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Analogical Mapping and Perception: Can Mapping Cause a Re-Representation of the Target Stimulus?

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Abstract

This paper is trying to explore the issue of whether analogical mapping may influence perception and cause re-interpretation of the target stimulus. An attempt is made to put this rather complicated issue at experimental test bed. Two experiments are described which demonstrate that the process of analogical mapping may reorganize the perceptual input and stimulate a re-representation of the input image thus allowing the participants to discover meanings that were not initially available to them. The experiments are not decisive on when this re-representation happens.

Keywords: analogy; perception; representation; re-representation; psychological experimentation.

Introduction

The debate about the inseparability of perception and mapping in analogy-making was very hot in the 90s (Chalmers, French, & Hofstadter, 1992, Morrison, & Dietrich, 1995, Hoffman, 1995, Forbus, Gentner, Markman, Ferguson, 1998) but began to fade out later on even though it remained unresolved. This debate was probably too emotional and needed some break. However, it is an important debate that needs to be continued in a more constructive way. One problematic aspect of the debate as it was carried out in the 90s was that it stayed at a very abstract philosophical level and there were no proposals for how to try to answer the questions in an empirical way. This paper makes an attempt to reinstate the debate, but to put it on experimental grounds. We fully realize that it is slippery to test empirically such subtle issues, but let us make some small steps in that direction.

First of all, let us point out that since the time the debate was initiated a number of models were developed that addressed related issues. Thus Keane & Brayshaw (1988), Keane, Ledgeway, and Duff (1994) and Forbus, Ferguson, & Gentner (1994) have given up the “one step view” on the mapping process and introduced the so called “incremental view”. This approach allowed the mapping to dynamically adjust to the new coming information about the target. These approaches also allowed backtracking, i.e. old partial mappings can be destroyed and new mappings to be built on their place. However, none of these approaches ever discussed the possibility for re-representation of the target

or the base themselves. In contrast, the CopyCat and TableTop models (Hofstadter, 1995, Mitchell, 1993, French, 1995) introduced the idea of re-representation of the target and the base, which are both perceived from the environment. Since the representation building is running in parallel with the mapping process in these models, there is constant re-representation of the target and the base (e.g. grouping and re-grouping of the elements, representing them as letters or numbers, etc.). The AMBR model introduced the idea of re-representation of the base while it is being retrieved from long term memory and mapped to the target (Kokinov & Petrov, 2000) and as result memory distortions were predicted which were later on experimentally confirmed. Finally, Yan, Forbus, and Gentner (2003) suggested a whole library of transformation functions that can allow for the re-representation of the target when it does not match well the base. Thus many models seem to have adopted the idea of re-representation to some degree and developed at least partial mechanisms for performing it (even though these mechanisms are often very different from each other). However, there are not many experimental studies that test whether such re-representations actually happen in human analogy-making.

The closest experimental study we are aware of is performed by Medin, Goldstone and Gentner (1993). They demonstrated that comparing two objects may influence their encoding. They used ambiguous abstract figures that could be seen in two different ways. Each ambiguous target figure was presented in pair with another unambiguous figure and the participants were instructed to compare the two figures and to list their similarities and differences. The same target figure was paired with two different figures in a between group design. Since the participants produced different sets of attributes, depending on the figure the target was compared with, the authors concluded that they perceive and encode the target figures differently depending on the figure to be compared with. These results coupled together with the mounting evidence that alignment is a central aspect of similarity comparisons (Goldstone and Medin, 1993; Markman and Gentner, 1990) are backing up the hypothesis that analogical mapping may cause re-representation of the target stimulus. However, this study was not designed explicitly to test this hypothesis and that is why the task was not to make an analogy, but rather to list superficial similarities in most cases. Another problem with

this study is that people may perceive the ambiguous figure in an unbiased way, but being *forced to describe* the similarities and differences in comparison with the other figure, they had to use a common terminology for both of them.

In the experiments described in this paper we tried to study *spontaneous re-representation during problem solving*, i.e. we do not ask them to describe what they see in relation to something else, but rather to solve a problem and we test whether during the problem solving process a spontaneous re-representation will happen. We ask the participants what they have seen after the problem solving has finished and the test stimulus is not anymore available to them. Also, we explicitly manipulated the analogical mapping the target stimulus is involved in, to test whether analogy is actually causing re-representation of the target.

Two experiments were performed. In both of them the target stimulus was an ambiguous figure which can potentially be interpreted either as a human face or as a rotated inscription, but the inscription is hard to be seen at the beginning (Figure 1). In a pre-test we found that hardly anyone sees the inscription spontaneously.



