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Learning and Cognition—Issues and Concepts: Concept Learning

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Abstract:
Concepts form the building blocks of thought and the present review demonstrates that concept learning is dynamic and complex. Various theories of concept representation and learning are reviewed, including classical, prototype, exemplar, and theory theories. Research suggests that the nature of conceptual organization changes as a function of expertise and cultural experience. Furthermore, research shows that individual goals influence the construction of concepts and that predisposed constraints on concept formation are specific to content domain. To illustrate the interaction between various factors in concept learning we examine the domains of folkbiology and mathematics and consider developmental and cross-cultural research.

Learning and Cognition—Issues and Concepts: Concept Learning

In what follows, we use concept to refer to a mental representation and category to refer to the set of entities or examples picked out by the concept. It is generally accepted that instances of a concept are organized into categories. Almost all theories about the structure of categories assume that, roughly speaking, similar things tend to belong to the same category and dissimilar things tend to be in different categories. For example, robins and sparrows both belong to the category *bird* and are more similar to each other than they are to squirrels or pumpkins. *Similarity* is a pretty vague term, but most commonly it is defined in terms of shared properties or attributes. Although alternative theories assume concepts are structured in terms of shared properties, theories differ greatly in their organizational principles.

The Classical View

The classical view assumes that concepts have defining features that act like criteria or rules for determining category membership. For example, a triangle is a closed geometric form of three sides with the sum of the interior angles equaling 180 degrees. Each of these properties is necessary for an entity to be a triangle, and together these properties are sufficient to define *triangle.*

A fair amount of research has examined people's knowledge about object categories like bird, chair, and furniture and this evidence goes against the classical view. Not only do people fail to come up with defining features but also they do not necessarily agree with each other (or even with themselves when asked at different times) on whether something is an example of a category. Philosophers and scientists also have worried about whether naturally occurring things like plants and animals (so-called "natural kinds") have defining features. The current consensus is that most natural concepts do not fit the classical view.

The Probabilistic View

The major alternative to the classical view is the probabilistic view which argues that concepts are organized around properties that are characteristic or typical of category members but crucially, they need not be true of all members. That is, the features are only *probable*. For example, most people's concept of bird may include the properties of building nests, flying, and having hollow bones, even though not all birds have these properties (e.g., ostriches, penguins).The probabilistic view has major implications for how we think about categories. First, if categories are organized around characteristic properties, some members may have more of these properties than other members. In this sense, some members may be better examples or more typical of a concept than others. For example, it has been found that the more frequently a category member's properties appeared within a category, the higher was its rated typicality for that category. For instance, robins were rated to be very typical birds and penguins are rated as very atypical birds. A second implication is that category boundaries may be fuzzy. Nonmembers of a category may have almost as many characteristic properties of a category as do certain members. For example, whales have a lot of the characteristic properties of fish, and yet they are mammals. Third, learning about a category cannot be equated with determining what the defining features are because there may not be any.

Typicality: Central Tendency vs. Ideality. Is typicality only based on central tendency? Although typicality effects are robust (and problematic for the classical view), other research shows that the underlying basis for typicality effects may vary with both the kind of category being studied and with the population being studied. While the internal structure of taxonomic categories is based primarily on the central tendency (or the average member) of a category, the internal structure of goal-derived categories such as “things to wear in the snow” is determined by some ideal (or the best possible member) associated with the category. The best example of snow clothing, a down jacket, was not the example that was most like other category members; instead it was the example with the maximum value of the goal-related dimension of providing warmth.

One might think that ideals will only come into play when the category of interest lacks the natural similarity structure that characterizes common taxonomic categories such as bird, fish, and tree. However, for tree experts (people who know a lot about trees such as landscapers, parks workers and taxonomists), the internal structure of the category *tree* is organized around the positive ideal of height and the negative ideal of weediness. The best examples of *tree* are not trees of average height but trees of extraordinary height (and free of “weedy” characteristics like having weak limbs, growing where they aren’t wanted, and being susceptible to disease).

