Categorization under the Influence

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Abstract

In the first experiment, participants learned an easy rule that allowed perfect categorization that they had to automate. During learning, a new ancillary dimension was systematically associated with the defining feature of each category. In the test phase, items in which the association created during learning was broken were categorized more slowly than those in which the association was present, even for participants who did not notice the association. However, when the category-defining and the ancillary features were reversed in a second experiment, we did not get the anticipated results: there was no effect of the implicit association created during the learning phase. Results are explained in terms of dependencies between properties during processing. It is argued that similarity to previous exemplars does not explain the results obtained here.

Introduction

When people are confronted with new stimuli, they can acquire knowledge that enables them to categorize the stimuli on the basis of features. In these situations, people attempt to build a vocabulary of features and a rule (or rules) constructed from this vocabulary (Thibaut & Schyns, 1995). Once people know the rule, i.e. the particular set of relevant properties, whatever its structure might be defined with necessary and sufficient features or constituting what has been called a family resemblance structure -, they can learn to apply it properly.

What does it mean to apply a rule? In most category learning experiments, it has to do, at the very least, with accuracy, correct generalization, and speed. In traditional approaches to categorization, the control of the structure of the stimuli presented to participants and the way participants generalize to new stimuli, enables the experimenter to derive models of the representation of concepts and, in particular, the weighting of the various dimensions of concepts (see Nosofsky, 1992, for a review), i.e. the attention paid to each dimension constituting the stimuli.

What does it mean to pay attention to a particular dimension in categorization? One possible meaning is that, during learning, participants explicitly noticed that a dimension or a set of dimensions in a stimulus is a relevant cue for categorization. This constitutes a rule for categorization and, with practice, application of the rule becomes automated, i.e., relying on the explicit dimension(s) consumes fewer processing resources. On this view, category learning starts by noticing the association between a dimension (or a set of dimensions) and a category. One does not normally consider the possible influence on categorization of characteristics of the stimuli that have not been explicitly noticed.

On the other hand, implicit learning studies have shown that characteristics of stimuli participants are unable to verbalize seem to contribute to their performance in the task (or what they say explicity does not account for their behavior in the task, see Cleeremans, 1993; Reber, 1993; Berry & Dienes, 1993 for reviews).

In most implicit learning experiments, the rule that would produce perfect control of the task is so complex that participants never find it or are unable to explicit it (see Berry & Dienes, 1993, for review). The question of which properties of the stimuli are encoded implicitly remains open (except if one denies the existence of implicit representations and argues for explicit representations, Perruchet & Pacteau, 1990, see also Shanks & Saint-John, 1994). Implicit learning has been defined as being "associated with incidental learning conditions rather than deliberate hypothesis testing" (Berry & Dienes, 1993, p. 14). Hayes and Broadbent (1988) define implicit learning as an "unselective and passive aggregation of information about the co-occurence of environmental events and features." Implicit learning should be particularly good at discovering nonsalient covariance between the variables defining the task.

What kind of properties are used during a categorization task? The prevalent view in category learning is that people use properties they have noticed and reference is frequently made to attentional weighting of properties, and so on. In the field of implicit learning, given the complexities of the situations, it is not always easy to know what properties of the stimuli are really encoded and used by the participants (part of the debate in the field is devoted to this issue; see the debate between Shanks & Saint-John, Perruchet, etc., and Reber, Lewicki, and their colleagues).

In the following experiments, we will address the problem of the properties that control classification in a categorization task, especially properties associated implicitly with an explicit simple rule of categorization. We designed a category learning task in which participants were expected to learn an explicit rule for categorization and to automate it through extensive training. During learning, they had to discover the rule for categorization for a set of unknown stimuli with two different arrangements of four legs (the rule was defined as a group of 1+3 legs for one category and 2+2 for the other category, see figure 1). The structure of the categories was conceived in such a way that apart from this rule (1-3 vs. 2-2), there was no other characteristic of the stimuli usable as a perfect rule for categorization. During the second phase of training, participants were required to categorize the stimuli according to the rule learned during the first phase as quickly as possible. This phase was intended to automate the explicit rule. However, in each category, a dimension perfectly correlated with the defining explicit dimension of the category was introduced (e.g., all the stimuli of the category 1-3 were rounded whereas 2-2 stimuli were elongated). In the test phase, we compared the classification reaction times for stimuli in which the explicit dimension defining a category was associated with the dimension introduced in the second phase (the association phase) (i.e., 1-3 and rounded, 2-2 and elongated; those were called *congruent* stimuli) with reaction times for stimuli that violated this association (i.e., 1-3 and elongated, 2-2 and rounded, these were called *contradictory* stimuli).

