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CONCEPTS AND CONCEPT FORMATION

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CONTENTS

INTRODUCTION 114
THREE VIEWS OF CONCEPTS 115
Background 115
The Classical View and its Problems 115
The Probabilistic View 117
The Exemplar View 118
Questions Raised by the Preceding Analysis 119
POSSIBLE ROLES FOR THE CLASSICAL VIEW 120
The Classical View and the Distinction Between the Core and Identification Procedure 120
The Classical View as a Backup Procedure 120
The Classical View and Other Types of Concepts 121
The Classical View and Other Functions of Concepts 122
The Classical View as a Metatheory of Concepts 122
Summary 123
CATEGORY COHESIVENESS 123
Proposed Constraints from the Classical and Probabilistic Views 123
The Basic Level 124
More Abstract Criteria of Category Cohesiveness 124
Correlated Attributes 125
Summary 126
CATEGORIZATION PROCESSES WITH PROTOTYPE CONCEPTS 126
Categorization as Decision Making 126
Activation of Properties and Concepts 127
Holistic Versus Component Processing 127
Summary 128
ACQUISITION OF PROTOTYPE CONCEPTS 128
Variables Controlling Learning 128
What is Learned? 129
Analytic Versus Nonanalytic Strategies 129
Summary 130

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DIFFERENT TYPES OF PROTOTYPE CONCEPTS 130
Goal-Derived Concepts 130
Person Concepts 131
Event Concepts Scripts 132
Summary 132
NEWER DIRECTIONS 132
Complex Categories 132
Is There More to Categorization than Similarity? 133
Summary 135

INTRODUCTION

In this chapter we review recent work on human concepts and concept formation Our first task is to specify what we mean by *concept* The term is a loaded one, as it serves several explanatory functions within psychology and related disciplines The following four functions (after Rey 1983) seem particularly important

1 *Simple categorization* the means by which people decide whether or not something belongs to a simple class (e g deciding that a particular object is an instance of the concept *boy*)
2 *Complex categorization* the means by which people decide whether or not something belongs to a complex class (e g deciding that a particular object is an instance of the concept *rich boy*)
3 *Linguistic meaning* that part of the meaning of a term that explains relations of synonymy, antinomy, and semantic implication (e g that part of the meaning of "boy" that explains why it is roughly synonymous to "lad" and implies being male and young[1])
4 *Components of cognitive states* the critical components of beliefs, preferences, and other cognitive states, in this role, concepts are what provide a cognitive explanation of complex thought and behavior (e g the roles played by the concepts *rich, boys,* and *spoiled* in someone's belief that rich boys are spoiled)

Of these functions, simple categorization has been the major focus in the literature that explicitly concerns itself with concepts We will emphasize this function in our review, and often take *concept* to mean a mental representation of a simple class (i e a class denoted by a single word) What holds for simple categorization, however, need not hold for other functions, so at various points we will deal explicitly with the other functions of concepts

Moving on to more specific issues, we begin by summarizing three different views of concepts that emerged from research on simple categorization The main body of this chapter will then examine questions raised by these previous analyses in light of newer research on concepts

[1]We use quotes to indicate words, while reserving italics for the concepts that the words denote

THREE VIEWS OF CONCEPTS

Background

Some of the central questions in categorization concern the structure of concepts After several decades during which one particular view of concept structure held sway, recent times have witnessed the emergence (or reemergence) of alternative views along with an associated frenzy of research activity There are several reviews of this work (Rosch 1978a,b, Herrnstein & deVilliers 1980, Mervis 1980, Millward 1980, Mervis & Rosch 1981, Epstein 1982), but for reasons both of familiarity and breadth, we will focus on our own published review of this literature, *Categories and Concepts* (Smith & Medin 1981)

Our 1981 review dealt mainly with object concepts, particularly natural kinds, e g *bird*, and artifacts, e g *hammer*, since such concepts have dominated categorization research Our review was organized around three views of concepts, which we called the "classical," "probabilistic," and "exemplar" views The classical view holds that all instances of a concept share common properties that are necessary and sufficient conditions for defining the concept The probabilistic view denies that there are defining properties, and instead argues that concepts are represented in terms of properties that are only characteristic or probable of class members Membership in a category can thus be graded rather than all-or-none, where the better members have more characteristic properties than the poorer ones The exemplar view agrees with the claim that concepts need not contain defining properties, but further claims that categories may be represented by their individual exemplars, and that assignment of a new instance to a category is determined by whether the instance is sufficiently similar to one or more of the category's known exemplars

The Classical View and its Problems

In *Categories and Concepts*, we detailed a number of criticisms of the classical view, here, we summarize the most important of them

FAILURE TO SPECIFY DEFINING PROPERTIES The severest problem for the classical view is that decades of analyses by linguists, philosophers, psychologists, and others have failed to turn up the defining properties of most object concepts

UNCLEAR CASES Since the classical view assumes that judgments about category membership are based on defining properties, category boundaries should be clear-cut But people are often uncertain about category membership—e g is a rug *furniture*?—and may not answer consistently when asked to judge membership on different occasions (e g McCloskey & Glucksberg 1978)

TYPICALITY EFFECTS Contrary to the classical view, not all members of a category have equal status Exemplars judged to be typical of a concept (e g a robin for the concept *bird*) can be categorized faster and more accurately than exemplars judged less typical (e g an ostrich) Also, children learn typical exemplars of concepts before they learn atypical ones, and when retrieving concept members, people access typical instances before atypical ones

FAMILY RESEMBLANCE AS A DETERMINANT OF TYPICALITY In an attempt to understand the basis of typicality, Rosch & Mervis (1975) had subjects list properties of exemplars of a particular concept Some exemplars had properties that occurred frequently in the concept while others had properties that occurred less frequently, the more frequent its properties the more typical an exemplar was rated This measure of an exemplar in terms of the frequency of its properties is called *family resemblance,* and it is highly correlated with the speed with which the exemplar can be categorized as well as with other typicality effects