Indeed, research does suggest that people who have considerable knowledge in a domain tend to base typicality judgments on ideals and not the number of typical features. For example, for Itzá Maya adults living in the rainforests of Guatemala the best example of bird is the wild turkey which is culturally significant, prized for its meat, and strikingly beautiful. The fact that U.S. tree experts based typicality on ideals suggests that it’s not just that the Itzá have a different notion of what typicality means. It has also been found that found that Native American and European American fishermen’s typicality judgments were based on ideals though those ideals differed somewhat across groups.

Prototype vs. Exemplar Theories. If categories are not represented in terms of definitions, what form do our mental representations take? One suggestion about how concepts are represented is known as the family resemblance principle. The general idea is that category members resemble each other in the way that family members do. A simple summary representation for such a family resemblance structure would be an example that possessed all the characteristic features of a category. The best example is referred to as the prototype.

In a prototype model of categorization, classifying a new example is done by comparing the new item to the prototype. If the candidate example is similar enough to the prototype for a category, it is classified as a member of that category. More detailed analyses, however, show problems with prototypes as mental representations. Prototype theory implies that the only information abstracted from categories is the central tendency. A prototype representation discards information concerning category size, the variability of the examples, and correlations among attributes, and people can use all three of these types of information.

An alternative approach, which is also consistent with the probabilistic view, assumes that much more information about specific examples is preserved. This approach appropriately falls under the general heading of exemplar theories. Exemplar models assume that people initially learn some examples of different concepts and then classify a new instance on the basis of how similar it is to the previously learned examples. The idea is that a new example reminds the person of similar old examples and that people assume that similar items will belong to the same category. For example, suppose you are asked whether large birds are more or less likely to fly than small birds. You probably will answer “less likely,” based on retrieving examples from memory and noting that the only non-flying birds you can think of are large (e.g., penguin, ostrich).

Quite a few experiments have contrasted the predictions of exemplar and prototype models. In head-to-head competition, exemplar models have been considerably more successful than prototype models. Why should exemplar models fare better than prototype models? One of the main functions of classification is to allow one to make inferences and predictions on the basis of partial information. Relative to prototype models, exemplar models tend to be conservative about discarding information that facilitates predictions. For instance, sensitivity to correlations of properties within a category enables finer predictions: From noting that a bird is large, one can predict that it cannot sing. In short, exemplar models support predictions and inferences better than do prototype models.

More recent research has pointed to three major limitations of these simple forms of prototype and exemplar models: 1. they have narrowly focused on categorization and have paid little attention to how other conceptual functions such as communication and inference may affect concept representation and learning, 2. they view learning as a passive accumulation of statistical information rather than active learning that may reflect particular learner goals, and 3. they pay little attention to how theoretical notions and causal reasoning organize learning. With respect to the second point, we have just reviewed evidence from a number of populations indicating that typicality is driven by ideals and that later learning builds on earlier learning. If category ideals tend to be learned first then they will have an important role in the development of categories, and modelers are beginning to shift to this more active view of learning. With respect to the role of theories, there is evidence that using (abstract) similarity relations may be likely to be a strategy of last resort, used only when more relevant information is unavailable. Let's examine the theory view in a bit more detail.

The Theory View

A number of researchers have argued that the organization of concepts is knowledge-based (rather than similarity-based) and driven by intuitive theories about the world. The idea that concepts might be knowledge-based rather than similarity-based suggests a natural way in which concepts may change—namely, through the addition of new knowledge and theoretical principles. There is also good evidence that these theories help determine which abstract and observable features learners pay attention to. We have a different set of categories for mental disorders now than we had 100 years ago, in part because our knowledge base has become more refined. Often knowledge of diseases develops from information about patterns of symptoms to a specification of underlying causes. For example, the advanced stages of syphilis were treated as a mental disorder until the causes and consequences of this venereal disease were better understood. Recently, it has been shown that clinical psychologists organize their knowledge of mental disorders in terms of rich causal theories and that these theories (and not the atheoretical diagnostic manual they are supposed to use) guide their diagnostic classification and reasoning.

