The Effects of Feature Necessity and Extrinsicity on Category Contrast in Natural Language Categories

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Abstract

This experiment tested two hypotheses: 1) that categories represented by features that many people believe to be necessary will demonstrate stronger category contrast than those represented by features that few people believe to be necessary, and 2) that categories that people believe are represented primarily by intrinsic features (i.e., features true of an entity in isolation) will have stronger category contrast than those that people believe are represented primarily by extrinsic features (i.e., features that represent relations between an entity and other entities). The findings support only the second hypothesis.

Introduction

In this paper, we examine contrast among hierarchically organized categories. Consider a classical nested hierarchy containing one superordinate node (A), and two subordinate nodes (B and C). The hierarchy should exhibit the property of class inclusion (a B is an A, and a C is an A), as well as mutual exclusivity among other categories (a B cannot be a C, and a C cannot be a B). In the experiment reported here, we examine the second kind of relation: category contrast. To use Kay's (1971) terms, we investigate categories that should demonstrate either direct contrast (i.e., two categories that share the same immediate superordinate), or indirect contrast (i.e., two categories that contrast because their superordinates are themselves in direct contrast). In the experiment reported here, we explore two possible mechanisms for inter-category differences in the degree to which such contrast holds: the extrinsicity of features in category representation (Barr & Caplan, 1985, 1987; Caplan & Barr, in press), and probabilistic features (e.g., Rosch, 1973, 1975).

Feature extrinsicity and category contrast

In previous work (Barr & Caplan, 1985, 1987; Caplan & Barr, in press), we have presented a model of category representation that accounts for inter-category differences in gradients of membership. According to that model, the features that comprise a category's representation may be considered to be either *intrinsic* or *extrinsic*. Intrinsic features are features that are true of a potential category member in isolation (e.g., "has leaves", "has hair"). Extrinsic features are features that represent relations between potential category members and other entities (e.g., "is used for transportation", "has a child"). We have demonstrated that class-inclusion relations are stronger for categories represented by intrinsic features than for those represented by extrinsic features (Caplan & Barr, in press).

Our model of category representation also predicts that inter-category contrast will be more likely to characterize relations among intrinsically represented than among extrinsically represented categories. Why should this be the case? Consider a person responding to questions of the form, "Can a B be a C?" (e.g., "Can a weapon be a tool?", "Can a plant be an animal?"), as subjects in the experiment reported below were asked to do. In order for a member of Category B to become a member of Category C, it must somehow acquire the features included in Category C's representation, and/or lose those of Category B's representation. Such feature change or acquisition should be more likely to occur for extrinsic than for intrinsic features. Because intrinsic features are represented as true of an object in isolation, whether or not an item is represented as possessing an intrinsic feature will

remain constant across situations. Although it is possible that an entity might lose the feature, that possibility is not expressed in the feature's representation. Therefore, intrinsic category representations do not include the possibility for feature change, and strong inter-category contrast should result. On the other hand, membership in extrinsically represented categories depends not on the attributes of the possible category member itself, but on the relations it holds with other entities or objects. Because such relations may change over different contexts (e.g., a possible weapon may sometimes be used to harm people, and sometimes not), entities may be conceived to slip in and out of membership. In other words, extrinsic representations include the possibility for change in category membership, since whether an object is a category member depends on the relations it holds with other objects, and those relations may change. Accordingly, extrinsically represented categories should show much weaker contrast.

Probabilistic features and category contrast

Over the last 20 years, "family resemblance" or probabilistic approaches to semantic category representation have challenged traditional approaches to category representation (see Smith & Medin, 1981, for a review). These theories (e.g., Rosch, 1973, 1975) posit that category exemplars typically exhibit some, but not all, of the pool of features associated with a category. According to most versions of probabilistic theory, category membership is determined by the sum of the weighted features possessed by the exemplar (see Smith & Medin, 1981). One of the major characteristics of probabilistically represented categories is the fact that categories may, through possessing some subset of the relevant features, be more or less good members of the category. Accordingly, categories may include many "borderline" members – members which may also be considered members of other, related categories. Presumably, borderline members of one category can also be members of another category from the same hierarchy if they possess the appropriate subsets of features for both categories; therefore, one would *not* expect to find strong evidence of inter-category contrast. For example, a large serrated knife may also be a saw. It possesses enough features to qualify for membership in both categories (knife and saw), without being a very good or very typical member of either.

