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SHORT COMMUNICATION

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Categorization and abstraction abilities in 3-year-old children: a comparison with monkey data

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Abstract Three-year-old children were tested on three categorization tasks of increasing levels of abstraction (used with adult baboons in an earlier study): the first was a conceptual categorization task (food vs toys), the second a perceptual matching task (same vs different objects), and the third a relational matching task in which the children had to sort pairs according to whether or not the two items belonged to the same or different categories. The children were tested using two different procedures, the first a replication of the procedure used with the baboons (pulling one rope for a category or a relationship between two objects, and another rope for the other category or relationship), the second a task based upon children's prior experiences with sorting objects (putting in the same box objects belonging to the same category or a pair of objects exemplifying the same relation). The children were able to solve the first task (conceptual categorization) when tested with the sorting into boxes procedure, and the second task (perceptual matching) when tested with both procedures. The children were able to master the third task (relational matching) only when the rules were clearly explained to them, but not when they could only watch sorting examples. In fact, the relational matching task without explanation requires analogy abilities that do not seem to be fully developed at 3 years of age. The discrepancies in performances between children tested with the two procedures, with the task explained or not, and the discrepancies observed between children and baboons are discussed in relation to differences between species and/or problem-solving strategies.

Keywords Categorization · Conceptual matching · Relational matching · Analogy · Children

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Introduction

The comparative study of humans and animals allows us to improve our knowledge of cognitive processes like perception, memory, or categorization. In this respect, a comparative investigation of the behavior of humans with that of other primates is particularly interesting because of their phylogenetic relatedness. Finding an appropriate methodology for comparing the cognitive abilities of primates is challenging; comparisons with adult humans are difficult because a task suitable for exploring nonhuman abilities may be too simplistic to reveal much about adult human cognition due to ceiling effects. However, comparisons between adult nonhuman primates and children (whose cognitive abilities are still developing) could help to solve this problem; nonhuman primate performance can be assessed against a particular stage of cognitive development. This approach can shed new light on research questions by framing them within phylogenetic or ontogenetic perspectives.

This study uses a comparative approach to examine behaviors corresponding to conceptual categorization, and to abstraction of relations between objects and between concepts, respectively. In our experiment with 3-year-old children, we presented a set of three tasks (tested previously in baboons), with increasing levels of difficulty. In the first task (conceptual categorization), the participants had to categorize objects into two different functional classes, food and nonfood. In the second task (perceptual matching), they had to judge two physical objects as being "the same" or "different." For example, they judged two apples as being the same, or an apple and

a padlock as being different. In the third task (relational matching), the participants had to combine their previously acquired skills in order to classify as "the same" two (different) objects that belong to the same functional category (food or nonfood). For example, they had to classify as "the same" an apple and a banana, or a teddy bear and a cup, and as "different" an apple and a teddy bear (see Fig. 1). We chose to test 3-year-old children, because at that age they are able to use concrete vocabulary, based on the people and things that are around them, and are also able to use more abstract relations like "bigger," "same as," and so on. Moreover, Goswami and Brown (1990) demonstrated that 3-year-old children could solve some very simple analogies.

Conceptual categorization is demonstrated when categorization is possible without any perceptual resemblance between the members of a class (Herrnstein 1990); for example, when objects are classified according to function only. In a study by Ross (1980), plastic toys representing furniture or food were shown to 12- to 24-month-old children and visual preferences were measured. After familiarization with the stimuli belonging to one of the categories, the infants looked longer at the stimuli that belonged to a new category. Kemler-Nelson et al. (2000) established that 2-year-olds can generalize new names on the basis of functional similarities. However, other experiments have shown that young children categorized much more easily on a perceptual basis than on a functional basis. For example, in a sorting task presented to 2- to 3-year-olds, Tomikawa and Dodd (1980) presented objects that varied according to both physical and functional features. Even when the experimenter insisted on the objects' function, the majority of children still relied on perceptual features.

For our second task (perceptual matching), the children had to attend to the same/different relationship between two pictures. Evans and Smith (1998) showed that identity becomes important for classification tasks between 3 and 4 years of age. However, before 5 years of age, children tend to have difficulty in using similarity or identity to form categories of more than two objects (Smith 1983).

