Preschoolers' superordinate taxonomic categorization as a function of individual processing of visual vs. contextual/functional information and object domain

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Abstract

A pluralistic approach to concept formation considers that object concepts can derive from perceptual similarity and contextual relations, their involvement varying according to individuals and object domain. Three experiments with children provided convergent results supporting this view. First, a longitudinal study revealed that for children between 3 and 4 years, visual similarity is increasingly more helpful in categorizing natural objects at the superordinate level, while contextual similarity facilitates specifically the categorization of artifacts. Second, 3-year-old children's individual preference for either basic level taxonomic (perceptually-based) or thematic (contextually-based) relations differently affected superordinate categorization of objects in both domains. Third, training 5-year-old-children to look for either common visual properties or common functions differently modified superordinate categorization of natural objects and artifacts. Altogether, the data revealed that different cues are involved in the formation of natural and artifact concepts. However, further studies should consider finer distinctions between objects, such as manipulability.

Preschoolers' superordinate taxonomic categorization as a function of individual processing of visual vs. contextual/functional information and object domain

The world includes thousands of different objects. Yet, young children and even babies are able to categorize objects of the same kind (i.e., taxonomically) and therefore to respond adaptively to their environment. This paper focuses on children's ability to rely on contextual/functional and perceptual/visual cues to form superordinate taxonomic concepts. Two alternative developmental models of concept formation are briefly reviewed. The first one claims that these concepts are rooted in how the objects are used, whereas the second one underlines that concepts originate in how objects look. We then present an original pluralistic approach in which developmental paths are thought to vary both as a function of objects (natural objects vs. artifacts) and children's preferential mode of processing. Three experiments involving children aged 3 to 5 years provide convergent data supporting this view.

Unitary models of concept formation

This section aims to present two alternative paths leading to mature object concepts, one originating in contextual/functional similarity (i.e., how objects are used), the other in perceptual/visual similarity (i.e., how objects look). We refer to them as unitary views since they claim that one single path leads to mature concepts for all children whatever the objects involved.

The contextual/functional origin of concepts

According to Nelson (e.g., 1983, 1985), infants have perceptual and motor experiences that lead them to detect some commonalities among objects that look alike or entail similar actions. However, this early detection of common properties cannot result in elaborated concepts but instead in relatively specific basic level concepts like cows or cars. At the end of the sensori-motor period, the child's conceptual representations of daily experiences would be in the form of event schemas or scripts, that is generalized representations involving the roles that people play and the objects that they interact with (e.g., going to bed). Objects, whatever their kind, would be linked by temporal or spatial proximity relations resulting in script or thematic categories (e.g., pajamas, teddy bear, and pillow). With increasing experience,

scripts are enriched in such a way that the objects which play the same role in a script can be substituted (e.g., what they wear to go to bed). This abstraction mechanism would lead to slot-filler categories, the first superordinate taxonomic categories to be acquired. In such categories, objects of the same kind share functional features and occur in a similar context. Later on, a generalization mechanism would allow the child to build decontextualized superordinate categories (e.g. clothes). The path leading from scripts to slot-fillers and superordinate categories in children between 2 and 7 or 8 years of age has received some empirical support (e.g., Lucariello, Kyratzis, & Nelson, 1992; Lucariello & Nelson, 1985).

Mandler (1992, 2000) also claims that concept formation is driven by the role objects play in events. Infants might consider "the paths that objects take, their onsets and end points, as well as various containment, contact, support, and contingent relations among objects" (Mandler, 2000, p. 19). However, according to her, global conceptual categories (e.g., animals or vehicles) close to Nelson's decontextualized ones would be already acquired by 7-9 months. Later on, more precise distinctions (e.g., basic level concepts) would be noticed.

Some results collected by Mandler to support global conceptual categories at this age (Mandler & McDonough, 1993, 1998a) have been re-interpreted as being similarity-based (Mareschal, Powell, & Volein, 2003). Nevertheless, Mandler has provided compelling evidence concerning infants as young as 14 months: specific functional properties, such as drinking from a cup, are more often generalized from a dog to animals than to vehicles, but non specific functional properties, such as entering a building, are generalized equally often to both animals and vehicles (Mandler & McDonough, 1998b). Therefore, at the end of the first year of life, some properties can be generalized independently of the visual appearance of objects. Furthermore, these results suggest that functional similarity might originate from event schemas. Other studies have pointed out the importance of schemas in adults' conceptual organization also (Lin & Murphy, 2001; Ross & Murphy, 1999). Hence contextual/functional information extracted from event schemas might be a basis first for superordinate taxonomic concepts, then for basic level concepts, and might remain a valid cue later in life. It is worth noting that neither Nelson nor Mandler assume that different concepts might be built differently. The proposed mechanism is thought to apply to all object concepts and to be used in the same way by all children.