USE OF NONNECESSARY PROPERTIES Most of the properties people list for exemplars are not true of all exemplars, i e the properties are nonnecessary for concept membership The fact that the distribution of these properties correlates with classification times (see above) strongly suggests that nonnecessary properties are being used to determine category membership

NESTED CONCEPTS The classical view assumes that a concept abstraction consists of the defining properties of its superordinate plus those defining properties that serve to distinguish it from other concepts at its own level That is, a specific concept (e g *sparrow*) includes all the properties of its superordinate (*bird*), which in turn includes all the properties of its superordinate (*animal*) This means that the specific concept (*sparrow*) has more common properties and fewer distinctive ones with its immediate superordinate (*bird*) than with its distant one (*animal*) It follows from many theories of similarity (e g Tversky 1977) that the specific concept should always be judged more similar to an immediate superordinate than to a distant one This prediction fails often enough (e g *chicken, bird,* and *animal*) to be an embarrassment to the classical view (Smith et al 1974, McCloskey 1980, Roth & Mervis 1983) [2]

SUMMARY None of the above criticisms is of and by itself decisive (see Smith & Medin 1981, Chapter 3), but the cumulative contortions needed to

[2]In this paragraph, we have talked in terms of whether a specific concept, e g *chicken,* is a subset of a more general one, while in other places we talk about whether a particular object, e g a chicken, belongs to a concept Experiments reveal little difference between these two kinds of categorization situations

address these criticisms reveal a picture not unlike Cinderella's stepsisters trying on the glass slipper—even if they could have gotten it on, certainly they would not have walked very gracefully. The upshot is that many investigators have turned to alternative views.

The Probabilistic View

The probabilistic view assumes that concepts are abstractions, or summary representations, but argues that for a property to be included in the summary it need have only a substantial probability of occurring in instances of the concept, i.e. it need only be characteristic of the concept, not defining. An object will then be categorized as an instance of some concept *A* if, for example, it possesses some criterial number of properties, or sum of weighted properties, included in the summary representation of *A*. Categorization is thus a matter of assessing similarity rather than of applying a definition.

ANSWERS TO PROBLEMS FOR THE CLASSICAL VIEW The probabilistic view can answer the problems that plagued its predecessor. First, since the probabilistic view does not require defining properties, it is not embarrassed by their apparent absence. As for unclear cases, they may arise when an object either is close to the threshold level of similarity for membership in a particular concept, or when an object is close to the threshold for more than one concept (e.g. a tomato may be equally similar to both *fruit* and *vegetable*).

The probabilistic view is also tailored to address typicality effects. Items are typical of a concept to the extent that they contain properties that are characteristic of the concept; this idea makes typicality a disguised form of similarity. And the more similar an item to a concept, the faster and more reliably it can be judged to exceed some threshold level of similarity, hence the effects of typicality on categorization. As for the use of nonnecessary properties, such properties are built into probabilistic models. Finally, the view is consistent with similarity judgments for nested concepts. While usually a concept shares more properties with concepts one level removed than with more distant ones, nothing in principle prevents a reversal of this situation, e.g. *chicken* is judged less similar to *bird* than to *animal* because chickens possess several properties (walking, being found on farms) that tend to be characteristic of *animal* but not of *bird*. In sum, this loosened view of concepts fits the relevant phenomena better than does the classical view.

PROBLEMS FOR THE PROBABILISTIC VIEW One general problem is that the probabilistic view may not adequately capture all of people's knowledge about concepts. In addition to knowing characteristic properties, people seem to know about the range of values a property of a concept might have (e.g. Walker 1975), as well as about relations among properties. For example, people know that birds are typically small and typically sing, and also that these properties are correlated such that large birds are unlikely to sing (Malt & Smith 1983) And there is evidence that people use knowledge about correlated attributes during categorization A second general problem for the probabilistic view is that it may be too unconstrained, both with respect to what can be a possible property and what can be a possible category Since similarity can be based on a *weighted* sum of properties, and since there are no constraints on the weights, this scheme may be too flexible

The Exemplar View

The exemplar view assumes that, at least in part, a concept consists of separate descriptions of some of its exemplars Some exemplar models allow for a more abstract representation as well (e.g Medin & Schaffer 1978), but others (e g the average distance model evaluated by Reed 1972) are based on only exemplars Exemplar models have in common the idea that categorization of an object relies on comparisons of that object to known exemplars of the category

ANSWERS TO PROBLEMS FOR THE CLASSICAL VIEW Since there is no reason why different exemplars need have the same properties, there is no reason to expect defining properties Unclear cases can arise when an object is similar to exemplars of more than one category (e g a tomato is similar to exemplars of both *fruit* and *vegetable*), or when an object is not very similar to the exemplars of any category (e g a sea horse)

Typicality effects may arise because people are more likely to represent only typical members (e.g Mervis 1980), or because more typical instances are more similar to other stored exemplars (this is just *family resemblance* at work) Being more similar to other stored exemplars of their own category, typical instances should readily retrieve exemplars from that category and hence be categorized quickly and accurately Again, nonnecessary properties are built directly into the view Finally, the exemplar view is consistent with similarity ratings for nested concepts, e g *chicken* might be rated more similar to *animal* than to *bird* because the particular exemplars associated with *chicken* may share more properties with the best exemplars of *animal* than with the best exemplars of *bird* In sum, the exemplar view can handle the problems that plagued the classical view

