

Can Analogy Help Children Make Transitive Inference?

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Abstract

This paper is exploring whether analogy-making as an early developing ability could potentially help children to develop deductive reasoning ability and in particular, transitive inference. Two experiments are presented. In the first one transitive mapping is explored further to make sure children at the age of 4 can do the transitive mapping task even when all three objects are hidden and no perceptual clues are available. After demonstrating that children can do that, the second experiment shows that the train analogy can help children correctly solve the transitive inference task. The empirical findings support Halford's suggestions that deductive reasoning is being developed on the basis of children's ability to make analogies.

Introduction

Transitive inference is an important deductive reasoning ability. Based on the two premises – $R(a,b)$ and $R(b,c)$ – a conclusion is made that $R(a,c)$. This can be true both for symmetric relations like “equals”, “similar to”, etc. and for asymmetric ordering relations like “bigger than”, “smarter than”, etc.

According to Inhelder and Piaget (1958, 1964) transitive inference is a relatively late developing ability and up to the age of 8 children fail to solve transitive problems based on size. For other dimensions such as weight and volume this happens even later on – up to 9 or 11. There are two main reasons for this failure according to them: the inability to do seriation and to understand relational reversibility and relativity.

Seriation refers to the ability to order a set of objects according to a single dimension, e.g. length. Seriation is mastered by children at the age of 6,5-7 according to Piaget.

Reversibility of relations means to understand that if I have a brother named John, then John also has a brother – me; that if John is taller than me, then I am shorter than John, etc. The relativity of relations requires the understanding that relations are not absolute attributes of the objects and therefore it is possible that John is “taller than” me, but “shorter than” Paul. This is important for transitive inference because the middle term is always in such a double position to the other two terms.

Sternberg (1980) introduced another form of the transitive inference task, namely “A is shorter than B”, “B is shorter than C”, “who is the shortest?”. We will be using this form in our experiments.

According to the “spatial model” (DeSoto, London & Handel, 1965, Huttenlocher, 1968) transitive inferences are

made on the basis of a spatial mental model built during the process of understanding of the premises. This model predicts that the transitive inference task will have various degrees of difficulty depending on how easy it is to map the situation to a linear spatial array. In our experiments we use a triangle configuration, which makes the task even harder for the children. The triangle configuration has certain advantages, however. It makes all three positions equal and makes their choice equally possible. More importantly, it allows all three relations between pairs of objects to be physically represented which is important in our experiments as we will see later on.

Bryant and Trabasso (1971) raised the memory issue related to the transitive inference task. It is clear that children have to remember the two premises in order to be able to make the conclusion. Thus, if they fail to correctly remember or recall who is bigger than whom, they cannot be expected to correctly make the inference. Bryant and Trabasso eliminated the memory problem by training children to associate length with color (red is always longer than green) and later on they provided the color as a visual cue during the transitive inference task. They used 5 objects instead of three and then tested the children with two objects that were never compared directly during the training phase. These experiments were hoping to demonstrate that the transitive inference failure in young children is due only to the memory problems, but otherwise children can reason deductively like adults. The experiments were criticized for their long training phase and that is why Pears and Bryant (1990) designed a new experiment in which the training phase was eliminated.

Kokinov (1990, 1992) put forward the hypothesis that deduction, induction, and analogy are actually performed by a single common mechanism, which was initially developed for analogy making and then adapted for usage in deductive and inductive reasoning. He presented empirical support for this claim from experiments with adults.

Halford (1993) also claimed that the development of deductive reasoning is based on the development of analogical reasoning and suggested the idea that the family domain that is very familiar to young children can be used as a base for analogy in various deductive tasks.

A series of experiments has been performed by Gentner and her collaborators (Gentner & Rattermann, 1991, Goswami, 1995, Rattermann & Gentner, 1998, Gentner & Loewenstein, 2002) that demonstrate that children can successfully perform on a transitive *mapping* task, i.e. they can map items with the same relative position (e.g. same

relative size) in a linearly ordered set of three objects to objects in another linearly ordered set. The results from the mapping task are a necessary condition for the analogy to be able to be used spontaneously in a transitive inference task; however, it is not sufficient and the *transitive inference* task per se was never given to children. It was always the mapping task that has been used. Gentner and colleagues demonstrated that when language labels were provided (such as “Daddy”, “Mommy”, “Baby”) children became better in the mapping task.

