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The Role of Similarity in Constructive Memory: Evidence from Tasks with Children and Adults

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Abstract

Literature on memory research shows that when memorizing, people may blend two situations, i.e. when memorizing one story, they add elements from another story. Most of the cognitive models assume that the superficial similarity between two episodes is the primary factor for blending. However, there is evidence that people blend dissimilar stories as well, if these stories share the same relational structure. We contrasted the two factors in a single study and performed experiments with the same design and stimuli with adults and with 4-5-year-old children. The results show that there is no qualitative difference between the performance of adults and children. Also, both adults and children blend either pictures that have surface or structural similarity depending on the abstractness of the objects in them.

Keywords: constructive memory; development; analogy-making.

Evidence for the Constructive Nature of Memory

The constructivist approach became a leading theory for human memory during the last decades. According to it, people continuously create hypotheses about what has happened in the past and verify them according to their current knowledge and the current context (Neisser, 1967). The subjective experience of recalling is the final product of this process of continuous creation and verification of hypotheses. There is a huge amount of empirical evidence that suggests that people wrongly recall stimuli and events that never have occurred (Bartlett & Burt, 1933, Roediger, 1996, Roediger & McDermott, 1995, Schacter, 2002); blend episodes and misattribute the source of their memories (Loftus, 1997, 2003, Loftus & Ketcham, 1992, Berkowitz et al., 2008, Kokinov & Zareva, 2001).

However, the mechanisms of memory distortion are questionable. Most of the models of memory blending (Metcalfe, 1990; McClelland, 1995; Schacter et al, 1998; Nystrom & McClelland, 1992) assume that the surface similarity between two episodes is the only factor for their blending. According to these models, the more similar two episodes are, the larger the overlapped part of their representation is and hence, the probability to blend them in the course of retrieval is higher.

However, Kokinov (1998) reported a case of blending between episodes that do not share common features but share a relational similarity. Even completely dissimilar episodes could be blended, if they participate in a double analogy, i.e. the target partially maps to these two dissimilar episodes (Kokinov & Zareva, 2001, Zareva & Kokinov, 2003). Pavlova & Kokinov (2014) demonstrated that people tend to blend analogical pictures in a higher extend compared to superficially similar ones.

The Role of Relational Knowledge in Human Cognition

There is a lot of evidence that relational similarity is probably a hallmark of various constructive processes. Relational mapping is the fundament of various models of vision and recognition (Hummel & Stankiewicz, 1998; Chalmers et al., 1992; Petkov & Shahbazyan, 2007). People's understanding of social relationships and their theories of other's minds depend highly on their relational knowledge (Day and Gentner, 2007; Shahbazyan et al., 2014; Wittenbrink et al., 1997). Even emotions are probably constructs that are based on relational coherence of various signals (Russell, 2003; Gallagher, 2012, de Bruin et al., 2014).

Analogy-making may lie at the core of human intelligence and most of the other cognitive processes (Penn & Povinelli, 2012, Hofstadter, 2001). This point of research, together with the evidence for the role of relational structure of episodes and situations in memory distortions of them, naturally implies the hypothesis that the process of relational mapping is a basic factor for the process of construction of human memories. However, there is evidence that analogy-making ability is not innate, something happens during the 4-5th year of development, the so-called "relational shift" (Gentner, 1988). Having in mind that analogy-making develops during childhood, the question whether memory illusions develop in parallel seems interesting and promising.

Development of Analogy-Making in Children

A lot of experimental data during the last decades overturn the Structure theory of Piaget (Piaget, 1977) according to which children need to develop abstract operations in order to be able to make analogies and this cannot happen before 12 years of age. On the contrary, it seems that even 4-5-

year-old children can make analogies as long as they have the conceptual knowledge required by the task (Goswami & Brown, 1989; Goswami, 1991; Vosniadou, 1989). However, Gentner (1988) disagrees that accumulation of abstract knowledge is a sufficient prerequisite for complete, rich analogy-making. Instead, something in the basic cognitive mechanisms must change; the so-called *relational shift* should occur, i.e. the change of strategy children use to judge similarity - they first use shared objects to judge it before they use shared relational structure (Gentner, 1988, Rattermann & Gentner, 1998, Gentner & Toupin, 1986). Halford et al. (1998) agree that something dramatically changes during the 4-5 year of child development but assume it is just a quantitative increase of working memory capacity. Bulloch & Opfer (2009) also oppose to the necessity to generalize over types of similarity and assume that what develops with age is the subjective judgment of the predictive validity of different types of similarity. In other words, when reasoning, both adults and children are able to use relational as well as superficial similarity but sometimes prefer different strategies, depending on which similarity is relevant to the task.

