Learning and Generalizing New Concepts

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Abstract

When subjects learn to categorize new stimuli adequately, they have to segment these stimuli into relevant features for categorization. In the experiments reported here, children had to discover a rule for categorization. Preliminary experiments have shown that depending on the nature of the irrelevant features, children could find the relevant features from age four or could not find them before the age of eleven or twelve. A central question is whether children aged four or six who have discovered the rule in a simplified version of the relevant features would generalize to a "complex" version (i.e., in which there is more background noise) of the relevant features, i.e., a version that they would be unable to learn before twelve without pre-training. Conditions promoting the generalization from the simple version to the complex version were also investigated. Two conditions were compared: relearning with or without feedback. Results showed that children aged 4 and 6 could generalize the "simple" version of the target concept to a more complex version of the same concept, either with and without feedback in the generalization phase.

Introduction

Children have to learn to categorize stimuli according to adults' standards. In order to achieve this correctly, they have to find the relevant features for categorization. If the particular task is to learn to categorize a set of new stimuli into two new categories, they will have to find the features that characterize stimuli of each category and that distinguish them from stimuli of the other category.

Imagine a traditional concept learning experiment in which participants have to discover one relevant feature that allows for perfect categorization. Stimuli are constituted of a number of dimensions, either relevant or irrelevant. Subjects are presumed to formulate and test simple hypotheses concerning the rule that define membership (Nosofsky, Palmeri, & McKinley, 1994). This means that participants will analyze stimuli into their dimensions and test whether each dimension partitions the set of stimuli. A number of characteristics of the stimuli contribute to the task difficulty. The salience of dimensions: a non salient relevant dimension among salient irrelevant dimensions presumably requires more systematic analyses of the stimuli than a salient relevant dimension among non salient irrelevant dimensions.

Variability in the perceptual manifestation of a relevant feature can hinder this relevant feature and impede its discovery. For example, compare Figure 1A stimuli with Figure 1C stimuli which define two experimental conditions. In the two conditions, the stimuli come from two categories defined by the same relevant features. Each stimulus has four "legs", with one category being defined as "1 isolated leg and 3 connected legs" (1+3), the other category being defined as "two sets of two connected legs" (2+2). In Figure 1C the length, shape, size of the legs were made more variable than in Figure 1A. Preliminary results obtained by Thibaut (1999) indicate that the rule (1+3 vs. 2+2) could be discovered from the age of four in the case of Figure 1A stimuli whereas children under thirteen could not find the equivalent rule for Figure 1C stimuli. Figure 1B stimuli elicited intermediary results: most children aged ten discovered the rule.

Thibaut (1999) suggested that young children had problems either in screening the stimuli, or inhibiting irrelevant features, or plan systematic comparisons between stimuli. The purpose of the present contribution is to assess to what extent young children (four- or six-year olds) who discovered the relevant features for categorization 1+3 vs. 2+2 in the simplified version (Figure 1A) would be able to generalize to more complex versions of the same features (Figure 1B and 1C). In other words, once he/she has learned to apply a classification rule in a low variability context (such as Figure 1A stimuli), is a child able to apply it in a high variability context ?

It has been emphasized in the developmental literature that there are differences between adults' and children's in processing abilities. According to Kemler (1989), children are more holistic processors than adults. She suggested that holistic processors would run into more difficulties when only one of many attributes is relevant for categorization than when categories are defined by overall similarity relationships, i.e., when stimuli share many characteristic features. Other authors consider that property-specific information is accessible to young children, even those aged 4 or 5 years. This means that children can analyze stimuli in terms of their constituent features, even if they do not analyze the stimuli in the same way older children and adults do. Ward (1989), Ward and Scott (1987) have argued that the difference between young learners and older learners is that younger learners may have rigid attribute preferences.

Following the holistic view, one can hypothesize that if young children perceive stimuli holistically, they should be unable to analyze the complex stimuli into their constituents and, thus, should also be unable to isolate specific aspects of the legs in order to generalize the simple version of the rule to the complex version. In the same way, if young children have rigid attribute preferences it might be that, when confronted to the complex stimuli, they will focus their attention on the salient irrelevant properties and be unable to analyze the legs in terms of less salient properties.

