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Analogical Reasoning

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Glossary

Analog Situation or domain involved in analogical mapping; either the base (source) or target.

Base (or source) Analog from which inferences and explanatory structure are drawn; typically, the more familiar or concrete domain: for example, in the analogy 'An electric circuit is like a plumbing system,' the base is a *plumbing system.*

Candidate inference Fact posited about the target analog based on completing the common relational structure between base and target: for example, in the above analogy, a possible inference is 'Higher voltage leads to greater current in an electric circuit, just as higher pressure leads to greater water flow in a plumbing system.'

Conceptual metaphor System of words and phrases used conventionally to talk about one domain by analogy with another: for example, 'Love is a journey: The road is sometimes steep; You have to take the rough with the smooth, etc.'

Literal similarity Likeness based on overall similarity; applies when two situations are similar in their objects and entities and also in their relational structure: for example, one dishwasher tends to be literally similar to another (alike in both appearance and causal structure).

Relational similarity Likeness based on relations common to both domains or situations (whether or not the objects in the two systems resemble each other): for example, an electrical circuit and a plumbing system can be relationally similar if they have a *common causal structure.*

Source (see *base*) structural alignment Identifying correspondences between two analogs, based on their common relational structure.

Structural consistency The property of having a clear set of matches between the two analogs. In a structurally consistent alignment, the parts of the two analogs are in one-to-one correspondence, and the analogy's inferences are clear.

Structural similarity (see *Relational Similarity*)

Surface similarity Likeness based only on similar objects and background context between two domains/situations, without a common relational structure: for example, a dishwasher may look like a clothes dryer, but their mechanical and causal relational structures are quite different.

Systematicity Preference for matching deep systems of connected relations, rather than smaller relational sets.

Target Analog one is drawing inferences about; typically the less familiar or more abstract domain: for example, *in the analogy* 'An electric circuit is like a plumbing system,' the target is *electric circuit.*

Introduction

Analogical reasoning – the ability to perceive and use relational similarity between two situations or events – is a fundamental aspect of human cognition. Indeed, some researchers suggest that it is the crucial cognitive mechanism that most distinguishes human cognition from that of other intelligent species. It is a core process in scientific discovery and problem-solving, as well as in categorization and decision-making.

Reasoning by analogy involves identifying a common relational system between two situations and generating further inferences driven by these commonalities. The commonalities may also include concrete property matches between the situations, but this is not necessary for analogy; what is necessary is overlap in relational structure. Although this may sound like a highly complex process, people routinely use analogy in everyday life. For example, people readily apply proverbs to situations based on purely relational matches. When you hear 'That's locking the barn door after the horse has gone,' you don't look for a barn; rather, you apply the relational pattern – *a precaution taken after the damage is done* – to some current situation. This kind of relational mapping is the essence of analogy.

In the most typical case of analogy, a familiar domain (the *base* or *source*) serves as a model by which one can comprehend and draw new inferences about a less familiar domain (the *target*). Consider a rather timely example, used by Sterman and his colleagues at MIT to explain the behavior of atmospheric carbon dioxide; they describe the balance of carbon dioxide (CO_2) in the atmosphere by analogy with a bathtub:

> The amount of water in a bathtub is determined by the rates of water flowing into the tub and water flowing out through the drain. As long as the inflow of water into the tub exceeds the outflow, the bathtub will continue to fill.
>
> Likewise, the amount of carbon dioxide (CO_2) in the atmosphere is determined by the rates of CO_2 emissions and CO_2 removal.

In this analogy, the bathtub corresponds to the atmosphere. Water inflow corresponds to CO_2 emissions into the atmosphere and water outflow to CO_2 removal. This analogy invites the (correct) inference that as long as CO_2 emissions exceed removal, CO_2 levels in the atmosphere will continue to rise. This illustrates a typical feature of analogy: A process that cannot be seen becomes easier to grasp by virtue of an analogy with a familiar situation. This example also reveals the power of analogy to highlight a common relational pattern. Often, such a common pattern is given a linguistic label – in this case, a *stock-and-flow* system – to facilitate remembering the abstraction and applying it to other situations. A student who grasps this analogy will find that this abstraction is useful in reasoning about other arenas, such as cash flow. Analogy is often the most effective way for people to learn a new relational abstraction; this makes it highly valuable in education.

