

Does the Family Analogy Help Young Children To Do Relational Mapping?

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Abstract

The experiment described in this paper tests the hypothesis that since the *family* is very familiar relational structure to even young children, the relational mapping between sets of objects will be significantly enhanced if children are invited to make an analogy with the family. This research is based on Gentner and Rattermann's, and Goswami's work in the same direction and tries to further extend it. The results present for the first time experimental support of Halford's hypothesis that the family analogy can help 4 years old children to manage the transitive mapping task. They can manage it even with non-monotonically displayed objects.

Introduction

In this paper we explore young children's ability to make transitive relational mapping, i.e. to map two sets of linearly ordered relations ($A>B>C$ and $X>Y>Z$). Why is this task important? It is of some interest because it is related to transitive inference ($A>B$; $B>C$, therefore $A>C$) and our ultimate goal to test whether transitive inference may benefit from analogy with a more familiar domain. The specific subgoal that is pursued in this paper is to find out whether analogy-making with a third set of objects may help children to accomplish the transitive mapping task. Let us now unfold our theoretical motivation.

Piaget argues that transitive inference is a concrete operation being a simple version of a deductive task that is closely related to the concrete set of objects and is a smooth transaction towards more abstract formal deductive reasoning operations. Thus according to Piaget an understanding of transitivity emerges around 6-7 years of age (Inhelder & Piaget, 1958, 1964, Piaget, 1971). Many researchers have questioned this belief. They demonstrated in various ways that the initial experiments by Piaget failed to demonstrate children's ability to make transitive inference before 6-7 years of age, mainly due to the heavy memory load of the task and when this load is reduced or eliminated they do demonstrate transitive inference abilities (Bryant & Trabasso, 1971; Halford, 1984; Pears & Bryant, 1990).

Halford (1993) proposed a new theory about logical development. He linked transitivity directly to the development of relational mapping in children. He proposed that the ability to map binary relations (relations that link two objects) or to make relational mapping occurs approximately at the age of two, and that mapping of ternary relations (relations that link three items) or system mapping

is available at the age of 5. Since, according to him, the ability for system mapping is closely related to the ability to make transitive inferences, the development of the transitive inference capacity is due to the development of the processing capacity of children, such as the ability to map complex relations.

Contrary to Piaget and his collaborators (Piaget, 1971; Inhelder & Piaget, 1958, Piaget) currently most researchers believe that analogy-making is a very basic ability and is present from early infancy (Gentner, 1989, Goswami, 1991, 1996, 2001; Halford, 1993). Thus an interesting hypothesis put forward by Halford (1993) is that logical development is analogical in its nature and children solve transitive inference problems by making analogies to an ordering schema that represent ternary relations between objects in the real world. And since the "family" domain is very familiar to young children it can serve as an excellent source of analogy for solving various tasks, including transitive reasoning tasks, class inclusion problems, etc. Gentner and Rattermann (1991), Goswami (1995), Rattermann and Gentner (1998), Goswami and Pauen (2005), Loewenstein & Gentner (2005) have empirically explored various aspects of this hypothesis and the current paper tries to shed further light on this possibility. More specifically we will explore the role the analogy with the family can play in the transitive mapping task.

Previous Experimental Studies

There are two lines of studies related to our research in this paper. Gentner and her colleagues (Rattermann & Gentner, 1991, Gentner & Rattermann, 1998, Loewenstein & Gentner, 2005) have studied *the role of language*, and more specifically the use of relational labels (relational words), in the development of relational mapping capacity. Goswami (1995) has studied *the potential role analogy* may play in the development of transitive mapping. We are trying to combine the two approaches and further extend them.

In the first line of studies Rattermann and Gentner (1991, 1998) examined young children's ability to spontaneously notice relational mapping and whether the use of relational labels would draw children's attention towards relations. They were not specifically interested in whether the analogy can play a role in that process.

