UC Merced

Proceedings of the Annual Meeting of the Cognitive Science Society

Title
Can Actions Represent Relations?

Permalink
https://escholarship.org/uc/item/0p68m6pb

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 31(31)

ISSN
1069-7977

Authors
Kokinov, Boicho
Mutafchieva, Milena

Publication Date
2009

Peer reviewed

Can Actions Represent Relations?

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 exploring alternative ways of representation of relations to be used effectively in a transitive mapping task. In the experiment described in the paper children had to map the 3 animals on their side to the 3 animals on the experimenter's side in terms of relative size. In all conditions physical objects "draw-bars" were used to connect the animals on each side. The draw-bars represent the relation "stronger than" in a physical way. However, in two conditions the draw-bars were lacking directions and thus there was no physical representation of the direction (who is stronger than whom). In the third condition the draw-bars ended with pointer on one side and thus physically represented the direction of the relation. In the second condition the direction of the relation was represented by a physical action (pulling) preformed both by the experimenter and the child on the animal. The results showed that both the motor action and the pointed draw-bars improved children's performance, thus actions can successfully replace physical objects in representing relations.

Introduction

Gentner (1989) and Smith (1989) suggest that children initially represent objects by overall attributes and only later on start to pay attention to relations. This might be the reason why children initially have problems with analogical mapping, since analogy is a mapping between relations according to most definitions (Gentner, 1983).

There are various studies trying to find out factors that facilitate children in attracting their attention to relations.

One such factor is language. Gentner and her colleagues have demonstrated that the use of relational words (labels) during the analogical task facilitates children's success in relational mapping (Gentner, & Rattermann, 1991; Rattermann, & Gentner, 1998; Gentner, & Loewenstein, 2002; Loewenstein & Gentner, 2005). The authors 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 making 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.

We take a different approach. We raise the question why is it so difficult for children to encode relations and how can we possibly facilitate them. One possible answer is that relations are more difficult to be perceived: in contrast to objects and attributes they are not salient in the world and they require more cognitive (and possibly even more physical) efforts to be noticed and recognized in the environment. The argument is that noticing a relation like *left-of, above*, etc. requires our gaze to be moved from one specific location to another and to represent the movement (eye movement or head movement) that we have made. In contrast, attributes like red, green, bright, round, etc. do not need comparison with other objects at different positions. 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 question we have posed is whether we can aid children in building representations of the relations in a way that is not language-based. One way to facilitate encoding is to use a physical object for representing the relation in a task. In our previous studies we used "draw-bars" as physical representation of the relation "stronger than".

The results have extended the findings of Gentner et al. by demonstrating that 4 years old children can equally well make transitive relational mapping under various conditions – with language labels such as "Big/Medium/Small"; and with physical representation of the relations – draw-bars (Mutafchieva & Kokinov, 2007b). We demonstrated also that analogy (both "the family" analogy and "the train" analogy) improves children's performance in a transitive mapping task with both linear and triangle configuration of the stimuli (Mutafchieva & Kokinov, 2007a, 2007b).

Based on these previous results we have decided to find out whether there is a third alternative to language and physical object – another way of representing the relations. One possibility could be to use an action.

The idea that action and perceptual content are coded in a common representation comes from the embodied cognition theories and from the Theory of Event Coding of Hommel (Hommel, Müsseler, Aschersleben, & Prinz, 2001; Hommel, 2002). Embodied cognition emerges from bodily interactions with the environment. According to this idea, cognition depends on the fact that we have body with particular motor and perceptual capabilities that are linked together with language, reasoning, memory, emotions and other aspects of mental life into one representation. Basically, Hommel and his colleagues suggest that cognitive representations of events (i.e. of any to-be-perceived or to-be-generated incident in a distant environment) subserve not only representational functions (e.g. for perception, imagery, memory, reasoning) but also action-related

functions (e.g. for action-planning and initiation). The perceptual content and action are coded in this action-related object representation by feature codes with distal references. If Hommel's intuition is right, action can serve as well as physical object in building a mental image of the relation.

