

IS IT POSSIBLE TO MANIPULATE THE STRENGTH OF THE STRUCTURAL CONSISTENCY PRESSURE?

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ABSTRACT

The one-to-one mapping constraint has been implemented in almost all of models for analogy making, but has not yet been studied systematically. A psychological experiment was performed that tested whether the strength of one-to-one mapping pressure can be manipulated by a prior task unrelated to analogy-making. The results demonstrate that people's answers to match-to-sample tasks can be systematically shifted toward one or another direction by a relatively short manipulation.

INTRODUCTION

According to the one-to-one mapping constraint, one of the structural consistency principles (Falkenhainer, Forbus, & Gentner, 1989; Gentner, 1982, 1983), people tend to maintain an isomorphism between mapped situations as much as possible. Thus if there are elements mapped to two or more elements, or if there remain unmapped elements, then the quality of the analogy decreases.

The structural consistency pressure is incorporated as a mechanism in almost all models of analogy-making. For example, in SME (Forbus, Ferguson, & Gentner, 1994) any violations from the one-to-one mapping constraint participate in the calculation of the structural evaluation score of the mappings. ACME (Holyoak, Thagard, 1989), LISA (Hummel & Holyoak, 1997), and AMBR (Kokinov & Petrov, 2001) implement the structural consistency pressures by inhibitory links between competing hypotheses. In Tabletop (French,

Hofstadter, 1991) and Copycat (Hofstadter, Mitchell, 1991) the one-to-one mapping constraint emerges implicitly from the rules for computing the probabilities for searching one or another relation.

Several psychological experiments (Spellman & Holyoak, 1992, 1996; Markman, 1997; Krawczyk, Holyoak, & Hummel, 2005) have tested whether the one-to-one mapping constraint can be violated during mapping or during transfer. However, the exact strength of the one-to-one mapping pressure has not been studied systematically, nor the factors that determine it. This paper focuses on the question of whether its strength is constant or can vary dynamically.

PSYCHOLOGICAL EXPERIMENT

This experiment was designed to test whether tasks unrelated to analogy-making can shift match-to-sample judgments of people. The participants were randomly assigned to one of three groups – two experimental and one control. People from the two experimental groups participated in two sessions of the experiment. During the first session (termed “priming session”) the participants from both groups saw slides with several dots and lines with different colors (Figure 1). However, the tasks were different for the two groups. People in the first group had to judge whether each dot lay on a line with the same color and vice versa (i.e., whether each line went through a dot with the same color). People in the second experimental group had to judge whether there were three or more dots on the same line. The expectation was that participants from the first group would be biased to search for one-to-one

correspondences, whereas people from the second group would be biased to search for one-to-many correspondences.

During the second session of the experiment, which followed immediately after the first, all participants had to solve several match-to sample tasks (see appendixes). People in the third group (the control) did not participate in the first session. They simply solved the match-to-sample tasks.

Design

This was a one-factor between-subjects design. The independent variable was the condition – the type of the first session – with three levels: “one-to-one” condition (“Does each dot lie on a line with the same color?”); “one-to-many” condition (“Are there three or more points on a same line?”); and “control” condition (without the first session).

We obtained results from three different types of match-to-sample-tasks (see section Stimuli and Figures 2, 3, and 4). For all three task types we measured the proportion of the answers, which corresponded to higher strength of one-to-one mapping bias.

Stimuli

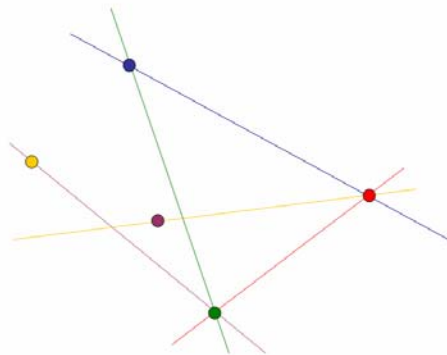


Figure 1. Example of the stimuli, used for the first session of the experiment

Forty-eight slides with coloured dots and lines were prepared for the first session of the experiment (Figure 1).

The 24 mach-to-sample tasks were divided into 3 groups of 8 tasks in each. The first group consisted of “property” tasks (Figure 2). A single property of common figures varied; either colour or form. Consider the example in Figure 2. There were 3 dots (red, green, and yellow) as a probe. The left alternative consisted of a red dot, a green dot, and again a green dot, whereas the three dots on the right alternative were red, green, and blue.

