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Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 29(29)

ISSN
1069-7977

Authors
Mutafchieva, Milena
Kokinov, Boicho

Publication Date
2007

Peer reviewed

Can Language be Replaced? Physical Representations of Relations Instead of Language Labels in Relational Mapping: Do They Help Young Children?

Milena Mutafchieva (mmutafchieva@nbu.bg)
Boicho Kokinov (bkokinov@nbu.bg)

Central and East European Center for Cognitive Science, Department of Cognitive Science and Psychology,
New Bulgarian University, 21 Montevideo Street
Sofia 1618, Bulgaria

Abstract

This paper is trying to explore whether language has a very specific role in analogy-making as claimed by many researchers, or it is just one very effective way of building mental representations of the relational structure of the task. If the latter is true there must be also alternative ways of aiding mental representations of relations by young children. In the experiments described in this paper we use physical objects as representing the relations within the task and it turns out that this is an effective way of helping children to build relational representations and use them successfully in an analogical mapping task.

Keywords: analogy; cognitive development; relational mapping; language; psychological experimentation.

Introduction

There is an extensive debate about the role language plays in analogy-making. This debate is especially hot in the animal cognition and cognitive development literature. When Gillan, Premack and Woodruff (1981) first demonstrated that the chimpanzee Sarah can make analogies this has produced a real revolution, since it was believed that such reasoning capabilities are uniquely possessed by humans (and even only by adults). However, Sarah was a special chimp – she was language trained and therefore she had developed and used a sophisticated symbol system. Moreover, she was explicitly trained to use certain symbols (geometric figures) for the "same" and "different" relations. Thus Sarah had the "same" and "different" concepts ready in her mind before starting the experiment. In addition, the experimental setting involved the use of the "same" and "different" relations explicitly, i.e. the corresponding signs were physically present on the table as physical objects and Sarah could perceive them and use the perceived image as a representation of the abstract relations. All these aspects seem to be crucial for the success Sarah has demonstrated repeatedly in consecutive experiments (Oden, Thompson, Premack, 2001). It was demonstrated that chimpanzees which are not language trained could not do the analogy task and that other monkeys cannot be trained to do the task as well. It was shown that there are other important differences among the animals that make the difference, e.g. their ability to perceive the relations (Oden, Thompson, & Premack, 1990; Thompson & Oden, 1998, 2000). Thus the importance of language was clearly demonstrated, but it might be at least two fold: language might be a necessity because analogy-making needs the presence and usage of an abstract symbolic system, and/or the specific language signs (in this case, the signs for "same" and "different") might be important for the mental representation of the specific relations to be used in the analogy. The two issues are a bit mixed up in the experiments described above since in all of them Sarah had both abstract language ability and the specific physical signs for the relations used in the task.

Recently the role of language for analogy-making has also been studied in the developmental literature (Gentner, & Rattermann, 1991; Rattermann, & Gentner, 1998; Gentner, & Loewenstein, 2002; Loewenstein & Gentner, 2005). Gentner and her colleagues have demonstrated that the use of relational words (labels) during the analogical task facilitates children's success in relational mapping. The authors are very careful when interpreting their results: they do not claim that the mapping cannot be performed without language. Taking into account that all children are at least 3 years olds and they are all capable of using language in general, their experiments concentrate on whether the use of the specific relational words for explicit representation of the relations in the task can help children to make the analogy. And the results are really positive, i.e. the use of explicit relational terms such as "Daddy", "Mommy", and "Baby" facilitates significantly the mapping process.

The question we pose in this article is whether we can aid children in building representations of the relations in a way that is not language-based. If that turns out to be possible this will open the issue whether language is necessary at all. It may turn out that language is simply the most often used and most convenient way to build and hold such representations in memory, but at least in some cases other possibilities will be open. This may even make it possible to study animal relational mapping in new ways without involving language and thus further test the hypothesis that language is a prerequisite for analogy-making.

Previous Experimental Studies

The experiments described in this paper are a continuation of the work of Gentner and her colleagues (Rattermann & Gentner, 1991, Gentner & Rattermann, 1998, Loewenstein & Gentner, 2005). That is why a brief review of these experiments is necessary.