Studies on generalization generally take a different perspective from the one followed here. Usually, children first learn a given concept, then they are presented with a set of new stimuli, the purpose being to analyze to which among these new stimuli they generalize the concept. Here the issue is to analyze to what extent children who discovered a rule for categorization in a simplified context will be able to generalize it to more complex objects for which they would be unable to discover the rule if they had to discover it without being first presented with the simple version. This is important because a positive answer would mean that an appropriate learning sequence can lead to an understanding of concepts which, otherwise, would remain out of the conceptual world of the child. Two generalization conditions will be compared. In the first one, children will be given feedback when they will learn to apply the simple rule to the complex stimuli. In the second condition, there will be no such feedback. It is believed that feedback will promote the understanding of the equivalence between the known simple version of the rule and its complex version. This is because, if young children do not perceive this equivalence at first glance, they can test different translations of the simple rule in terms of the complex rule and get feedback at each trial. In the no feedback condition, successive trials do not bring any information about children's successive hypotheses. If a child does not find the correct way to generalize the simple version of the rule after a limited number of trials, the absence of feedback increases the probability that his/her attention will be caught by salient irrelevant features.

Experimental Design

Preliminary results (Thibaut, 1997) have shown that children under thirteen could not parse Figure 1C stimuli adequately. In the same way, most of children under eight could not find the relevant feature for categorization in the stimuli displayed on Figure 1B. On the other hand, the majority of children aged four could find the relevant features 1+3 and 2+2 in stimuli such as the ones displayed in Figure 1A. The purpose of the experiment was to assess whether children aged four and six who are able to find the relevant features for categorization for the simple stimuli (Figure 1A) would be able to generalize them to the stimuli displayed in Figures 1B or 1C.

The design of the experiment is summarized in Table 1.

Methods

Participants. Fourteen 6-6.11-year-olds participated in the complex transfer items with feedback condition, eleven 6-6.11-year-olds participated in the complex transfer items with NO-feedback condition, fourteen 6-6.11-year-olds participated in the semi-complex transfer items with feedback condition, fifteen 6-6.11-year-olds participated in the semi-complex transfer items with NO feedback condition, eleven 4-4.11-year-olds participated in the complex transfer items with feedback condition, twelve 4-4.11-year-olds participated in the semi-complex transfer items with feedback condition and nine 4-4.1- year-olds participated in the complex transfer items with NO feedback condition. All children were tested individually.

Table 1 : design of the experiment.

Age / Conditions	Aged 4	Aged 6
Training condition and transfer with complex stimuli, NO feedback	x	
Training condition and transfer with complex stimuli, with feedback		
Training condition and transfer with semi-complex stimuli, with feedback		
Training condition and transfer with semi-complex stimuli, NO feedback		

Note. Cell marked "x" was not run.

Materials. The two categories (1+3 and 2+2) of eight stimuli were the ones used by Thibaut (1997). The learning stimuli (simple version) are presented on Figure 1A. The 16 stimuli were composed of four legs which were thin and vertical. There were eight 1-3 stimuli and eight 2-2. In this condition, the purpose was to remove salient irrelevant features for categorization. There were two sets of transfer stimuli, complex and semi-complex. The complex transfer stimuli were outlines of unknown shapes composed of two parts, the upper part (the body) and the lower part (four legs). The two categories had the same structure. In five out of the eight stimuli, the body had a mushroom-like shape that was slightly distorted over the stimuli in the case

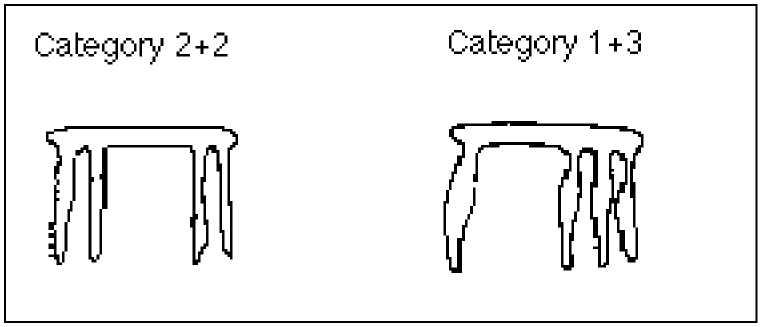

Figure 1A: two "simple" stimuli used in the training phase.

