Effect of background knowledge on object categorization and generalization in preschool children

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Abstract

Lin and Murphy (1997) have studied how adults learn to associate a new theory about an object with specific perceptual features of the object. In the present experiment, their paradigm was adapted for three- and four-year olds who were compared with adults. The role of perceptual similarity between the learning stimulus and transfer stimuli was also assessed. Data show that children aged three were able to understand the relationship between a new micro-theory and perceptual data (the stimuli). However, their generalization to new objects was more constrained by perceptual similarity between the learning object and transfer stimuli than adultsÕ generalization was.

Introduction

Categorization, a process by which people decides that an instance belongs to a category, is usually thought as a comparison between an instance and conceptual representations. Several theories of conceptual representations of categories have been developed such as the classical view, the probabilistic approach or the exemplar view (Rosch, 1978; Smith & Medin, 1981; Nosofsky, 1992; Hampton, 1993; Lamberts & Shanks, 1997; Medin & Coley, 1998; Murphy, 2002). Typically, these approaches assume that concepts are lists of unconnected features, free of any influence from background knowledge (Nakamura, 1985; Rips, 1989; Murphy, 1993, 2002).

Theories and background knowledge can be defined as beliefs about the relations between features (Keil, 1989; Murphy, 1993). One important feature of theories is that they allow the identification of relevant features (see also Wisniewski and Medin, 1994). Theories also explain surface similarities between members of the same category (Murphy and Medin, 1985). They also provide coherence between the dimensions that compose a stimulus (Keil, 1989).

Since the mid-eighties, the development of childrenÕs theories has been extensively studied. Most of these studies focused on the content of childrenÕs theories (Carey, 1985; Keil, 1989; Wellman & Gelman, 1998, for reviews). On the other hand, the role of theories in the acquisition of new concepts, especially in young children has been less investigated. Indeed, while there are numerous studies on the interaction between na ve theories and concept learning in adults (see the impressive number of contributions by Murphy and colleagues, Murphy, 2002), these studies remain rare for children.

In the cognitive development arena, Barrett, Abdi, Murphy and Gallagher (1993) have established the importance of features associations related to a theory in conceptsÕ definitions among children aged 6 to 9 years. Items containing these associations elicited better categorization and were judged as more typical. However, this work has been completed with children aged 6 and beyond, that is children who already have complex theories. Moreover, the authors failed to find a significant difference between the two groups, which suggests that the assessed background knowledge was equally established in both groups. By definition, this is not the best situation to study the development of the interaction between theories and stimuli. Krascum and Andrews (1998) have shown that 4- and 5-year-old children could learn family-resemblance concepts more easily when theories were available. In their paradigm, authors capitalize on a priori na ve theories available in children, in this particular case theories about aggressive and hiding animals. The experimenter explained how a na ve theory was related with perceptual features of the animals (claws, etc.). It was shown that children who had learned the relation categorized transfer items with only one or two features of the learning items much better than children in a condition in which each feature was mentioned but had no function associated with it. Thus, in this research, na ve theories were available a priori, and transfer stimuli were composed of a subset of the learning stimuli features. Children had not to generalize to stimuli that differed perceptually from the learning stimuli. More recently, Carmichael and Hayes (2001) have found, with

children aged 4 to 10 years that theories and exposure to exemplars work in conjunction during concept learning. Here, participants were shown exemplars of fictitious animal categories that were either unrelated or consistent with their prior knowledge. When exemplars were consistent with their theory, the theory was reinforced whereas when the exemplars were not consistent with the theory, participants revised it, especially in the case of older children.

All the studies above suggest that a unifying theme increases the speed of learning. It must be underlined that most of these contributions are with six-year-old children and beyond or compare four-year-olds with older children. Furthermore, when the influence of theories was observed, it was stronger with older children. However, it is important to assess concept learning and its relationship with theories in the case of younger children (letÕs say 3-to-4-year old children) because they learn many concepts at this age and children aged five or more have learned thousands of concepts already. We need to know more about earlier steps of concept learning when the conceptual system and theories are less developed.