PROBLEMS WITH THE EXEMPLAR VIEW Exemplar models appear to have some advantages over probabilistic ones in that exemplars can carry information concerning the range of values for a property as well as information about correlations among properties With regard to range information, one could compute it when needed by sampling some exemplars that comprise the concept and determining their range One could also use this kind of on-line computation to handle the effects of correlated attributes on categorization (Alternatively, the effects of correlated attributes on categorization could be attributed to how the similarity between an object and exemplar is computed, see Medin & Schaffer 1978) These successes, however, come at the cost of a total lack of constraints on what properties enter into concepts or even what constitutes a concept

Questions Raised by the Preceding Analysis

The present state of affairs is less than satisfying The classical view has its problems, which can be handled by the probabilistic and exemplar views, but, to return to our Cinderella analogy, if the slipper is too tight for the classical view, it may be too loose for the alternatives The rest of this review is organized around questions growing out of this dilemma

(*a*) Is there any role for the classical view? The facts about simple categorization fit the probabilistic and exemplar views better than they do the classical view Most of these facts, however, concern object concepts Further, what holds for simple categorization may not hold for other functions of concepts The classical view may work better for other kinds of concepts and other kinds of functions

(*b*) If concepts have the loose structure implied by the probabilistic and exemplar views, then what makes them psychologically cohesive? That is, how can we add constraints to what are called "prototype" views? (While the distinction between probabilistic and exemplar type concepts is important, sometimes all that matters is that the concept not contain defining properties, when this happens we refer to such concepts as "prototype" concepts)

(*c*) What principles of processing regulate the categorization of prototype concepts? Thus far all we have claimed is that categorization with prototype concept amounts to a similarity computation

(*d*) How are prototype concepts learned? While the knowledge in a concept is in part abstracted from experience with exemplars, little is known about the details of this process In considering this question, we will emphasize concept learning in adults, as a proper treatment of the literature on concept acquisition in children would require a chapter in its own right (For recent reviews, see Anglin 1977, Farah & Kosslyn 1982)

(*e*) Are there different types of prototype concepts governed by different principles? Most research on categorization employs object concepts, but some recent work tries to extend the prototype approach to very different kinds of concepts

(*f*) What are some of the newer directions in research on concepts? We will consider two new developments, research on complex concepts and challenges to the claim that categorization is nothing more than similarity

POSSIBLE ROLES FOR THE CLASSICAL VIEW

The Classical View and the Distinction Between the Core and Identification Procedure

In Smith & Medin (1981) we borrowed a distinction from Miller & Johnson-Laird (1976) between the "core" and "identification procedure" of a concept The core contains properties that reveal relations with other concepts, while the identification procedure contains properties that are used to categorize real-world objects Consider the concept *boy*, its core might contain the properties of being human, male, and young, while its identification procedure might contain information about height, weight, and dress The relevance of this distinction to the issue at hand is that while the identification procedure may have a prototype structure, the core may conform to the classic view

We noted this possibility (Smith & Medin 1981, Chapter 3), but could find little evidence to support it A recent paper by Armstrong et al (1983), however, provides some evidence These authors investigated concepts that almost certainly have a classical core, specifically *even number, odd number, plane geometry figure,* and *female* The intent of the authors was to show that even these concepts have identification procedures As support for this, Armstrong et al demonstrated that subjects rated instances of these concepts as varying in typicality and categorized typical instances faster than atypical ones For example, 22 was rated as more typical than 18 of *even number,* and 22 was also categorized faster (See Bourne 1982 for similar results in a paradigm using artificial concepts) Armstrong et al interpret their typicality effects as reflecting only an identification procedure, which supports the idea that a prototype identification procedure can co-exist with a classical core [3] Thus, many people's identification procedure for *even number* may focus only on the evenness of the last digit, since it is easier to establish that 2 is even than that 8 is, this would explain why subjects rated 22 as more typical than 18

The Classical View as a Backup Procedure

An idea related to the above is that the classical core of a concept may be used to back up or justify categorizations based on an identification procedure Again we considered but were unable to educe evidence bearing on this possibility earlier (Smith & Medin 1981, Chapter 3), but a recent paper provides some suggestive support for it Landau (1982) used concepts that presumably have classical cores, namely female kin relations such as *grandmother* She pre-

[3]In fairness to the spirit of the Armstrong et al paper, we should add that they argue that these and other observations raise serious problems with the general approach of analyzing concepts into features and the specific idea of using typicality effects to draw inferences concerning concept structure

sented pictures to her subjects (children and adults) and had them perform two tasks (*a*) categorize the picture as an instance or noninstance of some concept, e g *grandmother*, and (*b*) justify their decision The categorization task should be based on an identification procedure and hence reflect characteristic properties, while the justification task should presumably reveal the core and hence reflect defining properties To test these assumptions, Landau varied two aspects of the pictures In those used with *grandmother*, for example, she always presented an adult woman but varied (*a*) her age, which is primarily characteristic of *grandmother*, and (*b*) whether or not there were young children present, which is presumably suggestive of a defining property of *grandmother* (being the mother of a parent) In line with her assumptions, Landau found that subjects of all ages relied more on the age of the adult woman when making categorical decisions than when justifying them, but more on the presence of young children when justifying decisions than when making the actual categorizations

The Classical View and Other Types of Concepts

Although the classical view may not account for categorization with natural kinds and artifacts, it likely plays some role in categorization with other types of concepts Clearly this seems to be true for various concepts drawn from geometry (e g *square*), other branches of mathematics (e g *even number*), kinship systems (e g *grandmother*), legal systems (e g *perjury*), sciences (e g *molecule* and *gene*), and other areas where there are definitions that are taught explicitly to students Indeed, the studies of Armstrong et al (1983) and Landau (1982) reviewed above rest on the assumption that such "defined" concepts have a classical core What is more controversial, however, is whether there are some types of "nondefined" concepts whose categorization behavior is governed by the classical view We briefly consider two possibilities ontological concepts and action concepts

