Object Categorization in the Preschool Years and Its Relation with Cognitive Inhibition

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Abstract

The present study aimed to investigate the relationship between flexible categorization and cognitive inhibition in preschool children. Subjects (N=14) were aged between 3 and 4 ½ years. They were tested with two tasks: a Stroop-like day-night task for inhibition (Gerstadt, Hong & Diamond, 1994) and an object-sorting task for flexible categorization. As 6 children did not perform the inhibition task properly, it was impossible to measure any correlation. In consequence, the study presents the analysis of the individual performance of the 8 children that performed both tasks. Discussion regards the implications of investigating the interplay between external and internal factors for understanding the mechanisms and the development of categorization.

Keywords: categorization; cognitive inhibition; preschool children.

Development of Categorization

If one takes the vast literature there is on categorization, a broadly accepted definition for this process will lead him/her to view it as the grouping of stimuli in different classes. Studying its ontogenesis has at least two major aims: to understand the development of categorization and to identify the mechanisms that lead to the way categorization will function in the adult period. The choice of categorization as an investigation topic is motivated mainly by the fact that we can consider it as a first step in problem solving. This way it becomes a very valuable ability for the cognitive system and by understanding its nature we can find out the manner in which we could optimize its functioning.

For long time categorization was seen as referring to grouping stimuli on the basis of some necessary and sufficient features (as in the theory of Piaget, or as logical categorization – Ionescu, 2001b). In the last decades psychology has changed this view by adding several other approaches – one of the most known examples is the prototype-based categorization (see the theory of Rosch in Miclea, 1999). One of the most recent views defines categorization as "a systematic differential interaction between an autonomous, adaptive sensorimotor system and its world" (Harnad, 2003). Barsalou (2003) considers that "each represented category corresponds to a component of experience". In his Situated Simulation Theory (Barsalou, 2003) he states a link between sensorimotor and conceptual processing because "conceptual processing uses reenactments of sensory-motor states – simulations – to represent categories". So the author considers concepts as abilities to construct representations according to the current needs of an action, meaning in continuous change. This view will give us useful insights about flexible categorization that will be discussed in the following.

One of the most important uses of categorization is to give high efficiency to the cognitive system when it encounters the vast amount of information in the environment. This efficiency is given on the one hand by the existence of well defined categories in our representational system that help us to quickly label a new stimulus if it is similar to the members of a certain category (e.g., animals, furniture, flowers, etc.); and on the other hand, by the capacity to go beyond the boundaries of these categories and to reconsider the group a certain stimulus belongs to according to the current needs (e.g., a glass as "object to drink from" or as "bowl for flowers"). This second aspect, namely flexible categorization, which allows us to reorganize information according to the contextual demands, was long time considered as not accessible to children. The existence of well defined categories was recognized as a capacity of the child's cognitive system: it was accepted that we make a distinction among object classes from the first years of life, but the access to class inclusion was thought as possible only at school entrance (see the theory of Piaget, e.g., 1945). The accepted flow of categorization development was from thematic categorization (according to a shared event – e.g., dog and his master) to the taxonomic one (according to kinds of objects – e.g., dog and cat as animals), and only in later childhood to the ability to flexibly alternate among them. The last decades of research has outlined however that preschoolers, and even infants (Mareschal & Quinn, 2001) can categorize flexibly if certain conditions are met (Blanchet, Dunham & Dunham, 2001; Gopnik & Astington, 1988; Prasada, Ferencz & Haskell, 2002; Rice et al., 1997; Waxman & Namy, 1997).

Studies with preschool children show that they do not have a preference for thematic categorization and they can use both thematic and taxonomic categories. For example, Waxman and Namy (1997) outline that the tendency for thematic categorization comes mainly at the age of 4 after a coexistence with taxonomic categorization, and it is often the effect of instructions used in the experiment. Using a forced-choice task, with a thematic and a taxonomic alternative for the target item (e.g., *tulip*-target object, *daffodil*-taxonomic alternative, *vase*-thematic alternative), and manipulating the instructions, the authors showed that performance differs

significantly according to the instruction. In the "goes best" and "goes with" conditions there are more thematic categorization, while in the "another one" condition children choose more taxonomic alternatives. We see that preschoolers do not have a clear preference for one or the other type of categorization; on the contrary, at 3, children seem to choose more taxonomic objects in the "another one" condition, and at 4 they choose more thematic alternatives in the "goes best" condition (Waxman and Namy, 1997). The authors plead for the hypothesis that children, just like adults, build their categories as a response for situational demands. This way, we could speak about a gradual development of the flexible knowledge system up to the adult stage, development that is based on abilities that are present very early in ontogeny.

But how exactly can we explain flexible categorization in young children?

