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Expertise and categorization

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Experts exhibit various categorization phenomena, including category abstractness, use of second-order features, big chunks, category coherence, and category gradedness. Traditional views of categorization—the classical, prototype, and exemplar views—are variously successful in explaining these phenomena. We argue that our conceptual base view is more adequate.

We would like to juxtapose two areas of research that hitherto have passed like ships in the night: categorization and expertise. We are interested in these two topics for a simple enough reason: expertise stems, at least in part, from well-developed categorization processes. Thus, the question naturally arises as to whether current psychological views of categorization can elucidate expert categorization. In particular, we would like to assess the adequacy of three traditional views of categorization and of our own view.

To compare these several views of categorization, we must first ask what is known about experts' categories. At least five categorization issues can be identified. The issues are listed in Table 1.

CATEGORIZATION ISSUES

Abstract Categories

Experts develop categories that are more abstract than are novices'. For example, Larkin (1985) argues that expert physicists develop "scientific representations" that incorporate abstract principles of physics. In fact, Larkin argues that these scientific representations are built on a "naive representation," which is only a short inferential distance from an initial literal representation of a verbal physics problem. Experts in chess (Chase & Simon, 1973; de Groot, 1965), baseball (Voss, Vesonder, & Spilich, 1980), X-ray reading (Lesgold, 1984), dinosaurs (Chi & Koeske, 1983), and even the videogame Star Wars (Means & Voss, 1985) have been shown to possess complex, abstract categories. To illustrate, expert physicists might group problems involving blocks on an inclined plane with problems involving pulleys with different weights on either end, because both problems are conservation of energy problems (Chi, Feltovich, & Glaser, 1981). Novices are more likely to sort problems on the basis of surface features; for example, problems are grouped because they all mention an inclined plane.

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Table 1
A Scorecard for Various Views of Categorization

	Views of Categorization			
Issues	Exemplar	Prototype	Classical	Conceptual Base
Abstract Representation	−	+	+	+
Second-Order Features	−	−	?	+
Big Chunks	?	?	?	?
Category Coherence	−	+	?	+
Gradedness	?	+	−	+

Second-Order Features

Experts and novices identify different aspects of a problem as relevant. Experts respond more to second-order features, which are a step or two removed from the literal situation. As Chi et al. (1981) noted, "experts perceive more in a problem statement than do novices. They have a great deal of tacit knowledge that can be used to make inferences and derivations from the situation described by the problem statement" (pp. 148-149). Experts respond to what words might signify in terms of abstract principles rather than to the literal things mentioned.

A clear implication of the abstractness and second-order-features properties of experts' categories is that these categories are much more flexibly applied than are those of novices. An expert can spot an instance of a category regardless of its context and regardless of irrelevant surface-level cues in general. There is more breadth to the expert's categories, because they are both more abstract and decontextualized.

Big Chunks

Experts store information in bigger chunks than do novices, and these chunks are often hierarchically related (Chase & Simon, 1973; Chi & Koeske, 1983; McDermott & Larkin, 1978; Means & Voss, 1985).

Category Coherence

Expert knowledge is highly integrated and complete. For example, advanced students in political science show more awareness of the interrelatedness of problems and provide more extensive rationales for solutions to problems. Accurate medical diagnosis may also rely on complex, causally interrelated knowledge frames (Patel

& Groen, 1986), as does an expert solution to hypothetical Soviet socioeconomic problems (Voss, Tyler, & Yengo, in press).

Gradedness of Categories

It is well known that some natural categories show gradedness rather than discreteness of category membership (Rosch, 1978). There is also some evidence that experts' categories can show gradedness. For example, Adelson (1985) found that expert programmers used sorting algorithms that yielded to a Roschian prototypical structure. We will return to this point later.

We have discussed five categorization issues as they arise in the area of expertise. How well do the various views of categorization explain these phenomena? By Smith and Medin's (1981) taxonomy, there are three general views of categorization— the classical, probabilistic (or prototype), and exemplar views. We add our own conceptual base view to this taxonomy.

