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Title
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Permalink
https://escholarship.org/uc/item/524863qm

Journal
Proceedings of the Annual Meeting of the Cognitive Science Society, 25(25)

ISSN
1069-7977

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Publication Date
2003

Peer reviewed

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Schema-driven Memory and Structural Alignment

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Abstract

In the 1960s and 70s, researchers paid a great deal of attention to schematic memory, or memory for thematic information. In the 1980s and 90s, this research ground to a halt, in large part because researchers lacked a strong theoretical framework for the study of schematic memory. We suggest that structure-mapping theory, a theory of analogy and similarity comparisons, may provide such a framework. We conduct two experiments designed to replicate classic findings from the schematic memory literature - that memory for schema-relevant information is better than that for schema-irrelevant information, and that information in a schema can intrude on memory for instances - using a paradigm from work in analogical reasoning. Because we can replicate schema-driven findings in an analogy paradigm, we should be able to use what we know about analogy to understand schematic memory.

Introduction

Humans are experts at remembering information that is related by a common theme. This expertise underlies our ability to comprehend stories and sentences, as well as reason about everyday events. A great deal of attention was once paid to issues related to this type of memory, called *schematic memory*, but this research virtually disappeared two decades ago. While schematic memory research produced many interesting findings, its abrupt end left many questions unanswered. In this paper we argue that schematic memory can be understood using theories from research in analogy. To support this argument, we describe two experiments replicate important findings from the schematic memory research using an analogical reasoning paradigm, and discuss the implications of using this theoretical perspective.

Past Research on Schematic Memory

By the end of the 1970s, there was a wealth of empirical findings in the schematic memory literature. For example, people are more likely to remember information that is relevant to the gist or theme than information that is not relevant to it (Bransford & Johnson, 1972). Information related to the theme facilitates recall (Schustack & Anderston, 1979), and can also intrude on recall for related information (Sulin & Dooling, 1974).

All of these findings led to a common set of conclusions, which also served as the most prominent theoretical explanation of schematic memory phenomena. Following Bartlett (1995), memory for thematic information was thought to be abstracted from surface information, and stored in schemas. During recall, this information was reconstructed on-line from information contained in the schemas. This theoretical explanation was, however, too abstract, and left many questions unanswered. For instance, how and when does the abstraction process take place, and how is the information in schemas reconstructed in the retrieval situation? Without a more concrete theoretical explanation, it was difficult to derive new predictions to drive empirical research. This research suffered from a second problem, as well. In general, these experiments relied on schemas already present in participants' background knowledge, thus allowing for little control of the information that went into the schemas being studied. Eventually, these two problems led researchers to study other areas of memory, primarily using list-learning methodologies that allowed for more experimental control.

Our goal in this paper, therefore, is twofold. First, we develop an experimental method that uses an analogical reasoning paradigm to create a schema and then expose participants to an instance that reminds them of it. This gives us greater control over what goes into the schemas that participants' use in the experiments. Second, by using this methodology to replicate two important findings from the schematic memory literature, we hope to demonstrate that schematic memory can be treated as an analogical phenomenon, and therefore that we can use our knowledge of analogy to explain these past findings, as well as to answer

previously unanswered questions and to produce new predictions.

What We Know About Analogy

It is known that analogical comparisons, as well as other types of comparisons (e.g., similarity and metaphor), use the process of structural alignment (Gentner, 1983; Holyoak & Thagard, 1995; Markman & Gentner, 1993). During the structural alignment process, objects and relations from one domain are aligned with objects and relations from another, and information from the better-known of the two domains (called the *base*) can then be used to make inferences about the lesser-known domain (called the *target*). Three principles govern this alignment process. The first, called *one-to-one mapping*, insures that each object or relation from one domain is mapped onto one and only one object or relation in the other. The second, *systematicity*, states that all else being equal, higher-order mappings will be preferred to lower-order mappings. The third, *parallel connectivity*, states that when to relations are aligned, the objects of those relations are also aligned.