Domain Specificity

Several constraints have been hypothesized to mold concept formation in different domains, including the domains of biology, psychology, mathematics, and physics. The current consensus is that the potential for variation in conceptual knowledge across cultural communities is mediated by universal constraints on learning and the ways in which they interact with culture-specific experiences. Concepts are the building blocks of thought and one way to understand the flexibility of concept learning is to consider whether people in different cultures think differently. Usually this question is tied up with the question of whether and how language influences thought and we will not give a separate treatment of this issue. Of course, if thought processes of two cultural groups were radically incommensurable, one would quickly realize that there were dramatic differences but feel at something of a loss to explain them. The fact that one part of learning a foreign language involves finding out what term or word is used in that language to refer to bird or fish or chair or Tuesday or mother suggests that comparable concepts and categories are in play. Nevertheless, culture affects learning and knowledge construction. Rather than provide a comprehensive catalog of the various principles constraining knowledge construction in each domain, we present a few detailed accounts of cultural research on concept formation, using for illustration cross-cultural conceptions of plants and animals (the domain of folk biology) and counting and calculation (the domain of folk mathematics).

Concept Learning in the Domain of Biology

The field of folkbiology is blessed with many intriguing and important issues that lend themselves to an analysis in terms of culture and cognition. Biological concepts are believed to be processed and organized according to evolved cognitive structures that are functionally autonomous with respect to biological information, and for this reason are thought of as belonging to a separate domain of cognitive processing. Building on decades of work in ethnobiology, research has shown that a few key principles guide the recognition and organization of biological information in similar ways across cultures, although important variation is produced by differences in expertise and other cultural factors.

First, there is marked cross-cultural agreement on the hierarchical classification of living things, such that plants and animals are grouped according to a ranked taxonomy with mutually exclusive groupings of entities at each level. For instance, across cultural groups, the highest level of taxonomic organization includes the most general categories, such as the folk kingdom rank (which includes groupings such as plants and animals), and lower levels distinguish between increasingly greater degrees of specificity (e.g., life forms such as tree or bird; generic species level such as oak or blue jay). Furthermore, the generic species (in local settings the vast majority of genera are mono-specimic, so we use this term) level appears to be consistently privileged for inductive inference when generalizing properties across plants and animals (it is the most abstract level for which inductive confidence is strong and only minimal inductive advantage is gained at more subordinate levels). There is also cross-cultural agreement in the assumption that the appearance and behavior of every generic species is caused by an internal biological (and usually unspecified) essence that is inherited from the birth parents and is responsible for kindhood persistence in the face of physical and developmental transformation.

But there is also considerable variability within these universal constraints in concept formation as a function of both experience with the natural world and cultural salience (two highly related factors). For instance, the basic level (the level at which they possess the greatest knowledge) for urban undergraduates is the life form (e.g. bird, fish, tree), but for groups that have more direct experience with the natural environment and greater expertise, the basic level corresponds to the generic species level.

The remarkable cross-cultural agreement in the structure of folk biological organization is, at the same time, culturally variable. Correlations across groups of 0.70 appear quite strong but explain less than half the variance. Although some of these differences might be attributed to experience, other findings implicate cultural differences. For instance, when asked to sort biological kinds into categories, individuals from different communities vary not only in their taxonomic sorting but also in the degree to which they spontaneously sort along ecological dimensions. This difference is not as predictable on the basis of expertise alone. For example, Menominee Native American fisherman and European American fishermen, who both live in rural Wisconsin and have equivalent expertise about fish and fish habitats, differ in that Menominee fishermen are significantly more likely to sort in terms of ecological relationships.

Similar differences in ecological orientation have been found for children from these communities, such that Menominee children were more likely to reason about shared properties between living things using ecological relations, relative to rural European American children. In turn, rural European American children were more likely to employ ecological-based reasoning for shared properties than were urban children. In short, differences in ecological orientation reflect a confluence of experience-based and culturally-based factors in folk biological thought.

Cultural differences in cognitive processing, concept representation, and behavior can be thought of as reflecting *routines* of practices or 'habits of the mind'. Cultural groups establish practices over time, and the history of these practices may lead to regularities in the ways groups participate in the everyday activities within their communities. These practices may be associated, implicitly or explicitly, with different epistemologies that determine what sorts of things are presupposed, go without saying, and seem natural. For example, European-Americans tend to conceive of nature as something external, to be cared for and respected; in contrast, Native-American are more likely to see themselves as *part of nature*. These sorts of presuppositions are likely to be embedded in curricula and school practices and represent a challenge to students from cultures and communities that do not share them.

