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Analogical Reasoning

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Analogical Reasoning

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Analogical reasoning is the ability to perceive and use relational commonality between two situations. Most commonly, analogy involves mapping relational structures from a familiar (base situation to an unfamiliar situation (target). For example, solving the analogy “chicken is to chick like tiger is to___?” requires perceiving the relation *parent–offspring* in the base domain (chicken:chick) and mapping the same relation to the target (tiger:__?) to get to the answer *cub*. Relational similarity is the crux of analogical reasoning; what is crucial here is the sameness of the relation, not of other similarities—chickens and tigers do not look alike.

This reliance on relational similarity allows analogical reasoners to discover concepts and draw inferences in new and unfamiliar domains; situations and domains that at first do not look alike can become similar through analogy. This makes analogical reasoning a fundamental learning mechanism in development; young children and novice adult learners can extend and expand their knowledge through analogy. This entry discusses how humans learn to reason analogically, what makes analogical learning difficult, and which factors in development foster analogical reasoning.

Knowledge of Relations

Swiss clinical psychologist Jean Piaget claimed that children are not able to reason by analogy until adolescence. He tested young children with an analogy problem such as “A bicycle is to a handlebar as a ship to …” and concluded that children can notice only concrete elements of the situation—how a bicycle and a handlebar look—but not the abstract element of the relation between the bicycle and the handlebar. Developmental research in analogical reasoning has shown that Piaget was wrong; even young children can reason analogically if they *know* about the relations.

For example, work by researcher and professor of psychology Dedre Gentner shows that 3-year-olds can correctly answer an analogy problem such as, “If a tree had a knee where would it be?” Unlike the obscure relation of bicycle–handlebar, children know the structural relation between a knee and a body. This changes the view about the development of analogical reasoning: It does not depend on age but on the learners’ knowledge. The more relations the learners know, the better the likelihood they will reason analogically.

Similarity and Mapping

But knowing relations is not the only factor that limits analogical reasoning. Even if children know the relation “parent–offspring” in the chicken:chick example, they still may not solve the analogy because they overlook the relation. Instead of mapping relational similarity, children focus on *object similarity*—similarity based on concrete, easily discernible properties such as shape and color. For example, young children would match a cat in a “dog chases cat” event to another cat in a “cat chases mouse” event.

Despite understanding the relation “chasing,” young children do not find the relational similarity between one “chasee” (cat) and the other (mouse) salient. A large body of work shows that the preference for object similarity is robust in development. A *relational shift* is observed; children initially focus on object similarity and only later focus on relational similarity. Knowledge of relations, rather than age, is the main factor that influences this shift; the more one knows of relations in a particular domain, the more likely one finds relational similarity more salient than object similarity.

Even adults can find object similarity more salient than relational similarity if they have little knowledge of the domain. For example, when asked to sort physics problems, novice undergraduates sort based on object commonalities (e.g., “these problems both have blocks on an incline plane”), whereas expert physicists sort problems based on their underlying common structure (e.g., “solved using work–energy theorem”).

Whereas focusing on object similarity can prevent novice learners from noticing analogies, in some circumstances this focus can also initiate analogical reasoning because analogy requires a *structure mapping* process, as laid out by Gentner in 1983. Structure mapping theory posits that analogy starts with aligning two events (base and target events) on all kinds of similarity—including object similarity.

In everyday learning environments, children focusing on object similarity ("they both have eyes!") can catalyze this initial alignment. In the next step, people align the two events based on their common structure—for example, *parent–offspring* or *chasing* in the two previous examples. For an analogy to work out, this mapping of structures must yield a *one-to-one correspondence*—an object in one event (e.g., chick) can be mapped to only one object in the other event (e.g., cub).

Analogical reasoning is crucial in development because it promotes learning new things. Structure mapping theory spells out how this learning happens: Alignment of base and target events' structural commonality produces a new inference. For example, if children see that a cat hides because "dog chases cat," through structure mapping, they can infer that a mouse hides because "cat chases mouse."