The relationship between analogy and memory has been studied before (Markman & Gentner, 1997; Schustack & Anderson, 1979). However, this research stopped well short of claiming that memory for thematic information is an analogical phenomenon. Thus, as we mentioned above, the experiments in this paper seek to go further by replicating specific findings from the previous schematic memory literature using an analogical reasoning paradigm, in order to demonstrate that they can in fact be understood within the framework of structural alignment.

General Experimental Method

The following two experiments use the same general method. This method involves two tasks, separated by a delay. In the first task, participants are given series of story pairs and ask to rate the similarity of the two stories in each pair (see Figure 1). In each story pair, the second story, called the *target*, was given a title, and contained two short stories, or sub-stories, which involved the same main characters, but in different relations. For each target, two *base* stories were created, each of which was analogous (i.e., contains different characters in similar relations) to one of the two target sub-stories. The first story in each pair was one of the two base stories for the target. These base stories served, then, as schemas. The target sub-story that was analogous to the base a participant received was thus analogous to the schema, while the other target sub-story was not.

After a delay, participants were given a retrieval task in which they had to remember information about the target stories from the comparison task. This method allowed us to put the schemas (base stories) into participants heads, provide them with information

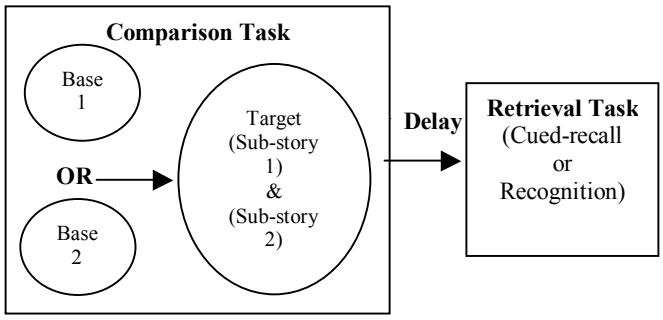


Figure 1: An outline of the tasks in Experiments 1 and 2, and their order.

that should activate those schemas (analogous target sub-stories) and information that should not activate them (non-analogous target sub-stories), and then test participants' memory for both types of information.

Experiment 1

The goal of Experiment 1 was to replicate the finding that memory is better for schema-relevant than schema-irrelevant information (Bransford & Johnson, 1972). In their experiment, Bransford and Johnson (1972) presented participants with a paragraph containing a sentence that did not seem to fit with the rest of the story. For instance, a paragraph that was ostensibly about a peace march contained a sentence about an alien spacecraft landing. During recall, participants were much less likely to remember this sentence than those that were relevant to the peace march schema. However, if the paragraph was given a title that made the strange sentence (e.g., the alien landing) make sense in the story, then people were able to recall it.

To replicate this finding, Experiment 1 used the general method described above. A 20-30 minute filler task served as the delay, and the retrieval task was a cued-recall task in which the titles of the targets served as retrieval cues. The prediction was that participants would recall information relevant to the analogical match between the base story and one of the target sub-stories, or schema-relevant information, more readily than information from the other, non-analogous sub-story, or schema-irrelevant information.

Method

Participants: Participants were 59 undergraduates at the University of Texas, Austin, who participated for course credit. Data from 5 participants had to be eliminated because they failed to complete one of the two tasks.

Materials and Procedure: Eighteen sets of three stories (2 base stories and one target) were composed, drawing heavily on the materials used in Gentner, Ratterman, & Forbus (1993). Booklets of six story pairs (one of the two bases and the corresponding target) were created. The pages with base stories simply contained the story. The target story pages had a title at the top, and at the bottom, asked participants to rate the similarity of the base-target pair by circling a number, and provided a 9-point scale with the words "Highly Dissimilar" under the 1 and "Highly Similar" under the 9. These booklets comprised the comparison task. The cued-recall task booklets contained six pages with lines for writing. Each page had the title of one of the targets participants had seen in the comparison task.

