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Analogical Encoding: Facilitating Knowledge Transfer and Integration

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Abstract

People's ability to recall and use prior experience when faced with current problems is surprisingly limited. We suggest that one reason is that information is often encoded in a situation-specific manner, so that subsequent reminders are limited to situations that are similar to the original both in content and in context. *Analogical encoding*—the explicit comparison of two partially understood situations—can foster the discovery of common principles and allow transfer to new structurally similar situations. This paper addresses two new questions: (1) whether comparison can also improve people's ability to retrieve examples from long term memory; and (2) whether simply providing the common principle would suffice to promote transfer. The results show (1) that not only does comparing examples facilitate transfer *forward* to a new problem, it can also facilitate transfer *backwards* to retrieve an example from memory; and (2) providing a common principle is not sufficient: comparison is still beneficial.

Introduction

The ability to transfer relational knowledge across contexts is of central importance in human cognition. (Gentner, 2003). Yet people do not acquire relational abstractions effortlessly (Chi, Feltovitch & Glaser, 1981; Chase & Simon, 1973), nor do they always apply them when they would be helpful (Gick & Holyoak, 1980). Drawing analogies during learning can address both of these challenges (Catrambone & Holyoak, 1989; Gentner, Loewenstein & Thompson, 2003). We will also examine another role of analogy in learning. Our findings indicate that comparing two structurally similar examples (analogical encoding) not only facilitates transfer to *future* structurally similar cases, but also the retrieval of *prior* structurally similar examples from memory.

An important means of learning is analogical transfer—the use of a prior familiar situation (the base) to solve a novel situation (the target) by mapping the solution from the base problem to the target problem. This kind of transfer has been shown to occur in reasoning and problem-solving (Bassok, 1990; Novick, 1988; Reed, 1987; Ross, 1987). Research on analogical transfer also reveals an Achilles' heel. When people succeed in accessing appropriate prior

examples to inform current problems, they perform well (e.g., Pirolli & Andersen, 1985). The importance of prior cases in current reasoning has been argued persuasively in the case-based reasoning literature (Kolodner, 1993; Schank & Riesbeck, 1981). However, people often fail to access prior cases that would be useful, even when they can be shown to have retained the material in memory (Gentner, Rattermann & Forbus, 1993; Gick & Holyoak, 1980). Indeed, people are often unable to solve a problem after having just solved an analogous problem (see Reeves & Weisberg, 1994 for a review).

One way to promote structural transfer is by comparing two initial examples (Gick & Holyoak, 1983). This process capitalizes on the fact that comparison between two exemplars tends to make common relational structure more salient (Gentner & Markman, 1997). We call this *analogical encoding*, to emphasize that one can compare two partly understood examples to derive a common interpretation (Kurtz, Miao & Gentner, 2001). As Gick & Holyoak (1983) demonstrated, comparing two initial examples can facilitate deriving a schema, which in turn facilitates transfer to a structurally-similar problem (Catrambone & Holyoak, 1989). In contrast, people learning from a single case tend to encode it in a context-specific manner, with the result that later reminders are often based on more obvious surface aspects (Gentner & Rattermann, 1991).

We are investigating analogical transfer in the domain of negotiation (Loewenstein, Thompson & Gentner, 2003; Thompson, Gentner & Loewenstein, 2000). Negotiation is a particularly apt arena, for several reasons. Negotiation principles must be applied across many different contexts, making transferability essential. Further, the learning must be applied in real time, often in stressful, competitive situations with the potential for considerable gain or loss. Finally, our participants are highly motivated; they are studying negotiation with a direct interest in raising their job effectiveness.

In a typical negotiation situation, there is a set of issues in which two parties have different preferences, and to which they assign different levels of importance. The goal is to achieve an agreement, with each participant trying to optimize their gain. The negotiation principle we focus on

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here is the idea of constructing contingent contracts: agreements whose terms depend on the outcome of a future event (Bazerman & Gillespie, 1999). These contracts allow people to reach agreement despite differences in opinion. Despite their usefulness, untrained negotiators tend not to form contingent contracts. Instead, most negotiators form inefficient compromises (Thompson & Hastie, 1990).

