Are natural kinds psychologically distinct from nominal kinds? Evidence from Learning and Development

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Abstract

Known theories of categorization operate under the assumption that most concepts are fundamentally similar. The current research argues that this assumption is unwarranted: Different types of concepts may differ in how they are represented and learned. We specifically focus on natural-kind and nominal-kind concepts, concepts that differ in their statistical structure. Natural kinds consist of highly redundant and intercorrelated features, whereas nominal kinds consist of isolated rules that do not correlate with other features. If these types of concepts are fundamentally different, they should exhibit important dissociations in how they are learned. Two learning regimes were contrasted: one in which participants were shown instances of the concept without being given a definition of the concept (implicit learning regime), and one in which participant were given a definition of the concept without being shown individual instances (explicit learning regime). Preschoolers and adults participated. The results show a strong dissociation between the two kinds of concepts in terms of acquisition, indicating that existing theories of categorization are incomplete.

Introduction

The ability to form categories by overlooking differences for the sake of generality is a critically important component of cognition. While the importance of concepts and categories is widely accepted, a number of puzzling questions remain unanswered. How do categories arise? Which processes underlie categorization? And how are categories represented in the cognitive system?

Several influential approaches have emerged in an attempt to answer these questions. According to the "classical view," categories are represented by sets of features that are individually necessary and jointly sufficient to determine category membership (Bruner, Goodnow, & Austin, 1956; Vygotsky, 1986/1934; for a review see Smith & Medin, 1981). For example, the concept *prime number* includes two features: an integer, and no remainder when divided by one or by itself. Each feature is necessary and they are jointly sufficient to determine whether or not a number is a prime.

By the 1980s, the classical view came under severe attack for its inability to predict and account for several key phenomena in the study of concepts, such as, for example, the gradedness of category membership. (Mervis & Rosch, 1981; see also Murphy, 2002, Smith & Medin, 1981, for extensive reviews).

With the demise of the classical view, two theoretical approaches to conceptual development have emerged: the naïve-theory approach and the similarity-based approach. The naïve-theory approach argues that even if there are no truly defining features, features differ in their conceptual centrality, this centrality being often determined by a feature's causal status (Medin, 1989; Gelman & Coley, 1991; Keil, Smith, Simons, & Levin, 1998). For example, apples and basketballs are round, but the feature "roundness" is more central for basketballs than it is for apples.

On the contrary, the similarity-based approach suggests that categorization decisions are made on the basis of similarity between a to-be-categorized entity and existing categories (see Murphy, 2002; Sloutsky, 2003, for reviews). Categories could be represented as best examples or prototypes (Posner & Keele, 1968, Rosch & Mervis, 1975) or as sets of encountered exemplars (e.g., Nosofsky, 1986, 1992). In the former case, an entity is categorized as A if it is similar to A's prototype, whereas in the latter case an entity is categorized as A if it is similar to individual exemplars of A encountered previously.

Despite the differences among these theoretical approaches, there is an important commonality – they implicitly assume that all (or at least most the concepts) concepts are fundamentally the same, and therefore, that concepts have to be learned and represented in the same or a similar way.

However, it is possible that there are different classes of concepts that give rise to different types of representation. The particular distinction considered here can be mapped onto the normative distinction between *natural kinds* and *nominal kinds* (Kripke, 1972; see also Keil, 1989, for a review). Natural kinds refer to classes of entities that exist in nature (e.g., *bird*), and nominal kinds refer to more arbitrary groupings based on a small set of necessary and sufficient properties (e.g., *triangle, acceleration*).

Natural kinds may differ in several ways from nominal kinds. However, the difference highlighted in the current experiments pertains to the difference in their statistical structure. Natural kinds have a rich correlational structure, meaning that the relevant features correlate among each other. For example, creatures that lay eggs also have feathers and fly. Nominal kinds, on the other hand, lack such correlations among relevant features. They are based instead on an isolated rule. For example, accelerated motion does not have any common features with other motions except the change in velocity or the change in vector of the moving body.

