Memory for Analogies and Analogical Inferences

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Abstract

An important property of analogical reasoning is that resulting inferences can be used to acquire new knowledge in a target domain. However, little is known about what happens to memory for these inferences. In this study, we explore the link between analogical reasoning, inferences, and memory. We gave participants information on a political debate. Some subjects were given a short text and other subjects were given a long text to read. In addition, half the subjects were given an analogy at the end of the text. A week later, subjects were brought back and asked to recall the information. We were particularly interested in whether subjects would (a) remember the analogy, and (b) incorporate analogical inferences into their memory for the text. We found that when they were given more information, subjects did not report the analogy, but falsely included analogical inferences in their recall. Results were different when subjects were given a lesser amount of information they remembered the analogy and did not erroneously recall analogical inferences. Overall, the results indicate that memory for analogical inferences is highly related to the amount of information that people are given.

Introduction

While much is known on the processes underlying analogical reasoning, relatively little is known about the effects of analogy on memory. Specifically, many accounts of analogical reasoning stress the idea that analogy can be used to fill in gaps in existing knowledge about new topics (Gentner & Holyoak, 1997; Holyoak & Thagard, 1995; Vosniadou & Ortony, 1989). Thus, an important component of analogical reasoning is drawing inferences. Surprisingly, little is known about the consequences of this process; how analogies and analogical inferences are remembered. The goal of the research reported in this paper is to examine the link between analogy and memory.

Much research has been conducted on the mechanisms underlying the process of making analogical inferences. When people engage in analogical reasoning, their representations of the source and target are aligned and elements of the source are matched to those of the target (Gentner & Markman, 1997; Markman, 1997). Missing information about the target can be filled by importing knowledge from the source domain, making an analogical inference. This is a powerful mechanism for the acquisition of new knowledge. Many studies have been conducted to identify the constraints placed on analogical mapping. The process of matching the two representations and drawing inferences is influenced by structural constraints, such as isomorphism and systematicity (Clement & Gentner, 1991; Markman, 1997), pragmatic considerations (Spellman & Holyoak, 1996), task given to the subject (Blanchette & Dunbar, in press; Dunbar, in press), and the semantic content of the source and target (Bassok, Chase, & Martin, 1998). While much is known about the constraints placed on this process, we know little about the consequences of making an analogical inference, and particularly how this will alter memory for the information presented.

One aspect of the link between analogy and memory that has been explored is whether an analogy can facilitate recall of specific concepts. Educational research has shown that, under some circumstances, a relevant analogy presented with other information can enhance memory for that information (e.g.; Halpern, Hansen & Riefer, 1990; Stepich & Newby, 1988; Vosniadou & Schommer, 1988). All this research suggests that the link between analogy and memory is highly complex. However, one thing that is clear is that analogies can affect how much information will be retained. When presenting information, relating it to a better-known domain (the source) through an analogy probably increases the amount of elaboration on the new information. This, in turn, can increase memory for that information.

Although we know that analogies can impact memory for other information, little is known about memory for analogies themselves and memory for analogical inferences that can be derived from the analogy but that were not explicitly present in the information supplied. If people engage in analogical reasoning when they are presented with both a source and a target, we can expect that, through mapping elements of the source onto the target, they will draw analogical inferences. What happens to the analogical inference? Does the inference become part of the underlying representation? Research in text comprehension has shown that people often cannot differentiate between information they actually read, and inferences they drew from this information (van den Broek, 1994). Although this process does not involve analogical reasoning, the same thing could occur with analogical inferences. Thus, we would predict that when

people are presented with a source and target analog, they will draw analogical inferences that will be incorporated into their representation of the information. Furthermore, it will be interesting to see whether this is related to an explicit memory for the analogical source itself.

These issues are important as in our previous research (Blanchette & Dunbar, 1997; Dunbar, 1995, 1997), we have found that analogy is frequently used in many naturalistic settings such as science and politics. We have also found that scientists often forgot the analogies that they had used.

We decided to investigate memory for analogies and analogical inferences using political debates. We used two debates that are often mentioned in the media -legalization of marijuana and funding of sports stadiums. Our choice was based on the fact that analogies used in these debates have a number of interesting properties that are common to many naturalistic uses of analogy. In naturalistic settings, analogies are usually not explicitly mapped out for the audience (see Blanchette & Dunbar, 1997). In most cases, the analogical source is described but the explicit mappings are left up to the reasoner to infer. This makes it possible to look at memory for inferences derived through analogical reasoning, information that was not explicitly presented.

