In relation to the "family resemblance" organization of features (Rosch and Mervis, 1975), more typical instances (e.g., coat in Clothing) would have Permissible as well as Obligatory features defining their membership in the category (e.g., "Used to Keep Warm" as well as "Worn"), and less typical instances (e.g., purse in Clothing) should have only Obligatory features defining their membership in the category and Impermissible features that define their membership in contrasting categories. As well, Obligatory features should vary in how they are applied to least typical instances (as in the "Worn" and purse example above), as these instances don't have Permissible feature definitions, and do have strong (Impermissible feature) connections to contrasting categories. Greater family resemblance would therefore be based on the sharing of Permissible as well as Obligatory features, and less family resemblance would be based on sharing only the Obligatory features and sharing Impermissible features with members of contrasting categories.

The organization of Obligatory, Permissible and Impermissible features should also be reflected in the taxonomic depth of categorization, as well as in cross-classifications. Where the least typical instances should have more memberships in contrasting categories (as Rosch and Mervis, 1975, found), most typical instances should belong to more subsets of the categories (see Figure 2). For example, coat should belong to the subset Warm Clothing under Clothing, because of the Permissible feature "Used to Keep Warm". This would be so because the membership of most typical instances can be defined by Permissible features, and these Permissible features in turn delimit salient subsets within the (superordinate) categories. As well, this subset level of taxonomization should be accessed before the higher, superordinate categories (in terms of least-upper-bound shared memberships), when comparing two instances that share membership in one of these subsets (e.g., coat and sweater in the subset Warm Clothing; see Figure 2). These subsets constitute part of the greater taxonomic depth that has not been traditionally studied in category research.

Experimental Procedures. All of the subjects were undergraduates in lower-division psychology classes, and all of the experimental tasks were paper and pencil tests. Each of the experiments had two tasks. In the first task of Experiment 1, subjects were asked for three categories for "most" and "least" typical instances from 4 superordinate categories, Tools, Clothing, Furniture, and Vehicles. The "most" typical instances were those instances that had received an average typicality rating of 2 or less in these categories (on a 7-point scale) in Rosch's (1975) norms, and the "least" typical instances received an average rating of 4.5 or greater. In the first task of Experiment 2, subjects were asked why most and least typical instances, and most-least typical instance pairs are members of the superordinate categories they had initially been taken from, and why the single instances are members of other categories frequently listed for them in Experiment 1. In the first task of Experiment 3, subjects were asked what is the same and different about most-most, most-least, and least-least typical instance pairs. An equal number of these different types of instance pairs were taken from three levels of categorization (as determined in Experiment 1). They either 1) shared membership in the same subset or contrasting category and the same superordinate (e.g., coat and sweater), 2) shared membership in a superordinate, but did not share membership in a subset or contrasting category (e.g., coat and pants), or 3) came from different superordinates and different contrasting categories (e.g., coat and car).

In the second task for each of the experiments, subjects were asked to compare the sets of the elicited categories and features to those of the superordinate categories (e.g., "Are all things that are worn types of clothing?" and "Are all types of clothing things that are worn?"). If they gave a "no" response, they were asked to list the exceptions (e.g., things that are worn that are not clothing).

Results. In Experiment 1, the most typical instances elicited the superordinate categories more often than the least typical instances did, both as dominant (most frequently listed) categories, $t(6) = 4.39$, p .01, and in terms of any listing of these categories for the instances, $t(6) = 3.25$, p .02. Of the other categories listed for the instances, 2 types were identified in Task 2, 1) "Contrasting" categories that have overlapping memberships with the superordinates, and 2) "Subset" categories that are subsumed within the superordinates. Comparing the most frequently listed categories in Task 1 (excluding the superordinates), most typical instances elicited a proposrtionally greater number of Subset categories, and least typical instances elicited a greater number of Contrasting categories, $X^2(1) = 6.19$, p .02.