One reason for the small number of studies on concept learning and theories with young children is that young children are very poor in tasks that involve systematic learning (Murphy, 2002): their use of new features is less flexible, they cannot change their mind when the chosen feature appears to be irrelevant for categorization, or they do not take the experimenter feedback into account. In experiments with adults, theories can easily be taught verbally or can be assumed to belong to the participantsÕ conceptual system. In the case of very young children, teaching new theories verbally is difficult. For all these reasons, one way to study the interactions between theories and concept learning is to teach children a very simple theory and implement it on a feature of an unfamiliar object and see how they generalize this association to new objects. In the experiment to be reported here, we rely on a situation devised for adults by Lin and Murphy (1997). Our purpose is to check whether young children will be able to learn the theory and associate it with a particular feature of an object. A second purpose is to manipulate the perceptual similarity between the learning stimulus and transfer stimuli.

Lin and Murphy (1997) demonstrated with adults that background knowledge influence learning and transfer of concepts to new instances, i.e. conceptual generalization. In their study, participants had to learn a new artificial object. Half of them was given a specific interpretation of the object (the object was described as a fertilizer and a specific part was associated with this function) whereas the remaining subjects received another interpretation (the object was used for hunting and another part of the object was associated with this function). Thus, both groups saw the same learning exemplar but the crucial part in one interpretation was different from the crucial one in the other interpretation. Once participants had learned the object, they were presented with three transfer items and had to decide whether they belonged to the same category as the learned object. They had also to rate typicality for objects that elicited a positive response. One test item was consistent with one interpretation of the object whereas a second one was consistent with the other interpretation. A third test item was inconsistent with both interpretations. Results showed that background knowledge affect categorization and typicality judgment. Participants gave four times more positive responses to test items that retained the crucial part consistent with the interpretation of the object they received in the learning phase and rejected the inconsistent object. In the present experiment, we compare adults (the Lin and Murphyǒ situation) with young preschool children.

Experiment

The goal of this experiment was to evaluate the effect of background knowledge on object learning and generalization in children. At each level of age, there were two groups of participants; each group had to learn a different interpretation of the same unfamiliar object. In one condition, knowledge background emphasized the function of one part of the object whereas in a second condition another part was highlighted. In the transfer phase, the influence of background knowledge was assessed through transfer items that were transformations of the learning phase stimulus. For example, the crucial part according to one interpretation was kept in a transfer stimulus, while the crucial part for the second interpretation was deleted, whereas the reverse was true for a second transfer item. Thus, these test items were consistent with one micro-theory only. Background knowledge will influence performance when participants who have learned one interpretation of the object categorize the test item consistent with this interpretation in the same category as the learning exemplar and reject transfer items consistent with the other interpretation of the learning phase stimulus. There were also simplified test items, in which the crucial parts associated with both micro-theories were deleted.

A second purpose of this experiment was to assess whether young children would be able to generalize their new theory to new stimuli that differed perceptually from the learning phase stimulus. In other words, are young children able to go beyond perceptual similarity (Jones and Smith, 1993)? In these test items, the crucial part was replaced by a part perceptually different but that could fulfill the same function. If participants rely on knowledge to make their categorical decisions, they should accept these transformed objects as members of the same category as the learning phase stimulus.

Methods

Participants Thirty children aged 3-to-4 (mean age = 3;6) (i.e., group 1) and thirty children aged 4-to-5 (mean age = 4;5) (i.e., group 2), participated in this experiment. Informed consent was obtained from their parents. Thirty students from the University of Li ge also participated in this study as volunteers. Participants were randomly assigned to one of the two interpretations, conditions A and B.

Materials Stimuli were created and transformed after those designed by Lin and Murphy (1997). The learning exemplar was a colored line drawing (i.e., old item). It was composed of three parts, a pole, a loop at the end of the pole. The third part was a sort of a container. The length of the stimuli was more or less 12 centimeters. They were also colored in order to make each stimulus more realistic (see Figure 1, first cell). The object was called a ÒpukÓ which is not a french word.