Previous Experimental Studies

The experiment described in this paper is a continuation of the work of Gentner and her colleagues (Rattermann & Gentner, 1991, Gentner & Rattermann, 1998, Loewenstein & Gentner, 2005) and Mutafchieva and Kokinov (Mutafchieva & Kokinov, 2007a, 2007b, 2008), because both lanes of research intend to study the role of different factors in facilitating children's performance in transitive relational mapping task. In another direction the experiment is closely related to the study of Smith (Smith, 2005). She claims that action alters shape categories formed by children. That is why a brief review of these experiments is necessary.

The design of our experiment is based on the study of Gentner and Rattermann (1991, 1998). They 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 experimenter 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 absolute size as the object pointed by the experimenter, but different relative size (e.g. was the smallest in the child's set). Pitting against each other the absolute and relative size the researchers intended to study whether children will prefer to base their answer on the surface or on the structural similarity (e.g. on the similarity between attributes and objects or on the similarity between relations). 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 Gentner et al. provided family language labels calling the set *family* and the particular objects *Dady, Mommy and Baby*. When language labels were involved the 3 years old children were correct in 87-89% of the trials. This rather significant improvement was attributed to the use of language relational labels which focused the child's attention towards the relations and they encoded and used them.

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

Our previous experiments aim to further explore the reason why relational terms are helpful for children and whether there is an alternative way to facilitate children in transitive relational mapping.

In our previous studies we have used the same task as the one in Gentner's study. In one particular experiment (Mutafchieva & Kokinov, 2007b) we are 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 we used physical objects (draw-bars) as representing the relation "stronger than" 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.

The idea of using action, which we are trying to explore in the current paper, can be traced in a study of Smith (2005). She suggests that action has a specific role in the development process of object recognition between 1 and 3 years of age. In the experiment children were given a 3-dimensional object which is called *"a wug"*. Children had done different actions with the object (holding it, moving up and down). At the second step the child was given two different objects and was asked which of them is also "a wug". The researchers hypothesised that the children will choose the vertically-extended object when they had moved the object along a vertical path and in another condition the child will choose the horizontally-extended object when they had moved the object along a horizontal path. She studied 30 months-old children and there were two procedures and five different conditions. In the forced-choice procedure in the training trials of two Action conditions the child and the experimenter moved the object three times either in horizontal or vertical way. In the test trials the experimenter presented two objects to the child and asked "Where is the wug?" There were two more conditions which differed from the Action conditions by the fact that only the experimenter moved the object while the child only observed this movement without moving the object himself or herself. In one condition the object was moved in a horizontal pathway again, and in another condition was moved in a vertical pathway.

In the fifth condition the experimenter only named the object several times without moving it. The child did not move the object either.

The "yes/no" procedure was exactly the same as "forced-choice" procedure except the fact that the test question required yes/no answer – "Is this a wug?" The results in both procedures in Action conditions showed that children chose the horizontally extended test object when they moved the exemplar along a horizontal path, but chose the vertically extended object when they had moved the exemplar along the vertical path. Children's choices in no-action conditions were at the chance level. In the two conditions in which the children only observed the experimenter to move the exemplar horizontally or

vertically there were no systematic directional effects, e.g. the observation of the experimenter's moving the object in a vertical path was not sufficient to choose the vertically extended object. In the second experiment Smith studied the generality of the phenomenon by examining the case of symmetry. The results are consistent with the previous ones.

The results of these two experiments show that action has a strong influence on the range of shapes 2 year-olds take as being similar and appear to do so by defining axes of elongation and symmetry.