Gentner and Rattermann (1991, 1998) presented young children (3, 4, and 5 years old) with an implicit analogical mapping task. The child and the experimenter had each three different sized objects (big, medium, small). The experimented hid her sticker under one of her objects (say the middle one) and said "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. If I put my sticker under this toy, where do you think yours is?". The child had to find out that this means under the object of the same relative size and search under her/his middle sized object. At the same time within the child's set of objects there was an object which was of the exact same size as the object pointed by the experimenter, but which was of different relative size (e.g. was the smallest in the child's set). Pitted against each other the absolute and relative size made the task quite difficult for the children. There are other ways to interpret the instruction, e.g. to use the same relative position (left, center, right), which may make the task even more difficult or easier depending on whether there is a correlation between the corresponding spatial position and the corresponding relative size. In these experiments Gentner and Rattermann always arranged the objects in a linear monotonically increasing or decreasing order and thus the correlation or anti-correlation between relative position and relative size is high. The results were that 3 years old children picked up in about 50-54 % of the trials the "correct" relative size object, and 4 years old children picked up the relational response in about 62% of the trial. In another condition the following instruction was given "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). 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?" When language labels were involved the 3 years old children were 87-89% of the trials correct. This is a rather significant improvement which was attributed to the use of language relational labels which focus the child's attention towards the relations and they encode and use them.

Later on, Gentner and Loewenstein performed various experiments (2002, 2005) to test the effect of other relational labels such as "On, in, under" or "top, middle, bottom". These labels also produced a significant improvement but it was not that strong as in the "Daddy, Mommy, Baby" condition.

Goswami (1995) replicated the original (Rattermann & Gentner, 1991) experiment while controlling for the spatial positions of the objects and she still obtained the relational labels effect. In addition she tried to see the effect of the family analogy on the relational mapping task but obtained no support for this hypothesis. Finally, Mutafchieva and Kokinov (2007) demonstrated a significant difference between the "big, middle, small" relational terms and the "Daddy, Mommy, Baby" terms arguing that the family analogy is used in the latter case.

The current study aims at further exploring the reason why relational terms are helpful for children. The main idea of Gentner and her colleagues is that children often fail to pay attention to the relations, so they either do not encode them in the representation of the task or simply do not use the formed representations while solving the task. Thus the language labels help children to focus their attention on the relations. If this is the case, we should be able to help children focus on the relations using also in other means. One way is to make it clear to the children that we expect a relational answer, for example, by giving them a more explicit initial instruction or by training them in a less ambiguous way.

In this paper we are using physical objects to represent the relationships between the basic objects in the scene. This might sound strange since relations are abstract and cannot be directly pointed to in the real world. However, this is exactly the point. Children may have difficulties noticing and encoding the relations simply because relations are not that salient and they require a greater cognitive effort to compute them from the scene. Thus objects correspond to a specific blob in the scene, which has some specific characteristics, while relations typically require comparing and relating certain properties of two different blobs. In addition, in order to mentally represent the object, we can use its mental image, while in order to represent a relation we typically cannot use a mental image, and that is why we need a word (which will replace the mental image).

The main idea of this paper is to use physical objects as representations of the relationships. In that way children will be able to use their mental image as a representation and memory device for the relations. In addition since the object will be always present, this mental image will be refreshed all the time and thus hold active in memory. Initially we tried with an object that will symbolize the relation (like in the Sarah experiment) – we used a toy-man pointing in one direction to represent "this is bigger than that". However, it did not work, mainly because actually this brought even more complication to children: they had to remember and hold active in memory not only the relations but also what the "pointing man" symbolises. Unlike the case of Sarah, where she studied the relational symbol for years before being engaged in the analogy task, children were introduced to the new symbol and its meaning immediately before the mapping task and they simply forgot its meaning during the subsequent task. Then the next step was to find an object that will "naturally" represent the relationship rather than symbolize it. That means an object that will really physically connect the related objects and will have a causal meaning in the domain. Thus we came to the idea of using "draw-bars" that connect to objects and cause the movement of one of them when the other one is being moved. To make the relation directed and even more natural we explained to the children that if the two animals (on platforms) are connected with a draw-bar the stronger animal will be able to pull the weaker one. In this way the draw-bar became oriented and we physically made it as an arrow with a red heading. The draw-bar was also causally related to the movement of the two connected objects. Thus we assumed that children will be able to easily notice the draw-bar objects and represent them together with the objects they connect. In this way the relation "stronger than" will be easily represented and hold in memory.

Experiment 1

The goal of our first experiment is to find out whether physical representation of relations could help young children to make relational mapping. This will be tested under an extremely difficult condition – the objects in the two sets are placed in a triangle configuration in contrast with all experiments described above which use linear configurations. We asked the children to connect the objects with two draw-bars and explained them that this configuration may be considered as a "train that is making a turn" (see Figure 1).