In Experiment 2, the features given as defining the membership of most and least typical instances in Task 1 were identified in Task 2 as either Obligatory (e.g., "Are all types of clothing worn?" receiving "yes" responses), Permissible (e.g., "Are all types of clothing used to keep warm?" receiving "no" responses), or Impermissible (features given as defining membership in contrasting categories that were not given as defining in the superordinate). For each of the superordinates in Task 1, Obligatory features were the most frequently received features defining membership across most and least typical instances, and for the most-least typical instance pairs. No difference was found between most and least typical instances in the frequency with which they elicited the Obligatory features, $t(6) = .22$, n.s.. On the other hand, most typical instances elicited Permissible features as defining their membership more often than least typical instances did, $t(6) = 3.99$, p .01. As well, most typical instances elicited more Permissible features (of the superordinates) as defining their membership in the Contrasting categories they belong to, while least typical instances elicited proportionally more Impermissible features (of the superordinates) as defining their membership in the Contrasting categories, $X^2(1) = 5.21$, p .05.

In Experiment 3, the categories and features most frequently received as responses for what is the same and different about instances corresponded to the least-upper-bound level of categorization instances shared membership in (i.e., subsets, superordinates, or higher features encompassing 2 or more superordinates), $X^2(1) = 20.04$, p .001. For "what is the same" about the instance pairs, the least-upper-bound categories the instances shared membership in (or the features corresponding to these categories) were elicited (e.g., gloves and coat elicited "you wear to keep warm", and jackets and pants elicited "Clothing" and "they are worn"). For "what is different" about the instance pairs, features and categories of the level immediately below the least-upper-bound category were received (e.g., two subset distinctions for instances that share membership in a superordinate, but not in a subset, such as jackets and pants eliciting "one is worn on the upper body and the other is worn lower"). Two more taxonomic levels were identified in this experiment as well. One was a level above the superordinates generally corresponding to "Functional Artifacts" (e.g., in responses such as "Man-made" and "Used by People" received for what is the same about instances belonging to different superordinates, such as shirt and bus). The other was a level below the subsets, and was found in responses to what is different about two instances of the same subset (e.g., for the subset Seats under Furniture, the instances sofa and chair received "many people sit on one and only one person sits on the other").

In Experiment 3, evidence was also found for shifts in (delimiting or extending) the sense of a feature according to the comparison being made. A significant proportion of instance pairs were found to elicit the defining features both for what is the same about them and for what is different about them (e.g., receiving "they are worn" for what is the same about coat and purse, and receiving "one is worn and the other holds items" for what is different about this pair), $X^2(1) = 4.0$, p .05. In each of these cases, the less typical instance was excluded when the contrast of what is different was made.

Conclusions. This research shows that people use a system of cross-classification and multiple taxonomic levels of categorization in their representation and retrieval of object information. Evidence was also found for this organization of natural category information being based on the use of deontic features. Obligatory features (of the superordinates) were most frequently received as defining the membership of instances.

They were also taken to be common to all members of these categories and were the most frequently elicited features when comparing superordinate members that did not share a common subset. The Permissible features were found to correspond to subsets within the superordinates, and as well were used to define the membership of instances within the superordinates. The Impermissible features on the other hand were not used to define membership in the superordinates, but were used to define membership in contrasting categories and distinguish why least typical instances are different from most typical instances.

This system of categorization and the use of deontic features may well explain "family resemblance" structuring (Rosch and Mervis, 1975). The greater "family resemblance" of most typical instances to other members of a category may come from the greater number of Permissible features which define their membership (these features being used to define their membership in contrasting categories as well), and the greater number of Subset categories they belong to. Least typical instances may bear less resemblance to other members because 1) their membership is defined primarily by Obligatory features, 2) they are members of more contrasting categories, and 3) their membership in these contrasting categories is defined by Impermissible features.

In contrast to Rosch and Mervis's (1975) "family resemblance" model, Obligatory features are taken to be common to all members, and to define the membership of instances. These features are not necessary features however, as they can be said to be applicable and not applicable to an instance, depending on the sense they are taken in. As found here, this use of Obligatory features is most evident in their application to least typical instances. As McCloskey and Glucksberg (1978) found, such boundary cases are far more subject to changes in opinion and differences in opinion in the determination of their membership. Obligatory features can therefore be used to define/determine membership of a borderline instance, when extended to a more general sense. They can also be used to exclude an instance when category contrasts are being made, and a more delimited sense of the feature is used.

