HOW ANALOGY COULD FORCE RE-REPRESENTATION OF THE TARGET AND INHIBITION OF AN ALTERNATIVE INTERPRETATION

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ABSTRACT

The representation-building and the analogical mapping processes run in parallel in the AMBR model and thus they can influence each other. This paper describes how the AMBR model could explain the re-representation of the target when the analogical mapping forces it. The mechanisms are presented and a simulation is described which shows that depending on how strong the mapping is sometimes we arrive at one representation (the dominant one) of the target, sometimes another one (the unobvious one). This simulation replicates the psychological data that were obtained earlier. The simulation allows to track the dynamics of the process and to make another prediction that there will be inhibition of the alternative interpretation of the target. Thus we arrive at a very strange prediction that people may see consciously only the dominant interpretation, but unconsciously they may have built partially the alternative interpretation which will remain inhibited by the competing dominant one, i.e. the prediction is that there might be cases of inhibition of something the subjects would claim they have not seen. This prediction is supported in a pilot psychological experiment.

INTRODUCTION

In the 90s a hot debate about the inseparability of perception and mapping in analogy-making took place (Chalmers, French, & Hofstadter, 1992, Morrison, & Dietrich, 1995, Hoffman, 1995, Forbus, Gentner, Markman, Ferguson, 1998). Even though unresolved this debate died down. However, it is an important debate that needs to be continued.

The debate is basically a classical one: between a more or less modular approach which keeps representation-building (perception) separately from mapping and preceeds it, with possible loops in this essentially linear process, and an interactionist approach which views perception and mapping as running in parallel and influencing each other.

In this paper we briefly review the empirical data on how analogical mapping can produce re-representation of the target, which is considered as evidence in support of the interactionist view. Then we present a simulation of these data with the AMBR model which is built upon the interactionist approach. We explore the dynamics of the changes in the internal representations of the model and based on this dynamics a novel, unexpected prediction is made. Finally, we present some empirical data in support of this prediction.

EXPERIMENT 1

In an experiment described in (Kokinov, Bliznashki, Kosev, Hristova, 2007) the prediction of the AMBR model (Kokinov, 1998, Kokinov & Petrov, 2000, 2001) that mapping and representation-building will interact and produce a re-representation of the target has been tested.

Figure 1. The ambiguous figure used in the experiment.

Look at the picture in Figure 1. What do you see there? – Most probably a human face. However, it can also be interpreted as an inscription rotated clockwise. The inscription reads "KOTKA" which means "cat" in Bulgarian. This second interpretation is hard to be seen, however, and in the pilot study almost no one has seen it. When this picture is included in various tasks this could potentially change. The experiment manipulated the type of task in which the ambiguous figure was involved and there were three conditions (see Figure 2):

- ***Strong mapping***: the figure is involved in a proportional analogy to be solved. There is a strong pressure to put Option 4 as a solution since this is the only case where the colour is reversed from white to black and in addition the picture is rotated. For doing so, however, one has to see the target picture as an inscription in order to have picture → picture ~ word → word. Thus mapping and perception interact in order to produce a re-interpretation of the target picture as a word.
- ***Weak mapping***: the figure is involved in the same proportional analogy, however the colour pressure is removed and now only a weak pressure (rotation only) exists for the mapping that will potentially lead to re-representation of the figure as an inscription.
- ***No mapping***: the figure is involved in an open ended task that does not require analogical mapping and therefore there is no pressure for re-representation.