The perceptual/visual origin of concepts

In contrast to Mandler's approach, some researchers have suggested that object concepts develop through the continual enrichment of perceptual categories (e.g., Quinn & Eimas, 1996, 2000; Rakison & Poulin-Dubois, 2001). During the first 3 to 4 months of life, infants can form categorical representations at both basic and superordinate levels (e.g., Arterberry & Bornstein, 2001; Behl-Chadha, 1996; Quinn & Eimas, 1996) for certain natural objects (e.g., dogs, mammals) and certain artifacts (e.g., tables, furniture). Quinn and Johnson (2000) further showed that global perceptual categories precede basic level categories. It is generally agreed that categorization in early infancy is fundamentally perceptual because modifications of the visual appearance of exemplars change infants' categorical responses, and connectionist networks which receive physical attributes as input reproduce infants' behavior (French, Mareschal, Mermillod, & Quinn, 2004; Quinn, Eimas, & Rosenkrantz, 1993; Quinn & Johnson, 2000). Quinn and Eimas (1996, 2000) suggest that with increasing age, additional knowledge is acquired in several ways through action with objects, language, and social interaction, and is associated with these early categorical representations. As in the former approach, object concepts are seen as having a single origin in all children, namely a perceptual/visual origin that is thought to be effective for all types of object. It is worth noting that visual information continue to influence preschoolers' categorization behavior, as for instance in novel noun generalization tasks – extending a novel name to a novel object - and in inductive generalization tasks – extending a novel property to a novel object (e.g., Baldwin, 1992; Fisher & Sloutsky, 2005; Jones & Smith, 2002; Sloutsky & Fisher, 2004; Yoshida & Smith, 2005).

To sum up, two alternative developmental paths leading first to superordinate taxonomic concepts and then to basic level concepts are put forward, one with a primary contextual/functional origin (Nelson, 1985; Mandler, 1992; 2000), the other with a primary perceptual/visual origin (Quinn & Eimas, 1996; 2000; Quinn & Johnson, 2000). In both views, all infants are assumed to follow one path whatever the objects involved. The following section focuses on a pluralistic view (Bonthoux, 2001; Lautrey, 1993; 2003) considering that if both perceptual/visual and contextual/functional information can lead to taxonomic categories, the different types of information might not be similarly used by all children and might not be equally efficient for all object concepts, resulting in several developmental paths to concept formation.

A pluralistic approach of concept formation

A general pluralistic approach to development proposed by Lautrey (2003) claims that in many cases, several processes can fulfill the same cognitive function. This point has already been demonstrated in the field of conceptual development. Both functional/contextual and perceptual/visual similarities appear to play a role in infants' and children's concept formation (Diesendruck, Hammer, & Catz, 2003; Kemler Nelson, 1995). Indeed, when both similarities are contrasted, children rely either on functional similarity (i.e., Diesendruck, Markson, & Bloom, 2003; Kemler Nelson, Russell, Duke, & Jones, 2000), or on physical similarity (i.e., Graham, Williams, & Huber, 1999; Landau, Smith, & Jones, 1998) as a function of situations. In such cases, the pluralistic view predicts furthermore that each process, being more or less fitted to a given situation, would be more or less utilized by a given individual. Thus, we further assume that contextual and visual cues are 1) differently weighted by individuals according to their own experience with objects and 2) are differently useful in the formation of different concepts such as for instance natural objects and artifacts (Bonthoux, Berger, & Blaye, 2004 ; Bonthoux & Blaye, 2007; Bonthoux, Scheuner, & Roll, 2003).

The 3 following experiments were aimed at testing these hypotheses. The first study focuses on the relative efficiency of visual and contextual cues for natural objects and artifacts. The 2 subsequent studies combine this aspect with individual differences. For the first one, the individual differences were obtained by spontaneous preference for thematic (contextually-based) or basic level taxonomic (perceptually-based) relations between objects. For the second one, they were induced via a learning session requiring the children to process either functional or visual similarities.