As to how this extending and delimiting of senses is done can be seen in the following examples. Where an Obligatory feature (such as "Used to Build" for Tools) can be taken to be applicable to all instances of a category in its more general sense, it may also be used in a "delimited" sense (e.g., as synonymous to "Putting (Joining) Things Together", which denotes a subset with sibling relations to "Taking Things Apart", "Making Holes", etc.). The delimited senses of Obligatory features may therefore be constructed through references to Permissible features and subsets (e.g., "Putting Things Together"). The more general senses would come from combining the Permissible feature, subset definitions (e.g., "Putting Things Together" and "Taking Things Apart", etc.). Or, an Obligatory feature may be used in an "extended" sense, the outer limits of extension being metaphor (e.g., with an Obligatory feature for Vehicles, "Gets you from one place to another" being extended to books).

Applications for Computer Knowledge Bases. This model has strong advantages for the programming of natural category information in computer knowledge bases. The present model indicates means for constructing a clearly defined structure of knowledge representation within which each piece of information has a specific location and can be accessed according to it's location. Well-structured, taxonomic inheritance is possible given the specification of cross-classifications and taxonomic levels of information (four general levels having been initially determined in the present research for simple object names). At the same time, typicality gradients of membership and "fuzzy" category boundaries can be handled without having to refer to prototype-related default values.

This power is dependent upon the deontic nature of the featural definitions, rather than categories being "well defined". That is, the deontic features are generic norms which are not invalidated by individual cases, and for which the senses can be shifted. This shifting of senses though is based upon the systematic extending and delimiting of instance sets. The means for this extension and delimitation was seen in the "Used to Build" example given earlier.

What does appear to be necessary to make this system of taxonomic structuring and inheritance work, is the ability to establish the different category sets and senses through the use of immediate "contexts". This use of "context" can be seen in the findings reported here (Experiment 3) on the accessing of specific taxonomic levels and the delimiting of senses, based on the objects being compared and the type of comparison (same or different) being made. This is similar to Artificial Intelligence work being done on interactive systems (e.g. Grosz's, 1981, "global focus" and Sidner's, 1983, "immediate local focus"). These processes are, of course, dependent on discourse. This appears to be the strength of deontic features however, that is, that they can be interpretted (and re-interpretted) during the negotiation of meanings. At the same time, the "interpretibility" of these features need not undermine the well-structured characteristics of this representation system. As with the "Used to Build" example given earlier, delimiting the sense of this feature to "Putting Things Together" is done by referencing an already-specified subset. An important characteristic of this model is, therefore, that meanings and shifts in senses can be established through reference to quantified instance sets.

The details of programming this system of representation do still need to be worked out. For example, in using the taxonomic inheritance structure of the knowledge representation language KL-ONE, what is true of a concept must be true of all its decendents. Therefore, how a shift in the sense of an Obligatory feature such as "Worn" would effect the sense of a Permissible feature decendent such as "Worn by Women" still needs to be attended to. It is felt though that the present model does hold promise for the programming of computer knowledge bases.

Finally, it should be noted that the "interpretable" nature of deontic features may be based upon a "functional" character of these features. Approximately three quarters of the features elicited in the research reported here were either "functional" features (e.g., "Used", "Used to Build" and "Holds Things") or had functional components (e.g., the feature "Used in Houses" having a functional component and a locational component, "In Houses"). As taken here, "functional" is broadly defined as the functions or purpose of an object, an action performed with it, or an action of an object independent of an agent. This broad definition of "functional features" could also be applied to natural kinds (e.g., "plants grow") and to abstract concepts (as seen in the extensions to metaphorical senses mentioned earlier), though further research is necessary to determine how these features are used with these types of concepts. As well, a number of other types of features had functional correlates. For example, the (structural) feature "Blade" and the (physical) feature "Sharp" have the (functional) correlate "Used to Cut". This use of functional information is in line with Miller and Johnson-Laird's (1976) proposal that functional "schemata" can be used to translate perceptual features into functional conditions. This character of functional features is relevant to the interpretiblity of features in context (Miller, 1976) and extensions to less typical instances. For example, a tree stump may be included as a Table (or a "Thing to Put Things On") in the context of a "picnic".

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