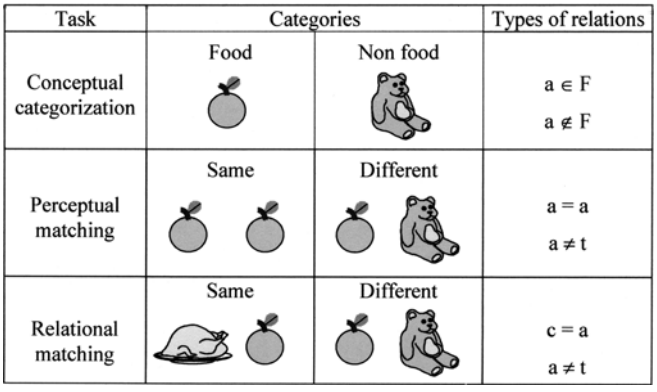

Fig. 1 Successive tasks presented to the participants. ∈ belongs to, = perceptual or conceptual identity, *F* food, *a* apple, *c* roasted chicken, *t* teddy bear

The third task in our experiment involves relational matching; this is the ability to match or to categorize not only objects, but also relations between the objects. Seven-month-old infants seem to be able to perceive a similarity between two different pairs of objects having the same relation (Tyrrell et al. 1991). They show more habituation, in terms of visual fixation time, when presented with two pairs of objects having the same type of relation (sameness or difference), than when presented with two pairs of objects with different relations (one sameness and the other difference). However, children are apparently not able to use this ability in a task requiring matching relations to relations before 5 years of age (Thompson 1995). Another experiment showed that 33-month-old children have more difficulties matching objects belonging to the same superordinate category (or objects functionally complementary) than matching objects that belong to the same basic-level category (Daehler et al. 1979).

In our earlier experiments, adult olive baboons were tested in the three tasks in succession (Bovet and Vauclair 1998, 2001). The baboons were individually tested in their home enclosure with a conditional responses apparatus. The apparatus was made of a vertical wooden board comprising a one-way screen, a horizontal board to present the stimuli behind a Plexiglas window and two openings for two ropes. When the experimenter placed one or two objects on the board, the subject had to respond by pulling one of the two ropes, according to the categories or to the relations presented. A food reward was provided when the baboon's response was correct. In each task, the baboons were trained with two stimuli (objects or pairs of objects) and when they succeeded, new objects were presented in order to assess transfer abilities. Four baboons were tested in the tasks of conceptual categorization and perceptual matching, and two were subsequently also tested in the relational matching task. The mean percentages of correct responses to the first presentations of new objects, after training with the initial objects (or pair of objects), were 92.8% for the conceptual categorization, 82.7% for perceptual matching and 86.1% for conceptual matching. These scores show that the baboons mastered the three tasks.

The aim of our study was to present those three tasks to children, and to compare the performance of the children with the results we obtained previously in baboons. The children were tested using two different procedures, the first being a replication of the one used with the baboons (procedure 1), the second a procedure based on the children's prior experiences with sorting objects (procedure 2). A group of children was tested with the three tasks, whereas another group was tested in the third task only, in order to test for the effect of task sequence. Finally, some of the children were tested with the third task when full explanations about this task were provided by the experimenter.

Methods

Participants

The participants were 32 children (21 boys and 11 girls) aged, at the beginning of the experiment, from 2 years and 6 months to 3 years and 11 months (mean age: 39 months, SD=3.5). The experiment was conducted over 7 months, 4 days a week, with those children who were willing to participate on each particular day (no child participated every day).

Stimuli

The stimuli were 40 photographic cutouts following the objects' outline, each pasted on white 11×12-cm cardboard. The photographs represented objects belonging to two categories: 20 food objects (fruits, vegetables, cooked meals, cakes, sweets, etc.) and 20 toys (dolls, stuffed animals, balls, vehicles, buildings, etc.). For each photograph's initial presentation, the experimenter made sure that the child recognized the picture by asking him/her to name it. When recognition was not perfect, the child was not tested with the picture. Thus each child was tested with 30 photographs, chosen from among the 40 pictures after recognition was verified.