Recently, Markman (1989) has suggested that categories differ in whether they are probabilistically or classically represented, with some categories represented by sets of features necessary for category membership, and others represented probabilistically.[1] In fact, we have demonstrated that such differences exist, and that hierarchies of categories represented by features which many subjects believe to be necessary are characterized by stronger class inclusion than are those represented by features that few subjects believe to be necessary for category membership (Caplan & Barr, in press). Similarly, whether a category is represented "classically" or probabilistically should determine whether or not strong inter-category contrast obtains among members of a hierarchy. Probabilistically represented categories should reveal weak contrast, and categories represented by sets of necessary features should be characterized by strong contrast.

Method

Subjects

Subjects were 96 undergraduates from a midwestern state university.

Stimuli

Twenty-eight categories, representing four hierarchies, each of which consisted of three levels of abstractness, were used. The four hierarchies were: (a) Man-made Objects (Artifacts), which included Tools (Hammers, Saws) and Weapons (Guns, Bombs), (b) Living Things, which included Animals (Cats, Dogs) and Plants (Trees, Cacti), (c) Occupations, which included Lawyers (Real-estate Lawyers, Corporate Lawyers) and Physicians (Dermatologists, Surgeons), and (d) Relatives, which included Parents (Mothers, Fathers) and Grandparents (Grandmothers, Grandfathers). Within each hierarchy, every subordinate (i.e., every term with the exception of Man-made Objects, Living Things, Occupations, and Relatives) was paired with every other subordinate in a question of the form "Can an x be a y?". Because this method of question construction yielded three pairs in the Relatives hierarchy that were actually questions of class inclusion (mother-grandmother, father-grandfather, and parent-grandparent), these pairs were excluded from analysis. In order to keep the length of the task manageable, reversals (i.e, "Can a y be an x?") were not included among the stimulus items for any hierarchy.

For each of these categories, we had collected necessity and extrinsicity information from previous groups of subjects. The extrinsicity ratings were provided by one group of subjects (N = 15) who rated each category in terms of how much the category's rules for membership relied on information about the relationships that category members hold with other things, on a nine-point scale. Each category's extrinsicity value was the mean rating (across subjects) for that category. To collect necessity information, we first had a second group of subjects (N = 48) list the features they believed defined the category. The categories were divided into three sets; each set was "defined" by a subgroup of 16 subjects. We then

[1] An extrinsic feature may be necessary for category membership, but because the possession of the feature is situation-dependent, may not characterize even very good category members under all circumstances (see Caplan & Barr, in press, for more detail). For example, most of the subjects in that study asserted that "covers the body" is a necessary characteristic of Clothing. However, a given shirt may have other uses, depending on the situation (e.g., one may use it as a dustcloth). Thus, a feature may be necessary for category membership (e.g., in order for something to be clothing, it must cover the body), but not necessarily true of a particular exemplar in a given situation (e.g., a given shirt need not always cover the body).

combined the features listed by at least five of the 16 subjects in each subgroup with features collected from definitions in two dictionaries (*Webster's New World Dictionary of the American Language*, 1980; *Thorndike-Barnhart Desk Dictionary*, 1952). These feature lists were our feature sets. A third group of subjects (N=19) then judged each feature from the feature sets as necessary, typical, or neither for category membership. Each category's "necessity" measure was the mean (across all features from the category's feature set which received at least one "necessary" judgment) proportion of subjects who gave "necessary" judgments.[2]

Procedure

The stimuli were presented in random order in a stimulus booklet. Subjects answered "yes" or "no" to each question by filling in a circle on a computer scorable answer sheet. Every subject received every question. The subjects were tested in groups of about 20.

Results

Table 1 shows the number of subjects who assented to each question. The more subjects who assented, then the less the members of the two categories contrast. For example, 89 out of the 96 subjects agreed that a weapon could be a tool. Therefore, the members of these two categories do not contrast well. On the other hand, just three out of 96 subjects agreed that a dog could be a cat. The members of these two categories, then, do contrast well.

We had predicted that the more extrinsic the representations of the two categories, or the more probabilistic, then the more subjects would agree to questions of the form "Can an x be a y?" However, the number of features by which the two categories differ must also be taken into account, because only distinctive features can contribute to contrast. In order to make this estimate, we counted the total number of features that had received at least one "necessary" judgment from the feature sets for the two categories, and subtracted all features that the two categories shared. We then conducted a multiple regression analysis in which the number of subjects assenting to each question was the criterion variable, and the predictor variables were: (1) the number of features by which the two categories differed, (2) the degree to which the representations of the two categories were extrinsic (expressed as the mean of the two categories' mean extrinsicity ratings), and (3) the mean of the two categories' necessity values. The multiple R resulting from this analysis was .70, F (3,33) = 10.74, p < .0001. Of the three predictor variables, only extrinsicity accounted for a significant portion of the variance, ß = .78, t (33) = 3.48, p < .01 in the final regression equation; the correlation between extrinsicity and number of subjects assenting was .70.