Developmental changes reflect many cognitive abilities simultaneously: children's ability to manipulate relations increases; they master high language abilities; they acquire Theory of Mind, etc. The question what kind of memory distortions occur at this age and what type of situations children tend to blend is undervalued in the research and deserves higher regard.

Experiments

We conducted a comparison study using similar tasks and stimuli for testing adults and 4-5-year-old children. We asked the participants to memorize sets of four pictures. However, the sets were constructed in a special manner, so that two pairs of pictures were structurally similar to each other, another two pairs were superficially similar; and the last two pairs were dissimilar. After a short delay we performed a memory test about all pictures and measured the amount of blending, i.e. false recognition of pictures that were not presented but consist of combination of elements from the presented pictures. Finally, we compared the amount of blending between structurally similar, superficially similar, and dissimilar pictures.

In the first experiment we used "rich" pictures with a lot of salient elements that may attract attention, whereas in the second experiment we repeated the procedure with "poor" pictures with abstract geometric figures, and expected that both adults and children would pay more attention to the relational structure.

Experiment 1

The main aim of the experiment is to check whether there is a qualitative difference between blending in children and in adults. Specifically, will children blend the superficially similar items more often than analogical or dissimilar ones, whereas adults will blend the analogical items more often than superficially similar or dissimilar ones.

Design. The experiment had a 2×3 mixed design. The between-subjects variable was the age of the participants and had two levels: adults or children. The within-subjects variable was the type of distracter given during the memory test and it had three levels:

- **Analogous** – distracters designed by combining two bases that share the same relations, but do not share the same elements.
- **Superficially similar** – distracters designed by combining two bases that share the same elements and thus are superficially similar, but do not share the same structure, i.e. the relations between the elements in the two bases are different.
- **Dissimilar** – distracters designed by combining two bases that share neither the same structure, nor the same elements.

Procedure. The experiment was run on the E-prime software and consisted of four phases that immediately followed one after another.

First, the participants were presented sequentially with the four pictures (called "bases") from each set. Their task was to describe each picture.

Then, they saw the four pictures of each set again but this time simultaneously (see Figure 1). Adults had to observe them for one minute. Children observed the bases and received feedback from the experimenter about the objects and relations in each base. The same procedure was immediately repeated for the second set of four pictures, and then for the last, third set.

In the third phase the participants performed a filler task. Adults solved simple addition math problems for 5 minutes. Children solved a puzzle for 2 minutes. The purpose of this phase was to ensure a retention interval.

Finally, the participants performed a recognition test. They were presented sequentially with pictures and were asked to indicate for each one whether they had seen it in the first phase of the experiment. Pictures were either the same as the original ones (i.e. "bases"), or different, i.e. distracters, constructed by combining elements from two different bases. The recognition test included all the bases and half of the possible distracters (see Figure 2), presented one by one and fully randomized. After the vocal answer by the participants, the experimenter pressed a corresponding key on the computer keyboard. No feedback was given to either adults, or children.

Stimuli. Three sets of 16 pictures were developed following the procedure of Pavlova & Kokinov (2014) and used in phases one and three. In each set, 4 of the pictures were the bases, and the other 12 were the distracters. The 4 bases were specifically constructed so that they formed three pairs

as follows: two pairs were structurally analogous to one another (A1~A2 and A3~A4), two pairs were superficially similar to one another, but did not share the same structure (A1≈A3 and A2≈A4), and finally the last two pairs were dissimilar and shared neither the same structure, nor the same superficial elements (A1≠A4 and A2≠A3). An example is shown in Figure 1. The distracters are designed by combining elements from two bases and there were three types of distractors depending on these bases – analogous distracters, superficially similar distracters, and dissimilar distracters (see Figure 2).