One important issue that we were concerned with is whether the way people use analogy will vary with the complexity of the materials provided. Most researchers use very simple stimuli, yet in our pilot studies we found that giving subjects analogies for simple texts, containing little information, had little effect on their understanding of an issue. Thus, we created two conditions, varying the amount of information on the target problem that we provided to subjects. We used both a simple text and a more complex text, providing more information. We expected that recall of analogical inferences would be more important in the condition where people have a lot of information about the target problem, simply because these inferences would be more readily drawn when the analogy is initially presented.

Overview of study

In this experiment, subjects received information on a social/political issue. We manipulated two variables: the presence of an analogy and the amount of information presented. Participants read a text corresponding to one of the four conditions resulting from the crossing of these two variables. One week later, subjects came back and we tested their memory for the information through a free recall task. We coded their recall for inclusion of analogical inferences and the analogy itself. In addition, we measured the total number of facts included in participants' recall. We also measured participants' opinion on the target issue to examine its possible influence.

Method

Participants and procedure

Forty-eight undergraduate students participated in this study. Participants were told the goal of the experiment was to investigate reasoning about complex issues. The experiment took place in two sessions. In the first session, participants read a text about the target issue and answered a few reasoning questions. Participants from all four groups answered the same questions. One asked them to list arguments for and against a specific position on the target issue and the other asked them to state and justify their opinion. The second session was held exactly one week later. Participants answered, by writing, a free recall question. This question instructed subjects to write down, as precisely as possible, all the information they could recall from the text they had read the previous week. Four participants had to be eliminated because they did not participate in the second session. Of these, one was in the complex/analogy condition, two were in the simple/no analogy, and one was in the simple/analogy condition.

Materials

We used two different issues to ensure replication. Each participant got only one of the two. The first issue was the debate over the legalization of marijuana. In this case, the source analog was the period of the prohibition of alcohol. It described how people continued to use alcohol even though it was illegal and how a black market for alcohol products developed. The second issue was whether public funds should be used to help professional sport teams build new infrastructures such as stadiums. In this case, the source analog referred to a situation people in Quebec (where the experiment was conducted) had experienced the previous year. During an ice storm which caused massive power failure, some people selling generators were abusively raising prices because the demand was very high. This could be related to sport teams asking money from cities knowing that the demand for a team is very high. In both cases, the analogy was inserted at the end of the text by using the sentence "The situation with [marijuana/sports teams] can be compared to...". A short paragraph then described the source analog. It is important to note that there were no explicit analogical inferences in the text. Only the source analog was described and the link between source and target was only made by the first sentence described above. In the control condition, participants read the exact same text apart form the analogy. The last paragraph containing the analogy was omitted and there was no mention of the source analog.

In order to vary the amount of information presented, two texts were prepared for each issue. In the "Complex" condition, the text was approximately three pages long. The text gave a lot of detailed information on the issue, often contradictory information, and it presented arguments for both sides. In the "Simple" condition, the text contained only one paragraph stating basic facts about the issue.

Measures

Participants' answers to the free recall question were coded for three things: explicit recall of the analogy, memory for analogical inferences, and total number of facts recalled. We used the following criterion to code recall of the analogy: if the subjects mentioned anything about the analogical source, or about the fact that there was an analogy, we coded it as positive, otherwise it was coded as negative.

We coded subject's recall for inclusion of analogical inferences. The list of possible inferences was determined as fol-

lows. The description of the source analog contained a number of statements. The list of possible inferences was established by listing all these statements as they would apply to the target. We took the paragraph describing the source and simply replaced words/concepts identified to the source by the equivalent for the target. For example, the description of the prohibition of alcohol source included the statement that making alcohol illegal gave rise to elaborate criminal organizations that took over distribution and production of the substance. Here, the analogical inference would be that having marijuana illegal results in criminal organizations taking care of the distribution and production of the substance. We coded subjects' answers for all such analogical inferences.

We calculated the total number of facts contained in each participant's recall. This measure was included to control for the possibility that differences found on the other dependent measures (memory for the analogy and for analogical inferences) were actually confounded with the overall amount of information recalled by participants in the different conditions. For each subject, we counted the number of different and mutually exclusive facts that were recalled.

In order to examine its possible mediating influence, we also measured participants' opinion on the target issue legalization of marijuana or public funding for stadiums. During session one, after they had read the text, subjects indicated their opinion on a seven-point scale, ranging from 'totally in favor' to 'totally opposed'.

Results

Memory for analogical inferences

Because most participants who included an inference in their recall only included one, we coded this measure as either yes or no. Overall, 18 out of 44 subjects (41%) included at least one analogical inference in their recall. To determine that inclusion of analogical inferences in the recall was actually related to the presence of an analogy in the text, we compared the analogy conditions to the no-analogy conditions using a chi square test. We needed to compare the two conditions as the analogical inferences were propositions that could be common knowledge and could just be intrusion errors not related to the presence of the analogy. There was a significant difference in the expected direction, χ^2 (1, N=44) = 4.86, p<.05. In the analogy conditions, 13 out of 23 subjects (57%) included at least one analogical inference in their recall whereas this was the case for only 5 of the 21 participants (24%) in the non-analogy conditions.