VIEWS OF CATEGORIZATION

Exemplar View

The exemplar view holds that an input is categorized by matching it against a set of stored, disjunctively arranged exemplars. If the input is similar enough to the exemplars, or some subset of them, then it is categorized. The most radical form of the exemplar view disavows abstract representation. This view would explain successful recognition of a robin as due to a match of the features of the real-world robin with *particular* remembered features of *particular* robins. Unfortunately, the exemplar view fails to address most of the categorization issues. The general reason is that this view implicitly assumes a first-order isomorphism between the to-be-categorized input and the stored exemplars. That is, the *same kind of information* must be present in the input and in the stored exemplar even to initiate the categorization process. Thus, recognition of a real-world robin requires that features such as shape and feathers be coded in memory in direct analog form. This constraint prevents this view from engaging problems of abstract representation and second-order features. Big chunks could theoretically be big sets of instances, but category coherence is precluded on any reading of the exemplar view. In fact, because of this problem, Medin, the main proponent of the exemplar view, adopted a conceptualist point of view (Murphy & Medin, 1985). Finally, because the exemplar view must treat all category members as being on the same level, it also fails to handle hierarchicalness and rich interconnections between categories. In conclusion, the exemplar view's batting average is miserable.

Probabilistic View

The more formidable probabilistic, or prototype, view posits that a category is represented by a central tendency or ideal, the prototype is often not identical to any particular instance, the prototype is used to classify new instances, and category membership is graded rather than all-or-none. Actually, Smith and Medin (1981) consider prototypes only one aspect of the probabilistic view, but for present purposes we will equate the two.

The prototype view arises from experimental work on artificial stimuli such as dot patterns or geometric forms, although Rosch (1978) provided strong evidence that the "basic level" of natural categories (e.g., furniture, fruit) is organized around prototypes. Rosch states that a prototype shares the most features with other category members and the fewest features with other categories. How does the prototype view fare? As Table 1 indicates, it allows abstract representation and gradedness but runs into difficulty on the other issues. There are two reasons for this.

The first reason entails the first-order-isomorphism constraint. Even an ideal prototype retains the same kind of information as the inputs from which it is formed. An ideal tree is still somehow a tree. So construed, the prototype view is a sophisticated exemplar view—instead of several distinct exemplars in memory, there is at least one that aptly summarizes the information in previously encountered exemplars.

Because of the first-order-isomorphism constraint, there is no obvious way to combine information from dissimilar literal inputs to produce an effective, high-order prototype. Any combinatorial process would have to cancel pieces of information in each input and replace them with higher level information. Any combination of such generalities could not, by definition, be a prototype. This is not to say that the more general probabilistic view cannot accomodate superordinate categories, because it can, but these categories retain all the feature kinds of their nested subordinates, and the superordinates are not prototypes.

To illustrate, take Chi, Feltovich, and Glaser's (1981) finding that expert physicists group problems that have no literal similarity, either verbal or pictorial. The only way to connect the problems is through an abstract intermediary, in this case a principle of physics. These principles could not function as prototypes, because prototypes remain at the level of their inputs. Since such principles undoubtedly incorporate several categories, the prototype view suffers proportionately.

A second reason why the prototype view is inadequate concerns hierarchies. Experts' categories often use nested high-level information, yet, as our preceding analysis implies, prototypes do not operate at a level above their category members. Empirical confirmation of this point comes from studies that have found that observers list very few features, let alone common features, for superordinates (Adelson, 1985; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976).

A third and final reason why the prototype view is inadequate involves conceptual complexity. The phenomena in Table 1 bespeak a high order of conceptual complexity. There is a clear need to include part-whole, synonymy, contrast, case relations, and so on in the categorization process. Prototypes, however, generally entail only one or a few possibilities for conceptual combination, especially conjunction; but even conjunction is problematical for this view (Osherson & Smith, 1981).

We conclude that although the categories of experts may exhibit prototype phenomena there is little reason to believe that prototypes constitute the *basis* of these categories. Note the distinction between category structure and exemplariness (Armstrong, Gleitman, & Gleitman, 1983). Typicality phenomena, which prototypes demonstrate, may not tell us anything about category structure. We would be hard-pressed to argue that a prototype causes typicality. In fact, categories that exhibit gradedness could actually be relatively discrete at their core.

Classical View

This brings us to a third view of categorization, the classical view. Like the prototype view, this view holds that categories can be abstract, but it makes category membership all-or-none. More formally, the classical view holds that there are features whose presence is "singly necessary and jointly sufficient" to determine category membership. Since category membership is all-or-none, no member can be more representative than another.

With the investigation of prototypes, gradedness, and so on, the classical view fell into disfavor. These days it is largely a straw man. Should we reject it too? After all, Armstrong, Gleitman, and Gleitman (1983) showed that supposedly classical concepts such as odd number produced gradedness effects for college students who knew what an odd number was; for example, 3 was judged to be a better odd number than 65.