Figure 1: An example of the bases. The bases compose the following pairs: analogous configurations (A1~A2, because in both the subject **holds** the object; and A3~A4, because in both the subject **looks at** the object), superficially similar configurations (A1≈A3, because in both there is a bear and a balloon and A2≈A4, because in both there is a rabbit and a kite), dissimilar configurations (A1≠A4 and A2≠A3).

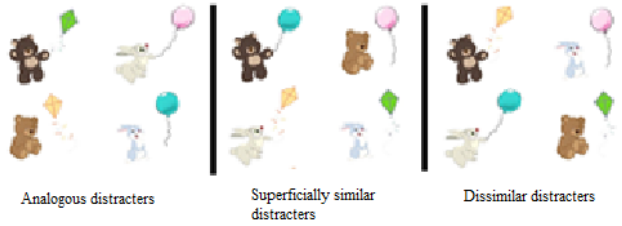

Figure 2: An example of the distracters designed for the bases in Figure 1. Each of the distracters combines elements from two of the bases.

Participants. The sample consisted of 32 participants – 12 adults (5 male; age 18 – 41 years, M = 26 years, SD = 7.5 years) and 20 children (10 male; age 48 – 63 months, M = 56 months, SD = 5.4 months). Children were recruited at a kindergarten in Sofia, Bulgaria; permission to participate was obtained from their parents prior to the study. Adults were students at New Bulgarian University and participated voluntarily.

Results and Discussion. The participants showed a very good performance on the recognition test with 88% correctly recognized bases for the adults and 93% for the children. Since we are interested in the source of blending, we analyzed only the answers for the distracters of each type. The data are presented in Figure 3.

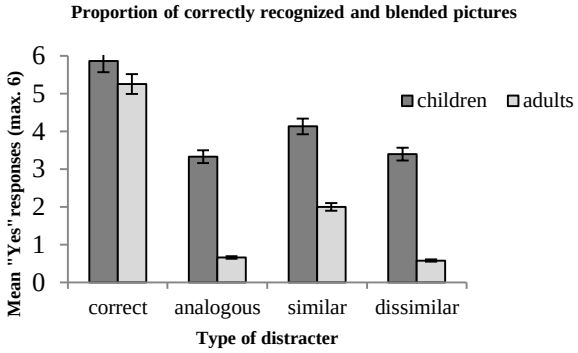

Figure 3: Distribution of "Yes" responses of adults and children among the various types of stimuli during the recognition test. The first column indicates the correct responses, whereas the next three columns indicate blending of various types.

Figure 3 illustrates the distribution of the "Yes" answers for all conditions, i.e. both the correct responses for the bases and the falsely recognized pictures for the three types of distracters. A repeated measures ANOVA showed that the main effect of type of stimulus was significant: $F(3,90) = 83.199$, $p < 0.001$, (partial $\eta^2 = 0.735$). The main effect of age was also significant: $F(1,30) = 12.707$, $p = 0.001$. Children are more likely to give a "Yes" answer irrelevant to what type the stimulus is. Analyzing adults' data for the distracters only, the pair-wise comparison showed that there was a significant difference between the superficially similar and the analogous distracters: $t(1,11) = 3.752$, $p = 0.003$, and between the superficially similar and the dissimilar distracters: $t(1,11) = 3.027$, $p = 0.012$. The same pattern was found for the children's data. There was a significant difference between the superficially similar and the analogous distracters: $t(1,19) = 2.904$, $p = 0.009$, and between the superficially similar and the dissimilar distracters: $t(1,19) = 2.774$, $p = 0.012$.

These results suggest that the responses of adults and children follow the same qualitative pattern: both adults and children falsely recognized more superficial distracters, which means that they blended the superficially similar bases more often compared to the analogous and dissimilar ones. Evidence in the literature suggests that object similarity plays an important role in similarity judgements for adults (Markman & Gentner, 1993) and children (Gentner & Namy, 1999).