They modified an experimental paradigm used by DeLoache (1989) where children would have to find an object hidden in the room that would analogically correspond to the place in the room model. Rattermann and Gentner used two sets of stimuli – one for the child and one

for the experimenter. Each of the sets consists of 3 objects (clay pots or blue plastic boxes) which are linearly ordered, i.e. increase in size (or decrease in size) monotonically. The experimenter points to one of her objects and the child would have to find the corresponding object in his/her set. The experimenter and the child play a game in which the experimenter hides a sticker under one of her objects and the child has to find her sticker under the corresponding objects of her. The stimulus set is designed to form cross-mappings, i.e. there is an object in the child's set that is exactly the same as the pointed object in the experimenter's set, and another one which is in the same relative position, although it is different in absolute size (and in some experiments also in its category). Thus superficial mapping was pitted against relational mapping. If the child chooses the corresponding relative size object (large, medium, or small) then her response is based on the relational similarity between the sets, but if she chooses the object with the same absolute size, then she relies on object similarity. In order to study the effects of object similarity, Rattermann and Gentner manipulate the degree of similarity between objects by varying the richness and distinctiveness of the stimulus (in the rich condition superficial similarity is based not only on size, but also on category – house, car, cup).

The results show that both age groups – 3- and 4-years-old find relational mapping quite difficult (only 47% of the responses are relational). There is an effect of the richness of the stimuli; children perform better in the simple set of the stimuli (54% relational responses for the 3-year-olds and 62% relational responses for the 4-year-olds) than in the rich set of the stimuli (32% relational responses for the 3-year-olds and 38% relational responses for the 4-year-old children). Thus spontaneous focusing on relations is not very common.

In a following up study Rattermann and Gentner explored if relational labels can direct children's attention to relations. They used labels like "Daddy", "Mummy" and "Baby" or "big", "small", and "tiny" for both stimulus sets, naming the objects on each trial. The assumption is that children at 3 are very familiar with these words.

The results show significant difference between the children's performance with and without labels. Rattermann and Gentner conclude that using familiar language labels can improve children's performance in transitive mapping task. Thus children and adults are possibly using the same similarity comparison processes and there is a change in the domain representation rather than a change in the cognitive competence. Thus the acquisition of language, specifically relational language, is an important contributor to this development.

There was no difference between the labels "Daddy, Mummy, Baby" and "Big, Small, Tiny" – 89-90% relational choices in 3 years old children. The assumption is that both have the same properties: ternary ordering relations which are well-known to the children. Loewenstein and Gentner (2005) performed a new series of experiments in which they explored various spatial relational labels, such as "on, in, under" and "top, bottom, and under". They found that "top, bottom, and under" has a much better effect. They explain the difference by the arity of the relations: "on", "in", and

"under" are examples of binary relations (they have two arguments), while "top, middle, bottom" is a ternary relation and thus contributes to the system mapping required for the transitive relational mapping.

There are a number of issues which are still problematic after these studies. The main issue is whether children can use some short-cut heuristics bypassing the transitive relational mapping and still get the same results. One such possibility is to use the location of the objects and respond with the "same location" regardless of the size of the objects. This strategy is possible because of the monotonically increasing size of the objects. Rattermann and Gentner argue that since the two sets are not exposed on parallel lines, but rather diagonally, this strategy cannot be used. On the other hand, they believe that monotonically increasing size of the objects is important because the transitive relation is one of linear order and if we present the objects in a random way children will be lost. Another potential weak point of the methodology is that naming the two sets by "Daddy", "Mummy" and "Baby" we give a chance to children to map the labels, instead of the objects. Thus they do not need to consider the rest of the objects in the set, they just need to remember who the "Mummy" was in this trial. A contra argument would be that still the children themselves decided who the "Daddy", "Mummy" and "Baby" are in their set and therefore they were able to do the mapping.

Goswami (1995) decided to test these possibilities and conducted three experiments, which examine young children's ability to map transitive size relations when both the spatial positions of the corresponding objects and the absolute size of the stimuli were systematically varied. In addition, in the naming condition, only the experimenter named her objects "Daddy", "Mummy" and "Baby", but not the child, thus precluding the possibility of mapping the labels. In addition, she was explicitly interested whether an analogy with a familiar domain may help children in the transitive mapping.