Goswami (1995) explicitly tested Halford’s prediction about the role of the family analogy. She used the transitive *mapping* task again and provided the Goldilocks story as an analogy which was supposed to help children to map the objects with different sizes to the sizes of family members. This particular manipulation, however, turned out not to be helpful and there was no analogy effect in this experiment. Thus the role of analogy even in transitive mapping is still unclear.

Our previous studies (Mutafchieva & Kokinov, 2007a, 2007b) have extended the results on transitive *mapping*. We introduced a new analogy domain – the train analogy – that we thought will be more appropriate for transferring the causal relations of pulling (the locomotive pulls the wagon since it is stronger) to the target domain (the stronger animal will pull the weaker one). We successfully demonstrated that this analogy used together with real (physical) draw-bars between the animals actually helped 4 years children to significantly improve their performance on the transitive *mapping* task. And that was even true for non-linear ordering: the animals were arranged in a triangle configuration.

Based on these previous results we have decided to go ahead and finally test the role of analogy in *transitive inferences*. The basic idea of the current study is to hide the three objects in the transitive inference task in boxes, so that their size is not perceptually available to the children, but at the same time to use draw-bars as external physical representations of the ordering relation, so that the children do not have to remember the premises and also to improve the encoding of the relations (in line with our previous studies). The task will go like this – if this hidden object is stronger than this hidden object, and this one is stronger than that, which would be the strongest hidden object. At the same time, however, we are planning to use one additional set of three visible objects with different sizes on the table available to the children in order to promote the spontaneous analogy between the hidden objects and the visible ones. This is being facilitated by using the explicit “train” analogy (each of the two sets of objects is like a train) which was demonstrated to be helpful in transitive mapping and is now assumed to facilitate children’s performance on the transitive inference task.

Before running this experiment, however, we have to run another experiment which is supposed to test whether children would be able to do the transitive mapping task when one of the sets is hidden. This has not been tested so far but it is a precondition for the final transitive inference task.

Experiment 1

The goal of this experiment was to find out whether children would be able to make transitive relational mapping between a set of visible objects and a set of hidden objects. Thus the experimenter’s set was visible for the child in all trials and the child’s set was always hidden.

Hypothesis

Our hypothesis was that when provided with the train analogy and with physical representations of the relations between the hidden objects (draw-bars between the objects as external representations of the relation “stronger than”), children will succeed in the transitive relational mapping task even if one of the sets is hidden.

The idea of using the train analogy and the draw-bars as physical representations of the relations was first introduced in (Mutafchieva & Kokinov, 2007b) and turned out to be useful in the case of visible objects.

Design

The experiment had a between group design:

- **Control condition:** both sets of objects were visible, no analogy is provided and no draw-bars were used;
- **Visible objects condition:** both sets of objects were visible and draw-bars were used in order to make a “train” out of the visible objects in each set.
- **Hidden objects condition:** the objects in the experimenter’s set were visible but the objects in the child’s set were hidden in equally sized boxes; draw-bars were used in order to make a “train” out of the objects in each set.

The dependent variable was the number of relational responses.

Stimuli

In each trial 6 animals of the same type were used: 6 owls, 6 eagles, 6 foxes and etc. Three of the animals formed the experimenter’s set and three of them formed the child’s set (Figure 1).

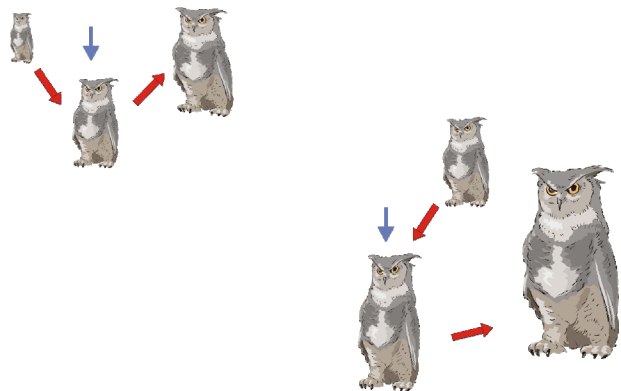


Figure 1. Example of the transitive mapping task in a triangular configuration.