The two conditions differed on the central feature they highlighted. In the first condition (A), the important part of the puk was the container. It was used for fishing. In condition B, the crucial part was the loop supposed to be used for closing shutters. Note that the crucial element in condition A had no central role in condition B (the recipient was useless for closing shutters), whereas the important part in condition B had no role in condition A (one cannot catch fishes with the fishes).
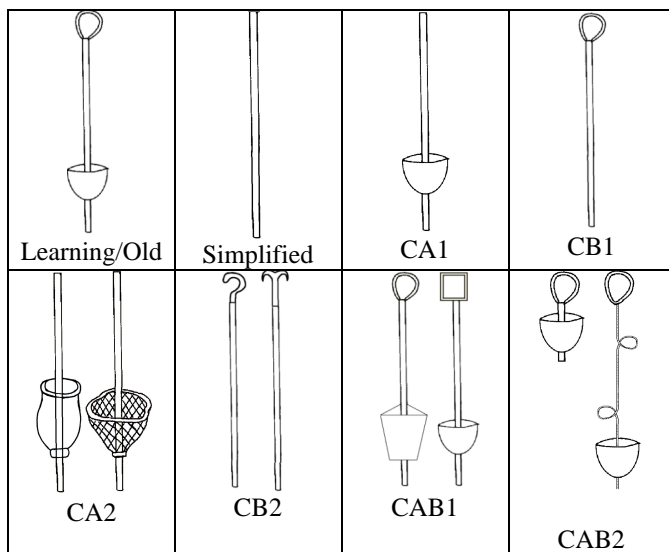

Figure 1: Type of test items.

Several test items were designed to assess whether background knowledge influenced the way participants interpreted the object (see Figure 1). The Old test item (Old) was the learning object. Test items consistent with one interpretation but not the other were constructed. CA1 and CA2 were consistent with condition A but not condition B; CB1 and CB2 were consistent with condition B but not condition A. The difference between CA1 and CB1 on the

one hand and CA2 and CB2 on the other hand, was that for the latter stimuli the crucial part had its shape completely modified even though it could still fulfill the same function as the corresponding part in the learning phase stimulus. There were also test items consistent with either condition A or condition B but one of the two important parts had its shape modified even though its structure was the same as in the learning item (CAB1): in one stimulus the container was modified (Figure 1, CAB1 left) whereas in the other it was the shape of the loop (CAB1 right). Two test items consistent with conditions A and B were modified in such a way that it was difficult to fulfill both functions (CAB2), in one case because the pole was so short that it was useless (or so) to catch something, in the other case because the pole was replaced by a string (see CAB2). Last, a test item was simplified with both conditions (S).

Procedure First, participants had to learn the function of the novel object corresponding to the condition he belonged to (A or B). The experimenter provided participants with a description of the object that he illustrated with the picture of the object. Participants in both conditions saw the same puk. Additional pictures were used to explain the function of the object to participants. In condition A (fish condition), pictures showed how fishes were caught with the object, whereas in condition B (shutter condition), pictures illustrated the shutter use.

Participants in condition A learned that the exemplar was an object used to catch fishes in a pool. The description was as followed: ÒIÕm going to show you an object that youÕve never seen before. This object is called a puk and is used for catching fishes in a pool. The puk is composed of a pole with a loop on the top and a metal container on the bottom. IÕm going to explain you how to use this puk. You put the puk into water; then you bring the metal container near and below a fish. You gently take back the puk until the fish is caught in the containerÓ Pictures were shown to implement this description in a real situation.

Participants in condition B learned that the object was used to close a shutter. They were provided with the following description: ÒIÕm going to show you an object that youÕve never seen before. This object is called a puk and is used to close shutter. The puk is composed of a pole with a loop on the top and a metal container on the bottom. IÕm going to explain you how to use a puk. You take the puk and bring the loop round the shutter hook. You gently take the puk back until the shutter reached the bottom of the windowÓ Again pictures were provided as a support. To be sure that participants had correctly learned what was a puk, they were asked to recall and explain its function to the experimenter.

Note that in the Lin and MurphyÕs description of the object, each part had a function. However, in each of the two interpretations of the object, one part was functionally central whereas the other parts had a less central role. For example, a less central part in one interpretation was used to hang up the tool. In our case, each part was mentioned but only the central part was given a function in the description.

This was done because, in preliminary experiments, we noticed that, younger participants were completely lost and, later, behaved either randomly or, on the other hand, in a stereotyped way. In other words, interestingly, they failed to integrate the description of the stimuli in a consistent way.