Hypothesis

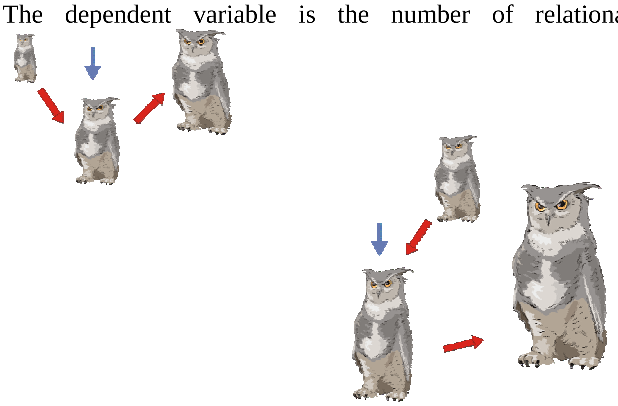
Our hypothesis is that 4 years old children will succeed in transitive relational mapping significantly better when there is a physical representation of the relation (the "draw-bars") than if there is no such representation.

Design

The experiment has a between group design and the manipulated variable is presence or absence of physical representations of the relations between objects:

- ***Draw-bar condition***: the animals are connected via draw-bars in order to make a "train".
- ***Control condition***: the animals are not physically connected and the concept of "train" is not introduced.

The dependent variable is the number of relational



responses.

Figure 1. An example of the stimulus material in a trial. The arrows between the owls depict the draw-bars fixed between the animals, and the vertical arrows show which animals have been picked up at this trial.

Stimuli

In each trial one set of 6 animals was used: 6 foxes, 6 bears, 6 owls, etc. All animals in the same set were of different size, except two who were the same size. Three of the animals formed the experimenter's set, and three – the child's set. In every set there was big, middle and small animal and there was a difference in the absolute size of the corresponding animals in the experimenter's and the child's set. One element of the child's set was exactly the same size as one of the animals in the experimenter's set. The stimuli were presented in a triangle and different sets of stimuli with different sizes and spatial positions as well as different animals were presented at every trial (See Figure 2b). In the Draw-bar condition four draw-bars of the same size and colour were used to mark the object relations - two for the experimenter's set and two for the child's set (Figure 2a).

Five transitive relational mapping tasks were presented to every child plus two in the training session. The five transitive relational trials were designed to fulfil some criteria: 1) to vary the spatial configuration of the stimuli sets (e.g. the Biggest – left, vs. right, vs. middle); 2) to vary the spatial position of the relational response and the object with the same absolute size (surface similarity) in every trial and in the two sets.

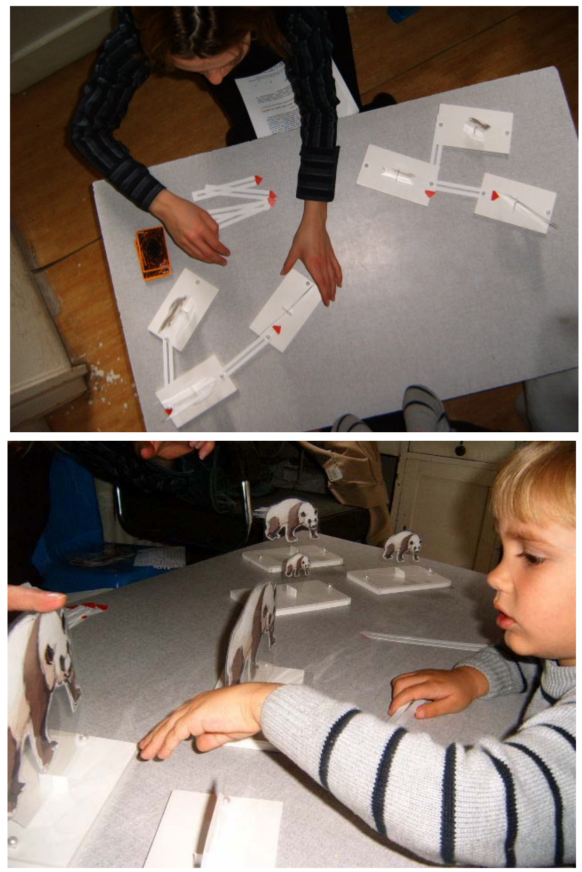


Figure 2. a) A picture of a draw-bar trial in which the tabletop is seen from above. From that perspective one can see the platforms and the connecting drawbars. b) A picture of a control group trial, the animals are placed the same why but are not connected by draw-bars and the concept of a train is not introduced.