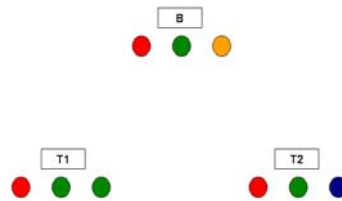


Figure 2. Example of the match-to-sample tasks of type “property”

The assumption was that if people were biased to respond according to the one-to-one mapping constraint, they would choose the right alternative. However, if they tend to search for literally corresponding colours only, with low pressure to avoid one-to-many mappings, they would prefer the left alternative – the blue dot on the right can not be mapped to anything.

The exact correspondences, as well as the position of the one-to-one response varied, thus forming four ‘colour’ tasks and four ‘form’ tasks (All slides for all task types are attached as appendixes.)

The second group of tasks consisted of eight so-called “relation” tasks. There were two types of “relation” tasks (Figure 3).

Consider the examples on Figure 3, upper part. The probe consisted of three elements with two different relations between them, thus having the form:

$$B: A - R1 - B - R2 - C$$

The two alternatives had the same technical form but the two relations were the same

for one of the alternatives. Thus, the alternatives were:

T1: A -- RI – B – RI – M

T2: A -- RI – B – R3 – Z

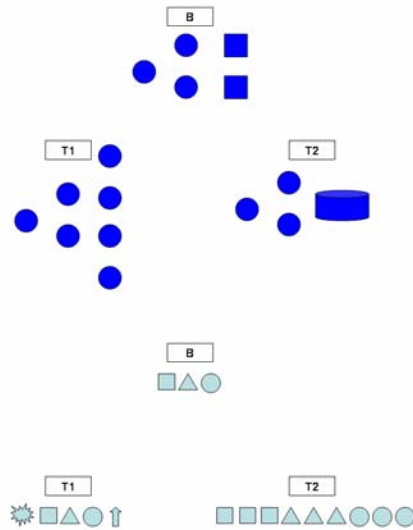


Figure 3. Example of the match-to-sample tasks from type “relation”

The important difference between the two alternatives was the second relation – whether it is a replication of the first one or is a completely new one. Our expectations were for people who are biased for one-to-one mapping to respond with T2, whereas people from the one-to-many group to choose T1. Again, the positions of the two answers were balanced among the tasks.

The second type of “relation” tasks had different structure (Figure 3, bottom part). There were three items in the probe. The same three items were surrounded by irrelevant objects in one of the alternatives, whereas the other alternative consisted of three groups of corresponding items. We expected a one-to-one bias to reflect more people’s answers of the former alternative and vice versa.

The last group of eight match-to-sample tasks was called “conflict” tasks (Figure 4).

People should choose either by the colour or by the form. However, one of the alternatives required the one-to-one mapping pressure to be low, whereas the other alternative required the tolerance to map very different items to be high. Thus, our expectation was that the manipulation we performed during the first session of the experiment may shift the responses to one or another direction.

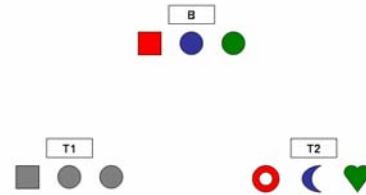


Figure 4. Example of the match-to-sample tasks from type “conflict”

The exact correspondences, as well as the position of the one-to-one response, were balanced for all 24 tasks. All tasks are attached at the end of the paper as appendixes.

Procedure

During the first session of the experiment, the participants from the two experimental groups saw 48 slides with coloured lines and dots on them (Figure 1), presented in a random order. The number of lines was equal to the number of dots on each slide and varied among slides between four and six. People from the first group (“one-to-one group”) had to answer to the following instruction: “Please, answer as quickly as possible by pressing the respective button whether each dot lies on a line with the same colour and vice versa, whether each line go through a dot with the same colour”. Participants from the second group (“one-to-many group”) received the instruction: “Please, an-

swer as quickly as possible by pressing the respective button whether there is a line that goes through three or more points". For 12 of the slides the right answer was "yes" for both conditions; for 12 it was "no" for both conditions; for 12 of the slides the right answer was "yes" for the first group and "no" for the second one; for the last 12 slides – vice versa.

