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Author
Ahn, Woo-kyoung

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# Effects of Background Knowledge on Family Resemblance Sorting and Missing Features

**Woo-kyoung Ahn**

Department of Psychology
University of Michigan
Ann Arbor, MI 48104
Wookyoung_ahn@um.cc.umich.edu

**Abstract**

Despite people's strong bias to sort exemplars based on a single dimension, various situations where family resemblance (FR) categories tend to be created have been identified. In a previous study (Ahn 1990b), knowing prototypes or theories underlying categories led subjects to create FR categories. The current study investigates why existence of background knowledge encourages creation of FR categories. Comparison of results from two experiments indicates that there is no intrinsic tie between knowing theories or prototypes and FR structure. The role of background knowledge on FR sorting seems to lie in leading subjects to weight dimensions equally, in helping them to infer unavailable values in favor or FR sorting, and / or in relating surface dimensions in terms of a deeper feature.

## Introduction

The general consensus is that natural categories do not have defining features and members in the same category are related in terms of a family resemblance (FR) principle: exemplars in the same category are generally similar to each other, but exemplars in different categories are dissimilar to each other (Rosch & Mervis 1975; Smith & Medin 1981). Along with this principle, it has also been expected that when sorting unclassified exemplars, people achieve a compromise between maximizing within-category similarity and minimizing between-category similarity (Rosch 1975). Unlike Rosch's prediction, however, subjects in free sorting experiments show a strong bias to sort exemplars based on values on a single dimension and create categories with defining features (Ahn 1990a; Ahn & Medin 1989; Imai & Garner 1965 1968; Medin, Wattenmaker, & Hampson 1987).

When do we observe FR category construction? Previous research shows that FR categories can be created through two stages where the first stage involves uni-dimensional sorting of exemplars into a prescribed number of categories and the second stage involves assigning exceptional exemplars into initially created categories based on their overall similarities (Ahn 1990a; Ahn & Medin 1989). FR categories can also be created when people know underlying dimensions or theories of surface dimensions and perform uni-dimensional sorting based on the deeper dimensions (Ahn 1990b; Medin et al 1987).

The current study concerns why background knowledge helps people create FR categories. Four possible reasons are investigated: (a) There is some intrinsic link between prototypes or theories and FR structure, (b) the background knowledge changes weights of dimensions, (c) the background knowledge helps people infer unavailable information, and (d) a deeper dimension constructed by underlying theories can be serve as a basis as uni-dimensional sorting. This paper first briefly reviews previous studies on the effect of background knowledge in FR categories. Then two experiments testing the above four possibilities is presented.

## Previous Studies on FR Sorting

**Sorting in Knowledge-Poor Domains.** In previous category construction experiments, subjects have shown a strong tendency to create categories with defining features. To capture this bias, Ahn and Medin (1989) proposed a two-stage model of category construction; people first sort exemplars based on the most salient dimension and then in the second stage they assign remaining exemplars based on their overall similarity to the initially created categories.

Ahn and Medin argued that the reason why FR sorting was not observed in the previous experiments was that the examples had characteristic features that would appear in contrast categories. Therefore, if subjects carry out uni-dimensional sorting in the first stage based on these characteristic features, FR categories could not be created. Take an example from the sets used in Ahn and Medin (1989) shown in Figure 1 under Characteristic Set. (There are ten examples with four dimensions (D1, D2, D3, and D4) in each set. They are represented in terms of the example number (e.g., E1), and values (0, 1, or 2) for each dimension. The examples in the same column (e.g., E1, E2, E3, E4, and E5) belong to the same category if the set is grouped according to the FR principle. )

Sufficient Set

| | D1 | D2 | D3 | D4 | | D1 | D2 | D3 | D4 |
|---|---|---|---|---|---|---|---|---|---|
| E1 | 0 | 0 | 0 | 0 | E6 | 2 | 2 | 2 | 2 |
| E2 | 0 | 0 | 0 | 1 | E7 | 2 | 2 | 2 | 1 |
| E3 | 0 | 0 | 1 | 0 | E8 | 2 | 2 | 1 | 2 |
| E4 | 0 | 1 | 0 | 0 | E9 | 2 | 1 | 2 | 2 |
| E5 | 1 | 0 | 0 | 0 | E10 | 1 | 2 | 2 | 2 |

Characteristic Set

| | D1 | D2 | D3 | D4 | | D1 | D2 | D3 | D4 |
|---|---|---|---|---|---|---|---|---|---|
| E1 | 0 | 0 | 0 | 0 | E6 | 2 | 2 | 2 | 2 |
| E2 | 0 | 0 | 0 | 1 | E7 | 2 | 2 | 2 | 0 |
| E3 | 0 | 0 | 2 | 0 | E8 | 2 | 2 | 1 | 2 |
| E4 | 0 | 1 | 0 | 0 | E9 | 2 | 0 | 2 | 2 |
| E5 | 2 | 0 | 0 | 0 | E10 | 1 | 2 | 2 | 2 |

**Figure 1. Structure of Examples used in Ahn & Medin (1989)**

Suppose the task is to create two categories. Then regardless of which dimension is chosen as the initial defining feature, the resulting categories cannot be FR categories.