Cultural practices are not immutable, static traits that are attached to participants (a view which can lead to overly deterministic views of cognition), but exist in tension with emergent goals, practices and situationally-specific affordances. Thus, one might design a biology curriculum for Native American students emphasizing ecological relationships, but then build on this base to suggest the value of other forms of organization (e.g. taxonomic). There is increasing evidence that taking advantage of the cultural practices that children, bring to the classroom leads to better motivation, identification with learning, and academic performance.

Concept Learning in the Domain of Mathematics

Folkbiological research has tended to compare different cultural groups and to identify robust similarities (and differences) in reasoning and representation. Studies of mathematical concepts have expanded on this strategy by using developmental comparisons and analyzing similarities between human and nonhuman species to identify universal or 'core' principles. The domain of mathematics spans a wide variety of concepts, including numerosity, geometry, trigonometry, and so on.

We will limit our review to numerosity, counting, and calculation. A great deal of evidence suggests that for humans and other species there are evolved principles that assist in the representation of numerosity, and that different principles can constrain representations in particular ways, depending on the set size of elements. Importantly, however, it has been proposed that the systems for large and small numerosity can interact for humans in ways not possible for non-human species. Number words and verbal counting may link together systems for small and large numerosities so that, through counting, distinctions can be made between large numerosities that differ in as little as one element.

The flexibility in concepts of numerosity afforded by natural language leads to questions about variability in representations of numerosity and counting as a function of language and other cultural inputs. Some innovative research has examined the different counting systems that have emerged in different cultural communities throughout the world. For instance, before contact with western culture in 1940, the Oksapmin people in the West Sepik province of Papua New Guinea used a 27 body part count system, beginning with the thumb on one hand and enumerating discrete points along the upper half of the body (including head and shoulders) and ending on the little finger on the other hand. Counting past 27 involves moving back along the same 27 points until the desired numerosity is reached. In addition, as individuals become more involved in the cash economy, this counting system becomes co-opted for arithmetic calculations in addition to or in the place of enumeration, and in some cases is even transformed to a base-10 system. Although cultural differences in counting systems are well-established, little work has examined the impact of these systems on the representation of numerosity.

Other research has examined the ways in which mathematical concepts, such as calculation processes and representations, are shaped by context-specific goals and culture-specific practices. For instance, grocery shoppers engage in mathematical calculations in response to specific shopping-related goals, and these calculations depend on the resources and environmental tools available to the shopper in the grocery store. Examples have been reported in which a shopper who, upon suspecting a price error for a block of cheese, sorted through a bin of cheese to find a block of similar weight and noted the difference in price that confirmed his suspicions. Had the bin of cheese not been available, the shopper would have had to mentally calculate the correct price based on listed price per weight information.

An important issue is the relation between these sorts of out of school goal-related strategies and in school mathematics learning. Community-specific goals can lead to a greater frequency and therefore greater proficiency for some calculations over others. For example, research has shown that 10-12 yr old children in Brazil with little or no education who sold candy in urban streets were highly likely to use ratio calculations during vending activities and were better at ratio comparisons than same-aged children with formal education experience. Other work has revealed that African American middle school and high school students vary in the extent to which they engage in mathematical calculations to evaluate basketball performance because of differences in the structure of the practice of basketball and level of commitment to basketball. High school students were more likely to calculate formal statistics (such as average and percent) of their own and others' basketball performance and these calculations were higher when ways of keeping and reporting basketball statistics were increasingly available to students. This work points out that the players' use and approach to mathematics during their everyday cultural practice may differ dramatically from the approach taken to school mathematics--the use of mathematics in a students' own cultural context is often more engaging. Related work with the children of sugarcane farmers found complementary tendencies to approach mathematical problem solving in different ways depending upon the value ascribed to the context or practice in play.

Conclusions

Concept learning is one of the most exciting and fundamental research areas within cognitive science because it concerns the very building blocks of thought. Early models which assumed that category learning consists of the accumulation of information about entities in the world have been super-ceded by approaches which stress that learning is in the service of goals, that it is guided by evolved, domain-specific constraints, and molded by cultural practices.

See also:

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Further Reading

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