She used again two identical of size sets of plastic colored stacking cups and the sizes of the corresponding cups in the two arrays were different in every trial. The cup color per se cannot be used to find the correct solution.

The child was told that the experimenter was going to choose one cup from her array and that to play this game he/she had to select the same cup from his/her array. The analogy was provided by the story about the "Goldilocks and the Three bears" in order to support the mapping task.

The results showed that children found the mapping task easy, because the mapping performance was extremely good, averaging around 80-90% correct in most of the manipulations. Changing the absolute size (and the color) of the cups caused a slight drop in the performance (around 10-15%), and so did the varying spatial positions of the corresponding cups. The results of this experiment showed that there is no significant influence of the analogy on the performance of the children in this kind of mapping task.

The second and third experiment in this study were designed to answer if the young children mapping performance would be so successful if the transitive size relations were represented by two different sets of objects

that differ in different dimensions (size in one set and proportion in the other) and if the relations between objects are mental, rather than directly observable. In order to answer the first question, Experiment 2 used two different types of stimuli – stacking cups and pictures of different proportions – for example one-half of a circle and one-fourth of a pica. The results showed that 3-year-old children found the cross-representational mapping task more difficult than 4-year-old children. The older children were less affected by changes in the spatial positions as well. The performance was significantly above chance – the lowest result was 54% for the 3-year-old children in Different Spatial Position Group.

In Experiment 3, the children were told a story of being in the Three bears' house and were told to imagine a different things they could find there. A number of different perceptual dimensions were also included in the context of the story about Three bears – for example loudness (of footsteps), pitch (of voice) and est. The results showed that 4-year-old children were successful in mapping transitive size relations onto various dimension (such as loudness, pitch, etc.), although they found some of the dimensions easier than the others. The majority of the responses of 3-year-olds were not relational.

Goswami concludes that children as young as 3 and 4 years of age can make transitive relational mappings based on size even when the size of the objects do not increase monotonically and the relative spatial position of the corresponding objects in the two sets differ. Four-years-old children are successful even when the presented transitive relations are rather abstract and represented mentally rather than directly observable. In contrast, 3-year-old children can only reliably coordinate and map relations when they are visually presented.

The three experiments examined the same children, so, there could be a training effect that was not measured, and it is not clear if the children would obtain the same results in the absence of prior experience.

To summarize the results from the previous studies it is clear that contrary to Piaget assumptions and even Halford's predictions 3 and 4 years old children are able to accomplish complex transitive relational mapping when they are supported by the use of relational language. As Rattermann and Gentner write relational terms invite the representation and use of relations.

A major still unresolved problem is the lack of support for the postulated by Halford role of analogy in transitive mapping. Rattermann and Gentner's results do not differentiate between "Daddy", "Mummy" and "Baby" on one side, and "big", "small", and "tiny" on the other. The first set of labels invites an analogy with the family domain, while the second does not, but the results were equivalent. Thus it seems that it is not the analogy, but rather the use of ternary relational terms that matters. Goswami's attempt to demonstrate the role of analogy by providing the Goldilocks story also failed – there was no difference between the analogy and non-analogy groups. Thus we decided to further explore the possible role of analogy using a similar experimental paradigm.

Experiment

The goal of our study was to find out whether the family domain makes any difference in a transitive relational mapping using relational labels, i.e. to explore the analogy effect. This will be tested under the severe conditions when the objects in the two sets have different spatial positions and do not increase monotonically.

Hypothesis

Our hypothesis was that 4 years old children will succeed in transitive relational mapping significantly better when the relational terms "Daddy, Mummy and Baby" are used than when the relational terms "Big, Medium, Small" are used, i.e. that in addition to the naming effect (the use of relational terms) there will be also an analogy effect because the relational terms "Daddy, Mummy and Baby" activate their knowledge about the family domain, while "Big, Medium, Small" does not.