It seems that the classical view of categorization considered nominal kinds as most representative concepts, whereas the similarity-based positions considered natural kinds as the most representative ones. The current study asks whether the normative distinction between natural and nominal kinds is accompanied by a psychological distinction between these two types of concepts. If true, such psychological distinction should manifest itself in how natural kinds and nominal kinds are represented and learned. The goal of this research is to examine dissociations in learning of natural and nominal kinds.

Statistical Structure of Concepts

To reiterate, natural-kind concepts often have multiple correlations among features of category members. Nominal kinds, on the other hand, are typically based on a small set of features uncorrelated with other features. It could be said then that natural kinds are statistically dense, embedded in multiple redundancies, whereas nominal kinds are statistically sparse, that is based on a single rule embedded in irrelevant variance.

Because natural kinds are statistically dense, it is possible that natural kinds are acquired spontaneously and do not require explicit training. Even infants are sensitive to multiple correlations and can spontaneously acquire categories based on multiple correlations. (e.g., Younger, 1993). Therefore, is likely that the mere exposure to instances of a natural kind could suffice for the acquisition of the concept. For example, infants may learn to group dogs together after seeing a variety of dogs (Quinn, Eimas, & Rosenkrantz, 1993). The basis for this learning is extraction of statistical information from a set of exemplars (Mareschal & Quinn, 2001). In fact, explicit training of a natural-kind category may hurt the acquisition of the natural kind. Billman and Knuston (1996) showed that in an unsupervised-learning setting, adults could learn the concept that was based on redundant relations, while failing to learn the concept when it was based on an isolated or orthogonal relation.

Nominal kinds are statistically sparse, meaning that they lack redundancy, and that only a limited set of features or feature relations is relevant. Because only a small portion of total information is relevant for the membership in a concept, it might be difficulty for the learner to spontaneously determine what is relevant, without having explicit instruction. This might be especially true for relational concepts, those that are based on a relation among features, not the features themselves (e.g., the concept of *ratio*). There are few reasons to believe that mere exposure to a limited set of instances would result in an acquisition of a relational concept. On the contrary, even feedback-based learning of relational concepts proved to be a challenge (e.g., Bruner, et al., 1956).

Based on these considerations, we hypothesize that there might be an acquisitional dissociation between natural and nominal kinds, with the former requiring unsupervised exposure (i.e., implicit learning regime), and the latter requiring an explicit instruction about the relevant rule (i.e., an explicit learning regime).

Overview of Experiments

In the three reported experiments, we systematically manipulated two factors: the type of the concept to be learned (“natural kind” vs. “nominal kind”) and the learning regime (implicit learning regime vs. explicit learning regime). Preschool children (Experiment 1) and adults (Experiment 2 and 3) participated in the four resulting conditions: implicit or explicit learning of a concept that mimics natural kinds, and implicit or explicit learning of a concept that mimics a nominal kind.

For both kinds of concepts, the same animal-like artificial stimuli were created, such that none of the single features were predictive of the category membership. Only the relations between features mattered. Similar to natural kinds in the real world, the natural kind of the current experiment was based on multiple correlations among features (e.g., creatures that had a dark body also had a long tail and lots of wings). Conversely, in the nominal kind of the current experiment only one, arbitrary selected, relation was predictive of category membership.

In the implicit learning regime, the learners were presented with instances of the target category without being told the defining rule of the category. Conversely, in the explicit learning regime, the learners were given the defining rule of the category without being shown specific instances.

We predicted an interaction between learning regime and kind of concept. The concept that is based on redundant relations (i.e., “natural kind”) should be best learned in the implicit learning regime, and the concept that is based on an isolated relation (i.e., “nominal kind”) should be best learned in the explicit learning regime.

Experiment 1

The goal of the first experiment was to examine the acquisition of natural-type and nominal-type concepts under different learning regimes by young children.