Discussion

All pairs of categories used in this experiment do contrast, in the sense that they are drawn from different branches of the same hierarchy. Nevertheless, as the results of the analysis showed, the extent to which the *members* of the two categories contrast is determined by the degree to which the representations of the two categories are extrinsic. Extrinsically represented categories showed much weaker contrast than did intrinsically represented categories.

We were somewhat surprised to find that people's judgments of feature necessity did not predict category contrast, particularly in light of our earlier findings that categories represented by features judged by many people to be necessary showed stronger class inclusion than categories represented by features judged to be necessary by fewer subjects (Caplan & Barr, in press). If anything, our present findings regarding the necessity measure were the reverse of predictions: category pairs with higher necessity values tended to have high numbers of subjects assenting to the questions (i.e., less inter-category contrast), r = .35. In combination with our earlier findings, these results suggest that feature necessity is more critical for class inclusion than for direct and indirect contrast relations among categories of a hierarchy.

In addition, these findings suggest that the inter-category relations implied by traditional hierarchies may not always describe psychological inter-category relations. In fact, it may be inappropriate to assume that relations among categories are characterized by unqualified "is a" links, or by unqualified contrast relations. Instead, these relations depend at least on the degree to which the categories' representations rely on intrinsic or extrinsic information.

Many authors have identified difficulties in the assumption that truly necessary features exist as criteria for category membership (e.g., Medin, 1989; Murphy & Medin, 1985). We do not mean to suggest that such features have been identified, or that they are the only source of information included in people's representations of natural language categories (see Caplan & Barr, in press, for further detail). Nevertheless, the findings reported here suggest that feature-level mechanisms, such as extrinsicity, may play a useful role in explaining psychological aspects of categorization phenomena.

[2] In previous research (see Caplan & Barr, in press, for more detail), we collected judgments of both feature extrinsicity and of feature necessity. Some examples follow. For the category Clothing, the features "covers the body" and "keeps the body warm" were both judged to be extrinsic by more than half the subjects; however, the former was judged to be a necessary feature by more than half the subjects, and the latter was judged necessary by fewer than half of the subjects. For the category Birds, the features "has wings" and "sings or chirps" were both judged to be extrinsic by less than half the subjects; however, the former was judged necessary by more than half of the subjects and the latter was judged necessary by less than half the subjects.

Category Terms in Question		Necessity	Extrinsicity	Number of Subjects Assenting
X	Y			
Weapon	Tool	.48	7.00	89
Weapon	Hammer	.40	6.23	92
Weapon	Saw	.44	5.86	94
Tool	Bomb	.56	6.14	58
Tool	Gun	.56	5.94	62
Bomb	Gun	.56	5.00	31
Bomb	Hammer	.49	5.36	21
Bomb	Saw	.53	5.00	15
Gun	Hammer	.49	5.16	15
Gun	Saw	.53	4.80	14
Hammer	Saw	.46	5.16	13
Mother	Father	.60	6.20	15
Mother	Grandfather	.82	6.30	15
Father	Grandmother	.62	6.36	14
Grandfather	Grandmother	.84	6.46	14
Plant	Animal	.52	3.14	14
Plant	Dog	.56	3.07	5
Plant	Cat	.54	3.14	9
Animal	Cactus	.48	2.80	10
Animal	Tree	.56	2.94	9
Tree	Cactus	.50	3.14	43
Tree	Cat	.57	2.94	10
Tree	Dog	.60	2.87	3
Dog	Cactus	.51	2.74	5
Dog	Cat	.58	2.54	3
Cat	Cactus	.48	2.80	7
Physician	Lawyer	.72	6.07	80
Physician	Real-estate lawyer	.72	6.00	86
Physician	Corporate lawyer	.67	5.97	83
Lawyer	Surgeon	.76	6.38	80
Lawyer	Dermatologist	.78	6.07	80
Dermatologist	Corporate lawyer	.72	5.97	82
Dermatologist	Real-estate lawyer	.78	6.18	80
Dermatologist	Surgeon	.84	6.18	87
Surgeon	Real-estate lawyer	.74	6.32	80
Surgeon	Corporate lawyer	.69	6.28	74
Corporate lawyer	Real-estate lawyer	.64	6.10	85

Table 1. Number of Subjects (N = 96) Assenting to Each of the 37 Questions of the Form "Can an X be a Y?", As a Function of Mean Necessity Value and Mean Extrinsicity Rating Across the Two Categories

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