On the other hand, consider the Sufficient Set. The resulting FR categories from this set consisted only of sufficient features (i.e., 0's and 2's). Suppose the first dimension was chosen for the most salient dimension in the first stage. Then the model categorizes E1, E2, E3, and E4 into one category and E6, E7, E8, and E9 into another category. In the second stage, one of the remaining exemplars, E5, is grouped with E1, E2, E3, and E4, and E10 is grouped with E6, E7, E8, and D9, based on overall similarity. As a result, the final categories have an FR structure.

In Ahn and Medin's experiments, as predicted by the model, no subjects given the Characteristic Set created FR categories whereas more than half of those given the Sufficient Set created FR categories. This failure to obtain FR categories from the Characteristic Set was a very robust effect that appeared in various types of materials as long as subjects could not use any existing background knowledge. (See also Ahn, 1990a.)

**Sorting in Knowledge-Rich Domains.** Ahn (1990) extended these results using materials in which some hypothetical background theories could be developed. For example, in one set of stimuli, subjects received pictures of flowers and one group of subjects, called Theory Group, received a theory about how each class of flowers can attract a hypothetical group of birds or bees. In the other group (Prototype Group), subjects simply received prototypes of the resulting FR categories before they started sorting. The structure of the exemplars was the same as the Characteristic Set in Figure 1. Using these materials, the Theory and Prototype Groups mostly produced FR sorting. Providing knowledge or an underlying theory before sorting had the greatest influence on producing FR sorting. In contrast, when no background knowledge was provided (Control Group), few FR sortings were obtained.

It is not clear why prototypes and underlying theory helped people create FR categories. Ahn (1990) provided three suggestions. First, there might be some intrinsic link between prototypes or theories and FR sorting. If this is the case, then providing background knowledge should result in FR sortings regardless of types of materials or domains. The two experiments presented in this paper used materials from two different domains in order to test effectiveness of different types of background knowledge.

Second, the effect of background knowledge on FR sorting might derive from its role in helping people infer missing features. In Ahn (1990b), the 1's in Figure 1 did not have particular values and subjects were told that these values were not available for the exemplars. Many real world cases seem to have features that are unavailable to us. Then, background knowledge might help people infer these parts of instances in accordance with the values in prototypes or theories that are the most similar to the instances in other respects. To test this possibility, in the current experiments the non-characteristic value 1's were either present or absent. Given an instance, 0 0 0 1, for example, if the value 1 is absent and if background knowledge would help people assume it is 0, then it would be more likely for 0 0 0 1 to be grouped with 0 0 0 0 than when the value 1 takes an actual value.

Third, although both the Prototype Group and the Theory Group produced more FR sorting in the previous experiment, the processes involved in FR sorting might be different in the two groups. The subjects' protocols in the previous experiment indicate that the Prototype Group seemed to be able to get over the strong bias of uni-dimensional sorting and instead they seemed to assign equal weights on all four dimensions present. Still, they seemed to treat the dimensions independently. On the other hand, the Theory Group seemed to abstract an underlying dimension of each category (e.g., degree of attracting hypothetical birds or bees in the above example) and consider how values in a given exemplar as a whole satisfies this underlying dimension. The difference in strategies seems subtle but the results from the following two experiments will be discussed in terms of this conjecture.

## Experiment 1

### Method

**Procedure.** Subjects received a set of exemplars and were asked to sort them into two groups of any size. After they sorted the exemplars, they wrote down how and why they created the categories.

| Dimensions | Value 0 | Value 2 | Value 1 |
|---|---|---|---|
| 1. types of clothes | cotton | leather | silk |
| 2. types of religion | monotheism | polytheism | atheism |
| 3. types of leadership | hierarchical leaders | a single leader | three leaders |
| 4. types of funeral | buried the dead | cremated the dead | buried in river |

**Table 1. Dimensions and Values used in Experiment 1**

**Design and Material.** The design of the experiment was a 3 (types of background knowledge) X 2 (presence or absence of value 1) between-subject factorial design. The structure of exemplars are the same as the Characteristic Set in Figure 1. The four dimensions and the values used for 0, 2, and 1 are illustrated in Table 1. The value 1's were present only in Presence Condition. In Absence Condition, no value was present and subjects were told that these values were not available.