Method

Participants Participants were 61 5-year-olds (32 girls and 29 boys), recruited from suburban middleclass preschools. The mean age in each condition (natural/implicit, natural/ explicit, nominal/implicit, nominal/ implicit) in months was 58.1 (*SD* = 4.6), 61.9 (*SD* = 2.7), 60.4 (*SD* = 5.2), and 60.3 (*SD* = 4.7), respectively. Additional 28 children were tested (*n* = 8, 5, 7, and 8 in the respective conditions) and omitted from the sample because their performance in the catch trials did not meet the criterion (see Procedure).

Stimuli The stimuli were colorful drawings of unfamiliar animals presented on a computer screen. Each instance had the following six parts: a body, antennas, horizontal and vertical wings, a tail, and buttons on the body (Figure 1). These six parts could vary in at least one characteristic. They could vary in size (e.g., long or small tail), in shade (e.g., dark or light body), or in number (e.g., few or lots of buttons).

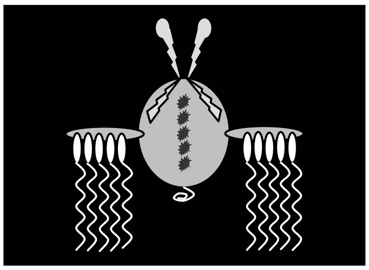

Figure 1: Example of the stimuli.

Two types of categories were created, one that included multiple correlations of features (i.e., they approximated a natural kind), and the other that were based on a single arbitrary selected relation (i.e., they approximated a nominal kind). Each type of category consisted of a target category and a contrasting category. Table 1 shows examples of items to illustrate how stimuli differed between natural and nominal kinds, and between target category and contrasting category.

For the natural kind, the sizes, shades, and number of parts correlated systematically. In the target category, a light body had light antennas, short horizontal wings, a short tail, few vertical wings, and few buttons. And a dark body had dark antennas, long horizontal wings, a long tail, many vertical wings, and many buttons. In the contrasting category the correlations were reversed. For example, a light body went with dark antennas, short horizontal wings, a long tail, few vertical wings, and many buttons. No single feature was predictive of the category.

For the nominal kind, only the number of parts mattered, while the correlations among sizes and shades were varied randomly. In the target category, there were *more* buttons than tails and vertical wings together, and in the contrasting category, there were *fewer* buttons than tails and vertical wings together. The numbers of buttons, tails, and vertical wings were chosen in such a way that neither the number of a single part nor the correlation between two of the parts were predictive. This ensured that no other information (e.g., difference in quantity) was redundant with the rule.

An additional set of stimuli was created that functioned as catch items. These items were from the contrasting category but with very salient changes. They had a diamond shaped body, no buttons, and no horizontal wings.

Table 1: Structure of Exemplar Items Used in Experiments 1 and 2

	Target Cat.		Contrasting Cat.	
	Item 1	Item 2	Item 1	Item 2
Natural Kind				
Parts				
Body	light	dark	light	dark
Antennas	light	dark	dark	light
Horiz. wings	short	long	short	long
Tails	short	long	long	short
Vert. wings	few	many	few	many
Buttons	few	many	many	few
Nominal Kind				
Parts				
Tails	1	3	3	5
Vert. wings	4	2	4	6
Buttons	7	9	5	9

Note. For the nominal kind, the numbers refer to the actual number of a particular part for the nominal kind (e.g., 1 = one tail).

Procedure The cover story presented to children involved the creature Fritz who lives on planet Elbee and who would like to get a pet. Pets on planet Elbee are called Ziblets and come from a magical store that carries both pets and dangerous wild animals. Children's task was to determine whether or not an animal from this magical store is a Ziblet.