In our studies, the basic method is as follows. We provide highly motivated students (typically MBA students or executives) with materials to prepare for a face-to-face negotiation. Before negotiating, all participants read two brief cases that illustrate a negotiation principle (e.g., a contingent contract) that would be advantageous to use in their face-to-face negotiation. Half the participants (the comparison group) are told to compare the two cases and write out their commonalities; the other half (the separate-cases group) is told to read each case and write out what is important about it. Participants are then paired with someone in the same condition to conduct the negotiation, which is set in a different context than the study cases. We have found that participants who compared the two cases are two to three times as likely to use the negotiation strategy in their subsequent face-to-face negotiations as those who analyzed the same cases one at a time (e.g., Thompson, Gentner and Loewenstein, 2000).

Comparing analogous cases promotes *forward transfer*. That is, it increases the likelihood that the common principle will be retrieved when an analogous situation occurs in the future. One route that has been proposed for this increased transfer may be that schema-abstraction leads to increased matching (Ross, 1989). This possibility follows directly from the assumptions of schema-abstraction. Comparison invites an alignment and re-representation of examples, yielding a common representation that is less context-specific than the initial ones (Gick & Holyoak, 1983; Loewenstein, Thompson & Gentner, 1999). Because this new representation has more general relational representations and fewer potentially conflicting object matches than the initial cases, the match with subsequent cases will be better, making reminders more likely (Forbus et al, 1995; Ross, 1989). However, there is another possible reason for the increase in forward transfer, namely, *learning-to-encode*. Having derived a common representation, people may encode future cases in the domain in a similar manner. (Medin & Ross, 1989). The learning-to-encode account predicts that future cases are likely to match the schema that resulted from the comparison, because they will be encoded in the same way.

Using retrieval to clarify the transfer process. Although most researchers have assumed that both increased matching and learning-to-encode are part of the story, the forward-transfer improvement could be explained solely by learning-to-encode. However, the learning-to-encode account cannot predict any effect on retrieval of cases acquired prior to the schema abstraction. Thus, if learning-to-encode is the main reason for improved transfer, then the effects of comparison should be unidirectional: better learning today will help

performance tomorrow, but will be of little help in retrieving examples that were learned yesterday. In contrast, if schema abstraction per se is an important force here, then we will see bi-directional effects: abstracting a schema should aid in retrieval whether it is forwards or backwards.

Experiment 1

In Experiment 1, we tested whether analogical encoding facilitates *both* forward transfer and backwards retrieval. If so, this would suggest a degree of symmetry in the memory retrieval process. That is, it would suggest that an abstract relational structure is better retrieved by future cases and also serves as a better probe for prior cases than a specific case.

We gave all participants two analogous examples. We asked half to compare them, and half to study the examples one at a time. Next, to test whether comparison aids memory *retrieval*, we asked people to recall an example from their own experience that illustrated the same principle as the initial examples. Finally, to test for *transfer*, we asked whether people would use the principle to form better agreements in a subsequent face-to-face negotiation (as in our prior studies).

Our participants were management consultants in a negotiation training program. Given the amount of money and time devoted to this training, there is no question that they were highly motivated to learn. They should also be professionally predisposed to value learning and generalization.

Method

Participants A total of 124 participants aged approximately 25 to 45 years, all full-time professional management consultants working at the same organization, participated through a negotiation training seminar. There were 64 in the comparison condition and 60 in the separate cases condition.

Materials and procedure. Participants read role materials to prepare to be either the buyer or seller in a negotiation role-playing scenario. Just prior to engaging in the role play, participants received a training packet. The first page concerned details about their upcoming negotiation. The next pages contained two cases exemplifying the contingent contract principle. The Comparison group read both cases and then was asked "What is going on in these negotiations? Think about the similarities between these two cases. What are the key parallels in the two negotiations? Please describe the solution and say how successful you think it is." The Separate case group received the following question after each case: "What is going on in this negotiation? Please describe the solution and say how successful you think it is."

For both groups, the next page of the training packet asked participants to recall an example like those they had just read: "Please think of an example, preferably from your own experience, that embodies the same principle as that on

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the previous page.” We then asked participants to state the source of their examples. Participants were not limited as to time and typically spent 45-60 minutes on these three pages (an indication of their motivation to learn). We saw no time-on-task differences by condition. Then they were paired with someone from the same condition to negotiate. The negotiation case was set in a different context than the training cases, and was designed to afford creating a mutually beneficial contingent contract.