Procedure

In each trial the child saw two triads of objects, both arranged in a triangle way. The child watched the experimenter to hide a sticker under one of the objects in the experimenter's set. The child was told that he/she could find his/her own sticker *"in the same place"* in the child's triad. The correct response was arranged always to be at the relational similarity place: thus, in order to pick it up, the child had to choose the object with the same relative size, but not the same absolute size (object similarity). The children were always given a feedback by showing the correct response (by receiving the sticker).

Each child participated in a single experimental session.

The experiment included two training trials and five test trials as described above. In the training trials the experimenter gave the child an explanation about the instruction and the question that she or he had to answer.

The test trial began with the following instruction for the Control Group (in Bulgarian language):

"We are going to play a game of hiding and finding stickers. I have three owls and you have three owls. From my two owls this owl is stronger than this owl (pointing e.g. to the biggest and the medium owl from the experimenter's set), *and this owl is stronger that this owl* (pointing e.g. to the medium and the smallest owl). *Please, tell me from these two of your animals, who is the stronger one? And from these two of your owls who is the stronger one? Now, I am going to hide my sticker* ***under this owl****, where do you think your sticker is hidden?"*

The corresponding instruction for the Draw-bar Group was the following:

"We are going to play a game of hiding and finding stickers. I have three owls and you have three owls. From my two owls (pointing e.g. to the biggest and the medium owl in the experimenter's set) *this one is stronger than this one and I will put this draw-bar in such a way that the stronger owl could pull the weaker one. From these two of your animals which one is the stronger one? Please, put this draw-bar in such a way that the stronger owl could pull the weaker owl. Now, from these two of my owls* (pointing e.g. to the medium and the smallest owl from the experimenter's set) *this one is stronger than this one and I will put the draw-bar in such a way that the stronger owl could pull the weaker one. From these two of your animals which one is the stronger one? Please, put this draw-bar in such a way that the stronger owl could pull the weaker one. Now look, my owls look like a train and your owls look like a train. I am going to hide my sticker* ***under this owl****, where do you think your sticker is hidden?"*

Figure 3. A picture of a trial in which the middle-sized animal has been picked up both by the experimenter and the child.

Participants

38 children were studied in this experiment; the average age of children was 4 years and 5 months, ranging from 4 years to 5 years. 18 children formed the Control Group, and 20 formed the Draw-bar Group.

Results and discussion

The results can be seen in Figure 4. The mean for the Control Group is 1,44 relational responses out of 5 (around the chance level of 1,66), and the mean for the Draw-bar Group is 3,65 relational responses. The difference is statistically significant at the level $p<0.001$ ($T(36)= 6,697$).

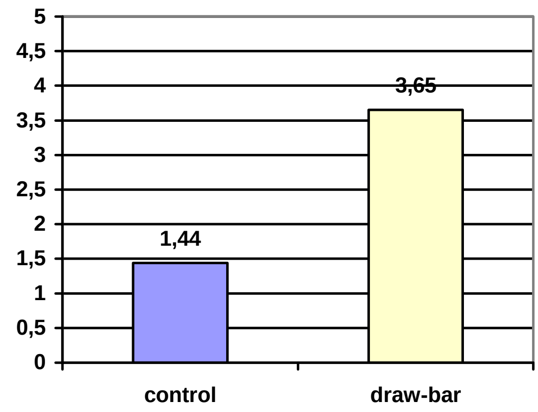


Figure 4. Score means for the two groups. $T(36)=6,697$, $p<0.001$

Our hypothesis was confirmed: the draw-bar physical representation of the relation "stronger than" seems very effective. Now the question is how this compares to the usage of language labels. This is tested in the next experiment.

Experiment 2

The goal of this second experiment is to find out whether language labels used for the objects will make it much better than the simple physical representation of the relations. Maybe the draw-bars were effective, but the use of language labels will be much better. Take into account that when language labels are used such as "Daddy, Mommy, Baby" or "Big, Small, Tiny", these labels are not only relational, since they do not only represent the binary relation between two objects, but in addition they are labels of one unique object from the triple. Thus children could potentially use this additional information and pick up the object with the same label on their side.

Hypothesis

Our hypothesis was that language labels should further improve the performance of the children.