Participants were given a comparison task booklet with 6 pairs of stories, and the instructions to read the stories carefully and rate the similarity of the two stories in each pair, using the scale provided. Each participant saw only one base with each target, and across participants, each of the two bases was seen with the corresponding target. After completing the comparison task, participants were given a filler task that took on average 20-30 minutes to complete. Finally, participants received the cued-recall packet with instructions to write down as much as they could remember about the story they had seen earlier with the title at the top of the page.

Results and Discussion: A 2(Base Story) X 2(Target Sub-Story) ANOVA was conducted on the mean recall data shown in Figure 2. There was a main effect of the target sub-story, such that participants recalled more from the sub-story they read first in each target (m = 5.62) than from the second sub-story (m = 4.03), regardless of which base story they had been given, $F(1,52) = 52.83$, $p < .05$[1]. This may be a result of a primacy effect, or simply because these stories were generally longer, and therefore contained more information to recall. The primary prediction for Experiment 1 was that participants would remember analogous, or schema-relevant information better than they would schema-irrelevant information. Thus, they would remember information from the target sub-story that corresponded to the base they received for that target. Consistent with this prediction, there was a significant base story by target-sub story interaction, $F(1,52) = 37.96$, $p < .05$. Participants recalled more from the first sub-story in each target when they had been given the corresponding base (m = 6.33) than when they had been given the base corresponding to the second sub-story (m = 4.91), $t(52) = 2.78$, $p < .05$[2].

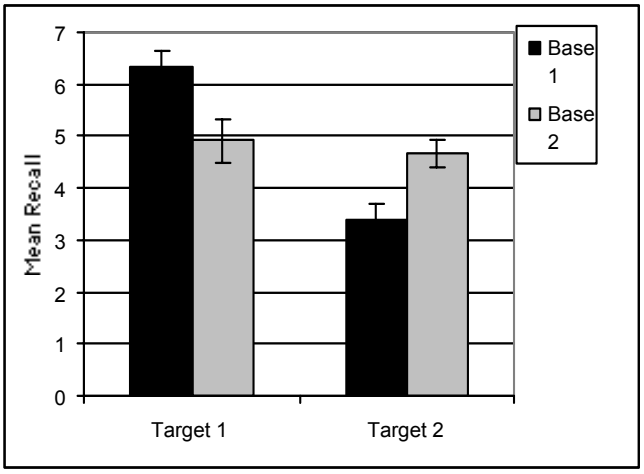


Figure 2: Mean amount of information participants recalled from Target Stories (1 or 2) as a function of the Base Story (1 or 2) they received. Error bars in this and all future graphs represent standard error.

Participants also recalled more from the second sub-story in each target when they had been given its corresponding base (m = 4.67) than when they had been given the base corresponding to the first target sub-story (m = 3.38), $t(52) = 3.40$, $p < .05$.

Thus, Experiment 1 provided a replication of the Bransford and Johnson (1972) finding that schema-relevant information is recalled more readily than schema-irrelevant information using an analogical reasoning paradigm. In our experiment, information in the target sub-story that stood in analogical correspondence to the base story served as schema-relevant information, and information from the target sub-story that was not analogous to the base served as schema-irrelevant information. Participants recalled more of the analogous information than the non-analogous information.

Experiment 2

Experiment 2 was designed to replicate the results of Experiment 1 using a recognition task with a longer delay, as well as to replicate the finding that when a story activates a schema, information from that schema that was not contained in the story can be mistakenly remembered during recall of the story. For example, Sulin & Dooling (1974) provided participants with biographical passages in which the main character was given either the name of a famous person (e.g., Helen Keller) or a novel person (e.g., Carol Harris). After a

[1] Unless otherwise indicated, analysis conducted across items and across subjects were significant, and for brevity's sake, only the subject analyses are reported.