However, the obtained results differ from those in Pavlova & Kokinov (2014) study. One possible explanation is that the stimuli used in the two experiments differ from each other. It is possible that the relations between the objects in this experiment are more subtle and thus harder to notice. Previous research shows that when stimuli are sparse both adults and children focus on relational similarity, whereas when stimuli are rich both adults and children focus on object similarity (Rattermann & Gentner, 1998;

Markman & Gentner, 1993; Bulloch & Opfer, 2009). Therefore, the more complex or rich the stimuli are, the more shared object similarities there are, the harder it is to notice the relations involved.

To test this assumption, a new experiment was conducted. Experiment 2 followed the same procedure as in Experiment 1, but with the stimuli used in Pavlova & Kokinov (2014). The main idea was to see whether by using more abstract stimuli we would obtain evidence for a qualitative difference between recognition responses in adults and children.

Experiment 2

Design and Procedure. Experiment 2 followed the same design and procedure as Experiment 1. The only difference was that we used the stimuli developed by Pavlova & Kokinov (2014) that consist of abstract geometrical relations instead of attractive pictures of toys.

Stimuli. Four sets (one more than in Experiment 1) of the original stimuli by Pavlova & Kokinov (2014) were used in phases one and three of Experiment 2. Each set consisted of 4 bases and 12 distracters. The bases formed three pairs: analogous, superficially similar, and dissimilar (Figure 4) and there were 3 types of distracters depending on the type of blending they represent: blending between analogous bases, blending between superficially similar bases, and blending between dissimilar bases (Figure 5).

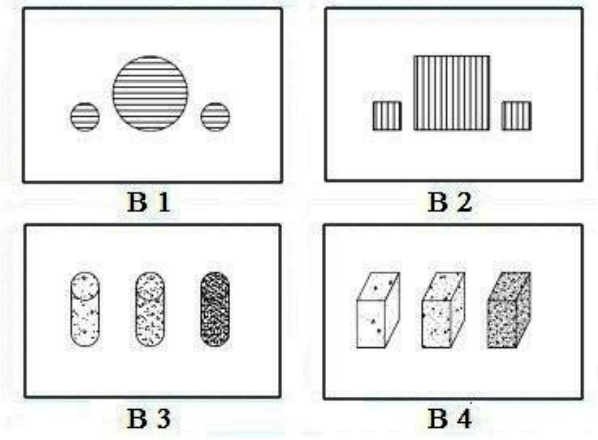

Figure 4: An example of the bases. The bases compose the following pairs: analogous configurations (B1~B2 and B3~B4), superficially similar configurations (B1≈B3 and B2≈B4), dissimilar configurations (B1≠B4 and B2≠B3).

Participants. The sample consisted of 30 participants – 11 adults (9 male; age 23 – 33 years, M = 27 years; SD = 3 years) and 19 children (10 male; age 51 – 71 months, M = 60 months; SD = 3.3 months). Children were recruited at a kindergarten in Sofia, Bulgaria; permission to participate was obtained from their parents prior to the study. Adults were students at New Bulgarian University and participated voluntarily.

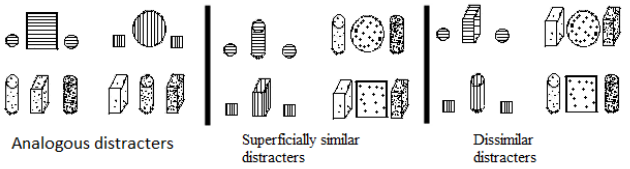

Figure 5: An example of the distracters designed for the bases in Figure 4. Each of the distracters combines elements from two of the bases.

Results and Discussion. The results showed a very good performance on the recognition test with 78% correctly recognized bases for the adults and 94% for the children. Since we are interested in the source of blending, we analyzed only the recognition for distracters of each type. The data are presented in Figure 6.