Smith proposes several explanations of the results. First of them is that children probably make an association between action and shape. Children's hand movements may be systematically related to the shape and there is a general knowledge that objects are moving on paths parallel to their long axes. If this association is specifically for motor action and shape, this could explain why watching the experimenter's action is not sufficient to influence the shape judgment in the same manner. Another explanation could be found in iconicity between action and perceived shape. Smith suggests that body movement may increase the similarity between objects because of the cross-modal correspondence between hand movement paths and aspects of visual shape and the increasing of similarity influences the selection of one object as "a wug". Yet another explanation could be ascribed to the role of visual motion – the effect of action on shape judgments is mediated by effects of visual motion of shape, for example moving edges of a form. Smith points out that this interpretation could not explain why when watching the experimenter's action the effect is dissimilar in comparison to doing the action. One possible explanation, provided by Smith, is that children's visual attention to the object is more focused when they are acting rather than watching another's action. Finally, Smith claims that it is also possible that there is some form of lower level recruitment by the motor system of the visual processes central to shape perception.

Alternative explanation could be found in the assumptions of Hommel (Hommel, Müsseler, Aschersleben, & Prinz, 2001; Hommel, 2002). He has proposed and found evidence that spontaneous integration of features of external objects also includes action-related spatial information. The represented spatial codes are very important for action planning. He claims that object representation includes spatial and nonspatial information of object's attributes which are bound into a single object file. This "object file" or object representation might subserve object perception and guidance of action. This is called by Hommel *action-related object representation*. He found out that the construction of action-related object representation takes time and the time lies between a quarter to half a second. The encoding of spatial information (object's location) facilitates the recognition of the object, but Hommel enriched this claim by saying that spatial information is also functional in planning an action associated with this object or includes information about what action it affords.

The main idea of this paper is to use action as representation tool for the relations and to find out whether movement could replace the use of physical objects. In addition since the object is always present, its mental image is refreshed all the time and thus hold active in memory during the mapping process; in contrast, the action is performed once and at the time of the mapping will not be present. This could lead to better results in the condition with physical object in comparison to the condition with action. Basically, the task contains two sets of animals – three for the experimenter and three for the child. There is small, medium and big animal in every set and the child has to choose the same relative size animal as the one chosen by the experimenter. In one condition we have used the draw-bars in order to represent the relation "stronger than", and in other condition we have used the action of "pulling" for the same representational purpose.

Experiment

The goal of this experiment was to find out whether physical action will be able to replace the physical object as a representation of relation – in other words whether children will be as good in making transitive relational mapping when using action "pulling" as they are when using physical object "draw-bar". These two conditions will be compared to a condition, where only visible connections between objects or undirected draw-bars are used.

Hypothesis

Our hypothesis was that the physical action of "pulling" will be as useful as the physical object in representing the relation "stronger than" and both ways will facilitate children in making transitive relational mapping.

The idea of using the draw-bars as physical representations of the relations was first introduced in (Mutafchieva & Kokinov, 2007b) and turned out to be very effective in facilitating children in transitive relational mapping task. Now we want to compare this tool with physical action and to extend the idea of using different kinds of representations of the relations.

Design

The experiment had between group design:
- **Control condition:** both sets of objects were connected via **undirected** draw-bars; no physical action of "pulling" was used.
- **Embodiment condition:** the objects in both sets were connected via **undirected** draw-bars and physical action of "***pulling***" was used in order to represent the relation.
- **Directed Draw-bar condition:** both sets of objects were connected via **directed** draw-bars and no physical action of "pulling" was used.

The dependent variable was the number of relational responses.
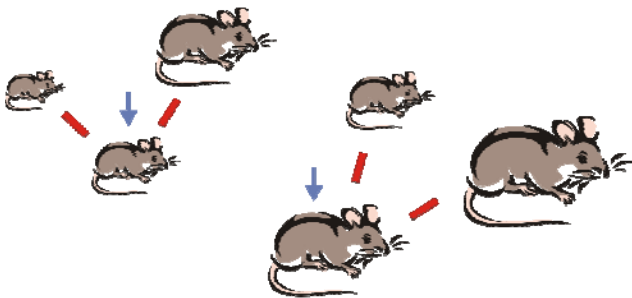
Stimuli

In each trial 6 animals of the same type were used: 6 mice, 6 swans, 6 bears, etc. Each animal among group of 6 was of different size except two animals with the same absolute size. Three of the animals formed the experimenter's set and three of them formed the child's set. There was big, middle

and small animal in every set and there was a difference in the absolute size of the corresponding objects from two sets – for example the biggest mouse from the experimenter's set and the biggest mouse from the child's set were different in size. One element from the child's set was exactly the same as one element in the experimenter's set.