Experiment 1. The relative importance of visual and contextual cues for the superordinate categorization of natural objects and artifacts

Several strands of empirical enquiry led to the idea that visual and contextual similarities might be differently helpful in the categorization of natural objects and artifacts. Neuropsychological studies have revealed a double dissociation between natural objects (e.g., animals) and artifacts (e.g., tools and vehicles; for a review, see Capitani, Laiacona, Mahon, & Caramazza, 2003). These category-specific deficits are frequently explained by the unequal

distribution of features across semantic categories: perceptual/visual features - shape, motion, or colour - are more important for natural objects; contextual/functional features - an object's use, where it is typically found, its social significance - are more important for artifacts. Property generation and property verification studies in healthy adults (e.g., Cree & McRae, 2003; Garrard, Lambon Ralph, Hodges, & Patterson, 2001; Laws, Humber, Ramsey, & McCarthy, 1995; Roll-Carpentier, Bonthoux, & Kalénine, 2006) and in children (Hughes, Woodcock, & Funnel, 2005) lend support to this explanation. For instance adults judged visual attributes for natural objects more quickly than for artifacts but judged functional attributes more quickly for artifacts (Laws et al., 1995). Results from 3- to 11-year-old children asked to define an object ("what is an X?") are consistent with research on adults (Hughes et al., 2005). These authors observed that perceptual responses outnumbered functional responses to natural objects by a ratio of 7:1 whereas functional responses outnumbered perceptual responses to artifacts by a ratio of about 2:1. Finally, neuroimagery data (for a recent review, see Martin, 2007) reveal that perceptual and semantic processes of animate objects and common tools rely on partially distinct sensorial and motor property-based neural networks. Hence, domain differences are likely to result from the way and the frequency people interact with objects.

The relative efficiency of visual and contextual cues in both domains was tested in a longitudinal study of children aged 3 to 4 years (Scheuner & Bonthoux, 2004). It was designed to improve understanding of the mechanisms involved in the formation of global concepts. Children's ability to identify superordinate taxonomic relations was assessed according to a) object domain and b) the type of cue involved in superordinate taxonomic relations. Various superordinate taxonomic relations were therefore designed by decorrelating visual and contextual similarity. We hypothesized that children would better identify visually similar taxonomic relations (e.g., goat-antelope) for natural objects whereas they would better identify contextually similar taxonomic relations (e.g., car-motorcycle) for artifacts.

Participants

Twenty-one children participated in 3 identical sessions, each separated by 6-months. Their mean age was 3 years 5 months at the first session. Two control groups were tested, matched for age either at the second or the third session.

Materials and procedure

The items consisted of 144 black and white drawings of familiar objects which constituted 16 sets of 9 pictures. Each set comprised a target picture (e.g. a goat) and 8

pictures related to it: 4 superordinate taxonomic associates (i.e., other animals) and 4 thematic associates (i.e., objects - non animals - from the same farm schema, e.g., a shepherd, a meadow, a farm, and a stool). Half of the targets were natural objects and half were artifacts. Each of the taxonomic associates was a) visually similar to the target or not and b) belonged to the same context or schema as the target or not (Figure 1). The visual and contextual similarities between each target and its associates were rated by adults. These ratings differed significantly between similar and dissimilar taxonomic associates in each domain. They did not differ between domains, neither for similar nor for dissimilar associates.

Insert Figure 1 about here

The same procedure was used in the 3 sessions. On each trial, the child was presented with the target picture along with 6 related pictures including the 4 taxonomic associates and 2 thematic associates. The selection of 2 thematic associates from the 4 available was counterbalanced among children. From these 6 pictures, the child was asked to find "two objects of the same kind, the same family" as the target. Given the instruction, only taxonomic choices were correct responses.

Three types of correct response were recorded: "perceptual sorting" when children chose the 2 taxonomic associates that were visually similar to the target, "contextual sorting" when they picked the 2 taxonomic associates which belonged to the same schema as the target, and "other taxonomic sorting" when they chose 2 other taxonomically related pictures. Visual similarity and contextual similarity were expected to be differently helpful for grouping objects at the superordinate level in both domains. More precisely, visual similarity was expected to be especially efficient for natural objects, resulting in more "perceptual sorting" for these objects than for artifacts. Conversely, we predicted that contextual similarity would be more helpful for artifacts resulting in more "contextual sorting" for these objects than for natural objects.

