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Author
Hristova, Penka

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Unconscious Analogical Mapping?

Penka Hristova (phristova@cogs.nbu.bg)
Central and East European Center for Cognitive Science, Department of Cognitive Science and Psychology,
New Bulgarian University, 21 Montevideo Street
Sofia 1618, Bulgaria

Abstract

The paper explores the possibility for unconscious analogy-making. The first experiment demonstrates that people may see different analogies when different relations are unconsciously "highlighted" in the base. The second experiment demonstrates that people unintentionally and unconsciously start to establish a mapping between two simple structures. Various points of view about analogy-making are discussed in light of these findings.

Keywords: analogy; unconscious; relational priming

Introduction

One way of thinking about analogy-making is that it is "the very blue that fills the whole sky of cognition" (Hofstater, 2001). Indeed, many researchers in the field adopt this view (Gentner, D., Holyoak, K., Kokinov, B., 2001). Analogy is considered to be a fundamental human ability that takes part in a number of automatic cognitive processes such as perception (Hofstadter, 1995; Mitchell, 1993; French, 1995; Petkov, Kiryazov, Grinberg, Kokinov, 2007), judgment (Kokinov, Hristova, Petkov, 2004; Hristova, Kokinov, 2006), decision-making (Markman & Moreau, 2001; Petkov, 2006), categorization (Medin, Goldstone, Gentner, 1993), memory (Kokinov & Petrov, 2001), etc. If analogy-making is so basic, it should at least partially be an automatic cognitive process (Kokinov, 1998). Finally, the interaction between top-down (i.e., conscious) processing and bottom-up (i.e., unconscious) processing was considered to be the key to analogy-making (Hofstadter, 1995; Mitchell, 1993; French, 1995; Kokinov & Petrov, 2001; Leech, Mareschal and Cooper, 2008).

Another way of thinking about analogy is that it is a complex cognitive activity that requires mapping between complex knowledge structures that should be integrated and maintained in the working memory until processed and that could only be sequentially processed in small pieces (Hummel & Holyoak, 1997; Cho, Holyoak and Cannon, 2007). Recent neuroimaging studies have demonstrated that relational integration and analogy-making involve frontal brain areas (Bunge, Wendelken, Badre, Wagner, 2005; Christoff, Prabhakaran, Dorfman, Zhao, Kroger., Holyoak, 2001; Green, Fugelsang, Kraemer, Shamosh, Dunbar, 2006; Luo, Perry , Peng, Jin, Xu, Ding, 2003) , which are typically considered to process thoughts we are aware of (Smith, Keramatian, Smallwood, Schooler, Luus, & Christoff, 2006)

There are a few attempts to demonstrate implicit analogy making through priming of analogical base. Kokinov (1990) demonstrated that priming of a specific episode may increase the likelihood of the corresponding analogies, but participants' awareness of the primed analogies was not measured in any way. Schunn and Dunbar (1996) also demonstrated priming of specific episodes and argued that subjects were not aware that they were making analogies. The role of analogy, however, was not well controlled in this particular study. It is not clear whether participants solved better the target problem because of priming of useful relevant past knowledge or because of the specific analogy that they were able to draw between the primed and the target episode. Kokinov and Yoveva (1996) have shown that presenting a seemingly irrelevant picture somewhere in the environment may prime the use of some concepts during the problem solving process, although participants reported to be unaware of any relation between the contextual picture and the target task. As in the previous two studies described in this paragraph, this study fails to describe unambiguously whether participants' problem solving was facilitated by priming of a relevant source for analogy-making or by just priming of a useful concept or of a useful relation.