Analogy is also frequently used in argumentation, where it allows the speaker to guide his or her audience toward a particular framing and set of inferences. For example, when a US district court judge in December 2002 ordered Microsoft to include Sun Microsystems' version of Java with the Windows operating system, a lively web discussion ensued, often involving analogy. One writer wrote: 'Please explain to me why Microsoft should be forced to include third party software in their OS? Every time I buy a six pack of coke, should a can of Pepsi be included?' and another wrote 'That would be like (my attorney) being forced to refer clients to his competition, since they didn't have as much business as him.' Many of these analogies were picked up and either extended or reversed. Defending the decision, another writer wrote 'If Ford had a monopoly on cars, they certainly would not be allowed to sell their cars with only Ford brand radios and tires . . .'

As demonstrated in the above examples, analogies vary widely in their appearance, content, and usage. But they can all be characterized by a set of processes common to analogical reasoning of all types. These processes are:

- *Retrieval*: Given some current topic in working memory, a person may be reminded of a prior analogous situation in long-term memory.
- *Mapping*: Given two cases present in working memory (either through analogical retrieval or simply through encountering two cases together), mapping involves a process of aligning the representations and projecting inferences from one analog to the other.
- *Evaluation*: Once an analogical mapping has been done, the analogy and its inferences are judged.

We begin with mapping, the core process in analogical reasoning, and its subprocesses, reserving retrieval for later. The rationale for this is that, while analogical reasoning invariably involves a mapping process, it does not always require finding a second analog in memory. For example, when analogies are used in argumentation, both analogs are typically presented to the reasoner, who must then carry out a mapping and evaluate the analogy.

Mapping

Mapping is the core process of analogy, and has therefore been the main focus of analogy research. At a first level, the mapping process consists of finding how two situations are similar, and then bringing across further inferences from the better-known situation (the *base*, or *source*) to the less familiar one (the *target*). What distinguishes analogy from other kinds of similarity is that for two situations to be analogical, they must be similar in their relational structure. Analogy research has largely agreed on a set of principles laid out by Dedre Gentner in 1983, in a theory called structure mapping. According to structure-mapping theory, analogical mapping requires *aligning* the two situations based on their commonalities – particularly their common relational structure – and *projecting inferences* from the base to the target, according to this alignment.

Alignment

In an analogy, the two situations being compared can be aligned on the basis of common *relational structure*. For example, consider the simple perceptual analogy in Figure 1. These two scenes are analogous: they can be aligned – that is, the elements can be placed in one-to-one correspondence such that the same relational structure (Circle 1 > Circle 2 > Circle 3, which could be labeled *steadily decreasing size*) holds in both scenes. There is something satisfying about noticing structural alignments like this one. For example, in this case, despite the obvious object similarity between the two circles indicated by black arrows (both circles are the same size), when people are led to compare these two scenes (i.e., to engage in analogical mapping), they will match objects that occupy the same relational role in their respective figures: for example, the smallest, rightmost circles.

This same kind of alignment process occurs with a complex analogy like the bathtub example. Here too, people will align two domains based on their common relations. However, for scientific analogies, the matching relational structure will generally be governed by causal relations rather than spatial relations.

Even though most of us are not aware of how we process analogies, research suggests that there are some implicit principles that people follow during analogical mapping. First, we like our alignments to be structurally consistent. Two things are required for an alignment to be structurally consistent. First, each object in the base should match to one and only one thing in the target; this is known as *one-to-one correspondence*.