Since the rule (1-3 vs. 2-2) was a perfect cue for categorization and since participants had automated it during the association phase, one would expect participants to extract the rule equally well from either congruent or contradictory stimuli, specifically because the associated properties --rounded and elongated-- do not affect the rule. In particular, this should be true for participants who did not notice the association between the explicit cues and the associated features. In addition, participants who noticed the association between the explicit cues and the associated dimension during the second phase should be slower for the contradictory stimuli. Previous research (Miller, 1987; Allen & Brooks, 1991) have shown that irrelevant information influences the use of relevant information in categorization. Though their experimental paradigms were different, one would predict that contradictory stimuli will be categorized more slowly than congruent stimuli.

Experiment 1

Methods

Participants. Thirty-three undergraduates from the University of Liège were volunteers for the experiment.

Material. Two categories of unknown stimuli composed of four connected appendages, called "legs", were constructed. The spatial layout of the legs distinguished the two categories. Stimuli in category A had one leg on the left and three legs on the right (1-3), and those in category B had two sets of two legs (2-2) (Figure 1). Participants had to learn this distinction between the two categories (1-3 versus 2-2) in order to categorize <u>all</u> the stimuli appropriately. A primary set of stimuli was constructed, composed of 1-3 and 2-2 stimuli called the neutral stimuli. These stimuli were then transformed with the "spherize" function of the Adobe Photoshop software. In one case a positive spherization was applied and in the other case a negative spherization. In the latter case, height of the stimuli was multiplied by 1.25. The "sherize" function was applied to each stimulus taken as a whole and not to parts taken separately. The positive transformation resulted in stimuli that were perceived as more rounded than the neutral, the negative were perceived as more angular and vertically elongated than the neutral. In the learning phase, each category was composed of ten stimuli: category A (1-3), six rounded stimuli, three neutral and one angular-elongated; category B (2-2), six angular-elongated stimuli, three neutral and one rounded. Since, in this phase, participants had to discover the explicit rule for categorization, neutral and angular stimuli were added to prevent them from using rounded versus angular as the explicit rule.

Keeping in mind that the purpose of the experiment was to create an association between an explicit rule and another characteristic of the stimuli, in the association phase, it was decided that participants would have to learn the association between 1-3 and a rounded shape (positive spherization) and between 2-2 and an angular shape (negative spherization). In the association phase, the six 1-3 rounded stimuli and the six 2-2 angular stimuli from the learning phase were presented. The aim of this phase was to create an association between 1-3 and rounded on the one hand, and 2-2 and angular on the other. In the test phase, 30 new stimuli were presented: five 1-3 rounded stimuli and five 2-2 angular-elongated (since these stimuli display the association created in the association phase, they are called *congruent* stimuli); five 1-3 angular-elongated stimuli and five 2-2 rounded stimuli (these stimuli contradict the association created and are therefore be called *contradictory*); five 1-3 and five 2-2 neutral stimuli.

