to apply relational labels to the stimuli and their performance improved markedly. It appears that relational language can call attention to domain relations and hence improve children's performance in an analogical mapping task.

A computer simulation of this mapping task was performed using domain representations that differed in their degree of elaboration of the relational structure. The results of the simulation paralleled the experimental results: that is, given deeply elaborated representations, SME's preferred interpretation produced the correct mapping response, while when given shallow representations its preferred interpretation produced an object similarity response. Taken together, the empirical and computational findings suggest that development of analogy and similarity may be explainable in large measure by changes in domain representation, as opposed to maturational changes in processing. They further suggest that relational language may be an important influence on this development.

Introduction

One of the developing child's major achievements is the acquisition of language. This acquisition process pervades almost every aspect of the young child's daily life. Our question in this research concerns the possible effects of language on one aspect of the child's developing abilities: the use of object similarity and relational similarity. Children and adults perform very differently in tasks which require the use of object similarity and/or relational similarity. For example, when given a metaphor such as "A cloud is like a sponge" young children (five years old) produced similarity comparisons based on common object-attributes (e.g., "they both are round and fluffy") while adults produced similarity comparisons based on common relational structures ("they both store water and then later give it back to you") (Gentner, 1988).

This and related developmental differences have led many researchers to suggest that young children use an inherently different mode of processing than adults. Piaget (Piaget, Montangero & Billeter, 1977) proposed that children lack the basic cognitive competence to perform an analogical mapping between objects. This ability is dependent upon cognitive

This work was supported by Center for the Study of Reading contract NIE 400-81-0030. The authors would like to thank Art Markman, Rebecca Campbell, and Jennifer Glenn for their help in the preparation of this paper, and Phyllis Koenig for the wonderful penguins.

structures and processes which do not emerge until they reach the formal operations period of development (approximately 14 years of age). Others propose that children are not "fundamentally different kinds of thinkers" than adults but rather that it is deficiencies in children's knowledge that limits their performance (Brown, 1989; Carey, 1984). The domain-knowledge account would emphasize that metaphor and analogy tasks like the ones described above require knowledge that young children may not possess or may not reliably represent: for instance, knowledge of the causal relations within the two domains.

In this research we sought to (1) trace possible changes in children's ability to perform relational mappings; (2) to investigate whether any such changes could be explained in terms of changes in domain representations and (3) in particular, whether use of relational labels would play a causal role. We wanted to study the child's ability to extract relational similarity from a situation in which other solutions are in principle possible. Therefore, we designed a task in which object similarity was pitted against relational similarity. We then observed whether the child would carry out the relational mapping between the two structures. To further investigate the effects of object similarity, we manipulated the degree of similarity in the object matches by varying the perceptual richness and distinctiveness of the stimulus (Tversky, 1977). With this task we established that preschool age children have difficulty focussing on relational similarity when there is a competing object similarity. We then asked whether language can help children extract relational similarity under these conditions. We first review the basic task and then discuss the language manipulation we used to try to improve children's performance.

The Basic Task

We presented three- and four-year-old children and adults with a simple mapping game in which both object similarity and relational similarity were manipulated (Rattermann, Gentner & DeLoache, 1989). The child and the experimenter each had a set of three objects (clay pots or blue plastic boxes) which increased in size along a continuum from left to right. (See Figure 1.).

Figure 1a.
SIMPLE

Figure 1b.
RICH

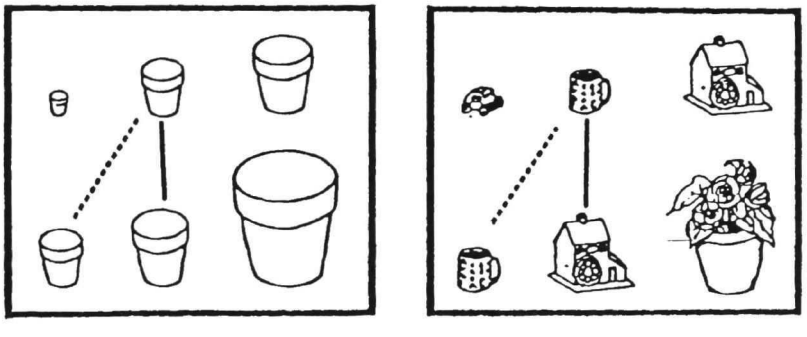

Figure 1. Stimulus sets used in mapping task.
The objects in Row 1 are the experimenter's set and the objects in Row 2 are the child's set.