Procedure

Four groups of children were tested (see Table 1): 12 children (group 1, mean age: 37 months, SD=4.6) were tested with the same kind of procedure as the one previously used with baboons (procedure 1: conditional responses apparatus), and 12 other children (group 2, mean age: 38 months, SD=2.3) were tested with a procedure closer to the sorting tasks used in school (procedure 2: sorting pictures in two boxes). In these first two groups, the participants were tested in the three tasks outlined above. Another group of six children (group 3, mean age: 43 months, SD=2.3) was tested with procedure 2 in the relational matching task, without any prior training with the other tasks. Four children of group 2 and two children who had not participated in our experiment before (group 4, mean age: 41 months, SD=4.2) were also tested with procedure 2 in the relational matching task, but the task was fully explained to them by the experimenter. In each condition, percentages of correct responses on the first presentation of each picture were compared to chance level with an χ^2-test.

Procedure 1: conditional responses apparatus

This procedure allowed us to use the same apparatus and the same procedure with children as the one previously used with baboons. The testing apparatus for the children was made of a cardboard box with two windows (one in the lower part of the apparatus to display the stimuli, and the other in the upper part to show the reward) and two ropes (see Fig. 2a).

Each test session lasted an average of 10 min, dependent upon the child's motivation to perform the task. On

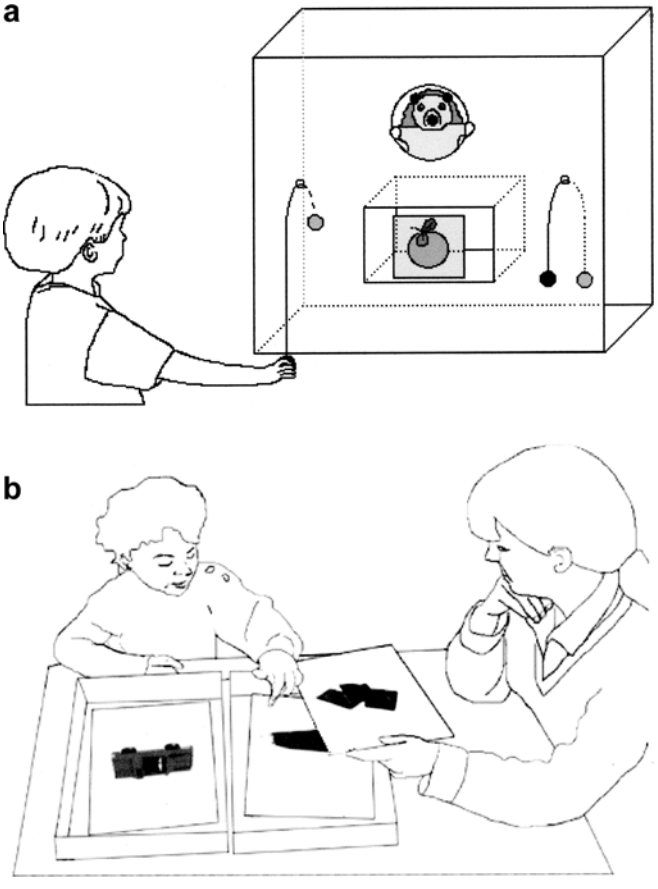

Fig. 2 **a** Conditional responses apparatus used in group 1. **b** Sorting into boxes apparatus used in groups 2–4

Table 1 Distribution of participants across groups

Group	Group 1		Group 2	Group 3	Group 4
Procedure	Procedure 1 (conditional responses apparatus)		Procedure 2 (sorting into boxes)	Procedure 2 (sorting into boxes)	Procedure 2 (sorting into boxes)
Task	Task 1–3 without explanations	Task 1–3 without explanations, then task 3 with explanations	Task 1–3 without explanations	Task 3 without explanations	Task 3 with explanations
Number of participants	8	4	12	6	2
Mean age	3 years 1 month	3 years 2 months	3 years 2 months	3 years 7 months	3 years 5 months

average, each child completed 20 trials per day. The children had to first learn a response between two stimuli (conceptual categorization) or two pairs of stimuli (perceptual and relational matching). They were told to look at the picture(s), then to pull one of the ropes. When the participant pulled the correct rope, a puppet appeared, congratulated the child, and gave him/her a sticker after five correct responses. Otherwise, the puppet did not appear and the experimenter told the child: "It is not the right rope. Try again." Each picture (or pair of pictures) was used as a test stimulus (the child's first response was recorded) and then as a training object (the picture was presented again, until the child had learned the rope associated with the picture). Once the child achieved eight out of ten or more correct responses, new stimuli were presented.