[2] The alpha levels for all pair-wise comparisons were corrected using the Bonferroni correction.

week delay, participants were given a recognition task containing sentences from the story and new sentences which were either true sentences about the famous person that were not contained in the passage or simply new sentences. When the biographical passage had contained the name of the famous person, participants mistakenly recalled having seen the new sentences that were true of that person. Thus, Sulin & Dooling (1974) concluded that information from the activated schemas was intruding on memory for the biographical passages.

In Experiment 2, participants again completed a comparison task with base and target story pairs. The target and base stories from Experiment 1 were altered so that each base contained information relevant to the story, but not contained in the corresponding sub-story in the target. After a two-day delay, participants completed a recognition task in which they were given the title and a series of sentences for each target they had seen. They were asked to indicate which sentences were from those targets and which were not. Included for each target were OLD sentences from both of the sub-stories and three types of NEW, or unseen sentences. The first type, *foils*, were sentences that were completely new for all participants. The other two types of unseen sentences, called *intrusion sentences,* were altered versions of sentences from each of the two bases that were relevant to the story but not contained in the targets. The alterations to these sentences were designed to change their surface information as well as to make them fit with the characters in the target story, but to retain the relational information of the sentences.

As in Experiment 1, the base stories served as schemas, the target stories as instances that should activate the schemas, and the information in the bases that was not in the target served as information from the schema that could potentially intrude on participants' memory for the target. We predict that, consistent with Experiment 1, participants will correctly recognize OLD sentences from the target sub-story that corresponds to the base they saw more often than OLD sentences from other target sub-story. We also predict that, consistent with Sulin & Dooling (1974), participants will be more likely to mistakenly remember intrusion sentences that were from the base they saw than either those that were from the base they did not see or foil sentences.

Method

Participants: Participants were 62 undergraduates taking a Cognitive Psychology course at the University of Texas, Austin, who participated for extra credit.

Materials and Procedure: As in Experiment 1, each participant received a comparison task booklet. These booklets consisted of 10 base-target story pairs. The bases and targets were selected from the 18 used in Experiment 1, and altered as described above. The instructions were identical to those for Experiment 1.

After a 2-day delay, participants were given a recognition task booklet. This booklet contained ten pages of sentences, with a title from one of the targets at the top of each page. For each target, there were fourteen recognition sentences. Seven of these were old sentences (four from one target sub-story and three from the other) and seven were new sentences (three foils, two intrusion sentences from one base, and two from the other). After each sentence were the letters Y and N, and participants were instructed to circle Y for those sentences that had appeared in the target story, and N for those that had not.

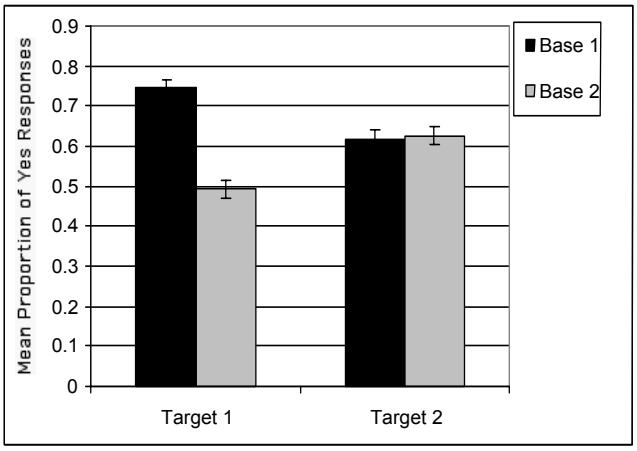


Figure 3: Mean proportion of yes responses for OLD sentences as a function of the Target Sub-story (1 or 2) from which they were taken, and the Base (1 or 2) that participants saw.