The experimenter and the child played a game in which the experimenter hid a sticker under the child's set and the child tried to find it. The child was told that if he watched the experimenter as she placed a sticker under one of the objects in her set, he could use the hiding place of her sticker as a clue to the location of his own sticker. We introduced a tension between object similarity and relational similarity by staggering the size of the objects within the triads, creating both a possible object match and a possible relational match (a cross-mapping of the stimuli (Gentner & Toupin, 1986)). That is, if the experimenter's set contained objects of size 1, 2, and 3 the child's set contained objects of size 2, 3, and 4. The task was designed so that the relational response was always correct: the correct response was always based on relative size (e.g., largest object to largest object) and relative position.[1] The child was shown the correct answer and if correct was allowed to keep the sticker. In Figure 1a, the solid line represents the correct relational response, which the child will make if he is able to align the two structures relationally, while the dotted line represents the object-based response which the child will make if he responds on the basis of object similarity rather than relational similarity.

We found an age shift in the performance of this task. The three- and four-year-old children performed quite poorly (an average of 47% relational responses across both ages), while the adults performed extremely well (an average of 87% relational responses). We also found the effect of stimulus richness predicted by Tversky's contrast model; the children performed significantly better with the simple stimulus objects (an average of 54% relational responses for the three-year-olds and 62% for the four-year-olds) than with the rich stimulus objects (an average of 32% relational responses for the three-year-olds and 38% for the four-year-olds), suggesting that the presence of rich, distinctive object matches creates a salient alternative to the relational response (at least for young children). In contrast, when simple objects are used, the resulting object similarity matches are less compelling and therefore less likely to make a competitive alternative to the relational response.[2]

Can Language Promote a Relational Focus?

A growing body of research has investigated the hypothesis that young children use words to focus attention on certain kinds of information. (Gelman & Markman, 1987; Waxman & Gelman, 1986). Gelman and Markman (1987) investigated the role of common word labels on three- and four-year-old children's willingness to extrapolate characteristics between objects. They presented children with a picture of a standard object, e.g., a bluebird, and taught the children a characteristic of this object (e.g. "feeds its baby mashed up food."). The children were then shown a set of several objects, some which shared perceptual similarity

1. The relations of relative size and relative position were perfectly correlated. That is, the middle-sized object was also the object in the middle position.

2. Adults performed roughly equal with the rich and the simple stimuli, suggesting that they can focus on relational commonalities relatively independent of object similarity.

with the standard and some which shared category membership (and therefore a common label) with the standard. When no labels were used the children, as expected, extended the characteristic to objects on the basis of shared perceptual similarity with the standard (e.g, a blue butterfly). When these new objects shared a category label with the standard (e.g. a blackbird) the children extended the characteristic based on the common label and, to a lesser extent, the shared perceptual similarity.

Given this evidence suggesting that labels can direct children's attention to taxonomic object concepts, the question we posed was whether relational labels can direct children's attention to relations. In particular, could the use of relational labels in the perceptual-mapping task influence children to respond relationally. To label the key relative-size relation we chose to use simple, familiar labels: "Daddy", "Mommy," and "Baby". "Daddy", "Mommy," and "Baby" are very salient relations to young children; in fact, children in the previous study occasionally used these labels spontaneously.[3] If the use of relational labels leads children to perform the mapping task correctly, this will support the position that developmental improvement can be accounted for by changes in representation (e.g. through accretion of knowledge) rather than by maturational change in underlying intellectual competence; and, more specifically, it will support the idea that acquisition of language is a contributor to this progression.