In this experiment the stimuli were presented in a triangle configuration. In every trial different sets of stimuli with different spatial positions and absolute sizes as well as different animals were used.

In addition, four directed and four undirected draw-bars were used – two for the experimenter's set and two for the child's set for both conditions.

Figure 1. Example of the stimuli used in the Control condition where the animals were connected via undirected draw-bars.
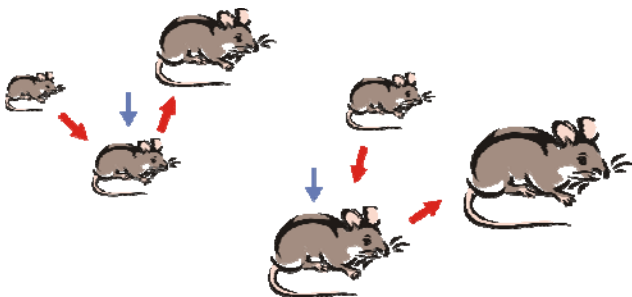
Figure 2. Example of the stimuli used in the Draw-bar condition where the animals were connected via directed draw-bars.

Procedure

In each trial the child saw two triads of objects, both arranged in a triangle way. The child watched the experimenter hid 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. 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 instruction for the Control Group in the test trials was (in Bulgarian language):

*"We are going to play a game of hiding and finding stickers. I have three mice and you have three mice. From these two of my mice (pointing e.g. to the biggest and the medium mouse 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 mouse 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 mouse could pull the weaker mouse. Now, from these two of my mice (pointing e.g. to the medium and the smallest mouse 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 mouse 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 mouse could pull the weaker one. I am going to hide my sticker **under this mouse**. Where do you think your sticker is hidden?"*

The corresponding instruction for the Directed Draw-bar Group in the test trials was the same as in the Control condition. The difference was that in the Directed Draw-bar condition were used directed draw-bars in contrast to the undirected draw-bars in the Control condition (Fig.1 and 2).

The instruction for the Embodiment group was following:

*"We are going to play a game of hiding and finding stickers. I have three mice and you have three mice. From these two of my mice (pointing e.g. to the biggest and the medium mouse in the experimenter's set) this one is stronger than this one and I will connect them with this and will pull in a way that that the stronger mouse could pull the weaker one. From these two of your animals which one is the stronger one? Please, connect them and pull in a way that the stronger mouse could pull the weaker one. Now, from these two of my mice (pointing e.g. to the medium and the smallest mouse from the experimenter's set) this one is stronger than this, I will connect them and will pull in such a way that the stronger mouse could pull the weaker one. From these two of your animals which one is the stronger one? Please, connect them and pull in such a way that the stronger mouse could pull the weaker one. I am going to hide my sticker **under this mouse**. Where do you think your sticker is hidden?"* (Fig.3).

Figure 3. Example of the stimuli used in the Embodiment condition. On the picture only two animals are seen and the action "pulling". The instruction was "This mouse is stronger than this mouse; please pull in such a way that the stronger mouse pulls the weaker one." This instruction is then repeated for the second relation.

Participants

75 children were studied in this experiment. 25 of them formed the Control group, 25 formed the Draw-bar group, and 25 formed the Embodiment group.

The average age of the children was 4 years and 4 months ranged from 4 years and 0 month to 4 years and 8 months.

Results

The descriptive statistics are presented in Table 1.