Figure 1. The ambiguous figures used in experiment 1 and 2, respectively. The inscription on the left figure reads “KOTKA” which means CAT in Bulgarian. The inscription on the right figure reads “VALK” which means WOLF.

The main idea of both experiments is to include these ambiguous figures in proportional analogies and see whether the mapping may influence the perceptual process and facilitate a re-representation that will allow the participants to see the inscription. We test this in two experiments.

Experiment 1

The goal of our first experiment is to find out whether analogical mapping can actually cause re-representation.

Hypothesis

Our hypothesis is that analogical mapping, if appropriate, will exert a pressure on the perceptual processes to re-

represent the stimulus and the ambiguous figure will be more often reinterpreted as an inscription..

Design

The experiment has a between group design and the manipulated variable is the type of task the ambiguous figure is involved:

- **Strong mapping:** the figure is involved in a proportional analogy with a strong pressure (rotation and colour reversal) for an unusual mapping that will potentially lead to re-representation of the figure as an inscription.
- **Weak mapping:** the figure is involved in a proportional analogy with a weak pressure (rotation only) for an unusual mapping that will potentially lead to re-representation of the figure as an inscription.
- **No mapping:** the figure is involved in a task that does not require analogical mapping and therefore there is no pressure for re-representation.

The dependent variable is the number of participants who will manage to see the inscription.

Procedure

Each participant is tested in a sound proven booth on a computer running e-Prime. The experiment consists of a series of 4 tasks each of which is a proportional analogy task with 4 possible answers to choose from. This is true for the two mapping groups. In the No mapping group the task is to choose between the four alternatives the one that the subject feels best fits the target figure. The participants have 30 seconds for each slide before they can respond (this was a way to ensure that even if they solve a task very rapidly, they will still have some time to observe the figure and eventually re-represent it). After the 4th slide (which was the test slide containing the ambiguous figure) disappears, a question is posed to the participants asking what they have seen at the target figure. We tell them that there might have been a nontrivial alternative interpretation of the figure, and ask them if they have seen it without any chance to look back at the picture itself.

Stimuli

In the last (the test) trial the participants saw one of the three slides presented in Figure 2 depending on the group they belonged to. The previous slides contained similar tasks and were arranged in an order of increasing difficulty.

These tasks do permit more than one possible answer. Thus participants may choose an alternative on various grounds.

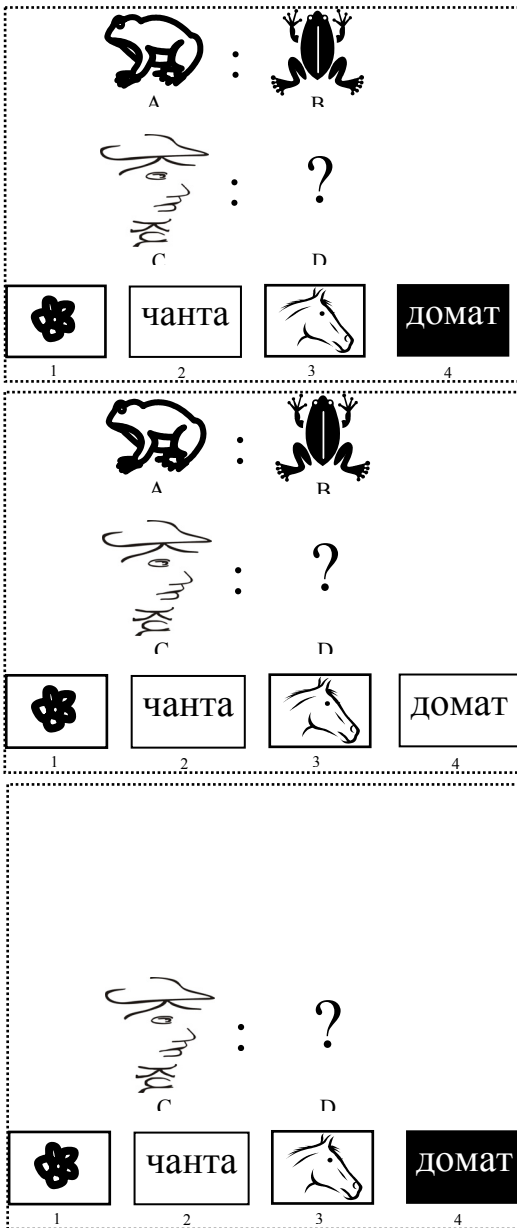


Figure 2. Test items: a) test item in the strong mapping group; b) test item in the weak mapping group; c) test item in the no mapping group. The two words in Bulgarian among the options provided are CHANTA (Bulgarian word for BAG) and DOMAT (Bulgarian word for tomato).