The procedure had two phases: a training phase and a testing phase. In the training phase, children were given information about Ziblets (target category in Table 1). In the implicit learning regime, they were shown 24 pictures of Ziblets, presented one by one. They were told: "I will show you the Ziblets that other families on planet Elbee have as pets. Can you look at them and try to remember them?" In the explicit learning regime, children were presented with the defining rule. They were either told (for the natural kind) "A Ziblet with a dark body has dark antennas, long horizontal wings, a long tail, one or two short vertical wings and two or three light buttons; and a Ziblet with a light body has light antennas, short horizontal wings, a short tail, four or five long vertical wings and five or six dark buttons", or they were told (for the nominal kind) "For a Ziblet, the number of buttons is smaller than the number of tails and vertical wings together". Each separate part mentioned in the rule (e.g., a long tail) was depicted on the computer screen.

The testing phase was identical in both learning regimes. Sixteen testing trials were presented in random order, half of them being instances of the target category (Ziblets) and half of them being instances of the contrasting category (Non-Ziblets). Children's task was to determine whether an instance is a Ziblet or not. Six catch trials followed intermixed with instances of the target category. To be included in the study, children had to reject four of the catcher trials.

Results and Discussion

Accuracy scores were calculated for each participant by subtracting the number of correctly accepted Ziblets from the number of incorrectly accepted Non-Ziblets and transforming the difference into a proportion. An accuracy score of zero (i.e., no difference between proportion of hits and proportion of false alarms) would be expected by chance.

Figure 2 shows the mean accuracy scores for each condition. A 2 (concept: natural, nominal) by 2 (learning regime: implicit, explicit) between-subjects ANOVA revealed a significant interaction ($F(1,53) = 14.46$, $p < .001$), with the mean accuracy scores being above chance in the conditions natural/implicit ($t(15) = 4.07$, $p < .01$) and nominal/explicit ($t(15) = 3.2$, $p < .01$) but not in the conditions natural/ explicit and nominal/implicit.

An analysis of individual pattern of responses corroborated this trend. Eleven children in the natural/implicit condition (69%) and 12 children in the nominal/explicit condition (75%) had an accuracy score above 0.20. Conversely, only 5 children in the natural/explicit condition (31%) and only 3 children in the nominal/implicit condition (23%) had an accuracy score above 0.20.

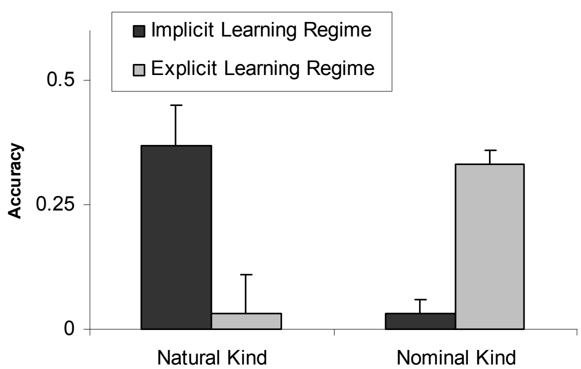

Figure 2: Accuracy Scores for Children.
Error bars represent standard errors.

In short, as predicted, children could learn the natural-type concept in the implicit learning regime, but not in the explicit learning regime; and they could learn the nominal-type concept in the explicit learning regime but not in the implicit learning regime. These findings cannot be due to differences in stimuli, as the same cartoon animals were used for both natural and nominal kinds. Furthermore, the findings cannot be due to differences in procedure, given that the learning regime for the natural kind (either implicit or explicit) was closely matched with the learning regime for the nominal kind.

These results reveal an important dissociation: while the implicit learning regime favored acquisition of concepts resembling natural kinds, the explicit learning regime favored acquisition of concepts resembling nominal kinds, thus supporting the contention that there is a psychological distinction between natural kinds and nominal kinds.

Experiment 2

The goal of this experiment was to extend the findings of Experiment 1 to adult participants. Adults participated in the same four conditions that were used for children in Experiment 1: natural/implicit, natural/explicit, nominal/ implicit, and nominal/explicit.