This inference can be drawn only by mapping common structure and following the one-to-one correspondence constraint. If children disregarded the common relation or mapped based on object commonality only, they would arrive at a wrong inference, such as cats always hide after every chasing event. But if they correctly map the structure, this analogical inference can be extended to unfamiliar animals—even to any unfamiliar domains with a chaser–chasee structure.

Analogy and Language Development

Language development and analogical reasoning are tightly connected for several reasons. First, language makes relational knowledge more salient and accessible. For instance, in solving the chasing analogy example, learners who know the word *chase* can access this relation more easily and are consequently more likely to use it to map events (cat the chaser to mouse the chasee). Knowing some relational words also initiates a chain reaction; it facilitates the acquisition of further relations. For example, knowing about rotations and translations in geometry helps one learn about less intuitive geometric transformations such as homothety. As a result, experts who possess a greater knowledge of relations and know more relational words are in a better position to reason analogically.

Second, common labels invite alignment, resulting in discovery of common relations. Children who heard about chasing yesterday and today may start wondering what is the same about the two events. Even if they do not know the relation well, aligning the two events can result in perceiving the common structure of chaser–chasee.

For example, 2-year-olds who had had difficulty mapping the simple relation *identity* (map XX to YY, not to AB) were able to do so upon hearing a novel label applied to XX. Children did not know the meaning of the novel label—it had no a priori meaning—but hearing this label invited them to think about commonalities, which fostered the discovery of common relations.

This learning mechanism circumvents the requirement of already knowing relational words in the first place; novice learners can become experts because even not-yet-meaningful words invite them to try many mini-analogies. Whether by making relations explicit and salient or by inviting alignment, language development drives the development of analogical reasoning.

Analogy in Everyday Learning

Learners can make use of analogical reasoning in practically any domain. Whether to learn word meanings, biological hierarchy, social relations, or mathematical structures, analogical reasoning can help both novice and expert learners—children and adults alike—gain new knowledge. This knowledge extends to completely new discoveries; many scientific advances have famously arisen from analogical reasoning. Several examples from developmental research are discussed here.

Analogy in Language Use

Language development fosters the development of analogical reasoning, but the ability to think analogically is also essential in everyday communication. For example, using a metaphor to convey an opinion such as “this book is a goldmine” requires people to identify a relational similarity between the book and the goldmine (both contain valuable things) as opposed to simple object similarity (words in the book do not look like gold nuggets.).

Even more fundamentally, most verbs, prepositions, and even many nouns have relational meaning; the usage of these words requires understanding particular relations across different contexts. “Mom gave a cookie to Jane” and “Jane gave a letter to Mom” would be very confusing if understood based on object similarity; the relation “give” (with arguments giver and recipient) is what matters.

Analogy in Education

Analogy is prevalently used in science education to teach novel relational concepts using examples familiar to the learners. Some classic examples are teaching the concept of electricity flow using the familiar concept of water flow or teaching the earth movement using the lava lamp analogy. Teaching using analogy is effective because it puts to use what learners already know, allowing them to carry a familiar relational structure from one domain over to another domain. This is a passive form of learning; students are given the analogy. Recent research also aims to identify how to foster active analogical thinking—how learners can employ analogical reasoning (looking for relational similarities between events and examples) to acquire or even discover new knowledge.