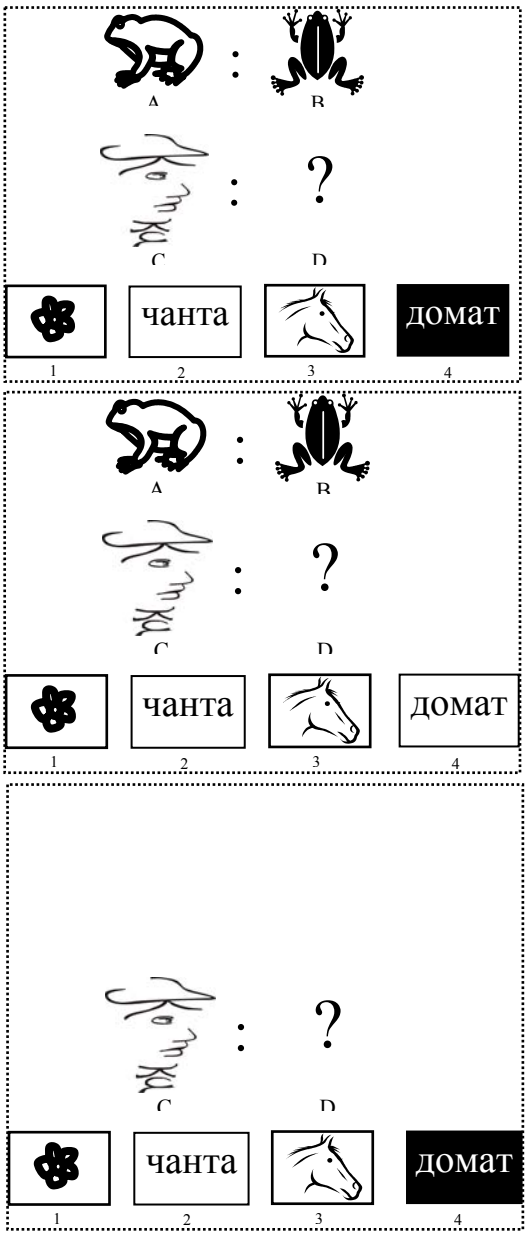

Figure 2. Test items: a) task in the strong mapping group; b) task in the weak mapping group; c) task in the control (no mapping) group. The two words in Bulgarian among the options provided are CHANTA (Bulgarian word for BAG) and DOMAT (Bulgarian word for TOMATO).

The participants had to solve the task presented in the corresponding condition, then the figures disappear, and then they are asked to describe the figure they have just seen. They typically say "a face", but they were additionally prompted whether they have seen anything else in this figure. The assumption here is that since the stimulus is not present at that moment, they cannot reinterpret it on the spot, they can report another interpretation only if they have seen it during the previous task.

The results from the experiment are reviewed in Figure 3. It turned out that the percentage of participants who saw the inscription in the strong mapping condition was significantly higher than the percentage in the other two groups and there was no difference between the weak mapping and no mapping groups.

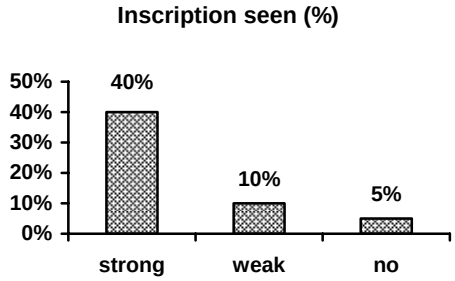

Figure 3. Percentage of participants who saw the inscription in each group. [$\chi^2(2)=9.573$, $p=0.008$]

SIMULATION

Representation

The re-representation was simulated with the AMBR model. The representation of the input was based on a number of primitive perceptual features and primitive grouping relations. Both kinds of representational primitives did not have any intrinsic meaning.

The semantic memory consisted of a number of localistically represented concepts standing for "Positive", "Negative", "Positive-negative" relation and "Animal" and two other concepts corresponding to the two alternative interpretations of the ambiguous figure – "Face" and "Cat inscription", these concepts are represented in a distributed manner (Figure 4). The face and the cat shared about 90% of the same perceptual primitives, the other 10% belonged to the representation of the 'face' concept, thus making it a dominant interpretation. The perceptual primitives which were used in the representation of both concepts were grouped by the grouping relations in non-corresponding ways in order to make the two representations mutually exclusive and to prevent a given instance to be categorized as both a 'cat inscription' and a 'face'.

The episodic memory consisted of two base items (BASE1, BASE2) – roughly corresponding to the white and black frogs in the experiment, the ambiguous figure (corresponding to the face/inscription figure in the experiment) and the four mapping alternatives (corresponding to the 4 options provided in the experiment). All items except for the ambiguous figure were represented localistically. The latter was modeled in a distributed fashion using the same perceptual primitives used for representing the alternative interpretations. The primitive grouping relations were not manually encoded in the input, but rather the perceptual primitives were grouped dynamically in the course of the simulation. Two perceptual primitives became grouped together by a binding node if they were mapped to the perceptual primitives participating in the representation of the corresponding grouping relation.

