Relational Versus Attributional Mode of Problem Solving?

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Abstract

We argue that the concept of relational priming (e.g. Schunn 1996, Day 2007) can be extended from priming of specific relations to generating a cognitive state during which subjects are particularly likely to encode and use relations. We conducted an experiment in which three groups of subjects did different tasks before a target matching to sample task was introduced which contrasted a relationally versus an attributionally similar alternative. Subjects in one condition were asked to solve tasks involving relational reasoning while subjects in another condition were asked to tasks involving only attributes. As expected subjects in the first condition were more likely to pick up the relationally similar alternative while in the second condition the results reversed relative to a control group. In conclusion we argue that this study shows that encoding of relations can be a subject to unconscious context influence.

Keywords: relational priming; context dependence; encoding of relations, cognitive state

Introduction

Since Gentner's Structure Mapping theory (Gentner 1983) a great deal of research has been concentrated upon analogical reasoning in terms of mapping of higher-order relations. Although the mechanisms employed by the mapping process have been extensively studied little is currently known about the nature of the processes involved in relational encoding. This study attempts to scratch the surface of this complex matter by asking the question of whether the process of relational encoding is subject to certain external and internal context influences. While the answer to this question certainly would not reveal the nature of the encoding process it would hopefully tell us something about certain specific aspects of its functioning.

Currently there is some agreement that the phenomenon of relational priming exhibits a somehow automatic (i.e. not subjected to voluntary control, external influence and conscious experience) nature (e.g. Kokinov 1996, Schunn 1996, Day 2007, Hristova 2009)[1]. The abovementioned studies employ different methodologies ranging from naturalistic-like settings (Schunn 1996) to Stroop-like interference Reaction Time paradigms (Hristova 2009). There is however a common thread among these research projects – the use of specific relations. In other words all these (and other) studies concentrated on exploring the relational priming by using concretely represented, nameable relations. The same naturally holds true for relational priming in psycholinguistic research (e.g. Gagne 2005, Estes 2006).

Instead of continuing this well established line of research we concentrated on the question of whether a global cognitive state can be induced in which people are more likely to encode relations in general. It can be said that we are still concerned with relational priming but we employ a rather broad, holistic and abstract definition of the phenomenon.

We hypothesized that subjects confronted with tasks explicitly involving relational reasoning will subsequently be more likely to continue this style of reasoning when dealing with completely different tasks. We also hypothesized that subjects forced to encode and use attributes of objects will be considerably less likely to encode (and use) relations in subsequent tasks. In other words we argue that not only specific relations can be primed with similar other relations but also a "relational mode of thinking" can be induced by use of specific task requirements. Thus we claim that relational priming (and consequently "attributional priming") is a much more complicated and abstract phenomenon than currently conceived by traditional research in the area.

Another hypothesis related to the current study concerns the subjects' ability to cope with the particular priming task. Since we argue that task requirements can possibly induce a particular cognitive state it follows that the degree to which this actually happens should depend upon a subject's particular ability to successfully cope with the task at hand (the priming task).

Experiment

In the current experiment we tested three different groups of subjects in order to see whether prior tasks influence significantly relational and attributional reasoning during a target task. In the first condition subjects solved six different mental rotation tasks, in the second condition subjects solved six items from Raven Progressive Matrices test (e.g. Raven 2003) and in a third condition no task preceded the target task. The three groups are called attributional, relational and control conditions respectively.

[1] But see Spellman et al. (2001) whose results indicate that relational priming took place only when participants were explicitly instructed to pay attention to the relations existing between the stimuli (words) involved in the studies.

The target task was a single matching to sample task borrowed from Medin et al. (1990). During this task subjects were required to choose the more similar from two alternative figures to a target figure. One of the alternatives embodied a unique common relation with the target (we called this one the relational alternative) while the other shared a unique attribution with the target (we called it the attributional alternative).

We hypothesized that subjects in the relational condition would be more likely to pick up the relational alternative in the target task (compared to the control group where no priming task was present) because the Raven Progressive Matrices test requires subjects to encode and map complex higher-order relations. On the other hand since the mental rotation task involved dealing with attributes and first order relations between parts of objects we expected that subjects from the attributional condition would be more likely to choose the attributional answer to the matching to sample task (again compared to the non primed control condition). As mentioned above we also hypothesized that there would be a correlation between subjects' levels of performance on the prior tasks and the degree of subsequent relational priming. Moreover since subjects in the attributional task were expected to be les likely to give relational answers to the target task we expected a negative correlation between levels of performance during the priming task and the proportion of relational answers to the target task in the attributional condition. By the same logic we expected a positive relationship to exist in the relational condition.