In every set there was a big, a middle and a small animal and the absolute sizes of the corresponding objects from the two sets were different (for example, the big owl from the experimenter's set and the big animal from the child's set had different sizes), however, one element from the child's set was exactly the same as one element in the experimenter's set (this was the superficially similar distracter from the relational mapping).

In every trial different animals were presented with different absolute sizes and with different distribution of the spatial positions of the same relative-sized animals. In addition four draw-bars were used – two for the experimenter's set and two for the child's set.

In the Hidden objects condition the objects from the child's set were covered by white boxes, all of the same size (Figure 2).



Figure 2. Example of the stimuli used in the Hidden objects condition.

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 "at the same place" in the child's triad. The correct response was arranged always to be at the relationally similar place: thus, in order to pick it up, the child had to choose the object with the same relative size, but not the one with 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 owls and you have three owls. Look, from these two owls of mine this one is stronger than this

one (pointing to the biggest and the medium owl in the experimenter's set), and from this two owls of mine this one is stronger than this one (pointing to the medium and the small owls from her set). Please, tell me from these two owls of yours, who is the stronger one? And from these two owls of yours who is the stronger one? Please, close your eyes to hide a sticker under one of your animals. Now, I am going to hide my sticker **under this owl**, where do you think your sticker is hidden?"

The corresponding instruction for the Visible Objects condition in the test trials 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 the two owls of mine (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 owls of yours 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 owls of mine (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 owls of yours 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?"

The instruction for the Hidden objects condition was the same as in the Visible objects condition except that one set was hidden:

"Now look, my owls look like a train and your hidden owls look like a train. I am going to hide my sticker under this owl, where do you think your sticker is hidden?"

One important note for this experiment is that the child has never seen the objects in his/her set and it is not possible to solve the task by remembering the absolute sizes of the stimuli.

Participants

58 children were studied in this experiment. 18 of them formed the Control group, 20 formed the Draw-bar group, and 20 formed the Hidden objects group.

The average age of the children was 4 years and 6 months ranged from 4 years and 1 month to 5 years and 0 months.

Results and discussion

The data are presented in Figure 3. The mean for the Control Group is 1.44 (out of 5), which is roughly at the chance level (1.66), while the mean for the Visible objects group is 3.65, and the mean for the Hidden objects group is 3.30, which are significantly above the chance level.

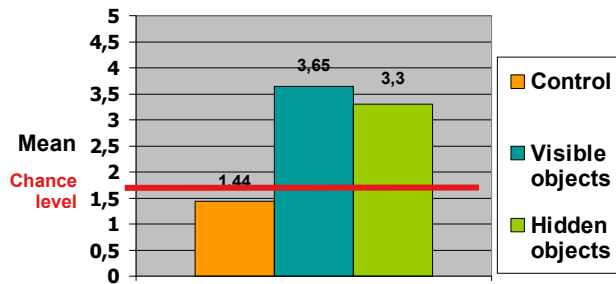


Fig. 3. Score means (out of 5) for the three groups.

The one way ANOVA showed significant effect of the manipulation $F(2, 55)=16,917$, $p<0.001$ and the pair-wise comparisons showed that both experimental groups are significantly better than the control group ($p<0.001$), but no difference was found between the two experimental groups ($p=0.394$).

These results demonstrated that children can do the relational *mapping* even with hidden objects, i.e. the train analogy with the draw-bars is an effective means for conveying the necessary information even when the perceptual information is not available. This allows us to make the next step: to test whether the train analogy will be an effective means for performing successfully the *transitive inference* task when the analogical mapping will not be explicitly required, i.e. whether a spontaneous analogy will be made and whether it will help children to solve the transitive inference task.

Experiment 2

The goal of this second experiment (in fact, the main one) was to test whether children's performance on the *transitive inference* task would improve when providing the "train" analogy to another set of animals. Although the transitive inference task itself concerned only the child set of animals, which were hidden in equally sized boxes, the experimenter's set remained visible, and an analogy between the two sets was provoked by the experimenter. The draw-bars were used again as physical representations of the relations to eliminate the potential problems of not remembering the premises.

Hypothesis

Our hypothesis was that the "train" analogy combined with the external representations of the relations "stronger than" by draw-bars would significantly facilitate children's ability to make transitive inference.