In both mapping conditions there is the possibility to choose either “bag” or “tomato”. This would be particularly true if one has seen the inscription in the ambiguous figure. In this case you get picture to picture in the first row, and text to text in the second row. However, the opposite influence could potentially also work: if for any other reason we choose a text answer, then there will be a pressure to re-interpret the figure as a text as well in order to have the nice “text to text, picture to picture” analogy. No such pressure is expected in the third group (the no mapping case).

If we now compare slides 1 and 2, we will see that the only difference is in the background colour: the “tomato”

word is presented in negative. The very presence of this black alternative makes another feature of the objects in the first row more accessible and we can expect this feature to be represented more often by the perceptual process: the second picture is in black while the first one is in white. This makes a really strong pressure to put the human face in correspondence with the “tomato” word. Once this correspondence is tried out it generates the pressure to reinterpret the ambiguous figure as a text. This pressure will be much higher in slide 1 than in slide 2, because of the higher systematicity of the mapping in slide 1.

Participants

Our sample consisted of 60 subjects randomly assigned to the three conditions. Thus each condition contained 15 subjects. Their age ranged from 18 to 43. Some of the subjects were students at NBU participating for credits, others were professors at NBU and a third part was recruited from outside the institution.

Results and discussion

The main effect of the group manipulation is significant ($\chi^2(2)=9.573, p=0.008$) and the average data for each group are presented in Figure 3. The result shows that higher percentage of participants are making reinterpretation and seeing the inscription in the strong mapping condition than in the weak mapping condition, and even more so compared to the no mapping condition. This is exactly what was expected.

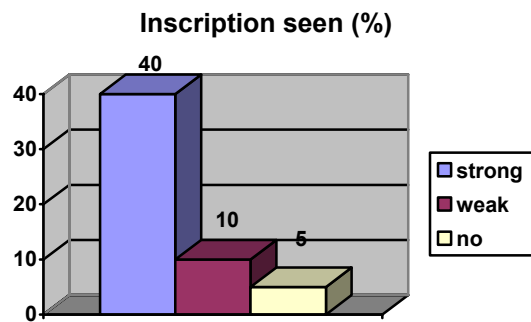


Figure 3. Percentage of participants who saw the inscription in each group. These differences are significant [$\chi^2(2)=9.573, p=0.008$]

Pairwise comparisons show that the strong mapping group result is significantly better than the result in each of the two other groups, but there is no significant difference between the weak mapping and no mapping groups. This speaks in favour of the role that analogical mapping plays in the process of the reinterpretation, and especially of the role of the systematicity constraint.

One may assume that making a textual response for whatever reason will force the participant to make a re-representation and see the target figure as a text as well. Let us see whether the group makes any difference in the above relationship (Figure 4). The data show that in the control

group (no analogy) even when the participant has chosen a textual response for whatever reason this is not reflected in a higher probability of seeing the inscription. Contrary to that in both mapping groups the textual responses increase the chances of the participant to see the CAT (from 6% to 25% in the weak group, and from 31% to 57% in the strong one). This is in line with our hypothesis that the analogical mapping will actually cause reinterpretation of the figure.

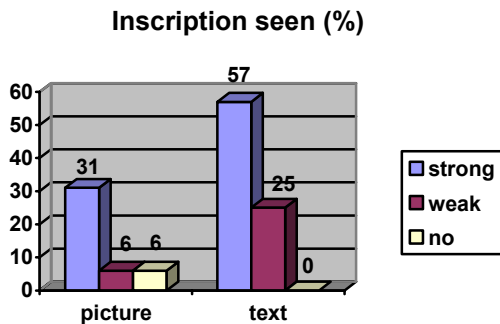


Figure 4. Percentage of subjects who have seen the inscription CAT as a function of their response and the mapping group they belonged to. There is an interaction (textual response increases the likelihood of reinterpretation but only in the mapping conditions, no reinterpretation at all when there is a lack of mapping pressure). In addition, the strong mapping produces more reinterpretations independently of the response (in both cases: when a picture response and a textual response is produced).