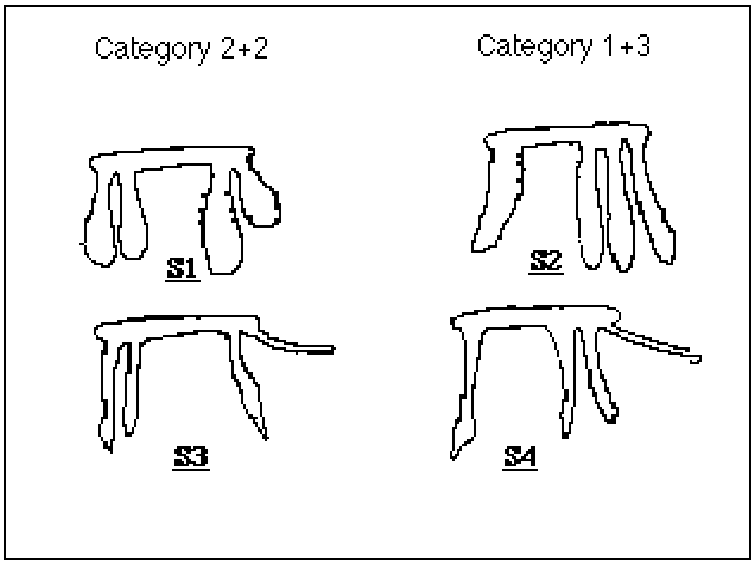

Figure 1B. Four semi-complex stimuli. Both categories (2+2 and 1+3) contain an equivalent proportion of thin and large stimuli.

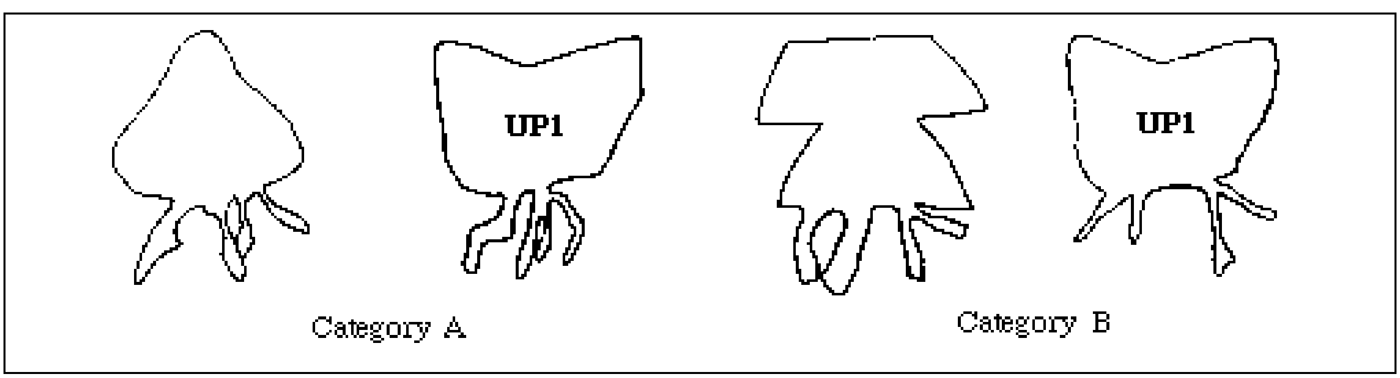

Figure 1C. Four complex stimuli from categories 1+3 and 2+2. The first stimulus has the body (upper part) characteristic of category 1+3 and the third stimulus has the body characteristic of category 2+2. The UP1 stimuli are neutral stimuli.

of category 1+3, and an angular shape in the case of category 2+2 stimuli. These two shapes were selected for their distinctiveness and perceptual saliency. The three remaining stimuli from each of the two categories were constructed with three different bodies (UP1, UP2, UP3). Since UP1, UP2, and UP3 were present in both categories they could not be considered as cues for categorization (see Figure 1C). For each stimulus, the lower part consisted of four legs which were spatially grouped either as one leg on the left and three legs on the right in category 1+3, or two pairs of legs in category 2+2 (see Figure 1C). These distinctive features (1-3 vs. 2-2) were the only ones available in order to categorize all the stimuli correctly.

For the semi-complex transfer stimuli, a set of 16 stimuli was constructed. The irrelevant cues "thin" "vertical", "the rightmost leg pointing to the right", and "large" were crossed with the cues "one leg plus three legs" (1+3) and "two pairs of legs" (2+2) according to four types of stimuli. There were four 1-3 stimuli and four 2-2 stimuli with "thin" legs and "the rightmost leg pointing to the right", and four 1-3 stimuli and four 2-2 stimuli composed of "broad and vertical legs" (see Figure 1B for examples of the 4 types of stimuli).

Procedure

Familiarization phase. The entire set of training stimuli (Figure 1A) was presented once to the subject. Each stimulus was shown for five seconds. Then, it was removed and followed by a new stimulus. There was no feedback during this phase, and when it was over, participants were then told that they would have to learn to sort the stimuli into two categories, the name of which was provided, “bollo” for the 1-3 category, “tipi” for the 2-2 stimuli.