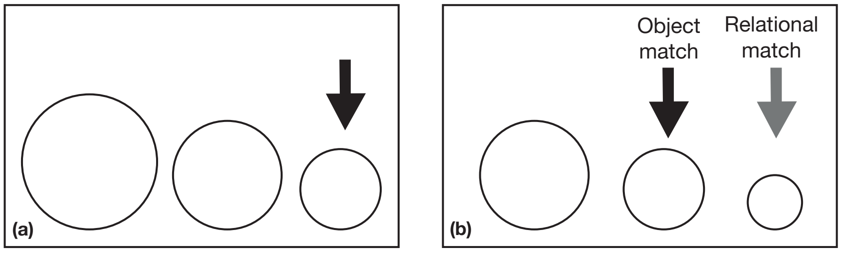

Figure 1 Perceptual analogy depicting *decreasing size*. The smallest circle in (a) could match either with the middle circle in (b) (an object match) or with the rightmost circle (the relational match). Adapted from Markman AB and Gentner D (1993) Structural alignment during similarity comparisons. *Cognitive Psychology* 25: 431–467.

For example, for the pair in Figure 1, people either map the smallest circle in 1A with the smallest circle in 1B (the relational match) or else with the middle circle (the object match) but not both. Second, if two relations are matched with one another, then their arguments must also be matched. We can see the principle of structural consistency at work in scientific analogies just as in simple spatial analogy above. For example, one-to-one correspondence holds in the bathtub analogy: water draining from the tub cannot correspond to both CO_2 emissions and CO_2 removal.

Further, when we align two situations, we do not simply find one pair of matching relations and stop there; rather, we prefer to match large, deep-connected systems. This preference is known as the *systematicity principle*: people prefer to align two domains based on large, connected relational systems, rather than just a single common relation. In the bathtub analogy, people generally prefer to align the entire stock-and-flow system that characterizes water flow and CO_2 flow, rather than simply noting that both involve the single relation of one thing flowing into another. Our desire for systematicity reflects an implicit preference for analogies that are highly informative and have inferential power.

Figure 2(a) provides a schematic depiction of structural alignment. Notice that this depiction shows a one-to-one correspondence between elements of the two domains – each element is mapped to (at most) one element in the other domain. Also, not only are relations matched but their corresponding arguments are matched as well. Finally, a large, inferentially rich relational pattern is matched, illustrating systematicity.

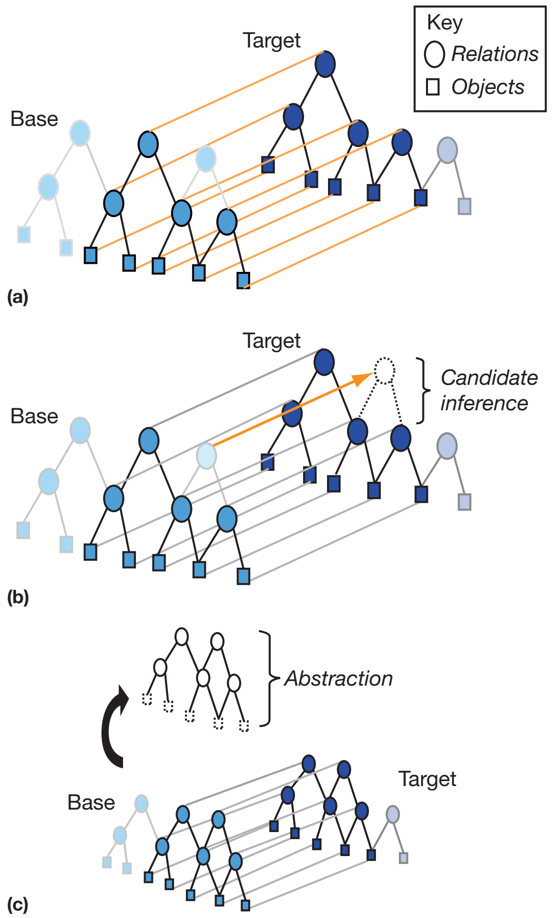

Figure 2 Analogy as structure mapping. (a) Initial alignment of common relational structure. Relations are matched between domains, and their arguments are also matched. (b) A frequent outcome of making an analogy is that candidate inferences are generated by completing the missing relational pattern in the target. (c) A possible outcome of structural alignment is abstraction of the common relational pattern.

Inference

Analogies permit us to draw new *inferences* about the target. Indeed, one major reason we use analogy is to learn something new about the target domain by recruiting our knowledge of a relationally similar base domain. But this brings up a key question: How do we avoid drawing the many wrong (or even ridiculous) inferences that we might make if we simply mapped across whatever we know about the base to the target? Clearly, analogical reasoning would be useless if we had to spend time rejecting inferences such as *pouring Mr. Bubble into the atmosphere can make for an enjoyable evening*, which could be derived from the bathtub analogy. One key finding in analogy research is that people are highly selective in the inferences they make from analogies – we do not simply bring over everything we know about the base to the target.