Within each Presence / Absence Condition, there were three groups depending on types of background knowledge they received before sorting. The types of background knowledge that the subjects received were either none (Control group), prototypes (Prototype Group), or underlying theories (Theory Group). The Control Group which did not receive any information was simply asked to sort ten cards in a way that seemed natural to them. The Prototype Group received eight non-prototype exemplars (i.e., eight exemplars except for 0 0 0 0 and 2 2 2 2 in Figure 1) to be sorted. They also received two prototypes of the potential FR categories before sorting and were told that these were the most typical exemplars of the two categories that they were to create. The Theory Group received only the eight non-prototype exemplars coupled with theories underlying each category they were to create. More specifically, they were told that one type of tribes were agricultural tribes and the other group were nomadic tribes. Then they were told that agricultural tribes wore cotton clothes obtained in their farms, were monotheists because they hardly had any chance to encounter other types of religion, had hierarchically organized leaders to control farmers living in their areas, and buried the dead near their farms. Subjects were also told that nomadic tribes wore leather clothes obtained from their hunting, were polytheists because they had contacted many types of religions while travelling, had a single leader to make flexible and quick decisions in their changing environments, and cremated the dead because they were always on the move.

There were 150 subjects randomly assigned to 6 groups with 25 subjects in each group.

## Results

The results are summarized in Figure 2. Numbers indicate percentages of FR sorting within each group within each set. Other responses were uni-dimensional sorting except for one or two in each group.

**Comparison between Absence and Presence Condition.** Overall, the Absence Condition produced more FR sortings in all three groups. The chi-square test (or the Fisher's exact test where it is appropriate)

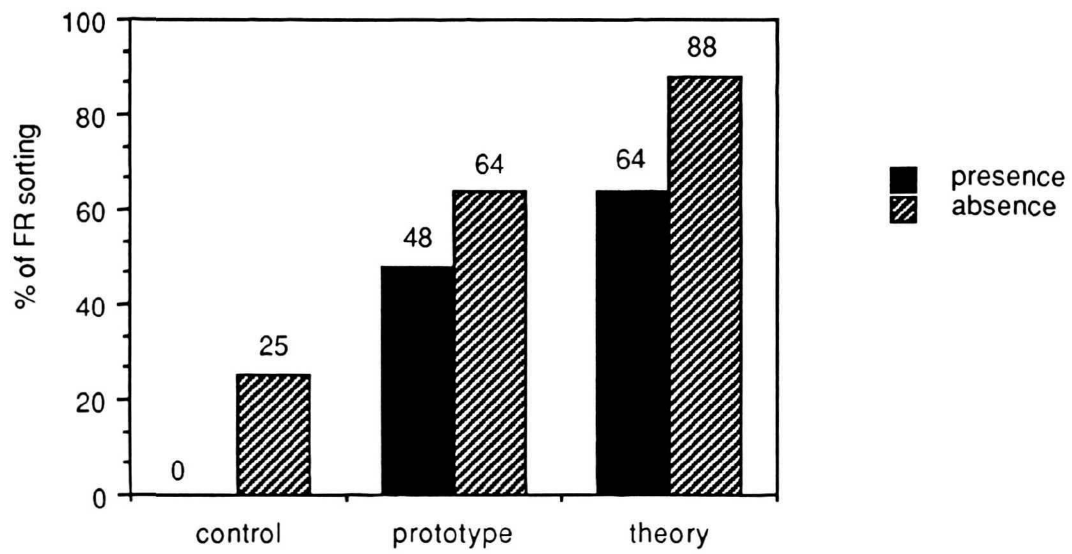


**Figure 2. Results of Experiment 1**

indicates a main effect of the Absence / Presence manipulation. Within each instructional group, the differences between the Absence and the Presence condition were significant for the Theory and the Control Groups ($p<0.05$) but it was not significant for the Prototype Group although the direction of the difference was consistent with other groups.

**Comparison among Groups within Each Condition.** Overall, in each condition, the Theory Group produced FR categories most frequently and the Prototype Group produced them next most frequently. Only a few FR sortings were obtained from the Control Group as in the previous studies (Ahn & Medin 1989). Within each condition (Presence / Absence), the pairwise comparisons among three groups were all significant ($p<.05$) except for the difference between the Prototype Group and the Theory Group in the Presence Condition.