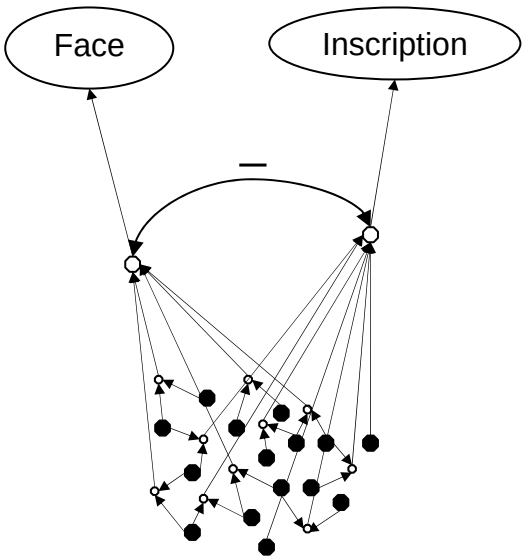

Figure 4. Alternative interpretations of an ambiguous stimulus. The black dots stand for perceptual primitives. The little circles denote binding nodes which organize the perceptual primitives into structured representations. The top binding nodes represent the final overall interpretations of the stimulus. All overlapping binding nodes inhibit each other (the inhibitory links between the lower level bindings are not shown in this figure).

Simulation experiment

The two sets of competing groupings modeled what human subjects actually saw. It was assumed that people would see the inscription if the perceptual primitives were grouped in the same way as the 'cat inscription' concept. The instances of grouping relations were organized by a top binding node, standing for the overall categorization of the ambiguous item (Figure 4).

The process of making a proportional analogy was modeled by introducing a target item (marked with "?" on the figure) with four possible categorizations, corresponding to the four mapping alternatives (Figure 5). As long as the target item was localistically represented and lacked any relevant information that would allow to make a choice, the decision which mapping item to choose was determined by how well the corresponding categorization of the target item would fit into the analogy.

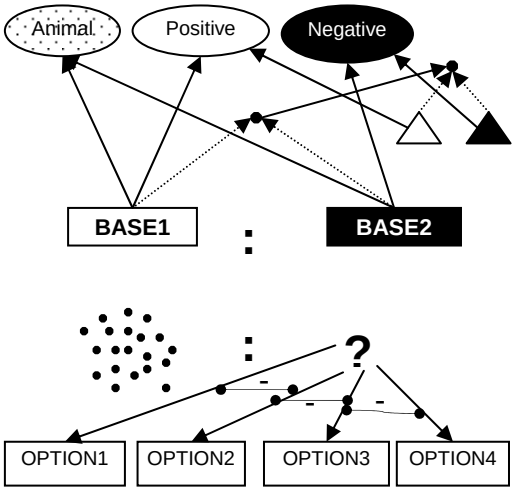

Figure 5. The representation of the proportional analogy task. The top four figures represent localist concepts. The question mark stands for the target item. Note the inhibitory links between the four possible mapping answers to the analog task.

The three experimental conditions were simulated by changing the mapping alternatives (to model the strong and weak conditions) and by removing the base items (to model the no mapping conditions). Individual differences were modeled by manipulating the recall connections between the perceptual primitives and their instances participating in the representation of the concepts. One hundred simulation runs were generated in each condition in order to determine the final results. The 'cat inscription' was counted as seen when the activation of the binding node standing for the corresponding interpretation of the ambiguous figure was higher than the activation of its rival: the binding node for 'face' interpretation.

Results

The results are displayed in Figure 6 and they qualitatively replicate the data from the psychological experiment (Experiment 1).

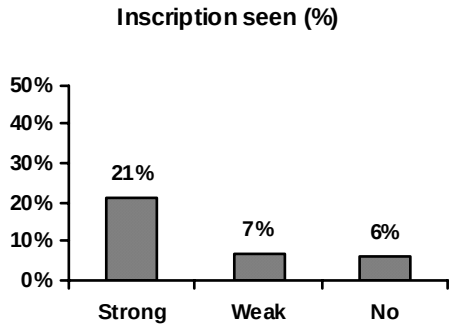

Figure 6. Simulation results. The inscription was noticed significantly more times in the 'strong mapping' condition compared to the other conditions. There was virtually no difference between the 'weak mapping' and the 'no mapping' conditions.

Dynamics of the process

Figure 7 presents two representative simulation runs. The two possible interpretations of the ambiguous figure co-existed and competed during the simulation. The differences were only in their activation levels. An interpretation becomes aware only when its activation level exceeds the activation of the competing interpretation because they are both based on the same perceptual primitives. The assumption that people may not be consciously aware of what they are seeing is consistent with the studies of unconscious object perception (Bolte, 2008; Bowers, 1990).