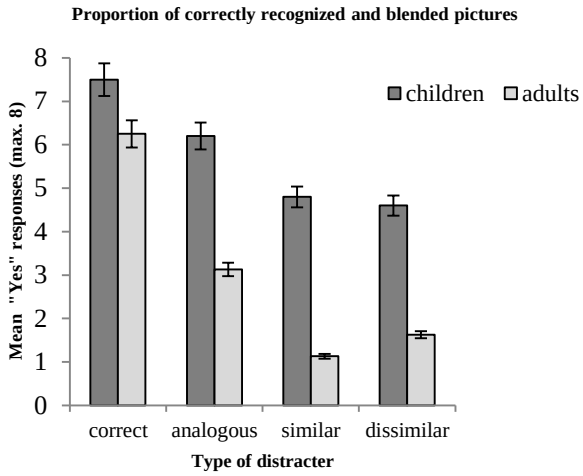

Figure 6: Distribution of "Yes" responses of adults and children among the various types of stimuli in during the recognition test in Experiment 2.

Figure 6 illustrates the distribution of both correct responses and falsely recognized pictures in the recognition task. A repeated measures ANOVA showed that the main effect of type of stimulus was significant: $F(3,84) = 53.352$, $p < 0.001$, (partial $\eta^2 = 0.656$). The main effect of age was also significant: $F(1,28) = 15.238$, $p = 0.001$, (partial $\eta^2 = 0.352$). Again, children are more likely to give a "Yes" answer irrelevant to the type of stimulus. Analyzing the adults' data for the distracters only, the pair-wise comparison showed that there was a significant difference between the analogous and the superficially similar distracters in favor of the analogous ones: $t(1,10) = 3.860$, $p = 0.003$, and between the analogous and the dissimilar distracters: $t(1,10) = 3.068$, $p = 0.012$. The same pattern was found for the children's data. There was a significant difference between the analogous and the superficially

similar distracters: $t(1,18) = 2.163$, $p = 0.044$, and between the analogous and the dissimilar distracters: $t(1,18) = 2.163$, $p = 0.012$. However, this time both adults and children more often gave a "Yes" answer for the analogous distracters, than for the superficially similar and the dissimilar ones.

Thus, again adults' and children's results share the same qualitative pattern but the results were exactly the opposite compared to the first experiment – this time the blending between analogous pictures was more frequent than between superficially similar ones.

General discussion

People blend similar pictures as well as superficially dissimilar pictures that share same relational structure. This result is in accordance with previous empirical evidence that blending cannot be fully explained by models that rely on superficial similarity alone. Most of the models of blending (Metcalfe, 1990; McClelland, 1995, Schacter et al, 1998, Nystrom & McClelland, 1992) assume that the overlap of the representations of the memories is the only factor for blending. Potentially, these models could account for the results; however, additional complications are necessary: the relational structure of the situations should be added to the representations, as well as mechanisms for weighting the different pieces of knowledge.

The most interesting result from the current experiments is that adults and children share the same qualitative pattern of results. It seems that there is no discrete difference between the cognitive mechanisms they use. These results do not support the relational shift hypothesis (Gentner, 1988, Rattermann & Gentner, 1998, Gentner & Toupin, 1986). Of course, one may assume that the children in our experiments have outgrown the stage of the relational shift (it is a complicated task to perform comparative study with same stimuli between adults and very young children). It should be mentioned that most of the evidence for the relational shift hypotheses emerge from explicit tasks, whereas memory blending is an implicit phenomenon. In addition, there is a small difference in the procedure in our experiments between adults and children – the latter received a feedback about the presented relations during the second phase of the experiment, when they observed the four pictures simultaneously. Additional research is required for a precise conclusion but the results from the second experiment definitely show that 4-5-year-old children are able to use relational structures in their representations. Moreover, relational structure may influence memory distortions.

During the recognition test children much more often say "Yes" compared to adults, no matter what the type of the stimuli is. This could be explained with a higher conformism, or trust to the experimenter, or searching for socially desirable answers in a higher extend.

Finally, it seems that the type of blending that occur more often depend not so much on the type of similarity (surface or structure) per se, but on the type of stimuli. The "rich", complex stimuli probably attract more attention to the concrete objects; whereas the "poor", abstract patterns make it easier for people to notice the relational structure. Of course, another possibility is that the accessibility of relations is better for the "poor" stimuli. The interesting fact is that both young children and adults seem to use the same cognitive mechanisms for this. Certainly, future work will shed more light on the mechanisms of memory construction and the role of different types of similarity in it.

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