## Experiment 2

### Method

The design and procedure of Experiment 2 were exactly the same as in Experiment 1. The materials used for Experiment 2 were descriptions of skin diseases instantiated for the Characteristic Set in Figure 1. The four dimensions and values are illustrated in Table 2. As in Experiment 1, value 1's were present only in the Presence Condition.

There was a slight change in instructions to make the sorting task more realistic. All subjects were told that each card had a description of one patient and that these patients suffered from inflammatory diseases of the skin and subcutaneous tissue characterized by tender red nodules. They were also told that their symptoms were very similar, but medical doctors had found that there were actually two different types of diseases with these symptoms and that it was important to distinguish these two skin diseases because they required different types of treatment. Then they were told about the four dimensions. The rest of the instructions for the Control Group and the Prototype Group were similar to those in Experiment 1.

For the Theory Group, subjects received the following additional instructions. They were told that Disease A was caused by Virus XB5 whereas Disease B involved symptoms associated with Ketasysm, which was a technical term for abnormal fat metabolism. Since Disease A was caused by an external virus in contact with the skin, the major infection usually, but not necessarily, appeared around exposed areas such as face, hands, and neck, it usually showed sudden onset because symptoms appeared as soon as a person contacted the virus, few family members of the patient had the same skin disease because the disease was produced by external agent, and the lesions were at first sharply limited to the site of contact and later spread to neighboring areas. On the other hand, since Disease B was produced due to Ketasysm, the major infection of Disease B usually appeared in hidden areas such as the abdomen and thighs where body fat was most concentrated, it usually showed gradual onset as Ketasysm progressed, about 50% of the patient's family members had history of the same skin disease due to genetic characteristics of Ketasysm, and the lesions were not sharply limited to a local area because body fat distribution was not sharply distinguished.

There were 120 subjects randomly assigned to 6 groups with 20 subjects in each group.

### Results

The results are summarized in Figure 3.

**Comparison between Absence and Presence Condition.** As in Experiment 1, the Absence Condition produced more FR sortings in all three groups. The chi-square test (or the Fisher's exact test where it is appropriate) indicates that the overall difference between the Absence and the Presence condition were marginally significant ($p=0.06$). Within each group with different background knowledge, only the difference between the Absence and the Presence Conditions of the Prototype Group was significantly different.

**Comparison among Control, Prototype, and Theory Groups.** There was a large main effect of type of background knowledge ($p<0.001$). Interestingly, however, the direction of the differences showed a pattern different from Experiment 1. Overall, the Prototype Group produced FR categories most frequently (80%) and the Theory Group produced next most frequently (72.5%). Again, only a few FR sortings were obtained

| Dimensions | Value 0 | Value 2 | Value 1 |
|---|---|---|---|
| 1. area of infection | face, hands, and neck | abdomen and thigh | hands and thigh |
| 2. onset | sudden | gradual | neither sudden nor gradual |
| 3. % of family members with the same disorder | no family members | 50 % of family members | 25% of family members |
| 4. boundaries of lesion | sharply limited | not sharply limited | somewhat moderately sharp boundaries |