Method

Participants Participants were 54 introductory psychology students at a large mid-western university who participated for class credit. Additional nine adults (two or three in each condition) were tested and omitted from the sample because their performance in the catch trials did not meet the criterion (see Procedure).

Stimuli The stimuli were identical to the ones used in Experiment 1.

Procedure Adults were asked to learn about creatures called Ziblets in order to distinguish them from creatures that are not Ziblets. In the implicit learning regime, they were presented with 24 instances and asked to remember them. In the explicit learning regime, they were given the same defining rule that was presented to children. Again, no instances were presented; only pictures of the parts accompanied the rule.

Thirty-two testing trials followed in which instances were presented on the screen, and adults had to determine whether they see a Ziblet or not. Half of the instances were from the target category (Ziblets) and half of them were from the contrasting category (Non-Ziblets).

Eight catch trials followed intermixed with three trials from the target category. To be included in the study, adults had to respond correctly in at least 6 catch trials. At the end of the procedure, adults were asked to give a verbal description of the difference between Ziblets and other animals presented on the screen.

Results and Discussion

Mean accuracy scores are presented in Figure 3 (with standard error as error bars). A 2 (concept: natural, nominal) by 2 (learning regime: implicit, explicit) between-subjects ANOVA revealed a significant effect of learning regime ($F(1,50) = 13.15$, $p < .01$) with accuracy scores being higher in the explicit learning regime ($M = 0.57$, $SD = .45$) than in the implicit learning regime ($M = 0.23$, $SD = .34$), and a significant interaction ($F(1,50) = 11.9$, $p < .01$). When presented with the natural kind, participants performed above chance in both learning regimes ($t_{implicit}(13) = 5.3$, $p < .001$; $t_{explicit}(13) = 3.68$, $p < .01$), but when presented with the nominal kind, they performed above chance only in the explicit learning regime ($t(10) = 6.12$, $p < .001$).

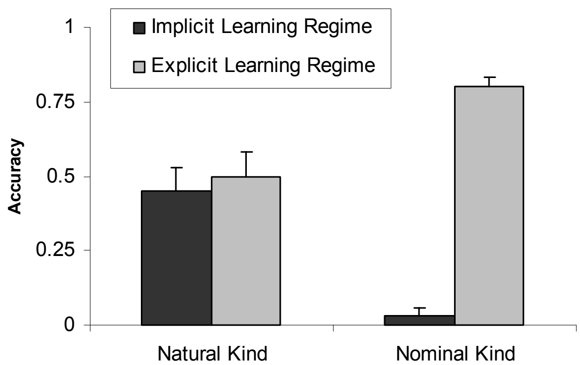

Figure 3: Accuracy Scores for Adults.
Error bars represent standard errors.

Adults' verbal responses were analyzed in terms of whether or not they contained the defining rule. For the natural kind, a response was coded as correct when the statement included at least one of the correlations. For the nominal kind, a response was coded as correct when the statement included the numerical relation. Table 2 shows the pattern of results. As expected, adults could verbalize the defining rule of the nominal kind in the explicit but not in the implicit learning regime. For the natural kind, even though adults' categorization accuracy did not differ as a function of learning regime, their verbal responses did. Only three the adults could verbalize the rule of natural kinds in the implicit learning regime whereas seven adults could verbalize the rule in the explicit learning regime[1].

Table 2: Number of Correct Verbal Statements
(Percentage correct in parentheses).

	Concept	
Learning Regime	Natural	Nominal
Implicit	3 (21%)	0
Explicit	7 (50%)	8 (73%)

Overall, learning of nominal kinds in adults exhibited tendencies similar to those in young children: participants ably learned the concept when presented with the defining rule of the concept, and they performed poorly when they were presented with instances of the category.

At the same time, unlike young children for the natural-kind concept, adults performed equally well under different learning regimes. This was surprising, given that the rule of the natural concept was rather lengthy, involving statements about the characteristics of six parts. We content that real natural kinds involve more than six simple correlations, thus making explicit learning of real natural kinds more difficult than explicit learning of current categories. This contention, however, remains speculative, and it will be examined in future research.