Procedure 2: sorting into boxes

Children's abilities to use the same categorization rules as in procedure 1 were tested using a procedure that was closer to their daily experiences. Thus, in procedure 2, children had to arrange the pictures belonging to the same category in the same box. As in procedure 1, children were individually tested. The child sat behind a table on the top of which two boxes were placed; one was white and the other blue (Fig. 2b). For the task of conceptual categorization, the experimenter asked the participant to put in the same box the pictures that "go well together." The child was congratulated when he/she classified the pictures in the boxes according to their categorical belonging together, and corrected if it was not the case. For perceptual matching, participants were requested to sort pictures into cardboard boxes in which two photographs were already displayed (two different photographs belonging to different categories). For relational matching, participants were requested to sort pictures into the boxes where two different photographs belonging to the same category were already displayed (see Fig. 1). Thirty different stimuli were presented for each task. The only reward in this procedure was the congratulations given by the experimenter.

Results

Conceptual categorization

In group 1, tested with the conditional responses apparatus, 6–23 pictures were presented to each participant according to individual learning speed. Each child performed between 342 and 1,055 trials (mean: 549, SD=197). Percentages of correct responses on the first presentation of each picture were never significantly different from 50%. In contrast, the sorting into boxes procedure (group 2) led the majority of the children (9 out of 12) to achieve results significantly different from chance (all Ps<0.05). When performing the task, most of them spontaneously declared "It is food" or "It is a toy."

Perceptual matching

In group 1, five out of ten children learned to pull one rope for a new pair of different pictures, and the other rope for a new pair of the same pictures (all Ps<0.05). They needed an average of 192 trials and five examples to reach the criterion of 8/10. In group 2, global percentages of correct responses were significantly different from chance for 6 out of 12 children (all Ps<0.05). Except for one child, all of the children who mastered this task had also understood the conceptual categorization task. Most of the children spontaneously declared: "They are the same" or "They are not the same," when they saw the first presentation.

Relational matching

The five children in group 1 who understood the tasks of conceptual categorization and perceptual matching were tested in the relational matching task. Relational matching requires combining conceptual categorization and perceptual matching. The observed difficulties in learning which rope was to be pulled for the six combinations made with four different pictures suggest that participants failed to relate the two initial tasks. The two participants who succeeded in learning (after 256 trials and 191 trials, respectively) responded at chance level when a new picture was presented in combination with the four previously shown photographs: one child gave two correct responses (χ^2=0, df=1, P=1), and the other only one (χ^2=1, df=1, P=0.32) of the four new combinations. Likewise, none of the children in group 2 solved the task: their results were never significantly different from chance.

In order to test for the effect of task sequence, a control condition was administered to six new participants. In this condition (group 3) children were only examined in a relational matching task (using the sorting pictures into boxes procedure), without previous exposure to the other experiments of functional categorization and perceptual matching. But again, the children's responses were never significantly different from chance.

Thus, the results were the same for the task of relational matching in groups 1, 2 and 3: none of the children mastered this task. Confronted with these negative findings, we devised a teaching situation in order to see whether verbal explanations from the experimenter would help the children to master the relational matching task. In order to control for potential interference due to previous phases of the experiment, the performances of four children already tested in group 1 were compared to those of two children who had not previously participated in our experiment (group 4), in a task (sorting pictures into boxes) where the rationale of the various steps was fully explained to the six children. At the beginning of the test,

the experimenter explained to the child that he/she should place pictures of pairs of things that go well together in one box, because they are both for eating or both for playing, and in the other box, pictures of pairs of things that do not go well together, because one is for playing and the other is for eating. After two examples had been provided, 28 new pairs were presented one by one and the participants were guided in all steps of their reasoning. Their mistakes were corrected immediately after occurrence. The children were always congratulated for each correct response. All of the children were further congratulated and given a sticker at the end of the test session. The four children previously tested in group 1 and one of the two naive children (group 4) obtained significant results showing that they understood the task. The results for all groups are summarized in Table 2.