There were different patterns in the simple and complex conditions, as can be seen in Figure 1. There was a marked difference between the analogy and no-analogy conditions when participants read a large amount of information (complex condition). In this condition, 9 out of 12 subjects in the analogy group (75%) mentioned an inference in their recall, compared to 3 out of 12 (25%) in the no-analogy group. This difference is significant, χ^2(1, N=23) = 5.24, p<.05. However, there was no difference between the analogy and no-analogy groups in the "Simple" condition, χ^2 (1, N=21)=0.69, p>.05. When participants read a smaller amount of information (one paragraph), being presented with

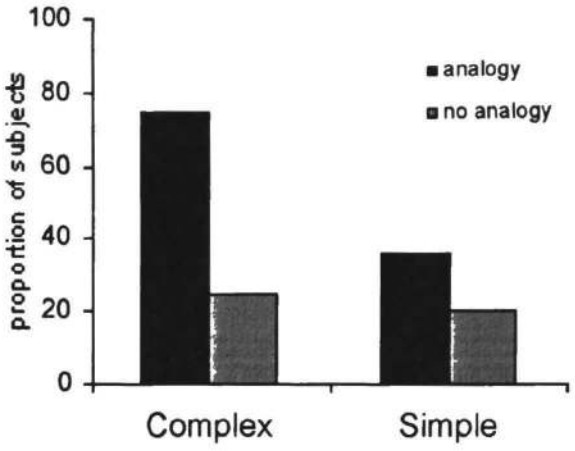

Figure 1: Inclusion of analogical inferences in recall as a function of condition and complexity

an analogy did not lead them to include inferences in their recall (4/11 in the analogy condition compared to 2/10 in the no-analogy group).

Memory for the analogy

Participants' recall of the analogies followed the opposite pattern as memory for analogical inferences. Overall, 9 out of the 23 subjects in the analogy conditions (39%) explicitly mentioned the analogy in their recall. However, there was a significant difference between the complex and simple conditions, χ^2 (1, N=23) = 5.32, p<.05 (see Figure 2). In the complex condition, only 2 out of 12 subjects (17%) reported the analogy whereas 7 out of 11 participants (64%) in the simple condition did. Thus, subjects in the simple conditions reported the analogy in their recall whereas most subjects in the complex condition did not.

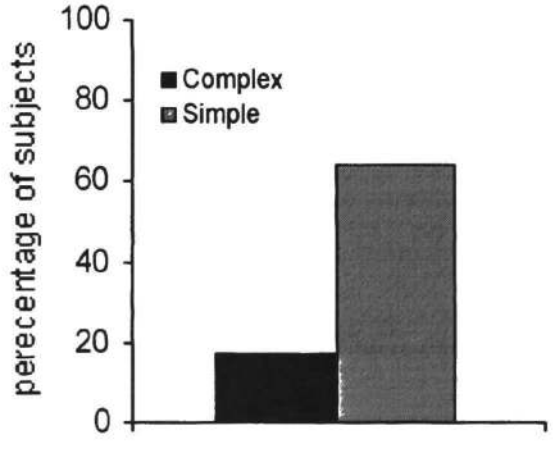

Figure2: Mention of analogy in free recall as a function of complexity

Total number of facts

We wanted to examine whether the differences in memory for the analogy and memory for analogical inferences were due to a difference in the overall amount of information recalled by participants in the different conditions. We performed a 2 by 2 (Analogy and Complexity) ANOVA on the total number of facts in the recall. There was no main effect of analogy, F (1, 40) = 1.11, p>.05. Participants in the analogy and no-analogy groups did not differ on the total number of facts that they recalled (M= 3.96, M=3.48 respectively). The difference found for inclusion of analogical inferences in recall therefore cannot be the result of a general effect of the analogy on memory. There was of course a significant main effect of complexity, $F(1, 40) = 88.64$, $p<.05$. Participants in the Complex condition recalled more facts (M=5.74) than participants in the Simple condition (M=1.52), simply because there was more information to be remembered. However the two-way interaction was not significant, $F(1, 40) = 0.91$, $p>.05$, showing that there was no more difference in number of facts recalled between the analogy and no-analogy groups in either the simple or complex conditions. This analysis provides evidence that our results are not a simple artifact resulting from a widespread impact of analogy on memory.