Scoring The negotiated agreements were scored by blind raters as to whether they contained a contingent contract (which was, by design, the optimal solution to the negotiation dilemma). Coders also rated the quality of the participants’ initial responses concerning the two cases—that is, the degree to which the contingent contract schema was described—using a 3-point scale: 0 = no elements of the schema were present, 1 = some elements, and 2 = all elements. They also rated whether participants linked the case and principle in any way (as a manipulation check on the condition difference). Finally, coders also rated whether the examples participants recalled were contingent contracts, using the same scale as above, and categorized the source domains in which participants’ examples were set. Overall, there was high agreement (87%); disagreements were resolved through discussion.

Results

As predicted, the comparison group was superior to the separate cases group on all three measures: schema quality, likelihood of transfer, and quality of reminders. Making comparisons led to grasping the contingency contract schema from the original examples, which in turn facilitated both linking it to prior examples in memory and using it in a new negotiation situation.

Schema understanding Comparison participants ($M = 1.45$) articulated the schema better than Separate case participants ($M = 0.98$), $t(122) = 2.97$, $p < .01$. Another striking finding was that fewer than one in five Separate cases participants linked the two cases in any way, despite the fact that they occurred contiguously and were analogous.

Transfer In their face-to-face negotiations, Comparison participants (59%) were nearly twice as likely to make contingent agreements than Separate case participants (33%), $\chi^2(1, N=62) = 4.22$, $p < .05$. As in our previous research, this suggests that comparison facilitates transfer.

Reminders Participants in the Comparison condition ($M = 1.25$) retrieved better examples of contingency agreements than did participants in the Separate cases condition ($M = 0.82$), $t(122) = 2.65$, $p < .01$. This suggests that comparison aided people’s understanding of the initial cases, thereby better guiding participants’ retrievals.

Participants retrieved examples from their own business experience or that of a colleague, and less frequently drew

upon examples from the popular press. The examples were mainly from the business domain (as expected—they were in a business training classroom), with the remainder being daily life examples such as betting on sports teams, uncertainty about the weather affecting a vacation activity, arranging a home mortgage, and so forth.

One source of participants’ examples had a name within their organization—*value billing*. Value billing is a particular type of contingent contract wherein a consulting firm bills clients a low base fee, with a generous bonus structure based on the outcome of the work. Given that every participant probably knew about value billing, it is striking that most of those who used this example were in the Comparison condition.

Cross-measure associations As expected, schema understanding predicted retrieval performance. The association between articulating the schema and retrieving a match was reliable, $\chi^2(1, N=124) = 8.68$, $p < .01$. In the transfer measure there was only a modest trend for the sum of a pair’s schema ratings to be associated with their transfer $\chi^2(1, N=62) = 1.70$, $p = .19$. However, “high performance pairs” (pairs in which at least one person articulated the schema and retrieved a matching example, and the pair formed a contingent contract—i.e., transferred) were marginally more likely to be in the Comparison condition (47%) than the Separate cases condition (23%), $\chi^2(1, N=62) = 3.75$, $p = .05$.

Distinguishing retrieval from invention. To conclude that there is a comparison advantage for retrieval, it is important to assess whether participants were simply fabricating examples rather than retrieving them. That is, the retrieval advantage for the comparison group could stem simply from their using the derived schema to invent examples, rather than from recalling them. But in this case, we should see the highest proportion of structurally correct “retrievals” from participants who failed to state a source. In fact, the 32 people who did not state the source produced the *lowest* proportion of structural reminders (31%). The proportion was higher for those who stated non-verifiable sources (45%), and highest for those whose source was verifiable (and verified) (68%). The opposite would have been expected on the ‘fabricating’ account, and hence it seems reasonable to take the participants at their word.