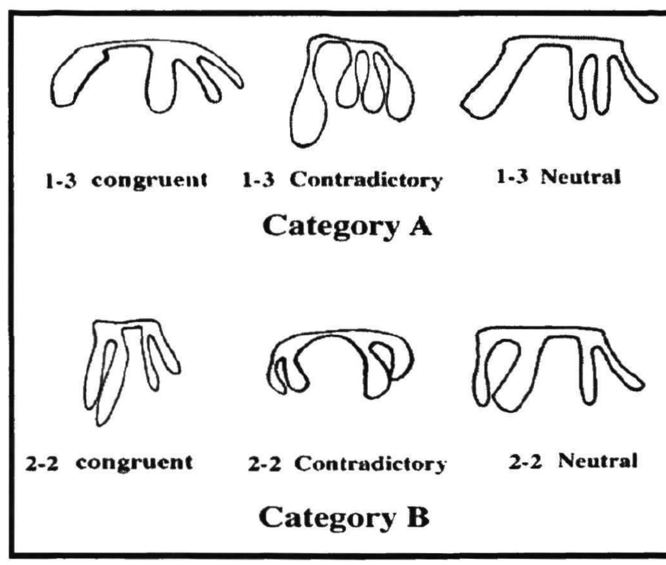

Figure 1 : the three types of stimuli for the learning phase. During the association phase, only congruent stimuli were used.

Procedure. Participants were seated at approximately 50 cm in front of a computer screen. The computer recorded the time elapsed from the presentation of a stimulus to the categorization of the stimulus. The experiment was composed of three phases: a learning phase, an association phase, and a test phase.

Learning phase. Participants were told that they would have to learn to classify a set of stimuli into two categories. The stimuli were displayed until the participants responded. A first stimulus was presented to the participant who had to guess its category name. They were asked to press the key corresponding to one category. Feedback was provided about the accuracy of the answer. The second stimulus was presented in the same way, and so forth, for the other stimuli. Feedback was provided for each stimulus. The order of presentation of the stimuli was random. Once the entire set had been presented to the participant, it was presented a second time, a third time, etc. The learning phase ended when the participant made no mistakes during two successive presentations of the set of the stimuli.

Association phase. In this phase, congruent stimuli were presented for 150 ms. The entire set was presented ten times. Participants were instructed to classify the stimuli as quickly as possible without sacrificing accuracy. Feedback was provided after each stimulus presentation.

Test phase. Participants were presented with the 30 test stimuli twice, each stimulus presented for 150 ms. Again, they had to categorize all stimuli as fast as possible. There was no feedback.

At the end of the experiment, the experimenter asked participants questions about the structure of the stimuli. The purpose of these questions was to assess whether they noticed the association "1-3 and rounded" and "2-2 and elongated." In order, to avoid questions that did not address the information they had encoded, we started with the participants description of the stimuli. Questions were formulated in terms of participants' descriptors and addressed the association between the different dimensions and the categories explicitly in the following way. During the association phase, "did you see 1-3 rounded and 2-2 elongated and/or more angular stimuli, or did you see 1-3 elongated and/or more angular stimuli and 2-2 rounded stimuli, or the same number of rounded and elongated stimuli in the two categories". With such a procedure, we addressed explicitly the association between the relevant features in our task (1-3, 2-2, rounded, and elongated).

Results and discussion

Since we wanted to know whether participants who did not notice the association between the 1-3 with rounded and 2-2 with elongated would be influenced by this association, we separated those participants from participants who noticed the association. A first 2 x 2 Anova with Type of stimuli (congruent vs. contradictory) and Category (1-3 vs. 2-2) as repeated measure variables was carried out on the reaction times obtained for the twenty participants who did not notice the association between the explicit rule (1-3 vs. 2-2) and the associated dimension (rounded vs. elongated). There was a main effect of Type of stimuli: $F(1,19) = 9.82$, $p < .01$ (congruent: $\underline{X} = 358$ ms, contradictory: $\underline{X} = 417$ ms). There was no main effect of Category and no interaction.

A second ANOVA with Type of stimuli and Category as repeated measure variables was carried out on the reaction times obtained by the 13 participants who noticed the association. Again, congruent stimuli were responded faster than contradictory stimuli (congruent, $\underline{X} = 337$ ms, contradictory, $\underline{X} = 414$ ms), $F(1,12) = 9.67$, $p < .01$. There was no main effect of category and no Type of stimuli-Category interaction.

A 2 x 2 mixed Anova with Type of stimuli and Participants (association noticed vs. association not noticed) with repeated measure on Type of stimuli revealed that there was no main effect of Participants and no Type of stimuli x Participants interaction.

To summarize so far, the results show that the two groups of participants were slower for the contradictory than for the congruent items. This means that even when they had not noticed the association between the rule (1-3, 2-2) and the associated features (rounded or elongated, respectively), participants nevertheless associated them during learning, even though the rule was easy to manipulate, had no exception, and that was easy to automate.