Results

Mean results over the 3 sessions were analyzed first. Overall, 74% of the sortings were correct (i.e., taxonomic). "Perceptual sorting" represented almost half of them (35% of all the sortings) whereas the level of "contextual sorting" was quite low (only 14%). However the number of "perceptual", "contextual" and "other taxonomic sorting" differed between domains. As expected, "perceptual sorting" was more frequent for natural objects than artifacts whereas "contextual sorting" was more frequent for artifacts than natural objects.

“Other taxonomic sorting” did not differ between domains. More interesting, developmental patterns over sessions also interacted with domains. “Contextual sorting” did not differ between domains in the first session but was more frequent for aretifacts in the second and third sessions. In contrast, “perceptual sorting” became more frequent for natural objects than artifacts in the third session only. These patterns can not be attributed to the repetition of the test because experimental and control groups’ results did not differ either at the first session or at the second session.

Discussion

These data clearly reveal the relative importance of visual and contextual cues for the superordinate categorization of natural objects and artifacts. Both perceptual and contextual similarities facilitated taxonomic grouping. Contextual cues remained overall less efficient than perceptual cues but became more efficient for categorizing artifacts than natural objects from the second session (beginning with the age of 4). Moreover, the influence of perceptual similarity increased over sessions facilitating superordinate taxonomic grouping of natural objects more importantly than that of artifacts at the third session (4 ½ years).

Several previous studies have shown that contextual/functional and perceptual/visual features are unequally weighted in adults and children’s concepts of natural objects and artifacts (Cree & McRae, 2003; Garrard et al., 2001; Hughes et al., 2005). Our experiment goes further because the independent manipulation of visual and contextual similarities helps to better understand the mechanisms underlying the formation of superordinate concepts in both domains. During the fourth year, contextual similarity becomes a more efficient cue to group artifacts than natural objects, while visual similarity becomes more helpful for natural object categorization. These results suggest that different mechanisms of concept formation might be at work as a function of the objects involved, hence supporting a pluralistic (Bonthoux, 2001; Lautrey, 2003) rather than a unitary view (Mandler, 2000; Nelson, 1985; Quinn & Eimas, 2000) of the development of superordinate concepts.

Neuroimagery data in adults (Martin, 2007) suggest that these results might stem from the fact that artifacts are more often used directly in context by young children than natural objects with which they rarely interact (they see animals in zoos and books or on television). It is likely that the acquisition context plays a fundamental role in the construction of taxonomic knowledge. As for the rather low efficacy of contextual cues observed in 3- to 4-year-old children, it might be attributed to insufficient experience with objects. Indeed the derivation of taxonomic grouping from event schemas (Nelson, 1983) requires repeated experiences with events.

Beyond differences between objects, the pluralistic view also claims that developmental paths would be differently implicated according to children's own preferences. This aspect was evaluated in the subsequent experiment.

Experiment 2. Individual sensitivity to basic level taxonomic and thematic relations affects the superordinate categorization of natural objects and artifacts differently

Few studies concern individual preferences in young children's categorization. Yet, Dunham & Dunham specifically addressed this issue in 3-year-old children (Dunham & Dunham, 1995, Exp. 1). Presented with a matching-to-sample task with 3 alternatives, a basic level taxonomic choice, a thematic choice, and a foil, most children showed a taxonomic tendency (their choices were predominantly taxonomic) but some children exhibited a thematic tendency (their choices were predominantly thematic). Hence young children's categorical choices depend on individual sensitivity to each type of relation. These tendencies were relatively stable over time (Exp. 2). Furthermore, the longitudinal study (Dunham & Dunham, 1995, Exp. 3) showed that a selective interest in object identity as assessed by pointing gestures at 1 year and the use of nouns and adjectives at 2 years were both antecedents of the basic level taxonomic tendency at 3 years. Alternatively, a selective interest in relations among objects as assessed by early functional-relational play at 1 year and the use of relational terms at 2 years were both antecedents of the thematic tendency at 3 years.