Immediately after the first session, the participants from both groups (as well as people from the control group, who did not participate in the first session) had to solve 24 match-to-sample tasks, presented in a random order. Each of the tasks consisted of a probe, named "B" at the top of the screen and two alternatives – "T1" and "T2", placed respectively at the left-bottom and right-bottom part of the screen. The participants had to follow the instruction: "Please, answer by pressing the corresponding button which of the alternatives - T1 or T2 – is more similar to the probe B".

Participants

30 students from New Bulgarian University, divided randomly into three groups of 10, took part in the experiment voluntarily, without a payment.

RESULTS

The results from the experiment are depicted in Figure 5. The pattern of the results among the tasks from each of the task type was the same (even for the two different kinds of "relation" tasks). Thus, the proportion of "one-to-one" responses was aggregated together for each subject and for each type of task ("property", "relation", and "conflict").

Analysis of variance showed significant differences between groups for the "property" task ($F(2, 27) = 3.490$, $p = 0.032$); and for the "relation" task ($F(2, 27) = 3.555$, $p = 0.043$). There was not a significant difference between groups for the "conflict" tasks ($F(2, 27) = 0.171$, $p = 0.844$).

The difference for the "relation" task, however, was in the direction, opposite to our expectations. People from the "one-to-one

group" gave less one-to-one responses than people from the "one-to-many group" (mean 0.34 versus 0.46 respectively).

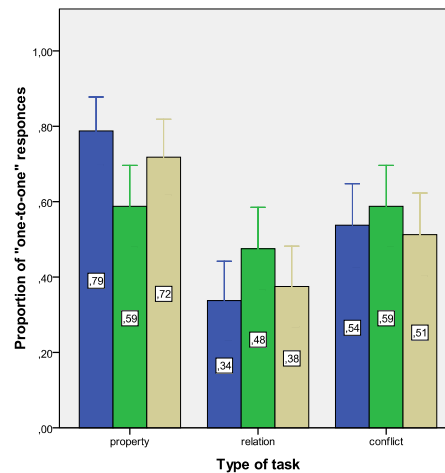


Figure 5. The results from the experiment. The three types of tasks are on the abscissa – "property", "relation", "conflict". The proportion of the "one-to-one" responses is on the ordinate. The condition is represented with different colors – blue bars for "one-to-one group", green bar for "one-to-many group", and yellow bar for the control group.

The responses for the "conflict" task type were predominantly (86.5%) based on the form of figures, not on their color. The factor 'type of one-to-one response', i.e. whether the response 'one-to-one' corresponded to form-based or color-based choice significantly influenced the responses ($F(1, 58) = 71.64$, $p = 0.000$). Thus, because the stimuli were balanced according to the conflict properties, we did not obtain any differences between groups.

DISCUSSION

The results for the tasks of type "property" were in accordance with our expectations. The manipulation during the first session systematically shifted people's judgments in a specific direction.

The manipulation, however, could not change the participant's behavior for the 'conflict' type tasks. It turned out that there is actually not any conflict. People preferred form over color and systematically based their responses on the form of the figures. This bias was too strong to be overcome by our manipulation.

The results for the "relation" tasks, which were exactly opposite to our expectations, deserve special attention. There are several possible explanations of this effect:

(1) Maybe the two priming tasks actually cause an increase in the tendency to select on the basis of matching properties or relations, respectively. The results, however, can not be fully explained in this way. The choice between the alternatives for the "relation" task, for example, is a choice between 'R1<->R1, R2<->R1' or 'R1<->R1, R2<->R3' mapping. If the choice is based on the higher order relations like 'same relations', 'different relations', than why the results are reversed for the 'property' task?

(2) Maybe people did not notice the relations. Maybe their judgments were based solely on the category of stimuli. Consider the example on Figure 3, upper panel. According to our initial assumptions, the sample figure consisted of three objects with two relations: **a-R1-b-R2-c**. The left possible alternative involves two times the relation R1, i.e., its structure is **a-R1-b-R1-d**, whereas the structure of the right alternative is **a-R1-b-R3-e**. Thus, if the pressure for one-to-one mapping is too strong, people would avoid the left choice, which provoked two conflicting hypotheses about **R1**. However, people may have looked at the task from the following perspective: In the right alternative there was an element (the cylinder) that could not be mapped onto any figure from the sample because of the internal structure of the items (the third element of the sample was 'two equal squares', while the third item of the right alternative was 'single cylinder'). Thus, from the point of view of the internal structure of objects themselves, instead of the relational structure among them,

isomorphism was violated exactly opposite to our assumptions cases.