Spellman, Holyoak, and Morrison (2001) have demonstrated relational priming but only under specific conditions – when participants were explicitly instructed to attend to the relations between the prime and the target pair of related words. Although the explicit instructions indicate a conscious rather than an automatic phenomenon, the authors argued that the delay of 400 ms between the prime and the target pair is too short for a strategic processing in the lexical decision task (LDT) that they had used, which is considered evidence for some degree of automaticity of the phenomenon. That is why the authors argued for a mixed automatic/strategic nature of the analogical priming found in their study. Later on a number of linguistic studies found evidence for relational priming with a sensicality task (a task in which participants indicate whether the two words in a pair make sense as a phrase (Gagne, 2001, 2002; Gagne et al., 2005; Estes, 2003; Estes and Jones, 2006)). Participants were not explicitly instructed that the same relation could be held between two subsequent pairs. Thus, although the inter-stimulus interval (i.e. the time between the prime and the target pair) was usually 1s, the fact that relational priming was obtained without specific and explicit instruction clusters these studies with the ones that may indicate the existence of some automatic processing. Still, the sensicality task itself definitely draws the attention toward the relations between the words in a pair and thus ruins the unintentionality of the process.

Thus, overall, there is still no clear evidence for the automatic nature of relational priming, which in turn casts doubts on the possibility for an automatic analogical

mapping. The first experiment tries to help people see a more difficult and nontrivial analogy by relational priming. It demonstrates that the unconscious automatic relational priming may help people find remote and highly original analogies. The second experiment focuses on unintentional analogies that people are not aware of. It tries to demonstrate that not only analogy may be influenced unconsciously but also that the whole analogy may remain unconscious.

Experiment 1: Seeing Nontrivial Relations

Method

Design

Within-subject design was used. Part of the target trials were primed with nontrivial but relevant relations, the other part was primed with other irrelevant relations. The dependent variable was the number of nontrivial analogies made in each experimental condition.

Between-subject counterbalancing: Items were between-subject counterbalanced with the type of relational prime, i.e. part of the analogy tasks were primed with nontrivial relations, the other part – with irrelevant relations.

Stimuli

26 target analogy tasks, 26 priming word pairs that prime nontrivial relations and 26 priming word pairs that prime other irrelevant relations were designed. The analogy task contained three word pairs. The base was always presented in the center of the computer screen. Participants were asked to decide whether the base is analogical to the word pair "A" or to the word pair "B". In fact, both "A" and "B" were analogous to the base word pairs. One of the analogies, however, was easier to find and in this sense, it was a trivial one[1]. The other possible analogy was non-trivial and usually a remote one (Table 1). The rest of the 26 analogy tasks were fillers and were "primed" with pairs of two "non-words".

Table1. Examples of analogy tasks which were used in experiment 1. Each row is one analogy task. The first pair in each row is the base word-pair. The second and the third word pairs are the options "A" and "B" respectively. The forth word pair primes the nontrivial relation, while the fifth primes a relation irrelevant to the analogy.

analogy task			Prime word pair	
base	word pair "A"	word pair "B"	Prime of nontrivial relation	Prime of irrelevant relation
motorcycle-helmet	coffee-caffeine free coffee	car–seat belt	sun-solarium	Cane-wood
fly- window	groom-marriage	airplane-airport	spirit-bottle	Deer-hoof
mouse- hole	lover - wardrobe	bird-nest	money-mattress	guitar-strings

[1] At least 10 out of 17 participants had chosen one of the word pairs as analogous to the base in the pre-test. This was the analogy that we consider to be easier and the trivial one.

Procedure

Two tasks alternate within every trial: LDT and analogy task. First, participants were asked to judge whether the two strings of letters presented in the center of the screen are words or non-words. This was the priming task, used for priming of a nontrivial or an irrelevant relation to the subsequent analogy task relation (figure 1). Second, participants were asked to indicate whether the word pair, presented in the lower left corner or the pair in the lower right corner of the screen makes a better analogy with the base word pair. Subjects replied by pressing the respective button.

Each participant was presented with a random sample of 26 out of 52 trials that contains target analogies primed with nontrivial relations, target analogies primed with another relation and filler trials.