According to the structure-mapping view, inference happens as a natural outcome of the structural alignment process. Once the base and target have been aligned and their common relational structure found, if there are additional parts of the relational pattern in the base that are not present in the target, then this missing pattern will be brought over as a candidate inference (Figure 2(b)). Thus, one way to think about inference generation is as a process of *relational pattern completion*. The requirement that candidate inferences be connected to the common relational pattern effectively filters which inferences will be considered. For example, in the bathtub analogy, *pouring in some Mr. Bubble makes for an enjoyable evening* is not connected to the common relational structure (as amplified below), so this inference would not normally be made.

Because inference and structural alignment are so tightly linked, perhaps it is not surprising that many of the constraints people impose on alignment they also use in inference. People prefer inferences that are consistent with the rest of the matching structure between the base and target. In addition, people prefer systematicity in inference: that is, people are more likely to project inferences that are connected to large relational patterns, rather than to project isolated parts of the base or inferences involving only a subset of the matching relational pattern. Clement and Gentner in a 1991 study found support for systematicity in inference: people were more likely to import a fact from the base to the target when it was connected to other facts shared with the target. In analogical matching and inference, people are not interested in isolated coincidental matches; rather, there is a tacit preference for deeply interconnected relational patterns.

Here is how you might generate an inference in the bathtub analogy. First, you align the known fact that *the amount of water entering and leaving the tub determines the total amount of water in the tub* with the known fact that *the amount of CO_2 entering and leaving the atmosphere determines the total amount of CO_2 in the* *atmosphere*. You can then draw new inferences. For example, let us assume you know that the amount of water in the tub will decrease only if the amount of water draining is greater than the amount of water entering. You can carry this fact over to the target as an analogical inference: 'The amount of CO_2 in the atmosphere will decrease only if CO_2 removal exceeds CO_2 emissions.' This inference is warranted by its connection to the aligned relational structure.

As just discussed, one way in which analogy is useful is that it helps us learn new information about the target by suggesting inferences. Another benefit of analogy is *abstraction*: that is, we may derive a more general understanding based on abstracting the common relational pattern (**Figure 2(c)**). For example, on the basis of the bathtub analogy, a student might extract an abstract schema of a stock-and-flow system: as long as inflow exceeds outflow, the stock will increase; and as long as outflow exceeds inflow the stock will decrease. Once formed, this abstraction can serve as a general schema for other stock-and-flow systems, such as those that occur in economics or biology.

In addition to highlighting potential abstractions, analogies can also call attention to certain differences between the analogs. For example, a salient difference between the CO_2 system and the bathtub system is that the amount of water in a bathtub can change rather quickly by adjusting the inflow or outflow, whereas if you adjust CO_2 emissions and removal, it takes several decades to see a corresponding change in CO_2 levels in the atmosphere.

Evaluation

Once the common alignment and the inferences have been generated, the analogy and its inferences are evaluated. The criteria for evaluation can be grouped into three classes. The first factor is the *factual correctness* of the inferences generated by the analogy. If the analogy yields inferences that are untrue, the inferences and the analogy will in general be rejected, or at least revised. Of course, in some cases one cannot immediately identify whether an inference is true or not, as when making predictions about a future event, or when predicting a scientific outcome by analogy with another domain. A related factor in evaluating inferences is *adaptability*: how easy it is to modify a fact from the base to fit the target. People accept inferences that are highly adaptable to the target more readily than those that are less adaptable.

A second factor that people use in the evaluation of inferences is *goal relevance*. Goal relevance has been explored as a major factor in analogical reasoning in the theories of Keith Holyoak and colleagues. They emphasize that inferences that are relevant to the current goals of the reasoner are more likely to be projected during analogical inference, and are more important in evaluating the analogy. This constraint is particularly germane in problem-solving situations. During problem-solving, even if an analogy yields a reasonable inference, it is unlikely to be retained if it does not bear on the problem at hand. Spellman and Holyoak showed in a 1996 study that when two possible mappings are available for a given analogy, people will select the mapping whose inferences are relevant to their goals.