Design

The experiment has a between group design and the factor is presence or absence of the family analogy:

- **Analogy condition:** the five mapping trials were presented by naming the objects in the experimenter set a "family" and the individual objects were called "Daddy", "Mummy", and "Baby" (the instruction is described in the section Procedure).
- **Control condition:** the five mapping trials were presented with naming the objects in the experimenter set "Big", "Medium", and "Small" without calling them a "family" (the instruction is described in the section Procedure).

The dependent variable was the number of relational responses.

Stimuli

In each trial one set of animals was used which consists of 6 animals of the same type: 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 (See Figure 1). Different sets of stimuli with different sizes and spatial positions as well as different animals were presented in every task.

Five transitive relational mapping tasks were presented to every child plus two in the training session. The five transitive relational trials were designed to fulfill 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.

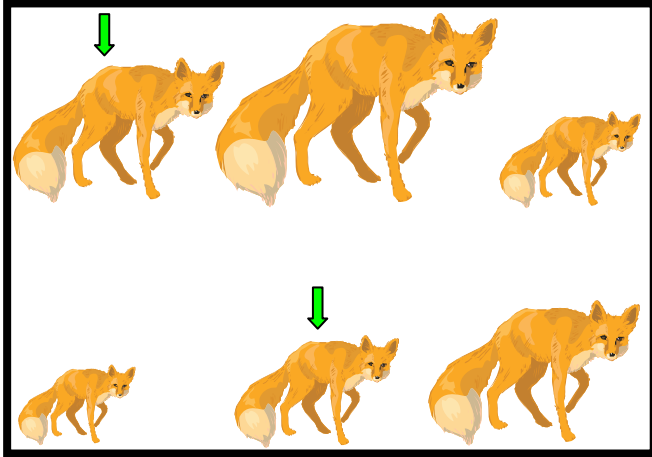


Figure 1. An example of the stimulus material for one trial.

Procedure

In each trial the child saw two triads of objects, both arranged in a random way (not always in monotonically increasing or decreasing order of size). 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) or the same relative position (because the spatial positions in the two sets varied in every trial). The children were always given a feedback by showing the correct response (and receiving the sticker) after their guess.

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 asked.

The test trial began with the following instruction for the Control Group:

"We are going to play a game of hiding and finding stickers. I have three foxes and you have three foxes. From my foxes this is the big fox, this is the medium one, and this is the small one. Please, tell me from your foxes which is the **big fox**, and the **medium one**, and the **small one**? Now, I am going to hide my sticker under my medium fox, where do you think your sticker is hidden?"

The instruction for the Analogy Group was the following:

"We are going to play a game of hiding and finding stickers. I have a family of foxes and you have a **family** of foxes. From my family the biggest fox is **Daddy fox**, the medium one is **Mummy fox**, and the smallest one is **Baby fox**. Please, tell me from your family which is **Daddy fox**, which is **Mummy fox**, and which is **Baby fox**? Now, I am going to hide my sticker under my **Mummy fox**, where do you think your sticker is hidden?"

Participants

Forty children were studied in this experiment; the average age of children was 4 years and 4 months, ranging from 4 years to 5 years. Nineteen from children formed the Control Group, and 21 formed the Analogy Group.

Results

Data shown in Table 1 show the group statistics and Figure 2 and 3 show the difference between the groups. The mean for Control Group is 2,79 correct responses out of 5, and the mean for the Experimental Group is 4,10 correct responses out of 5. Both groups perform at a level much higher than the chance level (for the control group the difference is significant $T(18)=3,627$, $p=0,002$) thus replicating the results of Rattermann and Gentner (1998) and Goswami (1995) that the use of relational labels improves the performance of young children. In addition, however, we obtain a significant difference between the control group and the experimental group ($T(38)=2,844$, $p=0,007$) therefore demonstrating that the family labels are better facilitators than the size relational labels.