Factors that Explain the Performance in Flexible Categorization Tasks. Cognitive Inhibition.

We can identify several factors that influence and facilitate complex forms of categorization in the preschool years. These factors can be grouped in two classes:

- external factors – represented by the constraints of the environment;
- internal factors – namely, the internal constraints of the cognitive system that categorizes.

There are in the literature studies that focus on the relationship between categorization and external factors. They show that factors like those listed below can influence the performance of children in flexible categorization tasks:

- instructions – Deak and Bauer (1995), Waxman and Namy (1997);
- training – Deak and Bauer (1995);
- the induction of certain contexts as well as the type of task – Blaye and Bonthoux (2001), Bonthoux, Cannard and Blaye (2000);
- type and features of stimuli – Ahn, Gelman, Amsterlaw, Hohenstein and Kalish (2000), Blanchet, Dunham and Dunham (2001), Chaigneau and Barsalou (in press), Gutheil, Bloom, Valderrama and Freedman (2004);
- different cues used in experiments – Nazzi and Gopnik (2003).

Regarding the internal factors (like knowledge base, working memory, cognitive inhibition, the comparison process, or language), we have very few studies that relate these with the ability of flexible categorization. They refer mainly to: language and concept acquisition or the influence of linguistic labels on categorization (Samuelson & Smith, 2000; Smith, Jones, Landau, Gershkoff-Stowe & Samuelson, 2002); the process of comparison and categorization (Gentner & Namy, 1999; Namy & Gentner, 2002); executive functions and flexible thinking (Jacques & Zelazo, 2001). There are no studies, to our knowledge, that investigate directly the link between performance in categorization tasks and in cognitive inhibition tasks, even though inhibition is considered in many studies on categorization in childhood a sine qua non condition for children's performance. In other words, the failure of little children to categorize flexibly is often explained via their reduced cognitive inhibition (due to the incomplete maturation of their frontal lobes), expressed in the perseveration of response (Zelazo & Jacques, 1996, apud Deak, 2000).

The present study aimed to investigate the relationship between flexible categorization and cognitive inhibition in preschool children (3 to 5 years). The assumption of the study is that there is a positive correlation among the two mentioned cognitive aspects, but a moderate one, because a good performance in categorization tasks is determined by external factors as well. This fact is demonstrated by the existence of flexible categorization even at 3-4 years of age, when the evaluation of cognitive inhibition would predict a high rigidity of information processing in children. Taking into account that for considering several possibilities of classification one needs to inhibit the previous categorization choice, we can consider inhibition as one of the important factors that intervene in the process of flexible categorization.

Cognitive Inhibition and Its Development. The inhibitor control is defined most often in developmental psychology as the capacity to suppress the actions or cognitive processes that interfere (Carlson, Moses & Hix, 1998, apud Benga, 2003). In the present paper, I have selected the cognitive aspect of the inhibitor control (see the procedure below), because cognitive inhibition is the closest to the nature of the categorization process.

The development of cognitive inhibition, as that of the executive functions in general, takes the shape of an inversed U-shaped curve – with low performance in childhood, optimal performance in the adult period, and again low scores in the third age (Zelazo, Craik & Booth, 2004). Its development depends on the maturation of the frontal cortex (Diamond & Taylor, 1996). There are a lot of precursors of inhibition from the first year of life (Benga, 2003), and between 3 and 7 years we are witnesses of a marked progress of this function.

The performance of children in tasks that require to remember two rules and alternative responses according to different demands is often explained via inhibition (Jacques & Zelazo, 2001). So far, there is no study to investigate the relationship among this "natural" constraint of the young cognitive system and the ability to categorize flexibly, and the experiments that investigate external factors explain children's failure via the procedures used in the studies (Waxman & Namy, 1997).

The Relationship between Flexible Categorization and Cognitive Inhibition

I have chosen for the assessment of inhibition the day-night Stroop-like task (Gerstadt, Hong & Diamond, 1994) because

it is the closest to the processing that takes place during categorization and because it evaluates cognitive inhibition. In order to evaluate object categorization I have chosen an object-sorting task that was derived form the literature (e.g., Waxman & Namy, 1997) and from some previous personal case studies (Ionescu, 2001a; Ionescu, 2003). They will be described in the section with the procedure.

According to the priority given either to external or to internal factors as essential in influencing flexible categorization behavior, we can make two predictions:

a) Children with low performance at the inhibition task will avoid to choose the object that was in the first category for the second one as well (see the Material section), and they will need longer time to solve the second categorization.

   Children with good inhibition will be as efficient in the second categorization as in the first.

b) There are no marked differences between the above mentioned groups of children regarding their performance in the categorization task.

After reviewing the literature we favor the second class of prediction, but we expect a positive moderate correlation.