Discussion

Conceptual categorization

In group 1, tested with the conditional responses apparatus (procedure 1), the children answered at chance level when tested with novel pictures. In group 2, tested with the sorting into boxes procedure (procedure 2), the majority of the children sorted food and toy pictures into two different boxes with success.

The use of a procedure better adapted to their competencies and experiences (group 2), namely, sorting the pictures into two boxes according to their categories, made the task easier for the children to understand. Three-year-old children are used to sorting objects, so it is likely that the second presentation of the task was more relevant to them than the first procedure we used with group 1, originally designed for baboons. Differences in categorization behaviors as a function of the procedure used have already been reported. For example, Oakes et al. (1996) found that 10-month-old children distinguished between people and animal categories in an object-examining task, but not in a sequential-touching task.

In contrast to human studies, few experiments involving sorting objects have been conducted in monkeys. They have been observed preferentially picking up objects belonging to the same category, but it is difficult to train them to sort objects into places (Tomasello and Call 1997); in nonhuman primates, only chimpanzees were able to sort real objects or pictures into two trays according to their belonging to "food" or "tool" categories (Savage-Rumbaugh et al. 1980). The chimpanzees were able to perform this task with great accuracy, even with objects that had not been used during training.

The current results replicate other findings on the ability of 3-year-olds to perform functional categorization (Ross 1980; Corrigan and Schommer 1984; Gelman and Markman 1987; Kemler-Nelson 1999; Kemler-Nelson et al. 2000). The rapidity with which baboons and chimpanzees, as well as children, were able to categorize (after only a few examples) is likely to result from the early construction of a food category, because of its importance in their daily life.

Perceptual matching

About half of the children in group 1 and group 2 understood the task. This may be due to the familiarity of the "same" relation, compared to the food or toy property. This interpretation is reinforced by the spontaneous labeling of the relations in the case of the sameness property but not in the case of functional categories.

The difference between baboons and children in terms of the number of stimuli seen before understanding the task can probably be explained by linguistic abilities of the latter. Children often hear and use words (and thus also concepts) like "the same." In contrast, baboons had never been trained to use same/different relations before we conducted our study.

Relational matching

The relational matching task is the most crucial one because it requires the most abstract reasoning abilities. We found a surprising difference between children's results and the performances previously attained with baboons. In effect, the baboons were able, after considerable training, to master this task (Bovet and Vauclair 2001). The children were also able to perform the relational matching task, but only if explanations were provided to them. However, they were unable to perform it

Table 2 Summary of the results: number of participants who solved each task

Procedure	Tasks			
	Conceptual categorization	Perceptual matching	Relational matching	Relational matching with explanation
Conditional responses apparatus (group 1)	0/12	5/12	0/12	
Sorting in boxes (group 2)	9/12	6/12	0/12	4/4
Sorting in boxes, without prior participation (group 3)			0/6	
Sorting in boxes, without prior participation (group 4)				1/2

without explanation, whatever the procedure, i.e., the use of a conditional responses apparatus or sorting into boxes.

We would like to emphasize that there is a crucial difference between the ability to solve the relational matching task after an explanation and to solve it without any explanation. Without explanation, the main difficulty is the abstraction of a complex rule, based on the relations (same or different) between the relations of the objects presented (whether or not they belong to the same category). It is therefore a task of analogical reasoning and the failure of the children might suggest that this ability had not yet developed sufficiently for them to succeed at the task. According to the literature, the relational matching task is only mastered by children of 5 years of age, or by chimpanzees first trained to use symbols to communicate (Thompson 1995; Thompson et al. 1997). Thus, our results are in agreement with those reported by Thompson (1995) in regard to children, but it seems that symbol training is not necessary for relational matching in nonhuman primates.