Design. A simple between group design was employed which involved three independent groups of subjects allocated to the attributional, the relational and the control conditions. The three levels of our independent variable were defined by the task the subjects in the respective condition had to solve before the target matching to sample task. The dependent measure was defined as whether a given subject gave a relational or attributional answer to the target task. The target task was the same for all participants.

Stimuli. The stimuli for the attributional condition consisted of six mental rotation tasks. Each task involved sixteen versions of a particular letter from the Latin alphabet. Thus there were six letters in that condition and each letter appeared sixteen times. Each version of a letter was presented in a rotated position. For eight of the versions it was possible to obtain the original letter via mental rotation (these represented the so called true versions of a particular task since the subjects' task was to indicate whether the particular version could or could not be rotated in order to arrive at the original letter) and for the other eight versions it was impossible to do so for these versions were rotated mirror images of the original letter (these were called the false versions). Each letter (both the true and the false versions) was rotated at eight different angles. The degrees of rotation were 40, 80, 120, 160, 200, 240, 280 and 320 degrees. The six letters used for each of the six tasks were Z, R, F, N, P, S. Each individual task was represented as the sixteen versions of a particular letter arranged in a 4x4 matrix printed on an A4 portrait sheet of paper. The order of the true and false versions as well as the order of the eight different angles of rotations was randomized across the six tasks. The order of the six tasks was randomized across participants. Since subjects were required to make a judgment for each letter version in each task (i.e. subjects were asked to indicate whether a particular version was a rotated original letter or a rotated mirror image of the original letter) there were 6x16=96 judgments made by each participant in the attributional condition. A sample of three letters is presented at figure 1. The top three letters represent instances of the false alternatives and the bottom three letters represent instances of the true alternatives.

Figure 1. Examples of the mental rotation task.

Subjects from the relational condition were presented with six of the Raven Progressive Matrices items. These items were the odd numbered items from series E (the last series) from the test. Thus subjects had to solve items E1, E3, E5, E7, E9 and E11. The items were presented in this ascending order for all participants in this condition. Subjects in this condition were asked to fill the blank in each item with one of the options available at the bottom of the page. The original instruction from the test was given to each participant. The original test panes were used.

The target matching to sample task presented to the participants at the end of the experiment was borrowed from Medin et al. (1990). It is depicted in figure 2. The target is at the top of the figure and is denoted with T. The two alternatives are denoted with B1 and B2 respectively. The subjects' task was to indicate which one of the two options was more similar to the target. As already mentioned the B1 option shared a unique attribute with T (a checked circle) while the B2 option shared a unique relation with T (same shading of the objects).

Procedure. In both the attributional and the relational conditions subjects were given a maximum amount of time of one minute for each individual task (one item from the Raven test or one mental rotation task consisting of sixteen individual versions of a letter). In the attributional condition subjects were instructed to make as many accurate judgments as possible for each task for one minute. In the relational condition subjects were instructed to try to solve each item correctly for one minute. Prior to the experiment subjects from the attributional condition were given a practice trial consisting of sixteen versions of the letter L.

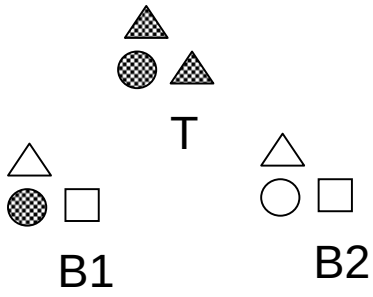


Figure 2. Example of the matching to sample task.

The subjects from the relational condition were given the original instruction from the Raven test as well as items C9, D3 and D8 as complementary practice trials. In each condition after the instruction the experimenter encouraged the participants to try to solve the practice task all by themselves and explained their errors as well as the correct solutions when needed after the one minute maximum time interval. After the experimenter was convinced that subjects understood the procedure the real study began.

The experimenter used a stop watch in order to keep track on time for each task.

In both the relational and the attributional conditions participants indicated their responses verbally and the experimenter wrote down their answers on a scoring sheet. In the attributional condition subjects were instructed to indicate whether a version of a letter could be rotated to its original position by moving from the top row down and moving from left to right within a particular row of a given matrix of sixteen versions of a letter. In case a participant failed to answer to all versions of a mental rotation task within a minute the sheet containing the matrix was removed out of her sight but the participant was asked to try to guess the correct answers for the remaining versions of the letter. Similarly in the relational condition if a person didn't answer to a Raven item within one minute the pane was taken out of her sight but the participant was asked to try to guess the correct answer anyway.