Results and Discussion: Because there were different numbers of sentences for each category of recognition sentences, we analyzed the mean proportions of sentences for which participants circled Y, indicating that it had been in the target story, for each sentence category[3]. The first prediction for Experiment 2 was that participants would recognize sentences from the target sub-story corresponding to the base they saw than from the other target sub-story, thus replicating Experiment 1 with a recognition task. To test this prediction, we conducted a 2(Base Story) X 2(Target Sub-story) ANOVA on the mean proportions of yes responses for the old sentences. These mean proportions for old sentences are presented in Figure 3. There was a main effect of target sub-story, with participants indicating that they had seen sentences from the first target sub-story in each more often than they indicated having seen the second, $F(1,61) = 49.36$,

[3] The pattern of data for both mean number and proportion of yes responses was the same.

$p < .05$. Consistent with our prediction, there was a significant base X target sub-story interaction, $F(1,61) = 45.92$, $p < .05$. Participants correctly recognized sentences from the first target sub-story when they had seen the analogous base ($m = 0.75$) at a higher rate than when they seen the non-analogous base ($m = .62$), $t(61) = 4.93$, $p < .05$. The pattern for sentences from the second target sub-story was the same, with participants correctly recognizing it when they had seen the analogous base ($m = 0.63$) than when they had seen the non-analogous one ($m = 0.49$), $t(61) = 3.98$, $p < .05$.

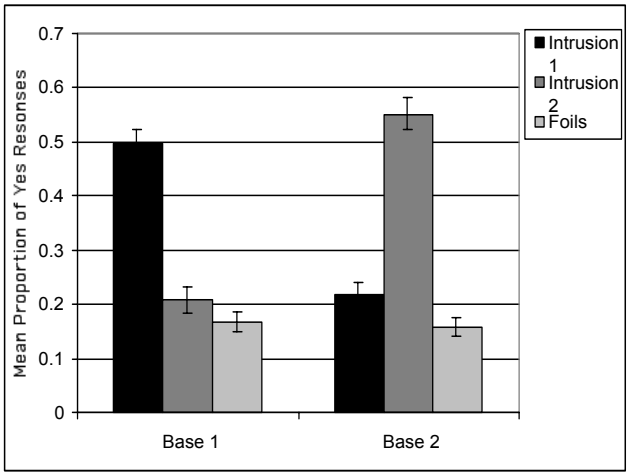


Figure 4: Mean proportion of yes responses for NEW sentences (Intrusion from Base 1, Intrusion from Base 2, and Foil) as a function of the Base (1 or 2) participants saw.

The second prediction for Experiment 2 was that, in replication of Sulin & Dooling (1972), participants would incorrectly indicate having seen intrusion sentences from the base they saw more often than intrusion sentences from the base they had not seen, thus indicating that information from the base was intruding on memory for the target. To test this prediction, we conducted a 2(Base Sentence) X 2(Intrusion Sentence) ANOVA on the mean proportion of yes responses for the intrusion sentences. This data is presented in Figure 4, along with the data from foil sentences. Consistent with the prediction, there was a significant base sentence X intrusion sentence interaction, $F(1,61) = 92.26$, $p < .05$. When participants received the base corresponding to the first target sub-story, they incorrectly recalled seeing the intrusion sentences from that base ($m = 0.50$) at a higher rate than intrusion sentences from the base they had not seen ($m = 0.22$), $t(61) = 7.65$, as well as than the foil sentences ($m = 0.17$), $t(61) = 11.10$, $p < .05$. The difference between intrusion sentences from the base they had not seen and foil sentences was not significant, $t(61) = 1.97$, $p > .10$. When participants received the base corresponding to the second target sub-story, they incorrectly indicated having seen intrusion sentences from that base ($m = 0.55$) more frequently than intrusion sentences from the unseen base ($m = 0.21$), $t(61) = 8.77$, $p < .05$, as well as than the foil sentences ($m = 0.16$), $t(61) = 11.68$, $p < .05$. The difference between intrusion sentences from the unseen base and foil sentences was not significant, $t(61) = 2.09$, $p > .10$.