After the learning phase, the various test items shown in Figure 1 were randomly presented to participants. For each item, they had to decide whether it was a puk or not.

Results

Our first purpose was to see whether participants correctly accepted the old stimulus while rejecting the simplified one, especially children. It is a way to assess that children did not answer randomly or produced too many errors. As shown by Table 1, children, like adults, accepted the old stimulus and rejected the simplified one correctly. In each condition, comparisons of proportions revealed no significant difference between the three groups for old and simplified stimuli ($p >.1$).

A second purpose was to replicate Lin and Murphy's (1997) results. More precisely, participants in the 'fishing' condition had to categorize CA1 as a fishing device and reject CB1 whereas participants in the 'shutter' condition had to categorize the test stimulus CB1 as a shutter device and reject CA1.

One way to test this hypothesis is to compare the proportion of positive categorizations for CA1 or CB1 with the proportion of positive categorizations for old items. When test items (CA1 and CB1) were congruent with their theory (the 'fishing' condition and the 'shutter' condition, respectively), we expected no difference between these items and the old item. For example, in the 'fishing' condition, one expected no difference between the proportion of positive categorizations for CA1 and the proportion of positive categorizations for the old stimulus in this condition. By contrast, when the test item was inconsistent with a theory (e.g., CB1 with 'fishing') the difference between the proportion of positive categorizations for this item and the old item should be significant. (Theoretically, while the proportion of positive categorizations should be 100% for old items, it should also be 100% for consistent test items and 0% for incongruent test items.) For consistent test items, comparisons of proportions revealed no significant difference between CA1 or CB1 and the corresponding proportion for the old stimulus ($p > .1$). Comparisons of proportions were in the opposite direction when CA1 or CB1 were not consistent with the theory. CA1 or CB1 differed significantly from the corresponding old item ($p < .05$), except for children aged three, in the 'shutter' condition, in which the difference did not reach significance ($p > .05$).

A related way to investigate the effect of a theory is to compare CA1 with CB1 for each age group. If participants understood the relationship between each of the two target parts and a theory, they should correctly accept the test item consistent with a theory and reject the test item inconsistent with the same theory. The results showed a reliable difference between CA1 and CB1 stimuli for each group

and for both theories ($p < .05$), except for children aged 3 in the 'shutter' condition ($p > .1$).

We also compared CA1 with CA2 and CB1 with CB2. Recall that for CA2 and CB2 the crucial part has been transformed though they can still perform their function (shut or fish). Comparisons of proportions showed that, for children aged 3, there was a significant difference between CA1 and CA2 in condition A ('fishing'), meaning that children accepted CA2 less often than CA1 ($p < .05$). The same was true for CB1 compared with CB2 in condition B ('shutter') ($p < .05$)(see Table 1). On the other hand, there was no reliable difference these pairs of stimuli for children aged 4 and adults ($p > .1$). As shown in Table 1, most older children and adults correctly accepted consistent transformations (though this is less clear for 4-year-olds in the 'fish' condition). Thus, for older children and adults perceptually different parts that fulfill the same function are members of the same category whereas this is much less the case for younger children.

Old items were also compared with CAB1 and CAB2. For the three groups, comparisons of proportions revealed no significant difference between old items and CAB1 test items in both conditions ($p > .1$). For children, comparisons of proportions showed no significant difference between old items and CAB2 ($p > .1$). For adults, the difference between old items and CAB2 items reached significance in condition B ('fishing') ($p < .05$). Thus, for the three groups, a transformation that did not affect the function of a part (CAB1) had no impact on categorization. When the transformation of the pole interfered with the object function (CAB2: this is because, as seen in Figure 1, when the pole is too short or is made of a non-rigid material, it cannot fulfill (or less) its function, even though the crucial part has not been transformed) there was a significant drop of positive categorizations for adults and in the 'shut' condition only. In other words, both groups of children and adults in the 'fish' condition failed to reject CAB2 items correctly

Table 1: Percentage of positive categorizations for each type of test items.