Method and Procedure

Training. A graded training procedure was used to introduce the "Daddy," "Mommy," "Baby" labels to the children. We used a family of stuffed teddy bears and a family of stuffed penguins in the training task. In the first phase the experimenter's set contained a large and a small penguin, while the child's set contained a large and a small bear. This meant that there was no object identity match yet, and the child was only confronted with two animals in each set. The experimenter explained the task to the child by saying "These bears and these penguins are each a family. In the your bear family, this (pointing to the larger bear) is the Daddy and this (pointing to the smaller bear) is the Mommy. In my penguin family this is the Daddy (pointing to the larger penguin) and this is the Mommy (pointing to the smaller penguin)."

The child was asked to repeat the labels. After the child could label all the stimuli in both sets the experimenter asked "If I put my sticker under my Daddy (Mommy) penguin, your sticker is under your Daddy (Mommy). Look, my sticker is under my Daddy; where do you thing your sticker is?" The child was then allowed to search for the sticker. Phase 2 was identical to Phase 1 except for the addition of a small bear and a small penguin resulting in two families consisting of three animals to which the labels "Daddy," "Mommy," and "Baby" were applied.

---

3. An alternative would have been to use "Big," "Medium," and "Little," however, young children are often quite slow to acquire relational terms such as "big" and "little," "high" and "low," etc. and they are often applied attributionally before they are applied relationally (Donaldson & Wales, 1970; Smith, Rattermann and Sera, 1988).

In Phases 3 and 4 we introduced competing object identity choices. That is, we tried to created the same tension that the children would face later in the mapping task. To do this, we gave both the experimenter and the child families of penguins. The sizes of the penguins were designed to create a cross-mapping between the stimuli in the experimenter's set and the child's set (e.g., the experimenter's family might contain sizes 1,2, and 3 and the child's family might contain sizes 2, 3, and 4). In phase 3 only two penguins were used in each family, while in phase 4 there were three penguins in each set. (See Figure 2.) Throughout the training task the child labeled both the experimenter's objects and the child's objects after every other trial.

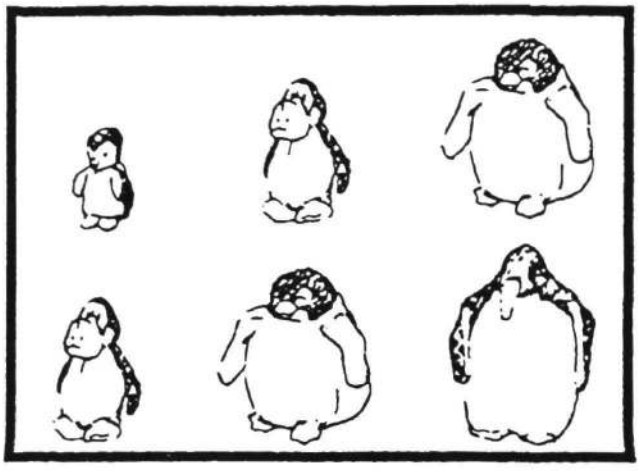

Figure 2. Stimulus set used in Phase 4 of training.

Mapping Task. After the training, each child was tested using the perceptual-mapping task using the stimuli described above (See Figure 1). Both the rich and the sparse stimuli were used, with half the children being tested with the sparse stimuli then the rich and the other half tested in the opposite order. Each child performed 28 trials; 14 sparse trials and 14 rich trials. The family labels were used in the same manner as in the training task.

Results

As can be seen in Figure 3, the children's performance in the labeled conditions was significantly higher than their performance when labels were not used with both the sparse stimuli (t (34) = 4.792, $p<.001$) and the rich stimuli ($t(34)=5.423$, $p<.001$). The use of relational labels helped the three-year-olds truly respond relationally even in the face of a very tempting object choice.

There was also a small effect of object richness in that the few mistakes the children made in this study were made in the rich object condition. A 2 (Order of stimulus type) x 2 (Random

order) x 2 (Object complexity) analysis of variance confirmed a significant effect of Object complexity F (1,20) = 4.44 p < .047.