Learning phase. A first stimulus (simple version, Figure 1A) was presented for approximately five seconds and the subject had to guess its name. The experimenter gave the appropriate feedback and presented the second stimulus in the same way, followed by the other stimuli. Feedback was provided after each answer. The order of presentation of the stimuli was random. Once the entire set of stimuli had been presented to the subject, it was presented a second time. The learning phase was stopped when children made no mistake during two successive presentations of the set of stimuli or if they were still making errors after the ninth presentation of the set. Subjects were tested individually. A session lasted for 10 to 25 minutes, depending on the number of trials necessary to complete the task.

Transfer phase. Children who had learned the rule for categorization had to categorize the transfer stimuli. Children were told that they would have to classify new "tipi" and "bollos" different from the ones they had seen before. In the complex stimuli with feedback condition, children were presented with the complex stimuli (Figure 1C) in the same way as in the learning phase. They received a feedback after each trial. In the semi-complex with feedback condition, children were presented with the semi-complex stimuli and received a feedback after each trial. In

Table 2. Number of subjects who reached the criterion in the two age groups and the various experimental conditions: with or without training with simple stimuli and with or without feedback in the transfer phase

	Four-year-olds		Six-year-olds	
Condition	Correct	Failure	Correct	Failure
Complex stimuli (no training with simple stimuli)	0	10	0	10
Semi complex stimuli (no training with simple stimuli)	0	10	6	8
Training condition and transfer with complex stimuli and no feedback	x	x	6	5
Training condition and transfer with complex stimuli and feedback	4	7	9	5
Training condition and transfer with semi-complex stimuli and with feedback	9	3	12	2
Training condition and transfer with semi-complex stimuli and NO feedback	8	6	11	4

Note. Cells marked "x" were not run.

the complex with NO feedback condition, complex stimuli were presented, and children never received a feedback after their classification. In the semi-complex with NO feedback condition, semi-complex stimuli were presented, and children never received a feedback after their classification. In all these experiments, the learning criterion was the same as in the learning phase.

Results and discussion

The purpose of the experiment was to assess whether children who had first learn the rule for categorization with simple stimuli would be able to generalize it to semi complex or complex stimuli when a feedback was provided or not. Results are summarized in Table 1. Khi square comparing data obtained in the control condition (no training with simple stimuli, Thibaut, 1997) with the new data (training with simple stimuli) revealed a significant difference in the majority of cases ($p < .05$). The only exception was the case of the "generalization to complex stimuli with feedback" condition with children aged four. In this condition, a majority of children failed to generalize correctly. In sum, in a majority of conditions, training with simple stimuli influenced generalization positively. This is important because it suggests that people can generalize what they have learned to new situations that would have been beyond their understanding without this pre-training. The results obtained in conditions with feedback were compared with the equivalent results in conditions with no feedback. Comparisons revealed no significant difference (Khi square, $p > .05$).

A number of authors have described children's concept learning in terms of attentional capacities (capacity to focus on specific dimensions) or of sensitivity towards dimensions (see introduction). The present results indicate that one has to include other dimensions in any model of concept learning. First, provided that exemplars of a given dimension can be highly variable (compare the simple and the complex versions of the rule), the notion of a "sensitivity to a dimension" cannot be assessed independently of the variability across instances of this dimension. This means that the probability that a relevant dimension will be discovered also depends on the presence and the structure of the other dimensions (irrelevant) that compose the stimuli. Second, in order to understand whether or not a particular instance of a dimension will be discovered by children, one has to include participants' history of categorization. By history of categorization, I mean the categorizations already performed by an individual (see Schyns, Goldstone, & Thibaut, 1998; Thibaut & Schyns, 1995). The present data suggest that the history of categorization influenced positively the way children generalized the rule. To summarize, a model of categorization and generalization has to take selective sensitivity to a particular dimension into account, provided that this notion incorporates the notion of variability in the instanciation of the dimension across stimuli. It must also incorporates the history of categorization with a particular category in order to understand whether or not children are able to generalize a given dimension to new instances of this dimension. The present data show that knowing the history of categorization, one can predict whether a set of new stimuli is learnable. Complementarily, one can predict which history of categorization is necessary to promote generalization to subsets of highly variable stimuli. This is particularly important given that, in a majority of cases, we do not encounter identical instances of the same category.

The results presented here are important because the status of the transfer stimuli is controlled *a priori* more systematically than in traditional category learning experiments. In these latter studies, participants are confronted with transfer items of which the "intrinsic complexity" is not known. Here, the stimuli complexity in terms of learnability was independently assessed before the experiment. This is important for the control of the "paths of generalization". Following the learning strategy used here, one can bypass the role of the salient irrelevant features that would mask the relevant features for categorization whereas starting with the complex stimuli would lead to the incorrect conclusion that young children are unable to abstract the rule for categorization.

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