Influence of opinion

In order to explore possible mediating effects of prior opinion, we analyzed recall for inferences and recall for the analogy in terms of participants' opinion (measured during session one). First, we needed to determine whether there was a difference in opinion between the four different groups. We performed a 2 by 2 ANOVA on the mean opinion score as a function of the two variables: presence of an analogy and complexity. There were no significant differences between the groups: there was no effect of the analogy manipulation, $F(1,40) = 3.14$, $p>.05$, and no effect of the information manipulation, $F(1, 40) = 2.78$, $p>.05$. To see if prior opinion had an impact on the recall for the analogy, we compared, for participants in the analogy condition, the mean opinion of those who had mentioned the analogy in their recall to those who hadn't. This was done through a simple unpaired t-test. This test indicated no significant difference, $t(21) = 1.28$, $p>.05$. We performed the same analysis for analogical inferences, comparing the mean opinion of those who included analogical inferences in their recall to those who didn't. Again, a t-test revealed no significant difference, $t(42) = .35$, $p>.05$. The mean opinion scores are presented in Table 2. Overall, it appears that the pattern of results we observed is not altered by prior opinion.

Table 1: Opinion score and inclusion of inferences in recall in the simple and complex conditions

	Included analogical inference in recall		No analogical inferences in recall	
	Mean	SD	Mean	SD
Complex	4.33	1.66	5.33	1.15
Simple	3.75	2.06	3.43	2.51
Total	4.04	1.86	4.38	1.83

Discussion

In this study, we looked at people's memory for analogies and analogical inferences. We manipulated the presence/absence of an analogy in a text that subjects read, and the amount of information that was provided.

Two important findings emerged from this study. First, the fact that analogical inferences can be falsely remembered as being part of information presented. Although analogical inferences were not part of the information presented, under some conditions, participants did not report the analogy itself but reported inferences drawn from it. The second important finding is that the amount of information people have on a topic will determine how the analogy will influence their memory. Recall in the simple and complex conditions followed opposite patterns. In the complex condition, people reported analogical inferences but not the analogy itself. In the simple condition, people did recall the analogy and did not report analogical inferences. Our results also allow us to rule out the possibility that the analogy simply influenced the overall amount of information recalled by participants.

The results of this study indicate that analogy can have a powerful influence on peoples' memory for a text. When participants are given complex information, this allows inferences to be drawn from the analogy and these inferences appear to become part of the underlying representation of the text as the analogy is forgotten. When the information provided is simple, the analogy does not change the underlying representation of the text and the analogy is correctly remembered. Of course, in the case where participants received less information, the description of the analogical source represented a greater proportion of the total amount of information presented. As such, it might be easier to recall the analogy. Interestingly, when they had a lot of information, participants reported the outcome of analogical reasoning processes, without reporting the source of this reasoning, which was explicitly present in the text.

A similar phenomenon has been observed in a real-world study of scientific reasoning. Dunbar (1995, 1997) studied different scientific laboratories over extended periods. He was able to follow the unfolding of a number of scientific discoveries. In many cases, analogies were used in reasoning about data that led to a discovery. Dunbar went back to these laboratories some time later and interviewed the scientists. The researchers' memory of the events included the discovery that had been made but often kept no trace of the analogies used.

The results of this experiment are similar to those on text comprehension. Many studies have shown that people spontaneously generate inferences based on the materials they read and later cannot distinguish between these inferences and information actually presented in the text (Graesser, Singer, & Trabasso, 1994; Lorch & van den Broek, 1997; van den Broek, 1994). Similarly, research on memory has shown that people can incorporate false information, information provided afterwards, into their memory for an event (Ayers & Reder, 1998; Belli & Loftus, 1996; Loftus, 1992). Thus in both our experiment and other experiments, people incorporated new information into their underlying representation either by making inferences or being told new information. This drawing of inferences does not appear to be a totally

explicit process (Schunn & Dunbar, 1997; Schacter, 1995), as people were unable to recall the source analog, or know that these inferences were drawn from an analogy. These findings thus suggest that drawing an inference from an analogy can alter the underlying representation for information just as other types of processes can.

Our results show that in order for participants' memory trace to incorporate analogical inferences, they must have a sufficient knowledge base that will allow them to draw the inference. Only participants who were provided with a greater amount of information on the target domain "recalled" the inferences. It must be emphasized that in our experiment, participants were not asked to draw inferences or to reason about the analogy. The inferences appear to have been drawn as part of the processing of the information presented, without any specific prompting being required

The results of this experiment demonstrate that people do use analogies to make inferences about a target problem and that these analogies can alter their underlying representation. Furthermore, when there is a lot of information present, people are unable to recall the analogies and incorporate inferences into their underlying representation. We suspect that one of the reasons that politicians so frequently use analogies when describing complex situations is that by making an analogy, they can deliver information covertly, without explicitly providing it.

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