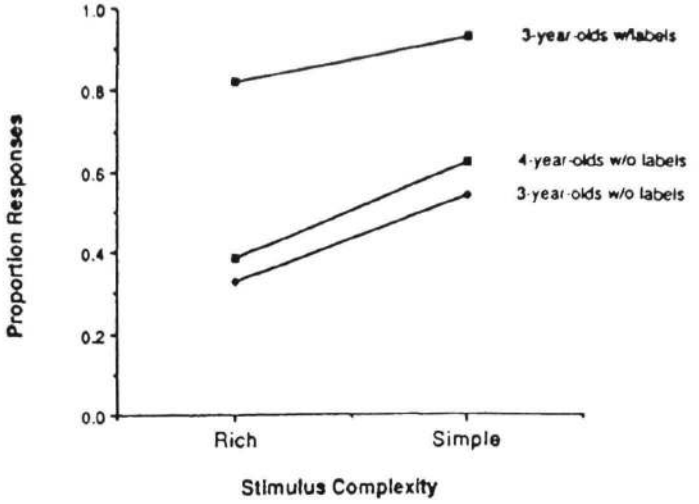

Figure 3. Results of labeling and non-labeling tasks.

Simulation

The use of relational labels helped the young children in our task to respond relationally. In fact, the familiar relational labels allowed the three-year-olds in this experiment to surpass the performance of the four-year-olds in the original mapping task suggesting a role of language in the perception of similarity.

More generally, this improvement in children's performance with relational labels strengthens the case for the domain-knowledge account of the development of similarity. That is, it suggests that children's model of processing is the same as that of adults. To further test this hypothesis, we carried out a computer simulation of the performance of children and adults in this task (Gentner, Markman, Rattermann & Kotovsky, 1990; Rattermann & Gentner, 1990). We gave propositional representations of the stimuli used in these experiments to the Structure-mapping Engine (SME) (Falkenhainer, Forbus & Gentner, 1986; 1989). (See Figure 4.) Based on the hypothesis that the accretion of domain knowledge is driving changes in similarity use, we formed two different knowledge representation of the stimulus sets.

We begin by making several working assumptions. We assume that children can vary in the degree of higher-order relations[4] present in their representation of the stimuli. We further assume that one role of language is to make the relational structure salient and increase the probability that the higher-order relations will be represented. Finally, we assume that children, in the absence of relational labels, possess shallow representations of the stimuli consisting of object attributes and first-order relations (The portion of Figure 4 in the dashed box.). When labels are provided they aid the children in forming

4. First-order relations are relations between objects, object-attributes or functions. Higher-order relations are relations between relations.

a systematic representation containing object attributes and an elaborated higher-order relational structure. Specifically, we assume that the higher-order relation of steady change in size is more likely to be represented when relational labels are used. In order to mimic the simple and the rich stimulus sets, we varied the number of object attributes; the rich objects possessed five attributes and the simple objects possessed three attributes. Given the systematic representations of the stimulus sets, SME's preferred mapping[5] was based on relational similarity for both the rich and the simple stimulus sets. Given shallow representations, however, SME's preferred mapping was based on relational similarity with the simple stimulus sets but based on object similarity with the rich stimulus sets. These results mimic our findings with the developmental task.

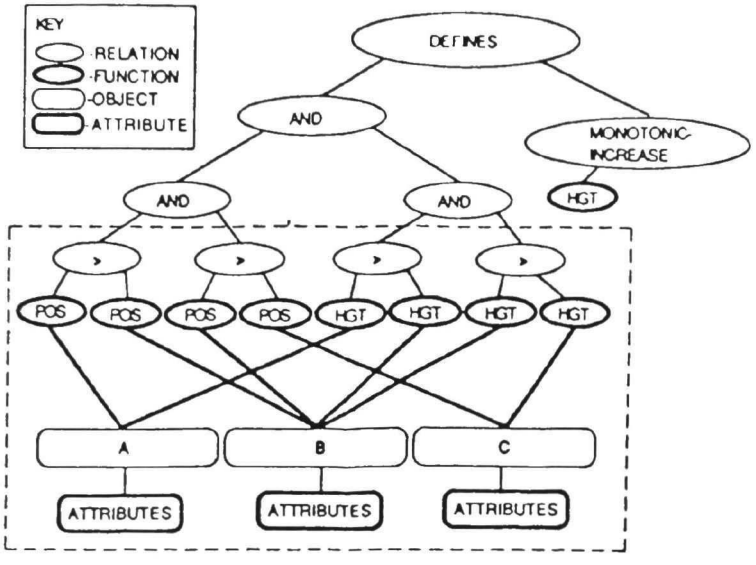

Figure 4. Knowledge representation used in simulation of developmental results.