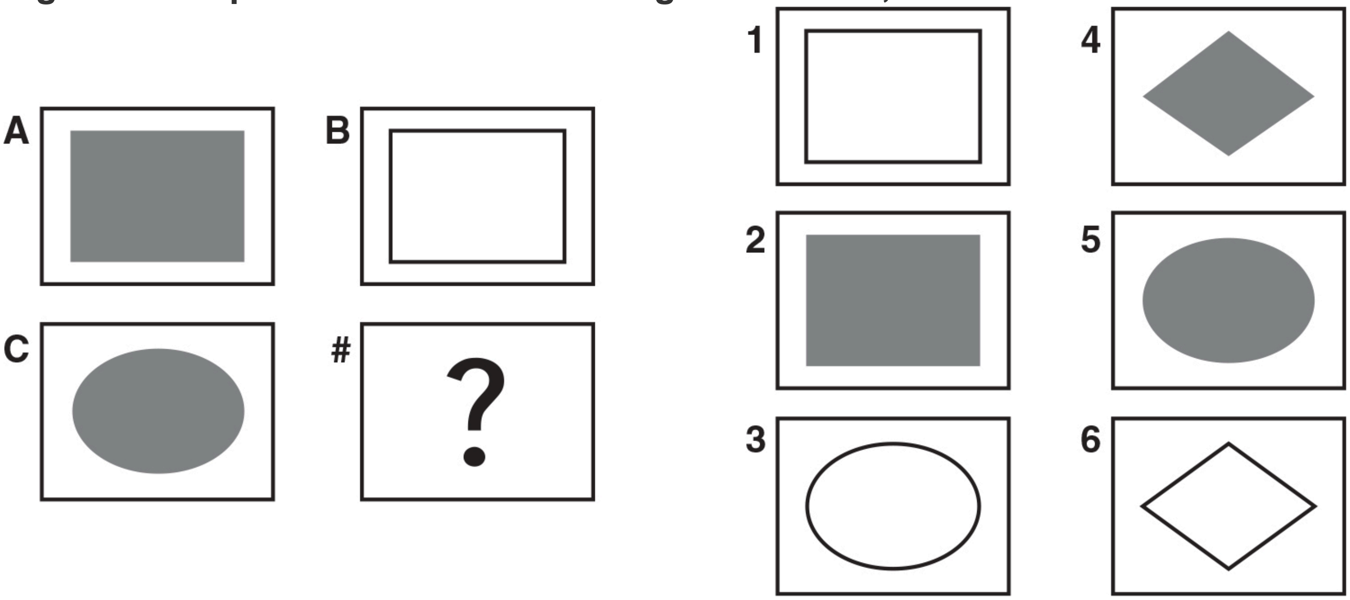
Analogical reasoning also plays a role in early education—for example, in mathematics classrooms. Primary school children learning proportion need to understand relational similarity; 2/4 is the same as 1/2, not because 2 matches to 2. This is challenging because object matches are salient and children may have difficulties grasping the relational similarity of proportion instead of focusing on the object matches.

Classroom research has shown that students can better understand solutions to mathematical problems if they align and compare different types of solutions. Consequently, teachers who compare examples in their teaching advance children’s mathematical learning. As a striking example, cross-cultural research comparing Japanese and Hongkongese versus American math teachers’ use of analogy in classrooms found that the Asian teachers used better analogies in mathematics instruction (e.g., using a familiar source to teach a new problem). It is well known that children from Japan and Hong Kong outperform their American peers in world standard mathematical tests.

Measuring Intelligence

Analogy is also used in standard tests of intelligence. A primary example is Raven’s Progressive Matrices, a widely used test designed to measure general intelligence. It is a collection of geometric analogy tests, with a typical question presenting a matrix of geometric figures with an entry missing in one cell (see Figure 1). To solve this correctly, children have to reason using relational similarity (Option 3, Figure 1). If they use object similarity, they arrive at the wrong answer, possibly choosing Options 1, 2, or 5.

Figure 1 Sample Raven’s Matrices Progressive Test, a 2 × 2 Matrix Problem



A large body of longitudinal research has found correlations between general intelligence and performance in schools and professional success, suggesting that analogy has a cumulative impact on human cognition. The ability to reason analogically in one domain but not in others affects problem-solving ability, creative thinking, and production or learning of new knowledge. Throughout the lifespan, one’s ability to reason analogically develops, influenced by factors such as domain knowledge and language ability.

See also Categorization; Causality; Cognitive Development; Creativity; Critical Thinking; Hypothesis Testing; Intelligence; Knowledge; Language; Learning; Logical Thinking; Problem-Solving; Reasoning; Thinking

- cats
- mice
- Raven's Progressive Matrices
- maps
- language development
- learners
- children

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