GROUP	N	Mean	Std. Deviation
Control	19	2,79	1,357
Experimental	21	4,10	1,546

Table1.Group Statistics.

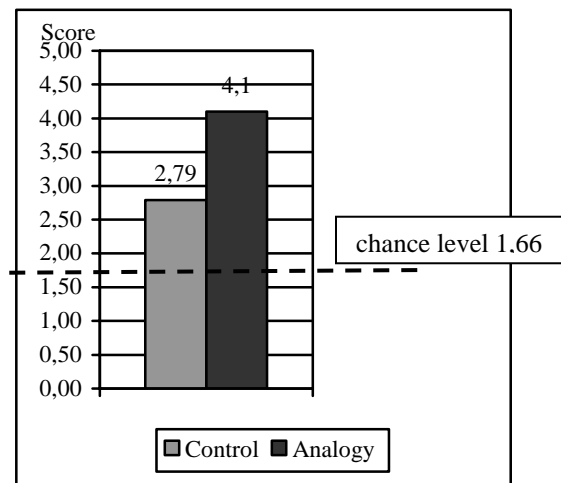


Figure 2. Score means for the two experimental groups.

$T(38)=-2,844$, $p=0,007$

The percentage of relational choices are 55,8% for the control group and 82% for the analogy group (chance level 33%). The Analogy group is comparable to Goswami's results in a similar condition: 71% of relational responses (Goswami, 1995).

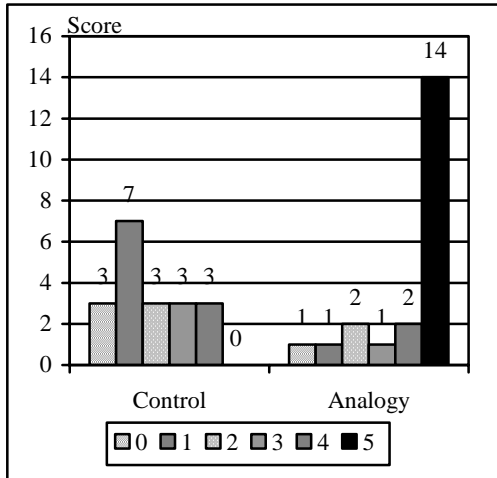


Figure 3. Number of children with each raw score in both groups.

The comparison of the two groups is even more evident if we consider the number of children with each raw score in both groups (Figure 3). As one can see in the figure, in the analogy group 14 out of 21 children responded always relationally, while 7 out of 19 children in the control group responded relationally only 2 times out of 5.

Group	Relational responses	Object-similarity responses	Other responses
Analogy	82%	8%	10%
Control	54%	20%	26%

Table 2. Percentage of the relational answers in the control and the analogy groups.

A more detailed description of the data can be seen in Table 2: 69,5% from all children’s answers were relational responses, and only 13% from all answers were based on the surface similarity. In the Control Group 54% of all responses were based on relational similarity versus 82% for the Analogy Group; 20% from all responses in the Control Group were based on the surface similarity versus 8% from all responses in the Experimental Group. 26% from the responses in Control Group were based on strategies different from relational and surface similarity versus 10% for responses in the Analogy Group.

Discussion

The results clearly demonstrate that the children in the Analogy group performed better than in the Control group. Thus the main hypothesis of this study was confirmed: Analogy does facilitate transitive relational mapping. Since both conditions (control and analogy) used ternary relational terms the difference is not due to the structure of these relations (which is the same) but is due to the content. While in the case of “big”, “medium”, and “small” only the abstract terms are used (i.e. only the language effect is present), in the case of “Daddy”, “Mummy”, and “Baby” the family domain is invited and used as a base for analogy in addition

to the language effect. This results supports Halford’s claim about the effect of family analogy.

Our data showed also that monotonic increase of size is not a necessary condition for relational labels to improve performance on the transitive mapping task. Thus this finding extends the results obtained by (Gentner & Loewenstein, 2002).

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