Conclusions

In conclusion, this research suggests that the use of familiar relational labels can improve children's ability to perform analogical mappings. There is support, both empirical and computational, for the conjecture that children and adults may use the same type of similarity processes and that it is changes in domain representations rather than changes in cognitive competence that cause the observed developmental improvement and (2) the acquisition and use of language - specifically relational language - is an important contributor to this development.

References

Brown, A. L. (1989). Analogical learning and transfer: What develops? In S. Vosniadou & A. Ortony (Eds.), Similarity and analogical reasoning (pp. 369-412). London: Cambridge University Press.

Carey, S. (1984). Are children fundamentally different kinds of thinkers and learners than adults? In S. Chipman, J. W.

5. SME performs local matches and by taking advantage of connectivity produces structurally consistent interpretations of analogies. It then performs structural evaluations of each interpretation. We based our results on SME's preferred evaluations.

Segal, & R. Glaser (Eds.), Thinking and learning skills: Current research and open question (Vol. 2, pp. 485-517). Hillsdale, NJ: Erlbaum.

Crisafi, M. A., & Brown, A. L. (1986). Analogical transfer in very young children: Combining two separately learned solutions to reach a goal. Child Development, 57, 953-968.

Donaldson, M., & Wales, R. (1970). On the acquistion of some relational terms. In J. R. Hayes (Ed.), Cognition and the development of language (pp. 269-278). New York: Wiley.

Falkenhainer, B., Forbus, K. D. & Gentner, D. (1986). The structure-mapping engine (Tech. Rep. No. UIUCDC-R86-1275). Urbana, IL: University of Illinois, Department of Computer Science. Also appears in Proceedings of the Fifth National Conference on Artificial Intelligence (pp.272-277), Philadelphia, PA: Morgan Kaufmann.

Falkenhainer, B., Forbus, K., & Gentner, D. (1989/90). The structure-mapping engine: Algorithm and examples. Artificial Intelligence, 41, 1-63.

Gelman, S. A., & Markman, E. M. (1987). Young children's inductions from natural kinds: The role of categories and appearances. Child Development, 58,1532-1541.

Gentner, D. (1988). Metaphor as structure mapping: The relational shift. Child Development, 59, 47-59.

Gentner, D., Markman, A., Rattermann, M.J., & Kotovsky, L. (1990) Similarity is like analogy. Paper presented at the Midwest Artificial Intelligence and Cognitive Science Conference, Carbondale, Illinois.

Gentner D., & Toupin, C. (1986). Systematicity and surface similarity in the development of analogy. Cognitive Science, 10, 277-300.

Piaget, J., Montangero, J., & Billeter, J. (1977). Les correlats. In J. Piaget (Ed.), L'Abstraction reflechissante. Paris: Presses Universitaires de France.

Rattermann, M.J., & Gentner, D. (1990). The development of similarity use: It's what you know, not how you know it. Paper presented at the Midwest Artificial Intelligence and Cognitive Science Conference, Carbondale, Illinois.

Rattermann, M. J., Gentner, D., & DeLoache, J. (1989). Effects of competing surface similarity on children's performance in an analogical task. Poster presented at the biennial Meeting of the Society for Reasearch in Child Development, Kansas City, Missouri.

Smith, L. B., Rattermann, M. J., & Sera, M. (1988). "Higher" and "lower": Comparative and categorical interpretations by children. Cognitive Development, 3, 341-358.

Tversky, A. (1977). Features of similarity. Psychological Review, 84, 327-352.

Waxman, S. & Gelman, R. (1986). Preschoolers use of superordinate relations in classification and language. Cognitive Development, 1, 139-156.