Before we discuss these results more thoroughly, we will present a second experiment which is the same as the first but in which the rule-defining and associated features are reversed. Participants learned the explicit rule "rounded shape versus elongated shape" in the first phase and automated it in the second (association) phase. In this experiment, the associated features introduced systematically in the association phase were 1-3 and 2-2.

Experiment 2

Given the results of the first experiment, we expected a significant difference between the congruent and the contradictory stimuli.

Methods

Participants. Eighteen undergraduates from the University of Liège.

Material. Category A consisted of rounded stimuli and category B of elongated stimuli. In the learning phase, category A was composed of 6 rounded stimuli with 1-3 legs (congruent), 3 neutral (the space between the legs was uniform), and 1 contradictory stimulus (rounded with 2-2 legs); category B was composed of 6 angular-elongated stimuli with 2-2 legs (congruent), 3 neutral stimuli and 1 contradictory (angular-elongated with 1-3 legs). In the association phase, only the congruent stimuli were presented. In the test phase, 10 new congruent and 10 new contradictory stimuli were presented. Note that, apart from the neutral stimuli, all the stimuli were those presented in the first experiment.

Procedure. The instructions were the same as in the previous experiment. Recall that in this experiment, the rule was rounded vs. elongated and the associated dimension was 1-3 vs. 2-2.

Results

A first 2 x 2 Anova with Type of stimuli (congruent vs. contradictory) and Category (rounded vs. angular) as repeated measure variables was carried out on the reaction times obtained for the 15 participants who did not notice the association between the explicit rule (rounded vs. angular) and the associated dimension (1-3 vs. 2-2). There was no main effect of Type of stimuli: $F(1,14) = 0.17$, $p > .5$; congruent: $\underline{X} = 318$ ms, contradictory: $\underline{X} = 324$ ms. There was no effect of Category and no interaction between Type of stimuli and Category. We did not carry out the analysis on the three participants who noticed the association.

Comparison between Experiment 1 and Experiment 2. In order to compare the results obtained in the 2 experiments, we analyzed the difference between congruent and contradictory stimuli in the 2 experiments. A t test revealed that the difference between congruent and contradictory stimuli in experiment 1 was significantly greater than the equivalent difference in experiment 2 : $t(33) = 2.22$, $p < .05$. (Experiment 1, $\underline{X} = 59$ ms; Experiment 2, $\underline{X} = 6$ ms).

Discussion

The main result of the first experiment is that the decision reaction time was influenced by the addition to the stimuli of certain (ancillary) characteristics that were associated with the explicit, rule-defining characteristics. The addition of these associated features increased reaction time even for participants who did not notice the association between the rule and the additional characteristics of the stimuli. If one considers only the properties of the rule --automated during the association phase and easy to apply--, this result is unexpected since the association phase should allow participants to learn to extract the relevant information and to filter out the irrelevant dimensions.

However, contrary to experiment 1 -- and quite unexpectedly --, there was no difference between congruent and contradictory stimuli in experiment 2. This is particularly intriguing because the only difference in the two experiments is that the rule-defining and associated (ancillary) features of the first experiment are switched in the second experiment. But in this latter experiment, the interference effect of the associated characteristics on the rule-defining characteristics that was observed in the first experiment disappears.

The explanation for this probably lies in the abstraction process itself and in the characteristics of the stimuli to which participants pay attention during the association phase. We will first discuss the implicit association created between the rule and other systematic properties of the stimuli. Then we will analyze the absence of a similar result in the second experiment.

The basic idea is that the defining features (1-3 and 2-2 groupings of legs in the first experiment; rounded and elongated in the second experiment) are aspects of the stimuli that are not independent of the other features of the stimuli. When a particular dimension of a stimulus is focused on, other properties of the stimulus are also processed. For example, to distinguish a 1-3 stimulus from a 2-2, one has to find the location of the largest space between the legs. This space does not exist independently of the legs and, therefore, one must look at the legs themselves, along with their characteristics, which include other dimensions, such as size, orientation, elongation, roundness, thickness of the lines, and so on. In our experiments, the stimuli were designed in such a way that a number of characteristics were systematically associated with each rule-defining feature (see material).