An important note is needed here: All subjects who actually saw the inscription spontaneously reported verbally seeing it¹ before the thirty seconds had passed. This was true for everybody except for one subject in the weak mapping condition. However when asked, she also claimed that she had seen the inscription before the sound signal. Thus it appears that it was not the case that the subjects in the strong mapping group saw the inscription more often because of spending more time looking at the slide than subjects from the other two groups. This result made it unnecessary to compare the reaction times of the subjects in the three conditions.

This experiment has demonstrated that analogical mapping does produce re-interpretation of the target stimulus and the stronger the mapping the bigger the effect is. Moreover, the observation above suggests that this re-interpretation is likely to happen somewhere during the mapping process and before a response is being produced. The difference between the strong and weak analogy conditions (which objectively differ only in the background color of the “tomato” alternative) shows how important the relational mapping is: the combined pressure of two relations being mapped is much higher than the pressure of just one relational mapping.

¹ This re-representation of the target picture was often accompanied by strong and positive emotional responses.

Experiment 2

The goal of this second experiment is to explore the process of reinterpretation in more detail. The main idea is to see whether a local correspondence established between elements of the two terms in the proportional analogy, will eventually spread over the entire group and produce a global reinterpretation of the whole image. This will be a good illustration of how the analogical mapping interplays with the perceptual processes and how small steps in the mapping process influence certain representation building subprocesses.

Hypothesis

Our hypothesis was that the type of local mapping established will be crucial for the process of reinterpretation.

Design

The experiment has a between group design and the manipulated variable is the type of the local correspondence established between the first and the second term of the proportional analogy:

- **literal condition:** the medal of the sportsman is put in correspondence with a medal.
- **reinterpretation condition:** the medal of the sportsman is put into correspondence with the letter O.

The dependent variable is the number of reinterpretations of the ambiguous figure, i.e. the number of participants who have seen the inscription “wolf” in each group.

Stimuli

The stimuli in this experiment are shown in Figure 5.

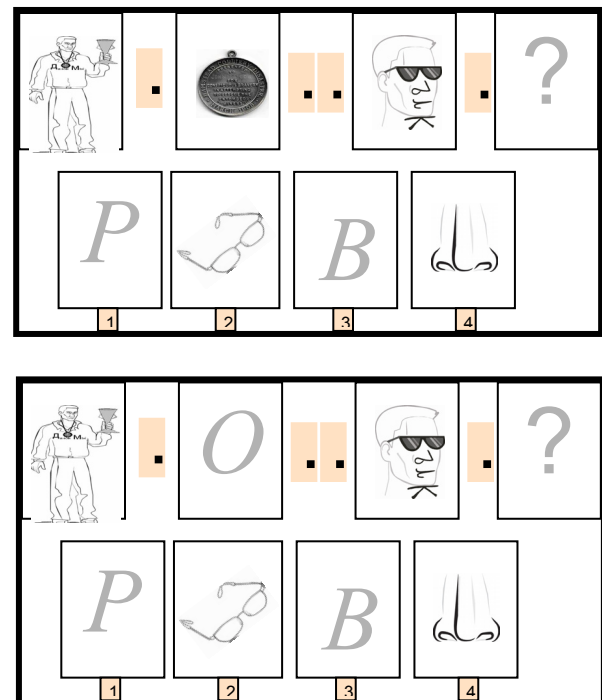


Figure 5. Test items in the two groups.

The two tasks are exactly the same, including the alternative provided. The only difference is in the second term of the analogy.

In the literal condition, the second term is a medal and this is supposed to establish a correspondence between the medal of the sportsman and the medal and to build a representation of the relation part-of(medal, sportsman), this is supposed to suggest the analogy: Sportsman:medal::human face:glasses. This analogy should not make any pressure for reinterpretation of the human face.

In the reinterpretation condition, the second term is the letter O. Trying to find what is the relation between the sportsman and the letter O one might discover that there is an inscription on the sportsman jacket and a correspondence might be established between the medal of the sportsman and the letter O, i.e. a representation is built of the relation is_like(medal, O). This is possibly going to activate the concept of IS LIKE and other similarities between objects and letter might be sought. This may result in establishing a correspondence between the glasses at the human face and the letter B. Here the analogy may stop happily and the response will be the letter B. When asked afterwards, participants may not necessarily have seen another interpretation of the human face. However, if the process of analogical mapping continues it may find new correspondences, e.g. the letter O corresponds to the medal, but the medal itself may be considered a letter O and thus the inscription on the jacket of the sportsman reads DOM (which means home in Bulgarian). In this way a more complicated correspondence may be established: O corresponds to a letter in a whole word. Than one may try to find out whether the same relation is present in the right term of the analogy. This could lead to seeing the glasses as only one letter among many in a word, and if that happens a strong pressure would exist for reinterpreting various elements of the human face and recognizing letters in it. This could finally result in a global reinterpretation of the face as the word VALK (“wolf” in Bulgarian).