Design

The experiment is an extension of Experiment 1 adding two more groups where language labels pointing to the objects will be used:

- ***Control condition***: no draw-bars and no labels are used (the same data from Experiment 1).
- ***Draw-bar condition***: no labels are used for the objects, only the draw-bars represent the relations between them (the same data from Experiment 1).
- ***Draw-bar + label condition***: the objects are called the ***"Locomotive",*** the ***"Middle wagon",*** and the ***"Last wagon"*** in addition to the draw-bars placed between the objects.
- ***Daddy condition***: the objects are called ***"Daddy", "Mommy", "Baby"***, and no draw-bars are presented.

The ***Draw-bar + label*** condition is testing whether adding a label will further improve the performance of children compared to the draw-bar condition. And since one can wonder whether the labels were adequately picked up, we added a classic ***Daddy condition***, which has been proved to be the most effective under various conditions (Gentner & Rattermann, 1991, 1998, Loewenstein & Gentner, 2005, Mutafchieva & Kokinov, 2007).

The dependent variable was the number of relational responses.

Stimuli

Stimuli were the same as the ones used in Experiment 1.

Procedure

The procedure was the same as in Experiment 1 except the instructions for the ***Draw-bar + label*** and ***Daddy*** Groups.

The instruction for the ***Draw-bar + label*** condition extends the one for the ***Draw-bar*** condition with the following:

*"**From my train this is the locomotive, this is the medium wagon, and this is the last wagon. Now, tell me from your train which one is the locomotive? Which one is the medium wagon? And which one is the last wagon? I am going to hide my sticker under this owl, which is the locomotive of my train.** Where do you think your sticker is hidden?"*

The corresponding instruction for the **Daddy condition** is ***"From my animals this is the Daddy, this is the Mommy, and this is the Baby. Now, tell me from your animals which one is Daddy, which one is Mommy, and which one is the Baby. I am going to hide my sticker under this owl, which is the Mommy among my animals.*** *Where do you think your sticker is hidden?"*

Participants

Seventy seven children were studied in this experiment; the average age of children was 4 years and 5 months, ranging from 4 years to 5 years.

Results and discussion

The main effect of the type of presentation of the relations on the number of relational mappings is significant ($F(3,73)=18.370$, $p<0.001$). However, the only group that is significantly different from the rest in the post-hoc analysis turns out to be the control group. Thus there is no evidence that the language labels can further improve the performance of the Draw-bar group (Figure 5). This may simply mean that the physical object representation of the relations is strong enough and comparable to the language labels used in previous experiments.

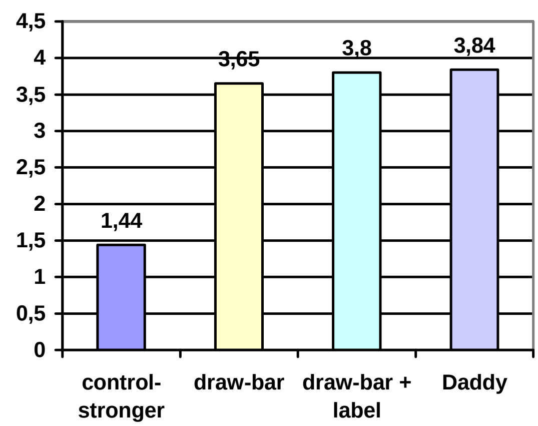


Figure 5. Mean scores for the various groups.
Main effect is significant ($F(3,73)=18.370$, $p<0.001$), but there are no significant differences between the experimental groups and in particular, between the draw-bar condition and any of the labelling conditions.

General Discussion

The results are coherent with the findings obtained by Gentner and Rattermann (1991, 1998), Gentner and Loewenstein (2002, 2005), and Goswami (1995), but they go well beyond them. They show that the use of language labels is not necessary for successful performance of 4 years old children in the mapping task and that the use of physical object representation of the relations is as useful as the language labels.

These findings open the door for further speculation and extensive experimental work. The speculation is that maybe analogical mapping can be performed also by primates or even monkeys who have not received language training, if a relevant physical representation of the relations can be designed, i.e. to find objects that connect other objects in a causal way which is understood by the corresponding animal. If this could be demonstrated, we could claim that language is not necessary for analogy-making, but only served as a universal and very effective way of representing the relations. It will still give advantage to humans since one can only rarely find a good way to represent physically the relations, but we will be closer to an understanding of the evolution of analogy-making.

Acknowledgments

This research was supported financially by the ANALOGY project (NEST program, contract 29088) funded by the EC. We would like to thank Elisaveta, Margarita, Irina, and Olimpia for their help in collecting the data.

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