A third factor that may influence evaluation is how much new knowledge the analogy and its inferences can potentially provide. The idea is that inferences that potentially yield a significant gain in new knowledge may be desirable (even if somewhat risky), especially when brainstorming or dealing with unfamiliar domains. The evaluation of inferences and of the whole analogy can mutually influence one another. Evaluation of particular inferences contributes to the larger evaluation of the analogy. If an analogy generates false inferences, we will generally reject or at least revise the analogy.

Analogical Retrieval

So far, we have been discussing a scenario in which two analogs are already present in working memory. However, sometimes only one analog is currently present, and we experience a reminding to something that may be similar or analogous (e.g., a previously solved problem). Thus, understanding the use of analogy in reasoning requires some account of how potential analogs are accessed in long-term memory – what leads people to think of analogies? While relational similarity exerts a strong influence on analogical mapping, it has much weaker effects on retrieval from memory. People often fail to retrieve potentially useful analogs, even if they share relational structure. In a classic 1980 study by Mary Gick and Keith Holyoak, participants were given a very difficult insight problem. When people simply read the problem and tried to solve it, only 10% succeeded. When another group was given a story with an analogous solution (but with different specific content) before receiving the insight problem, about 30% solved it – three times as many as without the analogy. Yet despite this impressive gain, the majority still typically failed to solve the problem. Although one might have suspected that they had simply forgotten or never encoded the analogous story, this was not the case. When people were given a hint to try using the prior story, the proportion solving the problem rose to around 90%. Thus, the solution rate tripled if people had heard an analogous story; and it tripled again if people were reminded of the prior analog. People's failure to access the prior analogous problem resulted not from forgetting it but from failure to be reminded of it by the current problem. This is an example of what Alfred North Whitehead called 'inert knowledge' – knowledge that is not accessed when needed.

Remindings to potential analogs are typically driven by surface similarities, such as similar objects and contexts, rather than by similarities in relational structure. Of course, it is important to bear in mind that in all these studies, some individuals show genuine relational transfer. It is not the case that relational remindings never occur; it's just that they are much rarer than surface remindings and overall similarity remindings. Gentner and colleagues have proposed two interrelated explanations for this. First, people often encode experiences in a content-specific manner, so that later remindings occur only for highly surface-similar experiences. Second, there is evidence that people's representations of relations are more context-specific than those of objects and entities. For example, Brian Ross gave people mathematical word problems to study, and later gave them new word problems. Most of their later remindings were to examples that were similar on the surface (e.g., both problems talked about mechanics), irrespective of whether the underlying mathematical principles matched.

Experts in a domain are more likely than novices to retrieve relationally similar examples, but even experts retrieve some examples that are similar only on the surface. However, as demonstrated by Laura Novick in 1988, experts reject misleading surface remindings more quickly than do novices. Thus, especially for novices, there is an unfortunate dissociation: while accuracy of transfer depends critically on the degree of relational pattern matching, memory retrieval depends largely on surface similarity between domains.

Factors that Influence Mapping

People's fluency in carrying out analogical mappings is influenced by three broad kinds of factors. First are factors internal to the analogical mapping itself, such as systematicity – whether the common relational system possesses a deeply connected structure – and transparency – the degree to which corresponding elements are similar. The second category includes characteristics of the reasoner, such as age and expertise. The third includes task factors such as processing load, time pressure, and context.