Group	Mean	Std. Deviation	N
Control=undirected draw-bars	1,76	1,332	25
Embodiment=undirected draw-bar + pulling	2,56	1,387	25
Directed draw-bars	2,80	1,607	25

Table 1: Group Statistics

The mean for the Control Group is 1.76 (out of 5), which is at the chance level, while the mean for the Directed Draw-bar group is 2.80, and the mean for the Embodiment group is 2.56, which are significantly above the chance level.
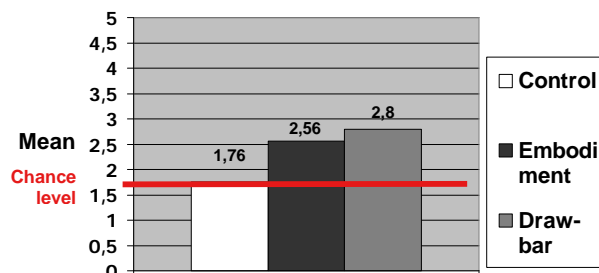
Figure 4. Score means for the three groups, F(2,72)=3,541, p=0.034

Pair-wise comparison shows that both the Draw-bars group and the Embodiment group perform significantly better than the Control group (T(48)=-2,491, p=0.016, and (T(48)=2,080, p=0.043, respectively), but no difference is found between the Embodiment group and the Draw-bars group (T(48)=-0,565, p=0.575).

General Discussion

The obtained results support our main hypothesis that motor actions can successfully represent the relations and are as effective as the physical objects as representation means. That is why both the action (of pulling) and the physical object (directed draw-bars) facilitate children's transitive relational mapping performance.

Mutafchieva and Kokinov (2007b) have speculated that one possible reason why young children have difficulties with the transitive mapping task is that relations are difficult to be detected (perceived) in the environment and then they are difficult to be remembered. That is why they designed the draw-bar objects as device for capturing children's attention and directing it to the relation between the objects rather than to the objects themselves. We the current experiment we have demonstrated that not only objects, but also motor actions can be effective in drawing the attention of children to the relations.

As far as the second role is concerned the objects (the draw-bars) were present at the test phase and therefore, if they do represent the relation, they are available for usage during the mapping process. Thus it is not necessary for the child to remember the direction of the relation when it is represented by a directed draw-bar, because the object is present at mapping and he/she only has to look at it. However, this is not the case with the action. It is not present at the time of mapping and thus children have to remember that the stronger animal pulls the weaker one and recall the action of pulling. That is why the results of this experiment are even more intriguing because regardless of the heavier memory load, the action seems very effective in representing relations. This might be a result of internal mental simulation of the action that is easy to reconstruct.

An obvious next step would be to improve the procedure by repeating the action several times (it is now performed just once) thus forming a better memory for the action. Another question will be whether the children really need to perform the action, or it would be enough for them to observe it performed by the experimenter. There are arguments in both ways: embodiment theory would predict that performing the action will have a stronger effect than observing it; on the other hand, mirror neuron theory would argue that observing someone performing an action will activate our motor system and the corresponding action representations and therefore no significant difference is expected. This would be a nice parallel to the study by Smith (2005).

The main conclusion for the moment is that the motor action, in its current form, can successfully replace the physical object as it facilitates children's performance in the mapping task.

References

DeLoache, J. S. (1989). Young children's understanding of the correspondence between a scale model and a larger space. *Cognitive Development*, 4, 121-139.

Gentner, D. (1983). Structure–mapping: A theoretical framework for analogy. *Cognitive Science, 7, 155-170.*

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

Gentner, D. (1989). Mechanisms of analogical learning. In S. Vosniadou and A. Ortony, (Eds.), Similarity and Analogical Reasoning, 199-241. London: Cambridge University Press.

Gentner, D., & Rattermann, M. J. (1991). Language and the career of similarity. In S. A. Gelman &. J. P. Byrnes (Eds.), Perspectives on thought and language: Interrelations in development (pp. 225-277). London: Cambridge University Press.

Gentner, D., Rattermann, M.J., Markman, A., & Kotovsky, L. (1995). Two forces in the development of relational similarity. *In G. Halford & T.Simon, Developing Cognitive Competence: New Approaches to Process Modeling (Eds.). Hillsdale: Erlbaum.*

Gentner, D., & Loewenstein, J. (2002). Relational language and relational thought. In Amsel, E. (Ed); Byrnes, J.P. (Ed). Language, literacy, and cognitive development. The development and consequences of symbolic communication, pp. 87-120.