In order to understand the asymmetry between experiments 1 and 2, we hypothesized that associated properties were processed differently in the 2 experiments. More precisely, the ancillary properties associated with the rule-defining features are not encoded in the same way in the two experiments. In the first experiment, it seems likely that the processing of the rule-defining features also necessarily involves some degree of processing of the associated features. This, however, is not the case in the second experiment.

To see this, consider the first experiment. The difference between 1-3 and 2-2 stimuli depends on the location of the space. In order to locate the space, one has to look at (and therefore process) the information about the legs because the space is defined in terms of the legs. Since in the 1-3 configuration, the legs are rounded and in the 2-2 configuration the legs are elongated and straight, the difference between 1-3 and 2-2 stimuli will also include information about the associated roundness and elongation. Now compare this to the second experiment. In order to identify a stimulus as rounded or elongated (the rule-defining feature in this experiment), one does not need to process the spatial ordering of the legs of the stimuli. In fact, "elongated and angular" or "rounded" are global properties of the stimuli that do not need a local analysis to be identified. In other words, one can identify the rule-defining features in this case without ever looking at the location of the largest space of the legs (first and second legs, or second and third legs). To summarize, in the first experiment, the identification of the rule-defining features 1-3 and 2-2 necessarily involves the processing of the properties directly associated with the legs, because in order to find the location of the largest space between the legs, one must directly observe the legs. On the other hand, in the second experiment, the identification of the rule-defining features "rounded" and "elongated" does not require the processing of the location of the space between the legs.

How can we explain the difference between congruent and contradictory stimuli in this light ? During the second (association) phase, participants learn to locate the relevant information on the stimuli as fast as possible, i.e. to extract the relevant information from the other features of the stimuli. During this phase, the attentional system becomes more efficient at extracting the defining feature of each category from the other features. At the end of this phase, the features associated by the experimenter with the defining features are encoded and play the role of a correlated cue for the perceptual system. In the test phase, participants are shown contradictory stimuli in which the rule-defining feature of category A (category B) is presented along with the ancillary feature previously associated (during the association phase) with the rule-defining feature of category B (category A). In the context of this contradictory evidence, participants answer more slowly.

In experiment 2, however, we suggest that the 1-3 and 2-2 leg-grouping feature was not encoded when participants looked for the defining features "rounded" and "elongated". Consequently, these features did not influence their performance. We are currently running experiments to further examine this hypothesis. Note that we have replicated the results from these two experiments in somewhat different experimental contexts or with transformed stimuli.

The difference between congruent and contradictory stimuli in experiment 1 can be interpreted as a case of interference. Our "microdevelopmental" approach is interesting because it investigates the emergence of an association between properties of stimuli and the origin of interference. The absence of such an interference in experiment 2 underlines the necessity of studying which properties of stimuli are processed when one learns to categorize them.

Allen and Brooks (1991) obtained similar results they interpreted differently. In their experiment, they used an additive rule defined in terms of three dimensions, each dimension assuming two values. Categorization in one or the other category depended on the value assumed by at least two of the three dimensions (e.g., in one experimental condition, two of the three following values were required for categorization in category A: presence of spots, long legs, or angular body). Consequently, no single value on the three relevant dimensions was perfectly correlated with either of the two categories. In the test phase, participants were given some stimuli that were similar to one category and had to be categorized in the same category (positive match) and to other stimuli similar to one category but that had to be categorized in the other category (negative match). Results indicated that participants categorized positive matches faster than negative matches and made more mistakes for negative matches. Allen and Brooks' interpretation emphasized the role of similarity of test items to exemplars presented during learning. Their interpretation can also be applied to our data. In this framework, the reaction times for our contradictory items (equivalent to the negative matches in Allen and Brooks's terminology) were slower because they were less similar than the congruent test stimuli (the positive matches) to the items in the association phase.