We have already discussed the importance of structural consistency and systematicity in analogical mapping, so we turn directly to transparency. *Transparency* depends chiefly on the degree of similarity between corresponding objects. A high-transparency analogy is one in which the objects that play the same roles in the common relational structure are highly similar (or identical), and the objects that play different roles are quite dissimilar. Such an analogy is generally both obvious and easy to align correctly. The most pronounced case of high transparency is *literal similarity*, in which both relations and objects match. As discussed above, literal-similarity matches are more reliably retrieved from memory than are purely relational analogies. To this, we can add that even in online processing, literal-similarity matches are processed faster than purely relational matches (in which the corresponding objects lack similarity). This fits with our intuitions: for example, it is easier to see how one tiger is like another than to see how a tiger is like an eagle (both are carnivores that hunt alone). However, although high-transparency matches are natural and easy to process, many useful explanatory analogies are of relatively low transparency – that is, the corresponding objects are not at all similar. The bathtub analogy discussed earlier is an example of a low-transparency analogy: the corresponding objects are very dissimilar, for example, water looks very different from CO_2 (and in any case, we never directly observe CO_2 molecules). Finally, as noted above, achieving a relational alignment is more difficult when noncorresponding objects are similar. Thus, the worst case of low transparency is *cross-mapped* analogy, in which similar objects play *different* roles within the relational structure, as exemplified below.

Both transparency and systematicity interact with individual characteristics of the reasoner, notably age and experience. For example, Gentner and Toupin gave children a simple story and asked them to reenact the story with new characters. Both 6- and 9-year-olds performed best when the corresponding characters were highly similar between the two stories (the literal-similarity condition – high transparency). They performed less well when corresponding characters were different (medium transparency), and they performed worst when similar characters played different roles across the two stories (the cross-mapped condition – low transparency). Thus, both age groups were sensitive to the transparency of the correspondences. In addition, older children (but not younger children) benefited strongly from systematicity: when they were given a summary statement that provided the structure for the plot, their performance stayed high regardless of transparency. They were able to use the relational system provided by the plot description to maintain relational correspondences despite the tempting object matches.

Further studies have corroborated this finding that when relational similarity is pitted against object similarity as in the cross-mapped conditions mentioned above, younger children are highly influenced by object matches and less able to attend to relational matches than are older participants. This shift from a focus on objects to a focus on relations has been termed the *relational shift*. Although there is widespread agreement that such a shift occurs, developmental researchers differ on why. Gentner and colleagues have argued that the relational shift is driven primarily by gains in relational knowledge. An alternative view, proposed by Graeme Halford and colleagues, is that the shift results from a developmental increase in processing capacity; according to this view, processing relational matches requires more processing capacity than processing simple object matches. A third view, championed by Lindsey Richland and colleagues, explains the relational shift as stemming from maturational increases in inhibitory control, which permits the child to suppress object matches in favor of relational matches.

The third class of factors affecting analogical processing concerns task variables such as time pressure, processing load, and immediate context. One generalization that emerges from several studies is that making relational matches requires more time and processing resources than making object attribute matches. For example, a study by Robert Goldstone and Doug Medin found that when people are forced to answer quickly, they are strongly influenced by object matches (such as a black wing with a black wing), even in cases where they would choose a relational match (such as both wings same color with each analog) if given sufficient time.

Adult performance in mapping tasks is also influenced by immediately preceding experiences. For example, in the one-shot mapping task of Markman and Gentner, subjects are shown a pair of cross-mapped pictures, such as a truck towing a car and a car towing a boat (**Figure 3**). The experimenter points to the car in the first picture, and the subject indicates which object in the second picture 'goes with' it. Subjects often choose the object match (e.g., the other car). However, if they have previously rated the similarity of the pair, they are likely to choose the relational match (the boat). These findings suggest that carrying out a similarity comparison encourages structural alignment.

This one-shot mapping task has also been used to test whether processing load influences analogical processing. The experimenter pointed to the cross-mapped object in the first picture (the car), and subjects were instructed to point to the relational correspondence (the boat) in the second picture. Subjects made more object-mapping errors when given an extra processing load, such as having to count backward.