Using this work as a base, we tried to connect children's individual preferences with domain differences (Kalénine & Bonthoux, 2006). To this end, 3-year-old children's individual sensitivity to basic level taxonomic or to thematic relations was assessed in a first session as in Dunham and Dunham's first study. Next, in a second session, children's performance on taxonomic superordinate categorization was evaluated as a function of a) object domain and b) each child's sensitivity for basic level taxonomic or thematic relations assessed in session 1.

We hypothesized that the children most sensitive to basic level taxonomic relations in session 1 should perform better when matching natural objects than artifacts in session 2 since perceptual similarity seems to mostly facilitate the superordinate categorization of natural objects, as reported in our previous study. On the other hand, a greater sensitivity to thematic links, from which taxonomic relations might derive (Nelson, 1983), should particularly enhance the superordinate categorization of artifacts in session 2 since contextual similarity is more efficient in this domain (previous study). This second assumption is more speculative

given the age of the participants (3 years). According to Nelson, children must have repeated and rich experiences to abstract common functional roles from event schemas. Consistent with this proposal, the previous experiment showed that contextual similarity was overall less efficient than visual similarity for 3- to 4-year-old children and became more efficient for artifacts than natural objects from the fourth year only.

Participants

Sixty children aged between 3 and 4 years (mean age: 3 years 6 months at the first session) participated in the longitudinal study.

Materials and procedure

Black-and-white drawings were used to construct 2 match-to-sample tasks. They were selected from a pretest administered to children of the same age to ensure that all the objects and all the associations were correctly identified.

The first session included 20 trials. Following Dunham and Dunham's first experiment (Dunham & Dunham, 1995), each trial involved 4 pictures: a target picture (e.g., a dog) and 3 choice pictures including a basic level taxonomic match (e.g., another dog), a thematic match (e.g. a bone) and a foil (e.g., a cactus). Half of the targets were natural objects and half were artifacts.

The children were asked to choose the picture that went "best with" the target. In this first task, instructions were neutral to prevent orienting the children to a particular response. Thus both taxonomic and thematic choices were correct responses.

The second session took place a month later. It comprised 18 trials. Each trial involved 5 cards: two target cards taxonomically linked at the superordinate level (e.g., two pieces of fruit: an apple and a banana) and 3 choice cards including a superordinate taxonomic match (e.g., grapes), a thematic match (e.g., a basket) and a foil (e.g., a plug). Half of the target pairs were natural objects and half were artifacts.

The experimenter explained that the two target pictures were put together because they were the "same kind of things", they belonged to the "same family". Then, the children were asked to pick the object of the "same kind", the "same family" as the 2 targets. Given the instruction, the only correct response was the superordinate taxonomic associate to the target pair. As the task was quite difficult for young children, we used two target pictures instead of one to facilitate superordinate taxonomic categorization. Gentner and Namy (Gentner & Namy, 2002; Namy & Gentner, 1999) have shown that engaging children in active comparison of multiple instances of an object category by introducing more than one target picture enables them to form conceptual abstractions (see also Liu, Golinkoff, & Sak, 2001).

Results

The results of session 1 replicated those of Dunham and Dunham (1995, Exp. 1). Choices were predominantly taxonomic (m = 14.5 taxonomic choices out of 20) but large individual differences appeared. Children were considered as having a strong taxonomic or thematic sensitivity when the number of taxonomic or thematic choices differed from the mean by more than 1 standard deviation. With this strict criterion, only 6 children (out of 37) showed a strong thematic sensitivity and 8 showed a strong taxonomic sensitivity.

Two analyses were conducted to explore the links between the children's sensitivity to basic level taxonomic or thematic relations (session 1) and superordinate categorization as a function of domains (session 2). First, an analysis of variance was run on the number of superordinate taxonomic responses made by the 14 children who manifested a strong sensitivity (Figure 2). Overall, natural objects were more correctly matched than artifacts and the children most sensitive to basic level taxonomic relations made more correct superordinate choices than those most sensitive to thematic relations. More importantly, the expected interaction between preference and domain almost reached significance ($p = .06$). Post-hoc comparisons revealed that the children most sensitive to taxonomic relations displayed a significant advantage for natural objects. However, no difference between domains was obtained for the children most sensitive to thematic relations.

Insert Figure 2 about here

The second analysis involved the entire sample. Correlations between the number of basic level taxonomic choices in session 1 and the number of superordinate taxonomic responses for natural objects and artifacts in session 2 were calculated. As expected, basic level taxonomic choices were positively linked to correct superordinate responses for natural objects ($r = .38$, age in months partialled out) but not for artifacts. Thematic choices were not linked to correct responses for either natural objects or artifacts.