Goswami, U. (1995). Transitive relational mappings in 3- and 4-year-olds: The analogy of Goldilocks and the Three Bears. *Child Development, 66, 877-892.*

Goswami, U. (1996). Analogical reasoning and cognitive development. In H.Reese (Ed.). Advances in Child Development and Behavior, 92-135. San Diego. CA: Academic Press.

Goswami, U., Pauen, S. (2005). The effects of family analogy on class inclusion reasoning in young children. *Swiss Journal of Psychology, vol. 64, n 2, pp. 115-124*

Halford, G.S. (1984). Can young children integrate premises in transitivity and serial order tasks? Cognitive Psychology, 16, 65-93

Halford, G. (1993). Children's understanding: The development of mental models. *Lawrence Erlbaum Associates, Publishers, Hillsdale, New Jersey.*

Halford, G. (1998). Relational processing in higher cognition: Implications for analogy, capacity and cognitive development. In K. Holyoak, D. Gentner, B. Kokinov (Eds.) Advances in Analogy Research: Integration of Theory and Data form the Cognitive, Computational, and Neural Sciences. New Bulgarian University, Sofia.

Halford, G. (1998). Processing capacity defined by relational complexity: Implications for comparative, developmental, and cognitive psychology. *Behavioral and Brain Sciences, 21, 803-864.*

Hommel, B., Müsseler, J., Aschersleben, G., & Prinz, W. (2001). The theory of event coding (TEC): A framework for perception and action planning. *Behavioral and Brain Sciences*, 24, 849-878.

Hommel, B. (2002). Responding to object files: Automatic integration of spatial information reveale d by stimulus-response compatibility effects. *Quarterly Journal of Experimental Psychology*, 55A, 567-580.

Hommel, B., & Klippel, A. (2007). Embodying spatial maps. *Proceedings of AAAI Spring Symposium on Control Mechanisms for Spatial Knowledge Processing in Cognitive / Intelligent Systems.* AAAI Press.

Inhelder, B. and J. Piaget (1958). The Growth of Logical Thinking from Childhood to Adolescence. New York: Basic Books.

Inhelder, B. and Piaget, J. (1964). *The Early Growth of Logic in the Child: Classification and Seriation.* London: Routledge and Kegan Paul.

Loewenstein, J. & Gentner, D., (2005). Relational language and the development of relational mapping. *Cognitive Psychology, vol. 50, pp. 315-353.*

Mutafchieva, M. & Kokinov, B. (2007a). Does the Family Analogy Help Young Children To Do Relational Mapping? In: *Proceedings of the European Cognitive Science Conference*. Erlbaum, Hillsdale, NJ.

Mutafchieva, M. & Kokinov, B. (2007b). Can Language be Replaced? Physical Representations of Relations Instead of Language Labels in Relational Mapping: Do They Help Young Children? In: *Proceedings of the 29th Annual Conference of the Cognitive Science Society.* Erlbaum, Hillsdale, NJ.

Piaget, J. (1971). *Biology and knowledge*. Edinburgh: Edinburgh University Press

Rattermann, M.J., & Gentner, D. (1998). The effect of language in similarity: The use of relational labels improves young children's performance in a mapping task. *In K. Holyoak, D. Gentner, & B. Kokinov. Advances in Analogy Research: Integration of Theory and Data from the Cognitive, Computational, and Neural Sciences. New Bulgarian University, Sofia.*

Smith, L.B. (1989). From global similarities to kinds of similarities: the construction of dimensions in development. *In S. Vosniadou and A. Ortony (Eds.), Similarity and analogical reasoning.* Cambridge University Press, Cambridge.

Smith, L. B. (2005) Action Alters Shape Categories. *Cognitive Science*, Vol. 29, 665-679