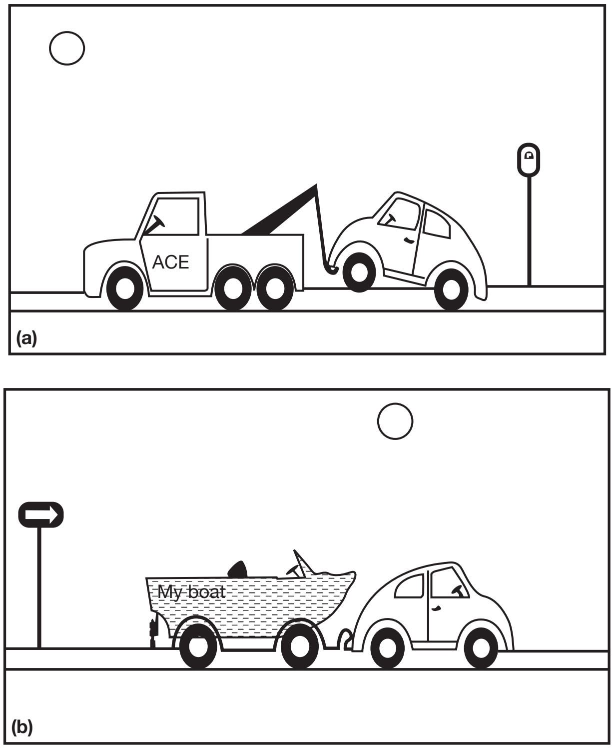

Figure 3 Sample cross-mapped pictures from the Markman and Gentner study. Carrying out a prior comparison increases the likelihood that adults will match the car in (a) with the boat in (b) based on their common relational role (both are the things being towed), rather than simply matching the two cars.

Neuropsychology of Analogical Reasoning

Recent studies have begun investigating the neural correlates of analogical processing. The studies so far converge on areas within the left prefrontal cortex as important in analogical reasoning. Of course, much remains to be discovered. We do not yet know the degree to which these prefrontal areas are specialized for analogy as compared to other higher order reasoning processes. We also do not yet know whether and to what degree other areas of the brain are involved in analogy, and whether this differs according to the type of analogy. Further studies exploring a greater range of analogical tasks and materials should give us a more complete picture.

Analogy in Naturalistic Settings

Analogy researchers note that analogy is a ubiquitous component of human thinking. However, much of the research focuses on analogy use in one very specific setting: the experimental psychology laboratory. Many studies of analogical reasoning in the laboratory have adopted an approach of explicitly providing participants with an analogy and eliciting particular responses from them (e.g., inference preference ratings, identifying correspondences). This method enables psychologists to closely observe phenomena tied to analogical mapping. However, this state of affairs suggests two questions: (1) To what degree do people spontaneously use analogies in real-world contexts? and (2) Is this analogical reasoning guided by the same preferences (e.g., relational priority, systematicity) identified in the laboratory? For this discussion, we move out of the laboratory to review work on analogy in real-world settings, or analogy 'in the wild.'

Dunbar and his colleagues have investigated the use of analogy in naturalistic environments in a variety of contexts. In one project, he studied the day-to-day processes of scientists in microbiology laboratories. Dunbar found that analogical thinking was a key component of all aspects of scientific reasoning, ranging from hypothesis generation to experimental design, data interpretation and explanation. Analogy is also a key component of the way scientists reason about unexpected findings. Interestingly, Dunbar observed that many of the analogies scientists made were of high overall similarity, sharing not only causal structure but also many superficial features. For example, a scientist working on a novel type of bacterium might hypothesize that its genetic sequence is like that of a highly similar species. These studies suggest that people frequently make analogies that reveal deep relational similarities, but that superficial similarity between domains aids in the noticing of these analogies, as many theories of analogy would predict.

However, scientists do sometimes use the kind of dramatic analogy that constitutes a true leap in understanding. For example, Robert Boyle likened molecular motion to leaves being swirled around by the wind; and Johannes Kepler likened the course of the planets around the sun to the course of a boat steering in a current (the gravitational attraction). Historical analyses have documented many cases like these, in which scientists have used analogies based on relational patterns that share little or no superficial similarity. These types of analogies often occur in connection with larger discoveries and shifts of paradigms, such as Rutherford's analogy likening the structure of an atom to that of the solar system, which displaced the then-dominant plum-pudding model.