There is another slant on this issue, however. Expertise implies an ability to make fine-grained distinctions. The experienced chicken farmer can distinguish the sex of newborn chicks. The rest of us cannot. The expert X-ray reader can distinguish a collapsed lung from a lung tumor (Lesgold, 1984). The experienced baseball player can distinguish a good base runner from a runner who merely knows the rules of the game. What would have happened had Armstrong et al. (1983) asked mathematicians whether 3 or 65 was a better odd number? When they asked their college students whether it made sense to rate the oddness of odd numbers, the students said "no." Categories may look more or less dichotomous depending on the questions asked.

Another point is that expertise goes hand in hand with an individual-differences, as opposed to a normative, approach to issues. Many experts seem to see only dichotomies where novices see degrees of things. Ask a chemist whether something is more or less a hydrogen compound and see what happens. Ask a linguist whether grammaticality is a continuum. On the other hand, experts may see continuity where the novice sees discreteness. An evolutionary biologist can marshal good arguments for the continuity and relatedness of all animal forms, whereas the child or naive adult sees only distinct forms. Still, the biologist could be using discrete principles that result in judgments of continuity.

Perhaps, then, the book on the classical view should not be closed. Expertise, indeed learning, pushes us to act more in accordance with high-level rules that generate fine but momentous distinctions. Moreover, these rules may be deterministic and formal, thereby immediately implicating the classical view.

This view warrants mainly question marks on Table 1, not because this view is inconsistent with or incapable in principle of addressing the issues. Rather, there is too little empirical information relevant to the issues in relation to expertise, and there is no psychological theory that takes this viewpoint.

Conceptual Base View

This view is an outgrowth of our work on semantic memory and figurative language (see Honeck, Sugar, & Kibler, 1982; Honeck, Voegtle, Dorfmueller, & Hoffman, 1980). This view's key assumption is that people construct an amodal, nonlinguistic microtheory that serves to organize a category. A microtheory codes the significance or underlying message among exemplars, which are thereby made similar. We have called the microtheory a *conceptual base*. Most of the evidence for the microtheory stems from work on proverbs, or proverb families, to be more specific. For example, the proverb "A net with a hole in it won't catch any fish" has a figurative meaning that might be expressed as "A flawed instrument cannot perform its normal function." The figurative meaning, actually the conceptual base, is instantiated by events such as "The missionary who could not speak the natives' language converted none of them," "The astronaut's suit had a small hole, and he froze when he went outside the spaceship," and "The sleeping security guard failed to notice the thieves who ransacked the place." These are verbally expressed instances from vastly different semantic domains, but instances can be pictorial/visual as well. Furthermore, an interpretation of a conceptual base can be an abstract picture (Feldhaus, 1987; Honeck, Case, & Firment, 1987). It is empirically clear that observers can make reliable connections, that is, they can match up proverbs with verbal and pictorial interpretations, proverbs with instances, literal pictures of proverbs with verbal instances, and even literal pictures of proverbs with abstract interpretive pictures (see Honeck & Kibler, 1985; Honeck, Kibler, & Sugar, 1985, for reviews). Note that all of these connections are nonliteral and that several are cross-modal. Thus proverbs, their interpretations, literal pictures of them, and their instances form a cohesive and, of necessity, abstractly mediated family.

In our admittedly biased opinion, the conceptual base view adequately addresses most of the categorization issues. Therefore, it explains expert categorization better than the other views. We have clear empirical evidence for abstract, nonliteral grouping of sentences, for selection of second-order features (the connections between family members are nonliteral), for gradedness, and for flexibility and breadth in category application (Honeck, Firment, & Kibler, 1987; Honeck, Kibler, & Sugar, 1985). It also seems necessary to believe that conceptual bases or microtheories are responsible for the coherence of the categories we have investigated. There is no other way of accounting for the "glue" that holds a proverb family together. They are also responsible for a variety of psychological functions, including recall of category members, generation of new exemplars, and "feelings of knowing" what a proverb means. Our observers were experts in language comprehension, but we have every confidence that our theorizing generalizes to some other forms of expertise.

In conclusion, it appears that the conceptual base view provides the best account of the phenomena listed in Table 1. We believe this is because this view places a premium on interpretation, whereas the three other views emphasize bottom-up learning processes at the expense of abstract thinking in the form of inferencing, making metaphorical connections, and so on. If there is any hope of accounting for the expert's high level of categorization skill, these sorts of cognitive processes will have to be given a predominant place in theorizing.

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