Discussion

Comparing cases yielded consistent advantages for schema abstraction, retrieving a matching example from memory, and transferring to solve a new problem. Although our participants were consultants whose jobs depend on their ability to apply their knowledge in new situations, and who spent considerable time with the training materials, we saw little spontaneous comparison across examples in the group not explicitly told to compare. Nonetheless, a brief instruction to compare was sufficient to advance the

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performance of their peers across all three measures of learning.

Another striking pattern is that despite the participants' considerable experience in the business world, over half of them did not recall any examples that were contingent contracts (or structural analogs). In fact, 11% failed to write down any case at all. Our results underscore that (1) transferring from analogous examples can be challenging even for sophisticated and motivated learners (Novick, 1988) (2) analogical encoding can dramatically increase transfer; (3) the benefits of analogical encoding derive in part from inducing a clearer schema for the common principle (Catrambone & Holyoak, 1989; Gick & Holyoak, 1983) and (4) analogical encoding can lead to increased retrieval of prior analogous examples.

Finally, the fact that analogical encoding aids in memory retrieval indicates that the effect of schema abstraction in memory access is bidirectional. The representations that resulted from comparison were *both* more readily retrieved by future analogs than were the separate cases and more effective as probes for prior analogs stored in memory. Thus, although we suspect that the transfer benefits of comparison derive in part from learning-to-encode—i.e., from encoding future examples in a structurally clear manner consistent with the schema—our results indicate that ease of matching must also play a role. The relatively abstract schemas that result from analogical encoding match better with prior examples just as they do with future examples.

Why not just give them the principle? The results of this study and prior work on analogical encoding lead naturally to a further question. If the advantage of mutual alignment is simply that comparing the two examples leads learners to derive the principle, then would learners not fare even better if the principle—in this case, the contingent contract principle—were simply given to them explicitly? We examine this directly in Experiment 2.

Experiment 2

In Experiment 2 we asked Masters of Business Administration (MBA) students to read a case and an abstract principle. If analyzing the principle and elaborating upon it is sufficient for transfer, we should find high rates of transfer in all groups. However, if principles need to be grounded in examples to be comprehensible and generalizable, then those asked to compare the case and principle should show a transfer advantage relative to those who study the example independently of the principle.

Method

Participants A total of 106 MBA students participated in the study, resulting in 27 pairs in the Comparison condition, and 26 pairs in the Separate condition.

Materials and Procedure The materials and procedure were similar to Experiment 1. The training packet did not

ask for memory retrievals, and instead of two cases presented people with one case and an abstract description of contingent contracts. Participants in the comparison group were asked to compare the case and principle and specify commonalities, and then describe implications for negotiation. Those in the separate group were asked to read the case and the abstract principle separately, and were asked after each to state its implications for negotiation. Both groups received case and principle on consecutive pages. Participants then engaged in the negotiation with someone else in the same condition.

Scoring As before, coders rated the quality of the contingent contract schemas. They also rated whether participants had paraphrased the case in their responses, whether their responses contained generic advice about negotiation that was unrelated to contingent contracts, and whether they linked the case and principle in any way. They agreed on 93% of their judgments, and disagreements were resolved through discussion.

Results

In their initial descriptions, Comparison participants were more likely than Separate cases participants to articulate the full schema (74% versus 56%) and they less often failed to articulate any of the schema (12% versus 35%), $\chi^2 (N=97, 2) = 7.36, p < .05$. In their face-to-face negotiations, participants who compared the case and principle (44%) were over twice as likely to form contingent contracts as were participants who analyzed the case and principle separately (19%), $\chi^2 (N=53, 1) = 3.87, p < .05$.

The additional ratings of people's individual responses to the training materials showed a further surprising and consistent pattern. Despite the fact that all participants had read and discussed the case and the principle on consecutive pages, almost none of the Separate participants noticed the link between them. Thus, the Separate participants did not appear to notice that the principle was the general statement of what the case exemplified. Comparison participants (88%) were also more likely than Separate participants (34/47, or 71%) to paraphrase the case as they discussed it, $\chi^2 (N=97, 1) = 4.24, p < .05$. Participants in the Separate cases condition were also more likely to give general panaceas as advice (e.g., "it helps to have a good relationship when you're negotiating" or "you want to reach win-win deals") (77%) than comparison participants (31%), $\chi^2 (N=97, 1) = 21.06, p < .001$.