In Smith & Medin (1981), we gave special attention to ontological concepts, i e concepts that represent the basic categories of existence such as *thing*, *physical object*, *event*, *solid*, and *fluid* Keil's (1979) work indicated that such concepts might conform to the classical view, at least in that they contain necessary properties For example, his results in a sentence acceptability task indicated that ontological concepts are structured in a hierarchy—say, *thing* on top, branching to *physical object* and *event*, and the former branching to *solid* and *fluid*—and that similarity judgments conformed to the hierarchy, i e a concept was always judged more similar to its immediate than to a distant superordinate These results have been challenged Carey (1983) provides counterexamples to the claim that ontological concepts form a strict hierarchy, and Gerard & Mandler (1983) failed to replicate some of the sentence acceptability results that Keil used to generate the hierarchies It is therefore unclear whether ontological concepts fit the classical view any better than do most object concepts

Some have said that those interested in categorization think that concept is spelled "N, O, U, N" (G A Miller 1982, personal communication) Perhaps the action concepts denoted by verbs are more likely to conform to a classical-view account of categorization As support for this possibility, we note that there are some psychologically motivated decompositions of verbs into meaning components where these components seem to function as defining conditions, e g Miller & Johnson-Laird 1976, Gentner 1981 However, we know of no adequate studies that directly address the question of whether categorization with simple action concepts conforms to the classical view

The Classical View and Other Functions of Concepts

As mentioned earlier, in addition to categorization, concepts can serve the functions of fixing linguistic meaning and comprising cognitive states (e g beliefs and preferences) Recently, a number of researchers have argued that often it is the cores of concepts that are used in the latter two functions, and these cores may conform to the classical view

With regard to linguistic meaning, Armstrong et al (1983) argue that it is the core of *grandmother* that allows one to infer that if someone is a *grandmother* then that someone is also a *female* and a *mother* More generally, it seems that inclusion relations between concepts must be based on cores, not identification procedures Suppose it were otherwise then we might not be able to infer that a *grandmother* is a *mother* because such an inference could require that all the properties of *mother* be included in those of *grandmother*, yet the identification procedure for *mother* would include the property of being young-to-middle aged while that for *grandmother* would not

Armstrong et al (1983) also argue that concept cores are often used to deduce one belief from another This claim receives support from an experiment by Rips & Stubbs (1980) Subjects had to answer questions about kin relations (e g "Is Hank the cousin to Maude?") for families known to them Rips and Stubbs were able to do a reasonable job of predicting the times to answer these questions by assuming that subjects considered only the core properties of these concepts, particularly the property denoted by "child of "

The Classical View as a Metatheory of Concepts[4]

The idea that object concepts do not have defining properties goes against many people's intuitions (see McNamara & Sternberg 1983) Though these intuitions frequently will yield to counterexamples, perhaps they should be considered as phenomena worthy of study And what these intuitions suggest is that people

[4]The ideas in this paragraph grew partly out of a discussion with Dedre Gentner

tend to approach the world as if it conformed to the classical view (even if it doesn't!) Thus, the classical view may serve as the layperson's metatheory of concepts (or the layperson's metaphysics) Assuming this is the case, how do *people reconcile their belief in the classical view with their lack of defining* properties for most object concepts? Perhaps by further assuming that the defining properties are hidden from ordinary observation but are available to experts, e g biologists, botanists, and so on [This is related to Putnam's (1973) claim that meaning is distributed through the community, and we are suggesting that an awareness of this distribution of linguistic labor is part of the layperson's metatheory of concepts]

Summary

There are reasons for maintaining the classical view With "defined" concepts, a core that conforms to the classical view may be used as a backup or source of justification in categorization It is possible that the classical view may play a comparable role with some nondefined concepts (e g action concepts) As for functions other than categorization, there are plausible arguments for thinking that the view has a role in accounting for linguistic meaning and reasoning, and speculative arguments for thinking the view may serve as a layperson's metatheory

CATEGORY COHESIVENESS

Our experiences can be partitioned in a limitless variety of ways, and it is natural to ask why we have the concepts we have and not others That is, what makes a concept sensible or a category cohesive?

Proposed Constraints from the Classical and Probabilistic Views

The classical view assumes that the defining properties provide the structure that holds a category together But this may not be enough structure For example, a category consisting of brown things bigger than a basketball and weighing between 10 and 240 kilograms satisfies a classical view definition but does not seem sensible or cohesive Osherson (1978) and Keil (e g 1979) have worried about this problem and suggested that some of the needed constraints result from the hierarchical structuring of ontological concepts, but as we noted earlier, this hierarchical structuring is now a matter of debate (see also Krueger & Osherson 1980)

The probabilistic view is constrained primarily in that it implies that categories be partitionable on the basis of a summing of evidence, i e that the categories be separable on the basis of a weighted, additive combination of component information [this is called "linear separability" (Sebestyen 1962)]

One way of evaluating the importance of linear separability is to set up two categorization tasks that are similar in major respects except that in one the categories are linearly separable while in the other they are not. Using this strategy, in a series of four experiments Medin & Schwanenflugel (1981) found no evidence that linearly separable categories were easier to learn than categories that were not linearly separable.

The Basic Level

Another possible source of constraints on categories comes from research on the basic level of categorization. While any particular object, say a particular apple, can be assigned to a number of different concepts, e.g. *fruit*, *apple*, and *McIntosh apple*, one level seems to be the preferred or basic one for categorization as judged by speed of categorization, ease of learning, and a host of other criteria (e.g. Rosch et al 1976, Daehler et al 1979, Mervis & Crisafi 1982, Murphy & Smith 1982). To the extent we can determine what makes a concept basic, we may have determined what makes a category cohesive.