These are the hypothetical processes that we envisaged when the stimulus material was designed.

Procedure

The procedure is the same as in Experiment 1.

Participants

Fifty students at the New Bulgarian University (25 males and 25 females) participated in the experiment, the age ranged from 19 to 35 years. They were randomly assigned to one of the two conditions.

Results and discussion

The results from the experiment are represented in Figure 6 and Figure 7. In line with our hypothesis there is a significant difference between the number of subjects who saw at least “some letters” at the human face (i.e. produced partial re-representation), and marginally significant difference between the number of subjects who fully re-represented the face into the word “wolf” (Figure 6). The difference is even stronger if we take into account only the

subjects who actually made the target analogy (Figure 7), because this analogy is not that obvious and only about half of the subjects in the “reinterpretation analogy” condition actually produced the analogy.

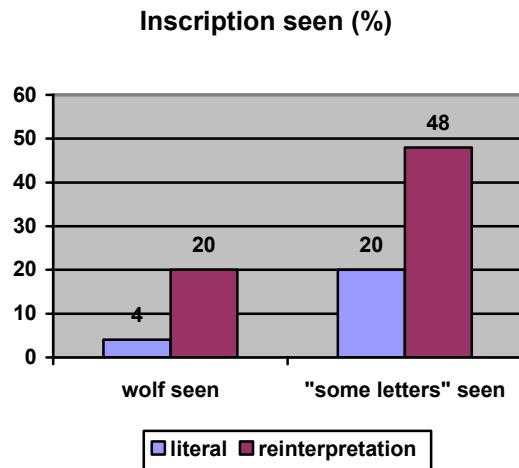


Figure 6. Percentage of participants in each group who saw “some letters” and the whole word “wolf” in the ambiguous picture as result of the analogy-making process. [the difference in the number of participants who have seen “some letters” is significant at the $p=0.036$ level, while the difference between those who have seen the whole word “wolf” in the two groups is significant at the $p=0.095$ level measured by the Fisher’s exact test]

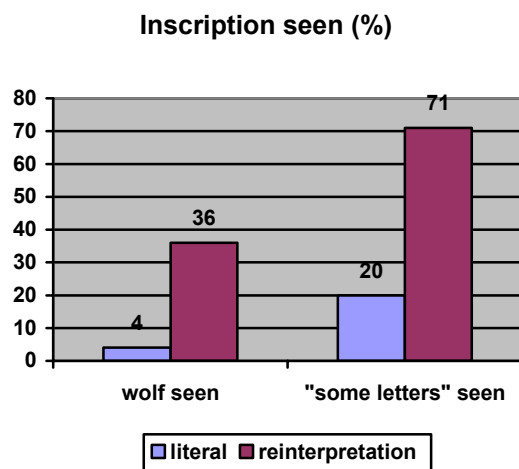


Figure 7. Percentage of participants who saw “some letters” and the whole word “wolf” in the ambiguous picture taking into account only those who made the target analogy. [the difference in the number of participants who have seen “some letters” is significant at the $p=0.016$ level, and the difference between those who have seen the whole word “wolf” is $p=0.002$ measured by the Fisher’s exact test]

There is a clear main effect of the type of analogy-making: literal vs. reinterpretation analogy. This effect is stronger if we take into account only the subjects who

successfully made the target analogy; if we take all subjects it is marginal for the effect on the whole word “wolf” but still significant on the recognition of some letters on the human face. This might mean that the process of reinterpretation requires some time, so some people stop before they have arrived at the global reinterpretation and are satisfied at a point when only a few letters are recognized.

General Discussion

The two experiments have demonstrated that as expected analogy-making can make a reverse pressure to reinterpret the initial perceptual data in order to make the mapping more coherent. This process seems to run gradually over time starting with some local correspondences established and gradually building a global mapping and exerting more and more pressure. The more consistent the mapping is, the stronger the effect seems to be (the systematicity principle in action).

These experiments cannot tell apart the interactionist and the modular view on the analogy-making process, since possibly both could explain the data. However, it seems that the gradual process of spreading the influence over the whole mapping and from reinterpreting local features to global reinterpretation will more naturally fit the interactionist view. Further experimentation is needed. In particular we are currently running a similar experiment using gaze tracking equipment, which may allow us to track the process of reinterpretation.

Acknowledgments

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