Our results differ from those found by Goswami and Brown (1990), who showed that some analogical abilities appear as early as 3 years of age. However, the 3-year-olds' performance remains limited; the analogies used in those experiments were simple physical transformations of same objects, like "box:open box::bottle:?." The relation between box and open box is one of opening, which the children understand and commonly use. The relationship between cake and salad is one of belonging to a superordinate category, which is less meaningful because, as we will see below, children at this age open bottles and boxes, but do not use superordinate categories. As observed by Goswami et al. (1998), even when children possess the relevant knowledge, some age effects can be found because analogy is not always appropriately used. The children we tested were not able to use the relationship "belong to the same taxonomic category," to solve an analogy, but they could use it when they had to sort pictures into boxes (conceptual categorization task in group 2).

Thus, the children's results indicate that the categories of food and toys are much more abstract than they might initially appear. Such findings are in agreement with the results of other studies in young children, which showed the privileged status of the basic level of categorization (Rosch et al. 1976) and that perceptual categorization is preferred to functional categorization (Tomikawa and Dodd 1980; Corrigan and Schommer 1984). Our results are also in agreement with the hypothesis of Lucariello et al. (1992), who identified that in 4-year-old children, the superordinate categories are primarily slot-filler categories, which concern objects sharing a function in the context of a precise event. Instead of categories like food or toys, young children use categories like "things you can eat for breakfast" or "toys to play with in the bath." Taxonomic categories, like food and toys, are used less than thematic categories in preschool children (Smiley and Brown 1979; Greenfield and Scott 1986).

As the aim of the present study was to compare conceptual abilities in two species, we wanted to test the children in a manner that was consistent with procedures we used previously to test the baboons. Thus, in procedure 1, we used the same kind of apparatus and a similar procedure. However, we were obviously unable to avoid some differences between the testing of baboons and children.

Firstly, the number of training examples was not the same for the children as for the baboons because the children were not as motivated to perform such a repetitive task. While it was possible to carry out about 150 trials per day with the baboons, the children in group 1 did only 20 trials per day on average. When the children had to sort pictures into boxes in groups 2–4, they saw more examples (30 different examples for each task) but unlike the baboons, they did not have to memorize all of these. Thus, training was obviously not as important for children as it was for baboons and boredom or memory capacity may have interfered with the children's abilities to solve the task. Therefore, training was obviously not the same for children as it was for baboons. This fact could have undermined the children's performance, compared to that of the baboons.

Secondly, the children were tested with photographs for practical reasons (safety, etc.), whereas the baboons were tested with real objects. Mandler (1997) has reported that 11-month-old infants differentiated animals from vehicles (even birds from airplanes) when tested on an object-examination task (the infants were allowed to touch toy animals or vehicles, and handling time was measured) but not when pictures were presented instead of objects. The recognition of each picture was verified and our children were much older than the infants tested by Mandler. Three-year-old children are used to speaking about things represented in photographs and to treating pictures as equivalents to the real objects they represent (DeLoache et al. 1998; Bovet and Vauclair 2000). Moreover, the spontaneous comments of the children always referred to properties of the real objects, and never to the properties of the photographs as pieces of paper. However, we cannot exclude the fact that the use of pictures instead of real objects made the task more difficult for the children.

If we compare the data obtained in this experiment with the results of previous studies conducted with baboons, our study provides new evidence of interesting disparities between 3-year-old children and adult monkeys. We found that children can make a conceptual categorization and perform perceptual matching, as had previously been found in baboons, but we had to adapt the task to allow for species differences. The most important disparity is the difference in performance on the relational matching task. Unlike the baboons, the 3-year-old children could not solve the relational matching task without any verbal guidance; they were only able to perform this task when the rationale of all of the steps was explained to them. As discussed above, those disparities may be explained by the nature of the tasks used, the difference in training intensity between baboons and children, the children's linguistic

capabilities, or by analogical reasoning abilities that seem to be more developed in adult baboons than in young children. More experiments are needed in order to establish which of these explanations is valid.

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