(3) Maybe the "relation" tasks were too difficult and rather than priming, we had obtained a saturation effect. This explanation, however, has a weak point. Usually priming and saturation do not react simultaneously and depend on the current task.

(4) Maybe there are completely different cognitive mechanisms, responsible for solving "property" or "relation" match-to-sample tasks. It remains unclear, however, how one and the same manipulation can prime isomorphism for one of these mechanisms and anti-isomorphism for the other one.

Although that there are many alternative explanations of the results for the "relation" group of tasks, it was clearly demonstrated that the manipulation during the first session shifted people's judgments in a specific direction.

CONCLUSION

The strength of the one-to-one structural consistency pressure can be dynamically shifted to one or another direction even by a relatively brief manipulation. This finding poses some problems for models of analogy-making, which typically assume a single global parameter for this strength. Being a variable, not a fixed parameter, it is important to define what it depends on.

From another point of view, the results from the experiment also provide evidence that human ability for analogy-making (more precisely, the ability for mapping) is not isolated but may be influenced by context. Some tasks unrelated to analogy-making may change the behavior of people in a match-to-sample task.

Thus, analogy-making seems much more integrated with various other cognitive abilities than has previously been assumed.

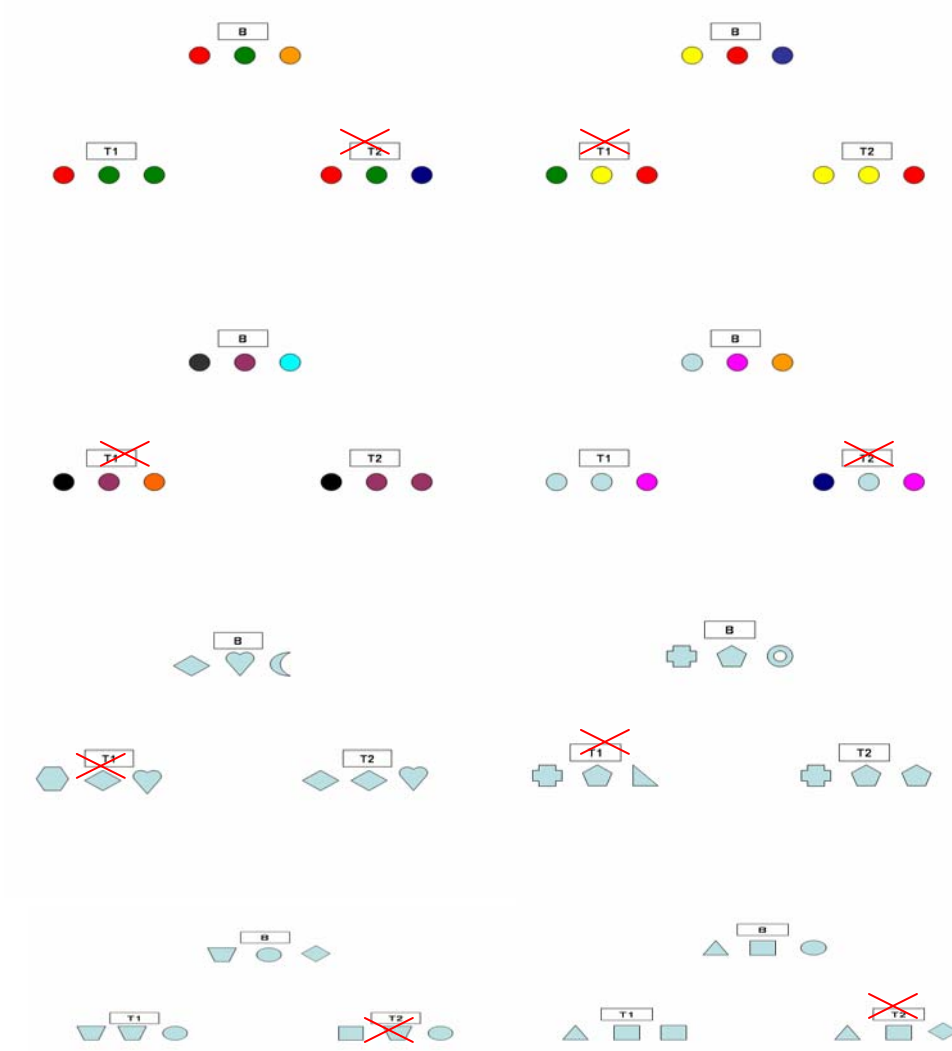
ACKNOWLEDGMENTS

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Appendix 1:
Stimuli for the “property” tasks (The responses, we measured as “one-to-one” type, are marked)