A thirty seconds interval separated the six priming trials from each other in each experimental condition.

Immediately after the end of the initial stage the target stimulus was presented in an ostensibly unrelated task and the subject was asked to indicate whether B1 or B2 option was "more similar" to the T figure (see figure 2). No time limit was present during the final task.

The subjects from the control condition proceeded immediately to this final stage of the experiment, i.e. they were not involved in any prior task.

After the participants indicated their answers they were asked whether they spotted the relational similarity between the target and the B2 option. After their answer was written down by the experimenter the subjects were debriefed and the experiment finished.

Note that the two priming task are both quite different from the target task. Thus it seems rather unlikely that some specific features of the priming tasks may have influenced subjects' judgments during the final matching to sample task.

Subjects. 110 students from New Bulgarian University participated in the study for partial course credit. Thirty five participated in the attributional condition, thirty five participated in the relational condition and forty participated in the control condition. Overall there were 62% females and 38% males in the study which were allocated proportionally to all three conditions.

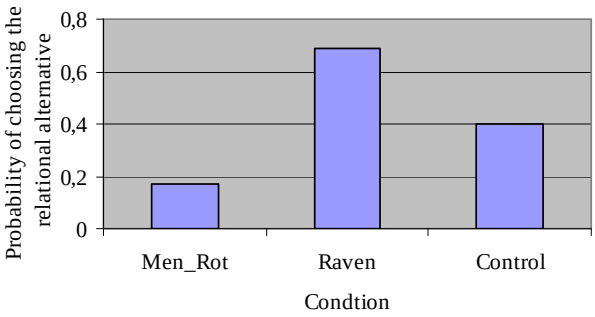
Results and Discussion. Table 1 below shows the raw number of subjects within each condition which gave the attributional and the relational answers to the target task. Numbers in parentheses represent the respective percentages.

table 1.

	#Attrib. Answers	# Rel. Answers	Total
Attrib. Cond.	29 (83%)	6 (17%)	35 (100%)
Rel. Cond.	11 (31%)	24 (69%)	35 (100%)
Contr. Cond.	24 (60%)	16 (40%)	40 (100%)

The results are summarized in figure 3 below. The bars represent the proportion of people giving the relational answer in each condition.

figure 3



As can be seen the data are in line with our hypotheses: subjects from the relational condition were more likely to pick up the relational answer during the matching to sample task compared to subjects in the control condition. Also the subjects from the attributional condition picked up the attributional answer more frequently compared to the baseline control condition. In order to asses the significance of our results we conducted a series of statistical analyses. First we fitted a logistic regression model to the data with our three experimental conditions treated as a single

categorical predictor and subject's answer as a categorical dependent variable (a relational answer was coded as 1 while an attributional answer was coded as 0 for each participant). The model including our independent variable significantly outperformed the null model (including only the intercept): Chi Square of Likelihood Ratio Change (2) = 20.049, $p<0.001$. Thus we see that there is a highly significant effect of our independent variable. Since we defined our control condition as the reference condition for the analysis the b coefficients of the model represent the difference between the other two conditions to the control condition. These were b = -1.17 (1), p = 0.034 for the attributional condition and b = 1.19 (1), p = 0.015 for the relational condition. Thus we see that the relational task significantly increases the probability of relational answer while the attributional task decreases it relative to the control condition.

The pseudo R^2 estimate (Nagelkerke) for the effect of the independent variable was equal to 0.224 – a reasonably high estimate.

Since both conditions were significantly different from the control condition and since their coefficients were with opposite signs it logically follows that the two experimental conditions were significantly different from each other.

In order to further support our results we conducted a series of chi squared analyses. First we assessed the significance of our independent variable as a whole. As with the regression analysis the results were highly significant – chi square (2) = 19.109, $p<0.001$. We proceeded with three post hoc comparisons which compared the proportions of relational answers between all three groups. The results showed that the relational and the attributional conditions were significantly different from each other – chi square (1) = 18.9, $p<0.001$. Both the conditions were also significantly different from the control condition – chi square (1) = 4.705, p = 0.03 for the difference between the control and the attributional conditions and chi square (1) = 6.122, p = 0.013 for the difference between the control and the relational conditions. Thus we see that all our conditions exhibited different proportions of relational answers[2]. Looking back at figure 3 we see that subjects from the relational condition were most likely to give a relational answer to the target task while those from the attributional condition were least likely to do so. The control condition was somewhere in between the other two.