Discussion

Our results lead to something of a paradox. We find that learners who derive a schema through analogical encoding—either by comparing cases, or by comparing a principle with an example—can readily transfer the schema to new cases. Yet learners who are explicitly given the same schema—even along with an example case—cannot. Why? Can we say anything more specific than that "active learning is good"? We suspect that abstract principles are ineffective

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because they are less well understood than specific cases (Forbus & Gentner, 1986; Regehr & Brooks, 1993). Indeed, in our study, some people had difficulty re-stating the principles. This is partly because learners may fail to understand the specific terms used, or how they are meant to combine. This is consistent with Ross & Kilbane's (1997) finding that if given an example followed by a principle, people remember the example but forget the principle. Another difficulty in understanding principles is that there are typically many different interpretations of a given relational abstraction. Thus, people may encode the principle in ways that are incompatible with the later example. The joint interpretation of an example and a principle helps overcome these limitations. People better understand the principle if they apply it to an example.

General Discussion

These studies show three learning advantages of analogical encoding. First, drawing comparisons facilitates acquiring an abstract schema. As Experiment 2 showed, it can do so better than studying a statement of the abstraction itself. Second, both studies replicated prior research showing that comparison facilitates applying derived abstractions to solve new problems. Third, analogical encoding of two current cases—that is, analogical encoding of a *probe*—leads to a retrieval advantage in accessing structurally matching cases from long-term memory. Our findings suggest that the second and third of these stem from the first: that it is the possession of clear schemas that facilitates both transfer and retrieval.

Implications for learning and transfer. Our findings have several implications for complex learning. On the dark side, the results of Experiment 1 suggest limitations on even experts' analogical thinking. Over half the participants failed to recall *any* structurally similar example from their own experience, despite the fact that they had considerable experience including specific experience in a particular kind of contingent contract (value billing) that would have qualified nicely. Prior studies suggest that people show more relational transfer in domains that are familiar or in which they possess expertise (Blanchette & Dunbar, 2001; Dunbar, 2001; Novick, 1988). However, as our results show, even for experts relational retrieval can be problematic.

A second rather gloomy finding is the failure of our (highly motivated) participants to spontaneously compare the two cases (Experiment 1) or the case and principle (Experiment 2). Here, as in our prior studies, participants in the Separate cases group almost never noticed the link between the two, despite the fact that they were on consecutive pages. The huge advantage found for the Comparison group, which did compare the two, makes this failure to notice the link all the more telling. It raises the question of how many potentially illuminating comparisons are missed in the course of learning. On the positive side, the relational fluency shown by the Comparison group offers a relatively simple technique whereby learners and

educators can improve their understanding and gain relational insight.

Implications for memory retrieval. That analogical encoding can facilitate retrieval is consistent with the point that the match between a specific case and a general abstraction (which has few or no concrete features and therefore few mismatches) is better than the match between two specific cases (unless, of course, the cases are closely similar, with many matches and few mismatches) (Tversky, 1977). Further, it indicates that this advantage holds whether the schema is in the memory bank (as in prior studies of analogical transfer) or in the probe position.

The retrieval effect suggests that people can use a well-articulated principle to retrieve prior examples and reinterpret them as examples of this new abstract structure. This implies a clear mechanism by which reflection can reorganize knowledge. A major question in both child development and the field of expertise is whether and how people's existing knowledge changes as they understand a domain in new depth. To the extent that abstractions can call forth matching cases from memory, the learner may gain a richer understanding of the new abstraction and a re-representation of the prior example in light of the new abstraction. This suggests a means by which new knowledge can connect to existing knowledge and can reorganize that knowledge along more expert lines.

One encouraging implication of our findings is that examples people learn prior to understanding key abstract principles in a domain are not necessarily lost or wasted. Given the increasing demands for adults to learn, this is encouraging news. Teachers can capitalize on people's prior knowledge by encouraging people to recall familiar examples of new principles. We may well rely on learned cases every bit as much as researchers on analogy, categorization and case-based reasoning suggest, but we nonetheless may benefit considerably from interventions in how we encode them.

In conclusion, analogical encoding appears to be a powerful starting point for learning. The resulting understandings may radiate both backwards and forwards.

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