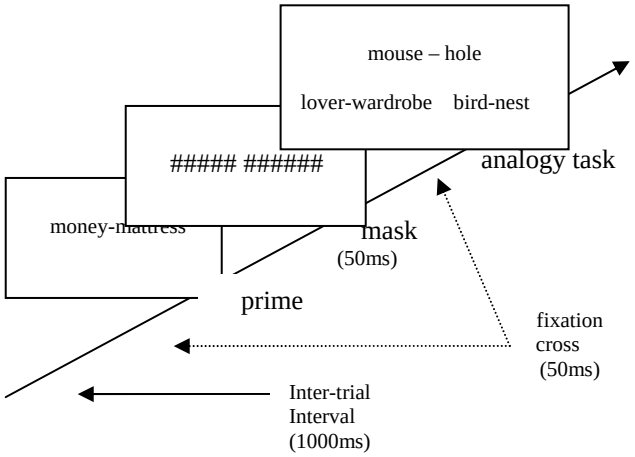

Figure1. Diagram of the stimulus displays and the timing of events in experiment 1.

Participants

32 students from New Bulgarian University (13 women and 19 men) took part as volunteers in the experiment. The mean age of the participants was 20.66 ranging form 19 to 26 years.

Results

The mean number of nontrivial analogies was calculated for each participant and for every experimental condition. People made more nontrivial analogies after priming of nontrivial relations between the words in the base (0.2424) than after priming of another relation irrelevant to the analogy (0.1760). This difference turned out to be significant, tested with the Repeated Measures ANOVA: $F(1, 31) = 5.318$, $p=0.028$, $ES=0.146$ (figure 2).

Thus, we may conclude that our manipulation successfully influenced the perception of the relations in the base and as a result participants were able to find the harder analogy. In support of this claim, response time for making the nontrivial analogy (7 999ms) was significantly longer than response time needed for making the trivial analogy (6 431ms): $F(1,26)=15.144$, $p=0.001$, $ES=0.368$[2].

In addition, it seems that relational priming influenced participant's choice on the subsequent analogy task completely unconsciously. During the debriefing interview at the end of the experiment, just one participant declared that he had found that some word pairs in the first task shared similar relations to the word pairs in the analogy task. Thus, overall, people were unaware that some irrelevant factor has influenced their capability of making interesting nontrivial and harder analogies.

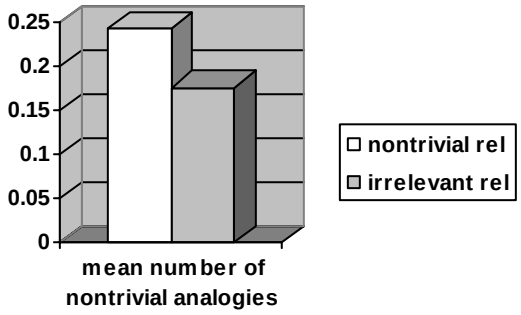

Figure 2. Mean number of nontrivial analogies per condition. The white bar stands for the mean number of nontrivial analogies that have been made after priming with nontrivial relations, while the grey bar stands for the mean number of nontrivial analogies made after priming with irrelevant relations.

This experiment, however, may not differentiate between the two points of view described at the beginning of the paper. Analogies could be sensitive to unconscious contextual influences but still, the analogical mapping may happen consciously. The second experiment tries to tackle exactly this question.

[2]The analysis was run on the data from 27 participants who have made both trivial and non-trivial analogies.