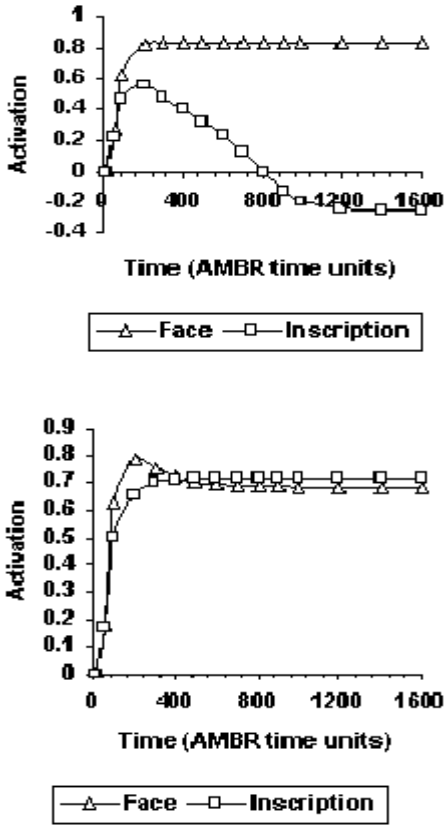

Figure 7. Dynamics of a simulation run in which the inscription was not seen (top figure) and it was seen (bottom figure).

The presented model of analogy-driven re-representation suggests that the role of analogy is not in constructing entirely new representations, but in activating existing alternative interpretations. This activation is not due to adding new sources of activation, but to changes in the flow of activation imposed by the top-down structural constraints. In particular, the interpretation of the ambiguous figure as an inscription benefited from the discovery of the 'negative-positive' relation in the strong mapping condition. The relation did not receive directly any activation (it was activated solely by means of its arguments) but it forced Base1 to be mapped to the inscription interpretation of the ambiguous figure, as they were

both arguments of the same relation. Thus the inscription interpretation received support from the structural constraint and in some of the cases managed to overcome its alternative (Figure 8).

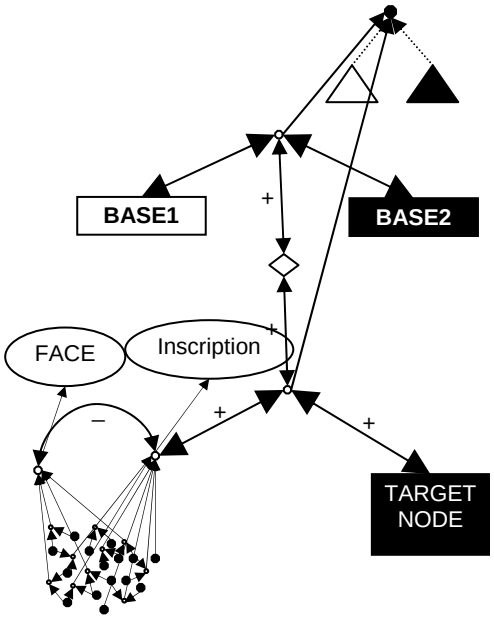

Figure 8. The inscription interpretation of the ambiguous figure received additional support from the negative-positive relation in the strong mapping condition.

Prediction

An interesting implication from the computational study is that in some of the cases when the inscription was not seen the corresponding inscription concept was inhibited (Figure 9). That happened because the inscription interpretation was inhibited by the dominant face interpretation and it, on its turn, inhibited the inscription concept by means of the ISA link between them. However this effect is expected to be weak: the inscription concept was inhibited only in 63% of the simulation runs in which the inscription was not seen (in the other cases the inscription concept activation was above zero, i.e. it was primed).

This simulation result predicts that even if people do not consciously see the inscription in the ambiguous figure they may build a representation of this inscription and since it will be suppressed by the alternative concept the inscription concept (in that case "CAT") will be often inhibited. This is a quite strange prediction and in the next section we are going to test it.