Design

The experiment had a between group design with three groups:

- **Draw-bar + train condition:** draw-bars and "train" analogy were used; the experimenter's set was visible while the child's set was hidden.
- **Draw-bar condition:** draw-bars were used, one visible and one hidden set of objects were presented, but no "train" was mentioned at all.

- **Control condition:** no draw-bars and no analogy were used; one visible and one hidden set were presented.

The dependent variable was the number of correct responses.

Stimuli

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

Procedure

The procedure was similar to the one in the first experiment.

In the *Control group* the instruction in the test trials was:

"I have three owls and you have three hidden owls. From these two owls of mine (pointing e.g. to the biggest and the medium owl in the experimenter's set) this one is stronger than this one and from these two owls of mine (pointing e.g. to the medium and the smallest owl in the experimenter's set) this one is stronger than this one. From these two of your hidden owls this one is stronger than this one. And from these two of your hidden owls this one is stronger than this one.

Please tell me, where your strongest owl is hidden?"

In the *Draw-bar + train group* the instruction was:

"I have three owls and you have three owls. From the two owls of mine (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 owls of yours 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 owls of mine (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 owls of yours which one is the stronger one? Please, put this draw-bar in such a way that the stronger owl could pull the weaker one.

Look, my owls look like a train and your hidden owls look like a train. Please tell me, where your strongest owl is hidden?"

In the *Draw-bar group* the instruction was similar, however, the train was never mentioned, i.e. the last paragraph consisted of one sentence only:

"Please tell me, where your strongest owl is hidden?"

Participants

55 children were studied in this experiment; 18 of them formed the Control group, 18 formed the "draw-bar" group, and 19 formed the "draw bar + train" group. The mean age of the children was 4 years and 1 month ranged from 3 years and 6 months to 4 years and 5 months.

Results and discussion

The results are presented in Figure 4.

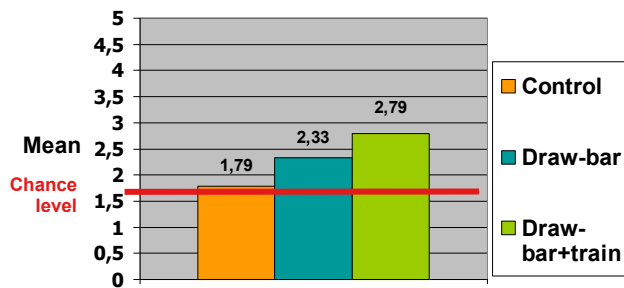


Fig. 4: Mean number of correct transitive inferences (out of 5 trials) in each group.

There is an effect of the group manipulation: $F(2,52)=4,246$, $p=0,020$. The control group (1,79) is practically at the chance level (1,66). In the pair-wise comparison, only the Analogy group (draw-bars + train analogy) turned out to be significantly different from the control group ($p=0,005$), while the difference between the draw-bars group and the control group is not significant ($p=0,220$).

General Discussion

The main hypothesis of our study was supported in this last experiment: there was a significant difference between the Control group and the “Draw bar + train analogy” group and this means that the analogy and the external physical representations were crucial for the improved children’s performance.

It is more difficult to interpret the individual role of each of the factors – the analogy and the physical representations, since there was an improvement of the performance in the “Draw-bar” group in comparison to the performance in the Control group but it was not significant, i.e. the external representations helped a bit, but could not significantly improve the performance on the transitive inference task. There was also no difference between the two experimental groups meaning that the analogy alone did not facilitated children significantly in comparison to the sole use of physical representations of the relations. The lack of difference between the two experimental groups could potentially be due to a spontaneous analogy generated by the children in the “draw-bar condition”, since the connected boxes by the draw-bars do resemble a train anyway even if it is not mentioned.

This means that further studies will be necessary to disentangle the role of analogy and external representations. An obvious next step would be to study a group with analogy, but without external representation of the relations. This condition will however, reintroduce the memory problem, since children would have to remember the given relations. Another possibility would be to introduce the analogy in a more convincing way – allowing the children to play more with or enact the “train”. Similarly, children may be allowed to play more with the draw-bars before starting the test session in order to explore whether the external representations alone might improve the performance on the transitive inference task.

The main conclusion for the moment is that the train analogy helps children to successfully make transitive inferences when the relations are physically represented.

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