[1] The finding that some adults failed to verbalize the correct rule even in the explicit learning regime may be an artifact of the procedure. Instead of describing the difference between Ziblets and Non-Ziblets, a large majority of the adults described the difference between test items and catch items.

Experiment 3

The goal of this experiment was to document that the dissociation found in Experiments 1 and 2 is not limited to the particular nominal kind used in those experiments. Recall that the nominal kind used in Experiments 1 and 2 was based on a mathematical relation – a relation that may differ considerably from the correlations relevant for the natural kind. This difference was minimized in Experiment 3 by using the same target category that was used for the "natural kind" in the previous experiments. The contrasting category was new. It was constructed in such a way that only one correlation – rather than multiple correlations – was violated. To distinguish between target category and contrasting category, adults had to keep in mind all correlations. Therefore, the category to be learned was statistically sparse (all correlation mattered, no redundancy was present) without differing in content form the correlations of the "natural kind".

Method

Participants A new group of 28 students participated in this experiment (14 in the implicit learning regime, and 14 in the explicit learning regime). Additional 3 adults were tested and omitted from the sample because their performance in the catch trials did not meet the criterion.

Stimuli The stimuli of the target category were identical to the ones used in Experiments 1 and 2. Table 3 shows in abstract notation the characteristics of the contrasting category (Non-Ziblets) used in this experiment. These items differ from the Ziblets in only one of the correlations, rather than in all three correlations.

Table 3: Exemplar Items of the Contrasting Category used in Experiment 3

	Contrasting Category					
Parts	Item 1	Item 2	Item 3	Item 4	Item 5	Item 6
Body	0	1	1	1	1	1
Antennas	1	0	1	1	1	1
Horiz. wings	1	1	0	1	1	1
Tails	1	1	1	0	1	1
Vert. wings	1	1	1	1	0	1
Buttons	1	1	1	1	1	0

Note. The numbers refer to the values of the respective characteristics (1 = light, small, or few; 0 = dark, large, or many). The target category is the same as in Experiment 2 (shown in Table 1)

Procedure The procedure was identical to the procedure used for the natural-kind concept in Experiment 2. Participants were presented either with the implicit or the explicit learning regime.

Results and Discussion

Mean accuracy scores were calculated for each learning condition. A significant difference was found (t(31) = 3.76, p < .001), with adults in the implicit-learning condition performing worse than adults in the explicit-learning condition (implicit: *M* = 0.17, *SE* = .05; explicit: *M* = 0.44, S*E* = .06). These results further indicate that the dissociation between natural kinds and nominal kinds reflects the structure of the to-be-learned categories rather than the property of the particular relation used in Experiments 1 and 2.

General Discussion

The results reported here support a psychological distinction between concepts that differ in their statistical structure. Concepts that are based on highly redundant features were best learned through an implicit learning regime (especially for children); and concepts that are based on non-redundant features were best learned through an explicit learning regime. The latter findings applied whether the concept was based on a mathematical relation (Experiment 2) or on a set of correlations between two features (Experiment 3). This suggests that the dissociation in acquisition reflects the statistical structure of the category rather than the particular relation.

Though not directly investigated in these sets of experiments, we argue that statistically dense concepts resemble natural kinds, while statistically sparse concepts resemble nominal kinds. It is likely then that natural kinds (e.g., the concept of *bird*) require a different learning environment than nominal kinds (e.g., the concept of *acceleration*). Furthermore, it is possible that this learning dissociation reflects itself in the way the concepts are represented. For example, it is possible that effects of gradedness are more likely to be found with natural kinds than with nominal kinds.

Finding dissociation in learning between different types of concepts indicates that a theory of categorization is incomplete if it pertains only to one kind of concept. A more complete account would address the processes of categorization for both natural and nominal kinds.

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