Experiment2: Unintentional and Unconscious Analogical Mapping

This experiment aims to demonstrate spontaneous mapping between pairs of analogically related words. We used the color-naming paradigm (i.e. a modified version of the classic Stroop task), which turned out to be sensitive to priming effects in general (Catena, Fuentes, & Tudela, 2002;Mari-Beffa, Estevez, & Danziger, 2000) and to conceptual priming in particular (Pritchard & Neumann, 2004; Segal, Gemar, Truchon, Guirguis, & Horowitz, 1995). This paradigm relies on the interference between the predisposition to read a word that is semantically related with an activated concept and naming the color of the ink of the word. Green, A., Fugelsang, J. and Dunbar, K. (2006) used the Stroop color-naming paradigm to demonstrate that concepts of a common analogical relation are activated when people find the analogy between two pairs of words joined by this particular relation. For example, if people decide that "gun" and "bullet" are analogical to "bow" and "arrow", naming of the ink of the word "shoot" was slower than if people judged categorically, whether the "gun" and the "bow" are weapons and whether the "arrow" and the "bullet" are projectiles. This experimental result, however, relied on the explicit instruction to find the analogy and on the implicit measure of what was activated as a sequence of the performed analogy. In contrast we would like to find evidence for an unintentional mapping, rather than a mapping between two entities that was explicitly suggested to exist.

Participants were instructed to name the color of the ink of a word presented simultaneously with another word on a screen. One of the words in the pair was always colored in red, blue or green color. Participants were asked to indicate their answer by pressing a button with the respective color. Half of the target trials were preceded by a pair of analogically related words and the other half - by a pair that did not share any analogical relation. All target pairs possessed a red word that allowed to oppose relational priming with recognition of the same color (i.e., red). The rest of the trials were fillers.

Method

Design

A mixed 2 (type of relational priming: priming of analogical relation or priming of non-analogical relation) by 3 (Inter stimulus interval: 100ms/400ms/700ms) design. For each participant half of the stimuli were preceded by pairs that share an analogical relation and the rest - by pairs that share another non-analogical relation. The dependent variable was the RT for indicating the color of the word in the pairs.

Between-subject counterbalancing: Items were between-subject counterbalanced with the type of the prime (i.e.,

analogical/non-analogical) in order to control for a specific pairing of the words. Half of the target word pairs preceded by analogically related words as well as the other half of the target word pairs preceded by non-analogically related words were given for judgment to one part of participants and the same target word pairs but preceded, respectively, by non-analogically paired words and analogically related words were given to the rest of the participants.

Within-subject counterbalancing: The inter-stimulus interval (ISI) between the target and prime word pair was varied on three levels: 100 ms; 400ms; 700ms.

Stimuli

A set of 60 target pairs of related words and 60 priming pairs of analogically related words was designed. Examples of target and priming stimuli are presented in table 2. One of the words in the target pairs was always red and one of the words in the analogically related word pairs was always green. Hence, whenever a target pair with a red colored word was presented, the proceeding pair contained a green word. Since, participants were supposed to judge 30 target pairs primed by 30 analogically related words and 30 target pairs proceeded by 30 non-analogically related words making a set of 60 red and 60 green words overall, the rest of the 120 filler trials consisted of 80 filler pairs with a blue word, 20 filler pairs with a red word and another 20 filler pairs with a green word. Thus, the whole set of 240 word pairs contained an equal number of red, green and blue words.

Table 2. Examples of priming and target stimuli that are analogically related.

Priming pair		*Target pair*	
musician	orchestra	book	library
dove	peace	clover	luck
acid	corrosion	bacteria	infection
button	cardigan	knob	door

Procedure

Participants were instructed to judge the color of a word in a pair by pushing the respective button on a BBOX.

Each trial started with a fixation cross presented for 100ms. Then a word pair with a colored word appeared and remained on the computer screen till the participant did not indicate its color. When the participant indicated his/her choice the next word pair appeared on the screen after 100ms, 400ms or 700ms and remained there until the respective button was pushed. Then next trial started after an inter-trial interval of 1000ms.

Participants

37 students from New Bulgarian University (27 women and 10 men) took part as volunteers in the experiment. The mean age of the participants was 23.49 ranging form 19 to 53 years.