There is no shortage of ideas about determinants of basic levels. One is that the basic level is the most abstract level at which the instances of a concept have roughly the same shape (e.g. Rosch et al 1976). A related position (according to Hemenway & Tversky 1984) is that the basic level is the most abstract level at which the instances of a concept have roughly the same parts.[5] These ideas translate readily into possible reasons for why categories cohere, at least for object concepts. Another possible determinant of basic levels has the potential to constrain abstract concepts as well as concrete ones; namely, the basic level is that which maximizes the number of distinctive properties, where a distinctive property is common to most members of a concept but lacking to most members of contrasting concepts (see, e.g., Mervis & Rosch 1981, Murphy & Smith 1982). Whichever determinants turn out to be right, however, they cannot be the whole story about category cohesiveness, since nonbasic concepts like *fruit*, *plant*, and *thing* would lack the critical determinant yet constitute a coherent concept.

More Abstract Criteria of Category Cohesiveness

Rosch & Mervis (1975) suggested that the basic level maximizes "cue validity," i.e. the probability than an object is a member of a particular category given that it has a particular property. Murphy (1982), however, argued that the

[5]Another reason for thinking there is some link between parts and category cohesiveness comes from the work of Markman and her associates, (e.g. Markman & Callahan 1983). These authors have investigated "collection" concepts (e.g. *family*, *forest*), which are based on part-whole relations rather than class-inclusion ones (e.g. a son is part of a *family*), and have shown that young children find collections easier to understand than concepts based on class inclusion. Markman suggests that this difference may be due to part structures being more cohesive.

principle of maximizing cue validity will always pick out the most inclusive or abstract categories That is, since cue validity is the probability of being in some category given some property, this probability will increase (or at worst not decrease) as the size of the category increases (e g the probability of being an *animal* given the property of flying is greater than the probability of *bird* given flying, since there must be more animals that fly than birds that fly) [6] The idea that cohesive categories maximize the probability of particular properties given the category fares no better In this case the most specific categories will always be picked out

Medin (1982) has analyzed a variety of formal measures of category cohesiveness and pointed out problems with all of them For example, one possible principle is to have concepts such that they minimize the similarity between contrasting categories, but minimizing between-category similarity will always lead one to sort a set of *n* objects into exactly two categories Similarly, functions based on maximizing within-category similarity while minimizing between-category similarity lead to a variety of problems and counterintuitive expectations about when to accept new members into existent categories versus when to set up new categories

At a less formal but still abstract level, Sternberg (1982) has tried to translate some of Goodman's (e g 1983) ideas about induction into possible constraints on natural concepts Sternberg suggests that the apparent naturalness of a concept increases with the familiarity of the concept (where familiarity is related to Goodman's notion of entrenchment), and decreases with the number of transformations specified in the concept (e g *aging* specifies certain transformations)

Correlated Attributes

Rosch and Mervis have argued that natural categories are formed to take advantage of correlated attribute clusters (e g Rosch 1978a, Mervis & Rosch 1981) Certain attributes tend to co-occur—e g animals with feathers are likely to have wings and beaks, whereas animals with fur are unlikely to have wings and beaks—and cohesive categories may be those that follow the natural correlation of attributes Medin (1983) has tried to extend this line of argument by noting that correlated attributes *within* a category provide further internal structure, e g birds with large wings tend to eat fish and live near the sea There is now evidence that the members of natural categories do indeed have correlated attributes (Malt & Smith 1983), and that people are sensitive to such

[6] W K Estes (personal communication, 1983) has pointed out that this drawback to maximizing cue validity may be overcome by normalizing or subtracting out the prior probability of the class Thus, the cue validity of flying for *bird* is now the (*a*) probability of *bird* given the property flying minus (*b*) the probability of *bird* Now cue validity need no longer increase with the inclusiveness of the class

correlated attributes when making categorization decisions (Medin et al 1982, Cohen & Younger 1983, Malt & Smith 1983) A major problem, however, with invoking correlated attributes as a constraint on concepts is that there are so many possible correlations that it is not clear how the correct ones are selected (see Keil 1981) Some auxiliary principles may be needed to provide further constraints on category cohesion

Summary

The probabilistic and exemplar views provide few constraints on what can count as a natural concept or cohesive category Research on the basic level of categorization—with its emphasis on shape, parts, and distinctive properties—may prove useful in formulating such constraints Other approaches focus on more abstract constraints, such as cue validity, or on correlated attributes

CATEGORIZATION PROCESSES WITH PROTOTYPE CONCEPTS

Recent work on prototype concepts has led to new problems and possibilities with respect to categorization models We can give but a brief sample of this literature

Categorization as Decision Making

Given that the distinction between categorization and decision making is rather fuzzy, there has been surprisingly little interplay between formal models in these two areas There are some interesting points of contact For example, categorization models that endorse linear separability correspond to linear decision models, this suggests that conjoint and functional measurement techniques developed in the domain of decision making can be brought to bear in categorization tasks This point was illustrated by Wallsten & Budescu (1981), who asked clinical psychologists and graduate students to classify MMPI profiles. They used conjoint and functional measurement analysis from decision theory to show that although some of the less experienced judges processed the dimensions in an additive manner, the more experienced judges tended to use correlated dimensions in an interactive manner

Another interesting relationship between categorization and decision making involves the analysis of optimal decision rules in psychophysical paradigms Noreen (1981) showed that in certain forms of same-different judgment tasks, the optimal decision rule is to first categorize the inputs and then base the same-different judgment on whether or not the inputs were assigned to the same category

Activation of Properties and Concepts

Many categorization models proceed as if the entire set of properties of a concept is invariably activated when the concept is mentioned Barsalou (1982) argues instead that a concept has a subset of context-independent properties that are activated whenever the concept is accessed, but also a subset of context-dependent properties that are activated only when the relevant context is instantiated For the concept *basketball*, for example, being round would be a context-independent property while being able to float would be a context-dependent property