These results strongly support our main hypothesis about the possibility to induce a cognitive state which enhances subjects' ability to encode relations. However there still exists the possibility of people encoding the relation embodied in the target task with approximately equal frequency but for some reason being more prone to choose it in the relational condition. When asked about whether they had spotted the "same shading" relation, however, only two participants from the control condition claimed they had and only one participant from the relational condition did so (these numbers refer only to subjects who gave the attributional answer to the target task, of course; all subjects who responded relationally reported spotting the unique relation). Thus such an alternative explanation seems highly unlikely. Overall the results support our hypothesis of relational priming being an abstract and profound phenomenon with deep impact on cognitive functioning.

Previously we stated our additional hypothesis that subjects' ability to cope with the priming tasks at question should correlate with the degree to relational priming they exhibit. Moreover we hypothesized that there should be a positive correlation between the number of correctly solved trials in the relational condition and the proportion of relational answers to the target task and a negative correlation between the number of correctly solved trials in the attributional condition and the proportion of relational answers to the target task. In both conditions we expressed the number of correctly solved trials as percentages from the overall number of trials. The overall number of trials was six in the relational condition and ninety six for the attributional condition. We calculated the point biserial correlations between these measures and the dependent variables separately for each experimental condition. The results indicated a significant positive relationship in the relational condition – r_{pbis} = 0.36, p=0.018 (one tailed). There was also a significant negative relationship in the attributional condition – r_{pbis} = -0.31, p=0.037. Thus it seems that our hypothesis is supported from the data[3]. These results seem reasonable since we can not expect subjects to be primed by task requirements if they are unable to fulfill the particular task.

Conclusion

In this study we successfully demonstrated that relational priming extends beyond the use of particular relations. It

[2] Technically speaking we should decrease our significance levels when performing these kinds of multiple comparisons in order to keep the type 1 error probability equal to 0.05 for all comparisons simultaneously. This was achieved by adopting a 0.033(3) level of significance for each comparison (we assumed a directed alternative hypotheses because we had strong prior expectations about the results from the study). We see that all our comparisons fall below this level of significance. Here we reported the probabilities from two-tailed tests which should be divided by a factor of two in order to obtain the one-tailed probabilities which fall way below the adopted significance level (although the chi square tests are regarded as inherently two-tailed a test of equality of proportions can be performed which has a one-tailed version; for the case of 2x2 tables the equality of proportions and the chi square tests are mathematically equivalent). Thus we can be confident that all three groups differ significantly from each other.

[3] We tested this hypothesis further by conducting logistic regression analyses with the percentage of correct responses as independent covariate and the response to the target task as a dependent variable. In the case of the relational condition the full model significantly outperformed the null model - Chi Square of Likelihood Ratio Change (1) = 4.63, p=0.031. In the case of the attributional condition the results were marginally significant - Chi Square of Likelihood Ratio Change (1) = 3.833, p=0.05. These results however test a two tailed hypothesis.

seems fertile to talk of cognitive states which enhance subjects' ability to encode relations. Moreover it appears that such cognitive states may be induced through external context factors. We consider our results relevant to the area of analogical mapping research since encoding of relations is obviously a prerequisite for subsequent mapping and transfer.

We also demonstrated that individual differences in terms of subjects' ability to cope with a particular task is a relevant variable for it significantly mediates the task's ability to induce the desired cognitive state for a particular subject.

We would like to stress that items from the Raven's test didn't embody the "same shading" relation of the target task and thus could not have possibly primed the relational answer directly. Also the tasks from the mental rotation condition did not involve any different or specific textures and consequently could not have primed the uniquely shared attribute of the attributional option of the matching to sample task.

Also few of the subjects who chose the attributional answer claimed to have spotted the uniquely shared relation so our results are likely to have arisen from influencing relational encoding rather than from manipulating subjects' relation vs. attribute preference.

Prior to the experiment we felt that using many matching to sample tasks (which would have enabled us to use parametric statistical analyses on one hand and would have granted our results with additional validity on the other) was not as warranted as it may appear at first. The reasons for this are straightforward – we suspected that once a particular subject have spotted the unique shared relation in one item they would search and easily find these relations on subsequent items. Thus we were afraid that no matter how many items we used our dependent measure would basically degenerate to a dichotomy. In such a case using parametric statistical analyses would be faulty and misleading. Another reason for avoiding the use of several different matching to sample tasks was that we speculated that our priming effect may exhibit a limited time duration and thus only the first few items would experience the effect. In case of counterbalancing the order of items across participants this effect might easily be obscured if we decided to run some comparisons at the items level.

Trying to replicate our results with different target item(s) and different priming tasks is a part of our future research agenda. Another part is exploring the duration of the priming effect.

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