Group	3-year-olds		4-year-olds		Adults	
Condition	Fish	shut	fish	shut	fish	shut
Old	100	93	100	100	100	100
Simplified	0	20	0	0	0	0
CA1	93	67	80	40	87	0
CB1	20	73	27	93	7	87
CA2	50	17	53	7	77	0
CB2	20	33	17	77	3	87
CAB1	83	83	83	97	93	90
CAB2	93	93	97	100	87	63

Discussion

Lin and Murphy (1997) showed that adults who had learned the function of a specific part of a multicomponent object (the learning phase stimulus) correctly generalized it to objects displaying a part with the same function (CA1 or

CB1, depending on the theory) and rejected objects with parts belonging to the training object but which could not fulfill the same function (CA1 or CB1, depending on the theory). We replicated this finding and, most importantly, extended it to very young children. This means that children were able to learn a micro-theory about an object and implement it on a particular part of the object. Children correctly rejected new items with parts of the original stimulus that could not fulfill the function. In sum, children and adults categorized transfer items according to the theory they had learned. This result is important because it shows that children can learn micro-theories and map them on perceptual data.

The evidence that both adults and children generalize the theories to new perceptual stimuli with the same function rules out the explanation of the effect in terms of pure perceptual similarity. As in Lin and Murphy, these observations suggest that children could use the association between a particular part and the theory about the object.

However, children differed from adults in important ways. Even though they could learn which feature was related with one of the two theories, they were more influenced by perceptual similarity than adults. This is suggested by the fact that 3-year-olds rejected less often items which were not consistent with a theory (especially for CA1 in the shutter condition) than other participants, and that they generalized less often when the structure of the consistent feature was transformed (i.e., CA2 and CB2). However, young children were not influenced by small perceptual transformations such as in CAB1. This means that they can overcome small transformations consistent with the theory whereas they interpret structural transformations as instances of the same category less easily than adults.

It is also important to mention that they accepted more CAB2 items than adults (especially with the shutter interpretation). This suggests that children were less able to see the relationship between the function of one part and other features. For example, even though the pulling feature is present, the object is difficult to use with this function if the pole has been replaced by a rope.

There is a debate in the literature between authors who posit a primacy of perceptual similarity over theories and those who claim that children rely on theories from the very beginning of their development (see Keil, Carter Smith, Simons, Levin, (1998). In the first case, children are supposed to process similarity first and use causal theories later. First learning is perceptually driven, progressing to forming abstract theories. The second group of authors claims that similarity has to be constrained in some way by general knowledge.

Our data suggest that this debate has to be thought in terms of an interaction between these two sets of information. Clearly children could learn to implement a theory on a perceptual structure. Our data regarding CA1 and CB1 show that each micro-theory constrained the interpretation of the perceptual information available. In other words, the perceptual part of the learning item that was highlighted depended on the background knowledge associated with the learning item. In other words, a model based on associative learning among properties would not explain the data. Among others, it would not explain easily how our brief 1-trial-exposition phase led to the focus on a specific part we observed. However, perceptual data influenced children's categorizations more than adults' categorizations, as shown by the results obtained for CA2 and CB2 on the one hand and CAB1 on the other hand.

Our data call for a hybrid model of concept in which similarity and rules are needed without reducing one to the other (Keil et al., 1998), the important question being how these two components interact. First, children understood the theory and could implement it on perceptual data in the same way as adults. Regarding this debate, the difference between adults resides in the CA2, CB2, and the CAB2 items. The fact that children were less prone to generalize to these items (CA2 and CB2) or reject them (CAB2) than adults clearly shows that the perceptual structures that are a good instantiation of a theory must be quite perceptually similar to the original stimuli. This is probably because probably because adults could rely on other pieces of background knowledge (about fishing and pulling) so that parts perceptually dissimilar could be evaluated in terms of function within a more general theory. General theories in adults also contributed to accept CA2 and CB2 objects.

In general, our data suggest that there is no opposition between theory and perception (see Jones & Smith, 1993 and the debate raised by this paper). In fact, there is a subtle dialogue between perceptual data and theories that evolves during development. Both adults and children rely on theories AND perceptual data. However, the difference between these groups is in the generality of this connection between theory and data. There is no qualitative difference between children and adults in the construction of relations between theories and data.

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