Context effects on property activation can alter standard typicality judgments Roth & Shoben (1983) used a reading-time paradigm and measured the time needed to establish an anaphoric reference between an exemplar (e g chicken) and a concept (e g *bird*) The context was either neutral or biased, e g in "The bird walked across the barnyard," the context is biased to make chicken more typical of *bird* than is robin Reading times were faster when the exemplar fit the bias, and the typicality rating for a usually atypical exemplar increased when it fit the bias

This kind of bias or priming also occurs at the level of the entire concept in situations where several concepts might apply to the input, e g in the domain of person concepts where multiple concepts frequently apply to the same person or behavior In a variety of paradigms it has been shown that the likelihood that a subject will use a particular concept to encode an input is increased by priming the concept in a context separate from that in which the input is presented (e g Higgins & King 1981, Wyer & Srull 1981)

Holistic Versus Component Processing

Although most categorization models assume that people are essentially making similarity judgments, often it is unclear whether these judgments constitute a holistic impression of overall similarity or a more analytic accumulation of matches and mismatches of components One well-known determinant of holistic versus component similarity is whether the dimensions of the inputs are integral (e g hue and saturation of colors) or separable (e g size and shape of geometric forms), where integral dimensions lead to holistic similarity and separable dimensions to component similarity (e g Shepard 1964, Garner 1974) It now appears that whether similarity is computed holistically or componentially can also be a consequence of the processing strategy, (see, e g , Pishkin & Bourne 1981) Indeed, it has been argued that for fixed inputs, there is a major developmental shift from treating the inputs in a holistic manner to treating them in a component-by-component manner (e g Burns et al 1978, L B Smith 1981, Kemler 1983, Ward 1983) This work indicates that categorization models must be flexible enough to permit either holistic or componential similarity computations, yet principled enough to specify why one type of similarity dominates in some circumstances and the other type dominates in other circumstances

Summary

Some of the formal models developed in decision making might prove useful in categorization Whatever their origin, categorization models are going to have to accommodate the facts that (*a*) some properties of a concept are activated only in certain contexts, and (*b*) similarity between an item and a concept can be computed either holistically or componentially

ACQUISITION OF PROTOTYPE CONCEPTS

The literature at issue here focuses on the acquisition of prototype concepts that are usually artificial (rather than natural), that are learned by adults (rather than children), and that are based on experience only with exemplars (rather than on category-level information) Even with these restrictions, this literature is a burgeoning one, and we will have to be selective

Variables Controlling Learning

Our knowledge of variables controlling learning is increasing Some of the critical findings include these basic-level concepts are easier to learn than their subordinates or superordinates (e g Murphy & Smith 1982), good examples of a concept are learned before poor ones (e g Rosch 1978a), transfer to new exemplars is facilitated by increases in the number of exemplars on which learning was originally based (e g Homa et al 1981, Omohundro 1981), and feedback is not always necessary for learning (e g Fried & Holyoak 1983)

Of the many variables that could be considered in detail, we will focus on one recent development the role of unique properties, i e those properties unique to exemplars that allow them to be identified individually While analyses of natural concepts assume that instances contain some unique properties, studies using artificial concepts usually employ instances with no unique properties (e g Medin & Schaffer 1978) A recent study of Medin et al (1983) suggests that when distinctive properties are present, abstraction is far from automatic Medin et al used photographs of faces where the concepts were defined in terms of dimensions such as hair color and length, but where individual faces differed from each other along numerous other dimensions In the first condition, subjects learned to assign photographs to one of two concepts, in a second condition, subjects learned not only the appropriate categorization but also a unique response for each photograph (the first name), which insured some attention to unique properties In a subsequent transfer test, only subjects in the first condition showed substantial transfer to new faces that had the appropriate dimension values These results imply that abstraction is not automatic, but rather governed by factors related to the presence or absence of unique properties (see Hartley & Homa 1981 for related work)

What is Learned?

Initial studies of learning prototype concepts were taken as evidence that people abstracted from exemplars the central tendency of a category Although people might have some information about individual exemplars, the evidence suggested that exemplars were forgotten more rapidly than the central tendency, and that with increasing delays performance was increasingly based on the central tendency (e g Posner & Keel 1968, 1970)

These studies have sparked considerable interest The major issue concerns whether the results taken as supporting extraction of a central tendency, or summary representation, can be derived from the assumption that people are representing only exemplars (e g Brooks 1978, Medin & Schaffer 1978, Nosofsky 1983) (This, of course, is the major issue that divides the probabilistic and exemplar views) As support for the exemplar position, Medin & Schaffer (1978) controlled the distance of transfer items to the central tendencies of two categories and manipulated the similarity of transfer items to known exemplars They found that learning and transfer were determined by similarity to known exemplars, not by distance from central tendencies Hintzman & Ludlam (1980) demonstrated that the forgetting effects originally taken as supporting abstraction of a central tendency could be predicted from an exemplar model The debate continues (see Homa et al 1981, for further criticism of exemplar models, and Medin, Busemeyer & Dewey 1983 for a reply)

In Smith & Medin (1981), we argued that models based on a mixture of exemplars and summary representations might be most successful in the long run And there are, in fact, numerous mixture models around (e g Medin & Schaffer 1978, Elio & Anderson 1981, Homa et al 1981, Kellogg 1981) Given all this attention, it is surprising that there are so few theories or models for describing the *learning* process associated with mastering prototype concepts (for an exception, see Anderson et al 1979)