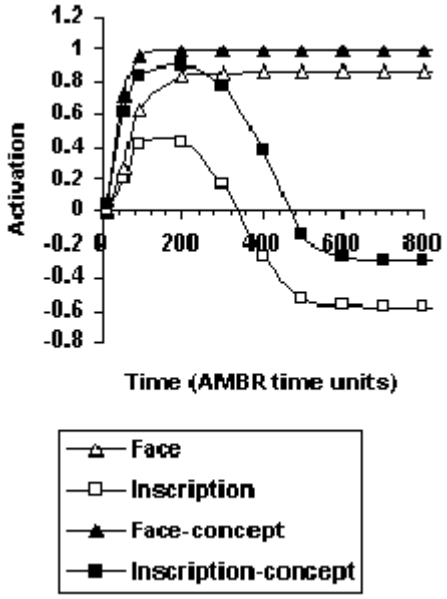

Figure 9. Dynamics of a simulation run, in which the 'cat inscription' concept was inhibited

EXPERIMENT 2

This experiment tested the prediction which fell out of the simulation and was described in the previous section. Experiment 2 extends Experiment 1 with two lexical decision tasks (LDTs) – one before and one after the main experimental manipulation (Experiment 1). With these LDTs we test whether the experimental manipulation – analogy-making – would produce an effect at the subconscious level when it has not produced and effect at the conscious level, i.e. when analogy-making has not produced a re-representation and people still see only the face, maybe, just like in the

simulation, an alternative representation of the "CAT" has been built, but has lost the competition. This could be measured by a (positive or negative) priming effect on the concept CAT (in the simulation we obtained predominantly negative priming – in 63% of the runs).

Design

We used a single factor between group design in this experiment with three levels of the independent variable "type of mapping", but we used also a further post-experimental selection criteria – we analyzed the data only for those who did not see the inscription. The dependent variable is the RT for the lexical decision task. Here are the three experimental conditions (the same as in Experiment 1):

- ***Strong mapping***: an open ended 4 term analogy where the ambiguous figure is under strong pressure to be mapped on a word: white goes to black, horizontal orientation goes to vertical orientation. For doing so, however, one has to see the target picture as an inscription in order to have picture → picture ~ word → word. Thus mapping and perception interact and produce a strong pressure for re-interpretation of the target picture as a word.
- ***Weak mapping***: an open ended 4 term analogy where the ambiguous figure is under weak pressure to be mapped on a word: horizontal orientation goes to vertical orientation, however the colour pressure is removed and now only a weak pressure (rotation) exists and it is less likely a re-representation of the figure as an inscription to happen.
- ***No mapping***: the figure is involved in an open ended task that does not require analogical mapping and therefore there is no pressure for re-representation at all.

Procedure

The experiment consisted of three sessions:

- Session 1 – the participants had to decide whether a string of letters constitutes a proper word in Bulgarian language (a LDT) for a series of 6 strings;
- Session 2 – the participants had to solve a problem (a 4 term analogy in the two mapping conditions and a similarity matching task in the no mapping control condition);
- Session 3 – the participants repeated the same LDT;
- Session 4 – the participants had to report whether they have seen something behind the face in session 1 (without looking back at the target screen).

The experiment was run on the e-Prime software in a sound-proof booth and the RTs on the LDT were recorded.

Stimuli

The stimuli for session 1 can be seen in Figure 2. They are exactly the same as in Experiment 1. The differences between them make up the experimental conditions.

The stimuli for session 2 were 6 words /non words matched for length and subjective frequency. Four of the letter strings were words and 2 non words (in previous training sessions we had 3 words vs. 3 non words). Two of the words were the words used as options for problem solutions ("TOMATO" and "BAG"), the third word was the crucial target word "CAT" and the last one was "TREE" – a base line control word matched for length and frequency with "CAT".[1] Two pseudo-words (pronounceable non words) were used as well.

Participants

60 NBU students took part in the experiment for course credits.

[1] Do not forget that the experiment was conducted in Bulgarian, thus the four words in Bulgarian have the same length and frequency: "ДОМАТ", "ЧАНТА", "КОТКА", "ДЪРВО". The two non words were: "ЛУПАН", "БУРОН".

Results

The results replicated the data from Experiment 1 on re-representation (see Figure 3), but what was interesting here was the analysis of the RT data on the LDT. We excluded the subjects who re-represented the perceptual input and saw the "CAT" inscription in each of the three experimental groups, since the point was to see what happens with the representations of "CAT" when there is no obvious evidence that such a representation is built at all (although our model predicts that such a representation has to be built).