One interesting case of everyday analogy is the use of conceptual metaphors, as discussed by George Lakoff, Mark Johnson, and colleagues. For example, statements like 'Their marriage is going over some serious bumps in the road' or 'They're just coasting along without putting in energy' would be part of the 'love is a journey' conceptual metaphor. Often, the same base term can be conventionally used with many different targets; for example, we can liken progress in a career, in college, or even in a specific project to a journey, as in 'she's zipping along on her paper, way ahead of the other students.' Many of these metaphoric systems behave like extended analogies, as illustrated by the journey example. Another frequently used example is the conventional mapping from space to time, as in 'The holidays will soon be here' and 'Exams will come after the holidays this year.' We also find extended analogical metaphors in the introduction of new technical concepts, such as *(computer) virus*, and accompanying ideas such as *antibodies* against such viruses.

Another everyday use of analogy is in humor. For example, Benjamin Franklin stated, "A countryman between two lawyers is like a fish between two cats." A more elaborate example comes from Louis Menand, writing in the *New Yorker* of February 23, 2009: "Postmodernism is the Swiss Army knife of critical concepts. It's definitely overloaded, and it can do almost any job you need done." Research by Jeff Loewenstein and Chip Heath in

2009 has shown that many jokes (as well as many children's stories and advertisements) follow a three-step *repetition-break plot structure*: two closely similar stories are given, followed by the *break* – a sudden change from the parallel plot structure. This kind of structure will be familiar to anyone who has heard a 'three guys walk into a bar' joke; the first two, closely similar, stories set up an aligned structure, and the humor comes from the surprise when the third story 'breaks' that structure.

Analogical Reasoning Without Awareness

Analogical reasoning has typically been considered a high-level reasoning process; for this reason, analogy has traditionally been thought of as a deliberate, conscious activity. Much of the research on analogy accords with this assumption: experimental work tends to focus on the deliberate use of analogy, where learners either discover or are given an analogy, use it to derive new inferences, and accept only those inferences that they consider structurally sound, plausible, and goal-relevant. However, research in the past decade has demonstrated that not all analogical reasoning is deliberate. Isabelle Blanchette and Kevin Dunbar first demonstrated the *analogical insertion effect*, in which analogical inferences are integrated unknowingly into mental representations of the target domain. In their studies, participants read descriptions of a target issue (e.g., legalizing marijuana) and then were given an analogy to another situation (e.g., ending Prohibition). On a subsequent recognition test, these participants often misidentified analogical inferences as facts actually presented about the target: that is, they mistakenly 'recognized' assertions about marijuana repeal as part of the passage, when what they had actually read was the analogous assertions about alcohol and Prohibition.

The studies just described demonstrate that analogical inferences can be drawn without the reasoner's full awareness. However, in both of these studies, the participants were explicitly told about the analogy between the two domains. This invites the question of whether analogical inference can occur without explicit awareness of the analogy. Recent research by Samuel Day and Dedre Gentner shows that the answer is yes. In their study, people read a series of brief passages and then answered questions about one of the later passages. Unbeknownst to the participants, the later passage was analogous to a prior passage, of which there were two versions. The results revealed that participants spontaneously made analogical inferences from whichever version of the early passage they had received, without recognition of having done so. These results show that information from a single analogous instance can influence the way in which another situation is understood or remembered without an individual's awareness. This suggests the intriguing possibility that analogy may be a process by which people implicitly understand and structure everyday experiences, and form abstract schemas over similar experiences.

Conclusion

Analogy is at the core of higher-order cognition. As Douglas Hofstadter puts it, "Analogy is the engine of cognition." Analogical thinking enters into creative discovery, problem-solving, categorization, and learning and transfer. This realization has led to a surge in research activity over the last three decades, resulting in great gains in our understanding of analogical processing. But there remain many open questions. We need a better understanding of how analogy operates in everyday learning and reasoning. What determines when people will spontaneously compare things, and how much they will profit from the comparison? Are spontaneous, nonaware analogies common, and if so what are their effects? When and how do people filter out bad analogies? Another area that is being actively explored is the neural underpinnings of analogical processing, as discussed above. There has also been recent interest in further specifying the development of analogical ability in children, and also in understanding the role of analogy in children's everyday learning across a variety of domains, from language acquisition to category formation. Finally, we are just beginning to explore analogical processing in other species. Cross-species comparisons will help to delineate the cognitive components of analogical ability.

See also: Creative and Imaginative Thinking; Human Intelligence; Reasoning.

Further Reading

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