Analytic Versus Nonanalytic Strategies

People learning prototype concepts may use a variety of strategies ranging from hypothesis testing (Martin & Caramazza 1980, Kellogg 1981) to memorization of individual instances (e g Kossan 1981) While hypothesis testing is taken for granted as an efficient strategy, nonanalytic processes, such as memorizing the exemplars presented and classifying new ones on the basis of their similarity to memorized ones, are often thought of as antithetical to strategies However, Brooks has made a convincing case for the benefits of nonanalytic processing (e g Brooks 1978, 1983, Vokey & Brooks 1983) (This, of course, fits well with the exemplar view of what is learned) For example, Brooks (1983) shows that when the categorizer does not know the form of the rule that describes whether an item belongs in a concept, often the most efficient strategy is to respond on the basis of the similarity of the to-be-categorized item to known exemplars in memory This holds true even for paradigms where the rules are well defined (i e the concepts have defining conditions) as long as the *form* of the rule is unknown

Summary

Although knowledge of variables controlling learning is accumulating. what remains controversial is exactly what is learned. The use of nonanalytic strategies, which rest heavily on memorizing exemplars, favors the idea that part of what is learned is in the form of individual exemplars

DIFFERENT TYPES OF PROTOTYPE CONCEPTS

Recently the prototype approach to categorization has been extended to domains other than object concepts Some of these new domains are the following abstract concepts such as *belief* (e g Hampton 1981), psychiatric diagnostic categories (Cantor et al 1980), the concept of *self* (Kihlstrom & Cantor 1983), concepts of psychological situations (Cantor et al 1982), emotion concepts (e g Fehr et al 1982), linguistic concepts (e g Lakoff 1982, Maratsos 1982), and concepts of environmental scenes (Tversky & Hemenway 1983) While the work in each of these domains seems promising, space limitations lead us to focus on just three new domains, namely goal-derived, person, and event concepts

Goal-Derived Concepts

Barsalou (1981) argues that in the course of engaging in goal-directed behavior people often create specialized concepts For example, a goal to lose weight can create the concept *foods not to eat on a diet* Though these concepts are very complex, they still give rise to typicality effects Thus, for the concept *foods not to eat on a diet,* people consider chocolate to be a better example than bread Interestingly, the basis for these typicality effects is qualitatively different from that with simple object concepts Recall that for the latter, family resemblance predicts typicality Barsalou (1981) has shown that family resemblance does not predict typicality for goal-derived concepts Rather the typicality of an item in a goal-derived concept is determined by (*a*) its value or amount on the dimension(s) relevant to the concept (e g for *foods not to eat on a diet,* amount of calories is the relevant dimension, and chocolate clearly has a higher value than bread), and (*b*) the frequency with which that item has been used as an instance of the concept in the past (e g chocolate frequently arises as an instance of *foods not to eat on a diet)* Thus, comparable typicality effects in two domains do not imply common determinants of typicality

Person Concepts

Cantor & Mischel (e g 1979) were among the first to investigate parallels between object concepts that have a prototype structure and person concepts such as *extrovert* and *cultured person* They showed that the extent to which an "instance," i e a description of an individual, was judged typical of, say, *extrovert* increased with the number of properties that the individual shared with extroverts in general This suggests that typicality effects with person concepts have the same basis—namely, family resemblance—as typicality effects with object concepts Such parallels merely scratch the surface of recent work done on social categorization (see, e g , Brown 1980, Hastie et al 1980, Cantor & Kihlstrom 1981, Higgins et al 1981, Srull 1981, Lingle et al 1983)

The similarities between person and object concepts are of considerable interest but so are their differences One kind of difference is in taxonomic structure Object concepts are tightly hierarchically structured, with concepts at the same level being mutually exclusive Person concepts need not have a tight hierarchical structure as concepts at the same level can apply to the same person, e g somebody can be both an *extrovert* and *cultured person* A second kind of difference concerns the consequences of categorization Person categorizations, particularly stereotyping, can produce substantial affect in both the categorizer and the categorized, while object categorization usually leaves both parties cold Also, person categorizations can be reactive One's categorizaton of another influences the behaviors one unconsciously elicits from the other, e g having categorized someone as an extravert, we unconsciously act more friendly toward that person (e g Snyder 1981) A third kind of difference between person and object concepts concerns the properties involved Presumably *extrovert* has properties like being outgoing and confident, which are more abstract and indeterminate than those of most object concepts

However, categorization based on indeterminant properties is by no means the rule for person concepts Brown (1980) points out that the most common means for classifying people are not concepts like *extrovert* but rather occupations (e g *butcher*), races (e g *black*), religions (e g *Jew*), and nationalities (e g *German*) Though these concepts are based on relatively easy-to-determine properties, somehow these concepts can mutate into stereotypes What seems to be going on is this (*a*) the properties needed to categorize someone as *black* are generally easier to determine that those needed to categorize an object, (*b*) but having classified someone as *black*, there are only weak links to nonperceptible properties, whereas usually there are strong links between object concept and nonperceptible properties In short, deciding on class membership can be easier with people than with objects, but inferring the consequences of class membership is much easier with objects than with people

Event Concepts: Scripts

Representations of sterotyped events, such as going to a restaurant, are called "scripts" (Schank & Abelson 1977). While usually thought of as components of story understanding, scripts can also be viewed as concepts (Abelson 1981) The properties of a script-as-concept would include the actions that comprise the event, e g some properties of the *restaurant* concept would include finding a table and getting a menu A specific story based on a script can be construed as an instance of the concept, and to the extent its actions match those in the script (i e to the extent its properties match those in the concept), it will be judged typical of the script In line with this view, Galambos & Rips (1982) found that when subjects had to make rapid decisions about whether a particular action was part of a script (e g determining that "getting a menu" is part of *restaurant*), the more important the action (as determined by prior ratings) the less time needed to make the decision This result parallels a finding with object concepts, namely, the more salient a property the less time needed to decide it is part of the concept [e g Holyoak & Glass 1975, see Nottenburg & Shoben (1980) for a similar parallel between a script and an object concept]