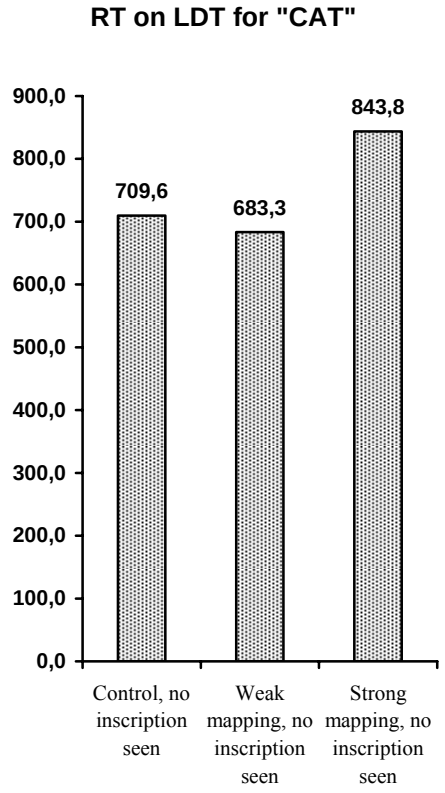

Figure 10. RT for lexical decision on the word "CAT" in all experimental conditions. Negative priming (inhibition) in strong mapping condition, when the CAT inscription is not seen.

The raw data are presented in Figure 10. We normalized the RT of cat with respect to a base line – the RT for lexical decision on "tree" ("tree", in Bulgarian "DARVO", has the same frequency and word length as cat, but has not been used in the experimental manipulation). We then analyzed the transformed data by means of ANOVA. The analysis found a significant group effect ($F(2, 46)=4.358$, $p=0.018$) and the pair-wise comparison found a significant difference between the strong mapping condition and the control condition ($p=0.005$), but not with the weak condition group ($p=0.102$). log-transformed data analysis found both pair-wise comparisons significant.

GENERAL DISCUSSION

The first interesting result is the fact that we obtained evidence that people do perceive unconsciously the "CAT", i.e. even though they say they have not seen anything else than a face in the figure, we have firm data showing that they have built not only partial representation of the inscription (e.g. some letters), but they have built a meaningful representation of the word "CAT" which turned out to be negatively primed (longer RT). Bowers, Regehr, Balthazard, and Parker (1990) as well as Bolte and Goschke, (2008) have obtained analogous results demonstrating that even though people cannot recognize a fragmented line drawing and cannot name the object, still they can distinguish between coherent and incoherent fragmented line drawings, and most importantly, the name of the object turned out to be positively primed. Nievas and Mari-Beffa (2002) demonstrated negative priming of the unselected meaning of a homograph. Thus a conclusion can be made that perception is an automatic and unselective process, i.e. we do build several alternative representations (interpretations) of the stimulus in parallel, even though we are aware only of the dominating interpretation.

The second interesting result is that analogy-making interacts with perception during this process of representation building. The AMBR model has demonstrated how this may

happen – the mapping process does not directly build or change the representation of the input, but it establishes various alternative correspondences and builds hypotheses. By that means the spread of activation changes and this can influence the outcome of the competition – which alternative representation will become the winner. Of course, even without an analogy the competition will be there and it will end in one way or another. The analogical mapping only pushes the process in one direction or another.

The third interesting result is that the more systematic the analogy is the stronger the pressure it exerts on the various alternatives, and this has two consequences: it can potentially help a perceptually weaker alternative to win (the "CAT" inscription in this case) but if it does not win, then this alternative will be even more suppressed because of the stronger competition between the hypotheses built by the analogical mapping process and the corresponding concept may turn out to be inhibited. This mechanism could potentially explain also the negative priming obtained by Nievas and Mari-Beffa (2002) which was still unexplained.

An important conclusion from this work is that in order to explain these experimental findings we do need an interactive model of analogy-making, where mapping and representation-building will run in parallel and influence each other. AMBR is not the only model that is interactive in that sense – CopyCat and TableTop (Hofstadter, 1995, Mitchell, 1993, French, 1995) are its intellectual precursors in modeling the interactions of perception and mapping. Recently, Yan, Forbus, and Gentner, (2003) proposed a model of re-representation based on SMT that can potentially also be extended in this direction although it looks more linearly cyclic (mapping attempt – failure – re-representation – next mapping attempt, etc.) at the moment. Another more recent attempt to explore the role of visual re-representation in analogy-making and modeling this process by the Galatea model was undertaken by Davies, Goel, and Nersessian (2003, 2009). These studies show that people often explicitly re-represent the objects and relations in order to extend the mapping.

Thus we hope that the current paper contributes to the further exploration of the issue of re-representation in analogy-making and the complex interactions between the processes of perception, memory and analogical mapping.

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