Method

Subjects. Children (N=14) are aged between 3 years and 4 years and 6 months (m=3 years and 5 months), 9 boys and 5 girls (gender was not considered as a variable in this phase of the research). All children attend kindergarten and the approval of the institution was obtained to carry out the research.

Materials.
Day-night Stroop-like task – 13.5X10 laminated cards with two types of images: a sun on a light blue background; a moon and stars on a dark blue background.

Object-sorting task – familiar objects (toys): 3 main objects (a cup, a knife, a sharpener), target objects (e. g, cup, fork, etc.) and distracters (e.g., a cube, a doll, etc.). For each of the main objects there are two categorization possibilities: among the 7 objects that are in front of the child in a test trial, two always fit the main objects according to a certain criterion (e.g., the cup can be put in the category of "things we drink from" – thematic criterion – and of "green toys" – perceptual criterion – see fig. 1). All toys have similar size and the color was controlled not to interfere with their possible choices. The belonging of each main object to the classification possibilities was tested on adult subjects, in order to verify the members of each category and the clarity of the classification criterions (N=10, mean age-21 years and 1 month). Where the agreement was not 100%, objects were replaced until they arrived to those used in the study with children (with a maximum agreement).

a)

b) c)

Figure 1: Example of materials used in the object-sorting task: a) total set of toys (7); b) the category "toys we can drink from"; c) the category "green toys".

Procedure.
Day-night Stroop-like task (D/N) – the task started with checking the knowledge about the association sun=day and moon=night. As there were no two age groups to compare, I used two versions for this tasks:

- Real D/N – where sun=day and moon=night (control version);
- Inhibition D/N where sun=night and moon=day.

In the Inhibition D/N children had to say "night" when they saw the card depicting the sun, and "day" when they saw the card with the moon. This kind of answer needs the inhibition of the prepotent response (i.e., sun=day). After specifying the rules, there were 2 trials without feedback – if children erred, rules were told again.
There were 16 testing trials with a pseudorandom sequence (as in the study of Gerstadt, Hong & Diamond, 1994), and the analyses looked at the number of correct responses (max. 16) and the execution time.
The mean testing time was 2 minutes; all the situations were videotaped, and children were tested individually in a room in their kindergarten.

Object-sorting task – this task took the form of a game: "Let's arrange toys with Mickey Mouse!" The general background of the task was that Mickey Mouse came with a lot of toys, all put together, the task of children being to help him to group the toys according to different rules.
In the familiarization phase, all objects and properties used in the game were named by the child (with different objects than those from the test phase), children being allowed to manipulate them. The demonstration phase consisted in showing children that one and the same object can be put into two categories (a blue flower - "flowers" and "blue toys"). The main instruction was "Let's give Mickey Mouse all the flowers/all the blue toys". Objects were put back in the larger

group of seven after each categorization trial. After that, the child himself/herself did the categorization in order to check the understanding of the rules and to exercise the possibility to integrate one object into two categories.
In the test phase, there were 6 test-situations, two for each main object (with different distracters for each). During the game there were minimal cues, mainly clarifications of the questions. The game stopped after all the three objects were tested, and the analysis looked at the number of correct responses (max. 6).
The mean testing time was 10 minutes, in the same conditions as for the precedent task.

Evaluations with the two tasks took place in two different days, and children were rewarded after each evaluation. Feedback was not provided during the testing phases. Videotapes were analyzed by two coders and disagreements were all solved by discussion.

Results

Day-night Stroop-like task (D/N).

Out of the 14 children:

- 2 children did not associate correctly sun=day and moon=night in the beginning of the task;
- 4 children could not keep in mind the rules, not even after three pairs of trials;
- 8 children did complete the task.

The 6 children that could not complete the task were eliminated, and as a consequence the correlation was impossible to estimate. Because this study is part of a larger research project focused on flexible categorization in children, I decided to analyze the individual performance of the 8 children who performed both tasks, as a premise for the future investigation of the relationship intended in this study. The mean age of these children was 3 years and 8 months (3 years and 5 months-4 years and 6 months), 5 boys and 3 girls.
Out of the 8 children:

- 7 children performed the Inhibition D/N to the end;
- 1 child did not perform the Real D/N (he was not at the kindergarten that day);
- 1 child did not perform to the end both versions; he stopped at the 14th test trial in Inhibition D/N, and at the 12th test trial in real D/N.