Results

The correct reaction times (RTs) bellow 150ms and above 1800ms were not included in data analysis, resulting in approximately 1% of discarded data. A 2 (priming of analogical relation/priming of non-analogical relation) by 3 (100ms/400ms/700ms) Repeated Measures ANOVA was carried out on RT. We found a main effect of the type of priming ($F(1, 36) = 5.150$, $p = 0.029$, $ES = 0.125$) and of the inter stimulus interval ($F(2, 72) = 18.162$, $p = 0.000$, $ES = 0.335$). The interaction between the type of priming and ISI did not reach significance: $F(2, 72) = 1.048$, $p = 0.356$. Figure 3 shows the mean RTs for each experimental condition. The only statistical difference between the types of priming appeared for ISI of 700 ms: $F(1, 36) = 4.671$, $p = 0.037$, $ES = 0.115$. Thus, although we found evidence for unintentional and unconscious analogical mapping, it seems that the effect needs time to be revealed.

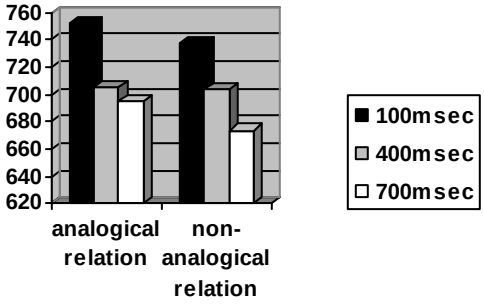

Figure 3. Mean RT in the six experimental conditions. The black bars stand for the RTs of target word pairs that were presented 100ms after the prime word pairs. The grey bars stand for the RTs of target trials that were presented 400ms after the prime word pairs. The white bars stand for RTs of target word pairs that were presented 700ms after the prime word pairs.

In the debriefing interview after the experiment 20 out of 37 participants reported that some words in a pair were related while other were not, but none of them reported that related word pairs followed analogically related word pairs. Thus we may conclude that participants were left blind for our experimental manipulation.

In summary, we found a significant delay of naming the color of a word in a pair only after an analogically related prime pair of words. In contrast to previous experiments that demonstrate relational priming we succeeded to explore this phenomenon within a completely automatic setting, i.e. by means of the color-naming paradigm. Participants were neither explicitly instructed to code relations between the words in a prime pair (Spellman et al, 2001) nor asked to judge the sense between two words in a pair (Gagne, 2001, 2002; Gagne et al., 2005; Estes, 2003; Estes and Jones,

2006) but rather to judge the color of the word in a pair. Moreover we found evidence for relational priming within comparably short inter stimulus interval (i.e., 700 ms for activation of the relation between 2 words) that allows arguing for an automatic activation of an analogical relation. Hence, it is possible and indeed probable that analogies start without intention and once started, analogies are difficult to be suppressed.

Conclusion

The first experiment demonstrates how finding of nontrivial analogies may be facilitated through a recent exposure to a relation involved in such analogies. People were able to find original solutions if they unconsciously were facilitated to encode the right relations. This experiment, however, does not "insist" on unconscious analogies per se. It rather demonstrates that analogy making may be influenced unconsciously from some extraneous factors. Thus, both points of view on analogies set out at the beginning of the paper may satisfyingly explain these results since encoding of relations may be influenced unconsciously, but the very process of analogy may still remain conscious.

In contrast, the second experiment demonstrated unintentional and unconscious analogical mapping. People seem to start building analogies although they were neither expected to do so nor explicitly instructed to attend to the relations between stimuli. Moreover, people were completely "blind" about this and were unaware that they have started to make analogies between word pairs in our experiment. What is clear is that analogical mapping may be initiated automatically and hence, may unconsciously influence our behavior. It could be, however, that analogical mapping starts outside of our awareness but if it finishes we became aware of this fact. Hence, in some circumstances we may be conscious about the final product of analogical mapping but not conscious about the very process of analogy. This research could not disambiguate such possibility, but still it empirically demonstrates that people are able to start analogies spontaneously. This appealing possibility strongly advocates the point of view that compares analogy to "the very blue that fills the whole sky of cognition" (Hofstater, 2001).

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