But their notion of similarity to prior exemplars (Allen & Brooks, 1991) does not seem able to account for the absence of difference between contradictory and congruent stimuli in experiment 2. According to Allen and Brooks, contradictory stimuli should have been categorized more slowly than congruent ones because they are more similar to the stimuli of the association phase. The problem with Allen & Brooks' explanation, at least in the present context, is that it does not include any reference to the way stimuli are processed. Our analysis is more in line with the notion of processing episodes (Jacoby & Brooks, 1984). However, to have some explanatory power, this notion must include a discussion of how the stimuli are processed, in other words, in other words, the extent to which the processing of one dimension (or set of dimensions) does or does not engender the processing of other properties of the stimuli.

Another possible explanation of the asymmetry that we observed between experiments 1 and 2 could involve saliency of dimensions 1-3 versus 2-2, on the one hand, and elongated versus rounded, on the other. However, such a proposal leads to the following problem. It is generally assumed that implicit learning deals with non-salient aspects of stimuli (otherwise they would be explicit). Such a proposal must assume that the association between the explicit dimensions and their correlated features was not salient enough to become explicit in either experiment AND that one of the two associations was more salient than the other. Since all the dimensions could be associated with their respective category as an explicit rule by participants (1-3 and 2-2 in experiment 1 and rounded and elongated in experiment 2) when it was relevant for categorization, the claim that these associations were more or less salient when they were not the rule to be learned, (1-3 and 2-2 in the second experiment and elongated and rounded in the first) seems unfounded. We think the explanation lies instead with the specifics of the encoding and processing the stimuli than with general notions like saliency or similarity to previous exemplars.

The power of implicit learning. Usually, it is claimed that implicit learning is more powerful than explicit learning in detecting regularities. Most experiments in implicit learning show that participants who cannot associate an explicit dimension to a particular decision can nevertheless use this association implicitly. Here we have the opposite situation: a dimension that is discovered and used explicitly (1-3 and 2-2) in one experiment does not influence reaction time in another in which it is systematically correlated with the rule-defining feature.

Is implicit learning passive? The difference between experiments 1 and 2 shows that, contrary to a prevalent view in the field, implicit learning is more than an "unselective and passive aggregation of information about the co-occurrence of environmental events and features" (Hayes & Broadbent, 1988, p. 251). To emphasize our key point once again, one has to understand the way in which people process associated dimensions when they focus their attention on particular aspects of stimuli. Surface features that are associated with the rule-defining features, the features that are explicitly focused on, will nonetheless be included in the representation of the stimuli and will influence participants in subsequent tasks performed on similar stimuli Consequently, the problem of learning is not whether or not it is implicit or explicit but, rather, to understand which dimensions of the stimuli are processed by participants, implicitly or explicitly. We agree with Whittlesea and Wright (1997) who "argue that implicit learning is not qualitatively different from explicit learning: in both cases, what is learned is dictated by an interaction between the structural affordances of stimuli and the processing conducted to satisfy the subjects' current intentions. (...) we suspect that the intention to process the stimuli ... guides and constrains their behavior but does not completely control it" (p. 182). In fact, we think that, even if participants can describe the rule for categorization explicitly and mention that they used it, this does not mean that they really used it or that they did not use other information.

Categorization under the influence. Our results raise the question of the nature of the rule used for categorization. In the standard literature on category learning, a characterization of categorization is that rules control behavior. What does it mean? An implicit assumption in the field seems to be that people know the rule they use. In other words, they compare a target stimulus with a set of potential rules (or concepts, i.e., sets of features) and decide to categorize it in one category. However, our data (experiment 1) show that participants' description is an approximative description of what guides their behavior. We think that their description is at best correlated with the information that really controls for their behavior. Complementarily, even though their description of the rule for categorization is perfectly correlated with their categorization, this does not mean that they used these information in order to categorize the stimuli.

In concept learning, the importance of a dimension in categorization is described in terms of the weighting of the dimension. This notion is supposed to mean that subjects pay more or less attention to this particular dimension. This notion of weighting is too general and cannot account for the difference between experiments 1 and 2. The notion remains empty until one has described how it interact with particular stimuli. In other words, our results show that as a result of the way stimuli are processed, dimensions subjects did not attend to explicitly influenced categorization or not. Attention does not seem to be a sufficient concept to account for what dimensions influence categorization.

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