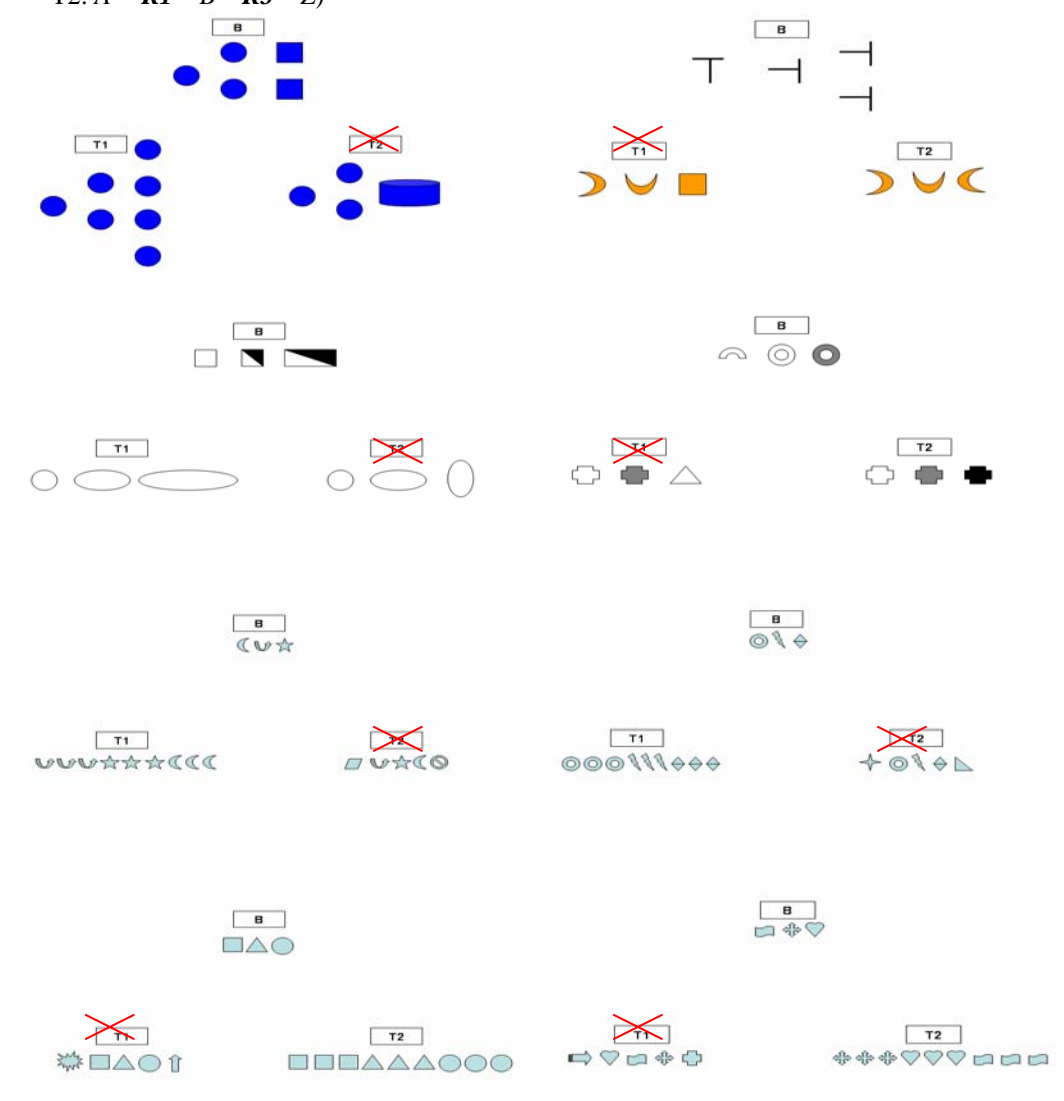


Appendix 2: Stimuli for the “relation” tasks

(B: A -- R1 - B -- R2 - C

T1: A -- R1 - B - R1 - M

T2: A -- R1 - B - R3 - Z)



Appendix 3: Stimuli for the “conflict” tasks