These results are consistent with both predictions. Participants correctly indicated having seen old sentences from the target sub-story corresponding to the base they saw more often than old sentences from the target sub-story that did not correspond to the base, replicating the results of Experiment 1. Participants also incorrectly indicated having seen new intrusion sentences taken from the base story they had seen more often than those taken from the base they did not see or foil sentences, thus replicating the finding of Sulin & Dooling (1974) that information in schemas that is not contained in the story to be remembered can intrude on the memory for that story and be mistakenly remembered. Sulin & Dooling (1974) also found that intrusion effects increased over time, with virtually no intrusion at short delays (5 minutes). Pilot studies indicate that this is the case in the analogical reasoning paradigm as well, with short delays (20-30 minutes) prdoducing little to no intrusion.

General Discussion

The experiments presented in this paper are the first in a series of experiments designed to replicate findings from the literature on schematic memory using an analogical reasoning paradigm. In Experiment 1, we presented participants with base-target story pairs, and after a delay, asked them to recall as much as they could about the targets. We found that participants remembered more about the sub-story within a target that was analogous to the base they saw. We argued that this was a replication of the Bransford & Johnson (1972) finding that people remember more schema-relevant than schema-irrelevant information. In Experiment 2, we again gave participants base-target story pairs, with bases that contained information not present in the targets. In a recognition task, participants saw old sentences and new sentences that included version of the information in the bases not present in the targets. We found that, consistent with Experiment 1, participants correctly recognized old sentences from the target sub-story that corresponded to the base they saw than from the sub-story that did not. In addition, participants were more likely to incorrectly recognize new intrusion sentences from the base they saw than sentences they had not seen before, thus replicating the finding of Sulin & Dooling (1974) that information contained in schemas can intrude on memory for instances of the schema.

Because we can replicate these findings using an analogical reasoning paradigm, we can carry over what we know about analogy to explain schematic memory phenomena. We know that analogy involves the structural alignment process, and thus we suggest that schematic memory does as well. This means that schematic memory uses the same principles that analogy does. This approach may help us to answer some of the outstanding questions about schematic memory. For instance, schema-intrusion may involve processes similar to those that produce inferences from one domain to another in analogy (Clement & Gentner, 1991; Holyoak, Novick, & Meltz, 1994). Furthermore, the primacy of schema-relevant information may be related to the focus of attention on information relevant to the relational match, goal-related information, and functionally-relevant information in analogy (Markman & Gentner, 1997; Spellman & Holyoak, 1996; Keane, 1985).

In addition to the benefits of this theoretical approach, by using the analogical reasoning method to study schematic memory, we are able to control what goes into schemas, allowing us to better test the predictions we derive with from the structure mapping theory of analogy. This method raises questions of its own. For instance, in these experiments, one exposure to a story was enough to lead to memory effects that resemble those which previous work attributed to abstract schemas. Thus, abstractions are not necessary to explain the observed pattern of memory phenomena. However, a key limitation of the present studies is that participants were directed to compare the stories. Presumably for schemas to be useful, people must be reminded of them during comprehension. Abstraction may be useful in that it allows for the retrieval of a schema in a wider variety of situations (Gick & Holyoak, 1983). Further research must address this issue.

Future experiments will replicate other classic findings, and address the issues that the structural alignment paradigm raises for research on schematic memory. The benefits of this research may go in both directions, as our knowledge of schematic memory may be able to guide future research in analogy as well. Thus, this research holds the promise that it will allow an important but long-neglected type of memory to be studied again within a concrete theoretical framework, using a well-controlled method, with the promise of answering old and providing new questions.

Acknowledgments

We would like to thank Dedre Gentner, Lisa Grimm, Kyungil Kim, and Lauretta Reeves for helpful discussion about and/or aid in conducting experiments.

This research was supported by NSF Grant SBC-99-05013.

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