Recent work by Abbott et al (1984), however, suggests that rather than a script being akin to an object concept, it may be more like an entire hierarchy of object concepts The contents of a script clearly seem to be hierarchically organized At the top level is the general goal (e g eating at a restaurant), at the intermediate level are "scenes" which denote sets of actions (e g entering the restaurant, ordering, eating, and leaving), and at the lowest level are the actions themselves Furthermore, Abbott et al found that the scenes appeared to be the basic level of description for events, which again fits with viewing a script as a hierarchy of concepts rather than as an individual concept

Summary

The prototype approach to concepts is spreading to many domains and turning up interesting differences as well as communalities While there are typicality effects with goal-derived concepts, their basis is *not* family resemblance And though person concepts are like object concepts in several respects, they differ from object concepts with regard to taxonomic structure, the consequences of categorization, and the nature of the properties involved As for event concepts, they are clearly related to concepts, but it is not yet clear whether they are more like concepts or taxonomies

NEWER DIRECTIONS

Complex Categories

While research on concepts has been dominated by simple categorization, interest is growing in complex categorization, or how we decide on membership in classes that are composites of simple ones (e g *leather shoes, shirt with blue stripes*) For composites that have three or more simple concepts or constituents, there is a question about the order of combination That is, when presented "shirt with blue stripes," in what order does one combine *shirt, blue,* and *stripes* in forming a new concept and using it to categorize a potential instance? One possibility is that the combination order is fixed, perhaps determined by syntactic considerations, e g first compose *blue stripes*, then combine this product with *shirt*) Contrary to this, Rips et al (1978) and Conrad & Rips (1981) found that subjects were able to vary the order in which they combined constituents, and that they favored those orders that made categorization easiest, i e first combining constituents that were easiest to check in the potential instance

Other work has dealt with composites that usually have only two constituents, and has focused on the nature of categorization with composites An important question has been What is the relation between the typicality of an object in a composite and its typicalities in the constituents? For example, what is the relation between the typicality of a particular object in the composite *pet fish* and its typicalities in *pet* and *fish*? Zadeh's (1965) fuzzy-set theory claims that typicality in the composite is the minimum of the typicalities in the constituents, which means that something cannot be a better example of *pet fish* than it is of *pet* or *fish* Osherson & Smith (1981), however, argue that there are many counterexamples to this—a guppie is a better example of *pet fish* than it is of either *pet* or *fish* Mervis & Roth (1981) provide similar counterexamples in the domain of colors

More recent studies provide extensive arguments against the use of fuzzy-set theory as an account of complex concepts (see Jones 1982, Osherson & Smith 1981, 1982 Smith & Osherson 1983, Roth & Mervis 1983, for rejoinders, see Lakoff 1982, Zadeh 1982) The problems with fuzzy-set theory are leading some to a more representational approach to the study of complex concepts Rather than trying to relate typicality in a composite directly to typicalities in the constituents, Osherson et al (1984) propose explicit means for combining property sets of constituents into a property set for the composite, and then determine the typicality of an object to a composite by determining the object's similarity to the composite property set

Is There More to Categorization than Similarity?

The prototype approach generally assumes that decisions about concept membership are based only on similarity (an item's similarity to a target concept as well as to contrasting concepts) This assumption is beginning to be challenged For one thing, some recent models of categorization are based on probabilities, not similarities In Fried & Holyoak (1983), for example, the critical information in each concept is captured by a probability distribution of exemplars over a feature space, the probability that a particular object will be judged to be an exemplar of a particular concept is determined, in part, by the frequency of known exemplars that have the features of the object This approach may be particularly useful in elucidating the categorization of novel objects Also, a model based on probabilities has a natural way of incorporating knowledge about the variability of properties

A recent finding by Rips & Handte (1984) on property variability fits especially well with probabilities rather than similarities We can best describe the finding by an example Subjects were asked whether an object 5 inches in diameter was more likely to be a coin or a pizza Though the object's size was roughly midway between large coins and small pizzas (as determined by prior norms), subjects tended to categorize it as a pizza Presumably they did this because pizzas are more variable in size, and though the probability of a 5 inch pizza is very low, it is still higher than that of a 5 inch coin As Rips & Handte (1984) point out, though, there may be more involved here than just brute knowledge about variability We know that coins cannot be too large because of how they are made, i e we have some knowledge, or a "theory," about the nature of coins which supplies the information about size variability

The idea of intuitive theories influencing categorization is a familiar one in conceptual development Carey (1982), in particular, has emphasized the role that children's theories of biology play in their categorizations of animals and other objects To cite one of her examples

> when subjects were asked to rate similarity, a mechanical monkey that banged cymbals together, wore clothes, and screeched was judged more similar to people than was a worm by subjects of all ages But when taught a new property of people ("has a spleen," where a spleen was described as a green thing inside people), spleens were attributed to worms more than to the mechanical monkey, even by 4-year-olds With respect to "spleenness," worms are more similar to people than are mechanical monkeys The point is that the child's rudimentary biological knowledge [or theory] influences the structure of his concept *animal* (Carey 1982, pp 385–86)

A theory-based approach is also showing up in other work on categorization. In the Fried & Holyoak (1983) model, which emphasizes probability distributions, people are assumed to approach each concept learning situation with some global assumptions, or rough theory, about the shape of the underlying distributions To take an example based on sorting algorithms in computer science, Michalski's work (e g 1983) suggests that the algorithm that best captures people's categorizations is one that operates on *descriptions* of clusters (rather than matrices of similarities) and aims to maximize criteria having to do with what constitutes a good description This is directly analogous to grouping entities in accordance with one's theory about them

Summary

Recent studies indicate that fuzzy-set theory cannot account for many phenomena involving complex concepts Another new direction challenges the idea that categorization is based solely on similarity, instead, newer work focuses on the role of probability and intuitive theories in making categorical decisions

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