The 6 children who performed completely the two versions had a mean error number of 2 (Inhibition D/N) and 1 (Real D/N), and a mean execution time of 58.5 sec (Inhibition D/N) and 54 sec (Real D/N). So, if we consider their performance as a "group" we could assert that they already have good cognitive inhibition.
Taken individually, 4 of the children had the expected differences in these kinds of tasks: more errors and a longer time in Inhibition D/N vs. Real D/N (e.g., 70 sec vs. 50 sec.; 4 errors vs. 2 errors). However, 3 children had a shorter time in Inhibition D/N (e.g., 46 sec vs. 53 sec) and an equal number of errors (1).
Analyzing the videotaped behavior of the child who did not complete the two versions we were able to observe a low behavioral inhibition as well.

Object-sorting task.

Out of the 8 children:

- 7 children did integrate correctly 2 or 3 main objects;
- 1 child did not make it further than the demonstration phase (the one that did not complete either version of D/N task).

We could observe children's tendency to put the object that belonged to the first category as the last one in the second, together with the visual search of feedback for the second categorization (remember that children were given no feedback at all).
We could also see that there is a relative independence of the performance in categorization and the performance in inhibition. Thus, there were children with good scores in inhibition that categorized correctly two main objects, and children with a lower score in inhibition who categorized correctly all three main objects. The time needed for the two categorizations/main object was similar, independent of the result in the inhibition task.

Discussion

The main observation that we can make on the basis of individual pattern analysis is that when the differences in the inhibition task (numbers of errors and execution time) are small, performance in categorization proves the flexibility of these children, namely the ability to integrate the same object in distinct categories. There are no differences in the categorization task – on the contrary, some of the children with lower inhibition categorize better the toys. Only if the score in the inhibition task is very low, leading to not completing the task, performance in categorization is also very low. In the case of that child, the most probable explanation is the interference of a low behavioral inhibition that has affected his focus on the task, and as a consequence his cognitive performance could not have been evaluated.

There is no avoidance of the objects that go in the first category for the second one, but they are postponed as if there were a "last moment choice". This can be a proof in favor of the interaction of cognitive inhibition with other factors, especially external ones, in determining the process of flexible categorization. In other words, there may be an initial inhibition, but the object is correctly chosen for the second category as well, maybe because of the initial training, the type of task and the familiarity of toys. In flexible object sorting one needs to go beyond the first classification criterion (e.g., thematic) and to reconsider the category that object belongs to (to put it for instance in a perceptually based category). This complex process is dependent ***both on*** cognitive inhibition ***and*** external factors. Most of the studies has focused so far on these types of factors (internal and external) separately (e.g., Bonthoux, Cannard & Blaye, 2000; Jacques & Zelazo, 2001; Waxman & Namy, 1997). We consider it useful to study their interaction in order to get a

better image about the mechanisms and the development of flexible categorization in childhood.

It is possible that the task used for the assessment of cognitive inhibition was not discriminative enough for children of 3-4 years, an aspect mentioned by other authors who used this task as well (Benga, 2003). Therefore, even if we could favor the second type of behavioral prediction, we need to repeat the study with a larger number of subjects and with alternative tasks for inhibition.

Speaking about the determinants of the ability to categorize, Dunham and Dunham (1995) showed that the preference for one kind or another of categorization in the preschool period seems to depend on the type of senzorimotor activity and on the early language production from the previous age periods. Thus, children who at 24 months use gestures for showing objects and names for their identity will favor taxonomic strategies at 3 years; children who at 24 months play relational-functional games with objects and who use terms for the relations among objects will favor thematic strategies at 3 years of age. We see here a sensorimotor grounding of categorization as we could see in the approach of Harnad (2003) and Barsalou (2003). The authors (Dunham & Dunham, 1995) propose two alternative explanations. The first refers to a neurological explanation: children who have a semantic bias to spatial and relational terms would base their activity on the right hemisphere, building holistic scenes for stimuli; on the other hand, children who perceive more analytically and have a bias toward naming individual objects seem to base their activity on the left hemisphere. However, this hypothesis has to be tested with neurological tests. The second hypothesis refers to the social history of the child. In other words, it is the parental style which is either oriented toward functional relationships among objects, or on the identity of objects, that influence the preference of the child. Even though this seems very intuitive, this hypothesis is very difficult to test in rigorous conditions. As we can see, the authors outline the early social context as an external factor for determining the shape categorization will take, but we need thorough future studies to investigate this hypotheses.

As a conclusion, we can see that preschoolers are already capable of doing multiple categorizations with the same object, by appropriately taking into account the contextual demands. The studies from the literature do not agree however all the time with respect to the mechanisms and to the factors that influence the ability to categorize in childhood. Therefore, what remains essential in further investigations is to study the interplay between external and internal factors that allows and fosters flexible categorization in preschool children.

Acknowledgements

The author wishes to thank the children and the staff from the Kindergarten no. 59, Cluj-Napoca for their collaboration. She also wishes to thank Assoc. Prof. Oana Benga and Assoc. Prof. Adrian Bivolaru for their valuable comments all along the research.

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