**Table 2. Dimensions and Values used in Experiment 2**

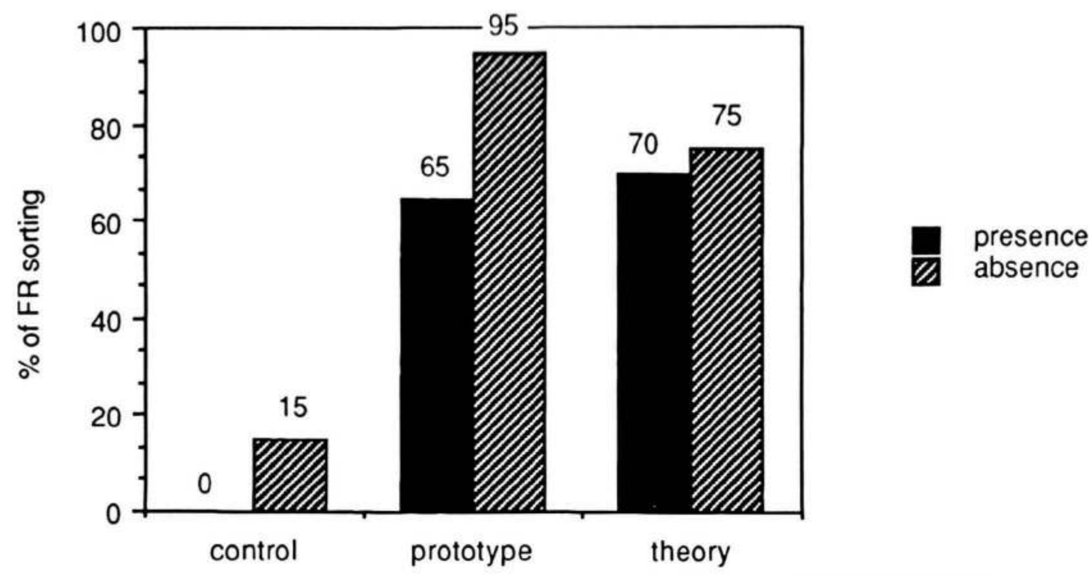


**Figure 3. Results of Experiment 2**

from the Control Group as before. Within the Absence Condition, the Prototype Group produced significantly more FR sortings (95%) than the Theory Group (75%), which in turn produced more FR sortings than the Control Group (15%). Within the Presence Condition, the Theory and the Prototype Groups produced more FR categories than the Control Group but no difference was found between the Theory and the Prototype Groups.

## General Discussion

### General Effect of Background Knowledge

The basic results of Experiments 1 and 2 replicated the previous findings in Ahn (1990). Knowing underlying theories or prototypes before sorting led to more FR category constructions.

### Differences Between Theory and Prototype

However, the Theory Group was not always more likely to produce FR sorting than the Prototype Group as shown in Experiment 2. This result suggests that knowing theories is not necessarily better than knowing prototypes in producing FR sortings. Instead, the advantage of knowing underlying theories in producing FR categories seems to depend on factors such as domains.

### Differences Between Theory and Prototype with Respect to Missing Features

Comparing the Absence and the Presence Conditions in Experiment 1, FR sortings were obtained more frequently when the value 1 was absent. In Experiment 2, however, this difference disappeared in the Theory Group whereas it still appeared in the Control and the Prototype Groups. These results suggest that there might be some differences between simply knowing surface features (Control and Prototype Groups) and knowing deeper features (Theory Group).

The reason why the Control and Prototype Groups produced more FR sorting in the Absence Condition seems to be the following. In these groups, subject might fill or infer unknown features with values that are consistent with correlational structure shown in other similar instances or prototypes. The other possibility is that if people follow the two-stage model, the absence of value 1 on the most salient dimension used in the first stage might force them to pay attention to the other dimensions, resulting in sorting based on all the present dimensions.

To investigate reasons why the Theory Group showed different patterns across the two experiments, the differences between the two experiments in materials and instructions were further analyzed. First, the types of features were different. In Experiment 1, the values were used as nominal values so that value 1's, when they were present, are not intermediate values between value 0's and 2's. In contrast, the values in Experiment 2 were continuous in that value 1's always were a middle or a mixture of the two extreme values on the same dimension.

How could the different types of dimensions lead to differences in the two Theory Groups? Perhaps the Theory Group is doing a special kind of uni-dimensional sorting where the defining dimension is the underlying dimension constructed by the theories. If this is the case, the continuous values used in Experiment 2 have more advantages over the nominal values in Experiment 1 because continuous values might be easier to be incorporated. Take an example of the tribe stimuli. If a person knows theories about why a tribe wearing cotton clothes tends to be monotheistic, it would be much more difficult to explain why a tribe wearing silk clothes (i.e., nominal value) tends to be monotheistic than to explain why a tribe sometimes wearing cotton clothes and sometimes leather clothes (i.e., continuous value) tends to be monotheistic. That is, for 'silk clothes', subjects had to develop a new explanation for the novel feature. This idea needs to be tested in more systematic ways in future studies.

The second difference between Experiments 1 and 2 is that in Experiment 2, the goal of sorting was specified (i.e., treatment of diseases). Also the theories in Experiment 2 were in terms of causes of diseases. Several investigations of lay people's belief in psychopathological disorders showed that people have a strong belief in the interaction between causes of disorders and their treatment. For example, if people believe schizophrenia is an innate disorder, they believe the appropriate treatment is hormonal and not behavioral (e.g. Furnham 1988). Due to this kind of existing belief, the Theory Group might have given more weight to those dimensions that seem to be a better indicator of causes no matter whether the value 1 was present or absent. This peculiarity of domains can also serve as an explanation for why the theories in Experiment 2 were not as effective as those in Experiment 1 in comparison to prototypes.

### Conclusion

All of the issues discussed above deserve further investigation. What can be concluded from the current studies seem to be the following. First, there seems to be no intrinsic tie between theories and family resemblance sorting. The advantage of theories over prototypes depends on domains, the goal of category construction, and the types of theories. Secondly, exemplars with missing features are more easily categorized in terms of the FR principle than exemplars with non-characteristic features. This result suggests that FR structure might be obtained because sometimes we do not have complete information about instances, and we infer these missing features in accordance with other similar features.

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