Discussion

The purpose of the study was to link spontaneous sensitivity to basic level taxonomic and thematic relations to superordinate categorization performance as a function of domains. As in Dunham and Dunham's first experiment (1995), some 3-year-old children displayed a strong sensitivity to either taxonomic or thematic relations when few constraints weighed on the situation (i.e. "choose the picture that goes best with the target"; Lautrey, 2003). In such a situation, it is likely that both relations are activated (e.g. dog-other dog and dog-bone) but not

necessarily with the same strength in all the children (Scheuner, Bonthoux, Cannard, & Blaye, 2004). One possibility is that a child's favourite way to deal with her/his environment during infancy reinforces one connection more than the other as suggested by Dunham and Dunham's longitudinal experiment (1995, Exp. 3).

Furthermore, those children most sensitive to basic level taxonomic relations better categorized natural objects at the superordinate level whereas the performance of the children most sensitive to thematic relations did not differ between domains. This result brings empirical evidence to support a pluralistic view of concept formation: two processes are more or less implicated depending on the individual and the situation (Lautrey, 1993, 2003). We suggest that children's sensitivity to either basic level taxonomic or thematic relations, probably resulting from their own experience, may influence the type of cue they use to form concepts.

A particular sensitivity to basic level taxonomic relations might reflect a tendency to compare stimuli and thus to detect common and distinctive properties (Wisniewski & Bassok, 1999). Our data show that this hypothetical process is particularly efficient at categorizing natural objects at the superordinate level. Analogously, a particular sensitivity to thematic relations is likely to reflect a tendency to integrate objects in a context (Wisniewski & Bassok, 1999). We supposed that this tendency would facilitate the superordinate categorization of artifacts for which contextual relations are more helpful, at least from age 4 years based on the results of the previous experiment (Scheuner & Bonthoux, 2004). However, our results did not support this hypothesis. It is likely that children as young as 3 years cannot yet benefit from their greater sensitivity to thematic relations in order to access superordinate concepts. It appears that a sufficient amount of experience is probably required for the integration of various objects playing the same role in a given situation. If this interpretation is correct, then older children (4-5 year-olds) sensitive to thematic relations should better categorize artifacts than natural objects at the superordinate level. Further studies are needed to test this hypothesis.

A limitation of this study is that few of the children had a strong sensitivity to taxonomic/thematic relations. Therefore the analysis had a low statistical power. To overcome this difficulty, we designed another experiment, in which we tried to orient children's processing toward either visual or functional similarity and assessed the influence of these two interventions on the superordinate categorization of natural objects and artifacts (Kalénine, Garnier, Bouisson, & Bonthoux, 2007).

Experiment 3. Training visual or functional similarity processing differently affects the superordinate categorization of natural objects and artifacts

As already explained, we claim that at least 2 developmental mechanisms play a role in the formation of superordinate concepts, one originating from the extraction of the perceptual/visual similarity between objects (Quinn & Eimas, 1996, 2000), another based on the emergence of functional similarity from contextual links (Nelson, 1983, 1985). We further claim that each mechanism is differently weighted according to individual and object type. More particularly, an intervention which focuses on the processing of common visual attributes between objects should facilitate the superordinate categorization of natural objects, for which perceptual/visual information is strongly weighted. On the other hand, an intervention focused on the processing of common functions between objects should facilitate the superordinate categorization of artifacts for which contextual/functional information is more important.

To test these hypotheses, superordinate categorization performance was assessed before and after 3 training sessions. In these sessions, the children were trained to look for either visual or functional features common to sets of objects.

Participants

Thirty-two 5-year-old children (mean age 5 years 9 months) participated in this experiment. They were randomly assigned to either the "function" or "perception" intervention.

Materials and procedure

Eighty black and white drawings of familiar objects were used in the superordinate categorization task. As in the preceding experiment, they were grouped into sets of 5 cards. Each set included 2 target cards taxonomically related at the superordinate level (e.g., 2 vehicles: a car and a motorcycle), and 3 choice cards: a taxonomic associate (e.g., another vehicle: a train), a thematic associate (e.g., traffic lights) and a foil (e.g., a caterpillar). Half of the target pairs were natural objects and half were artifacts.

The procedure was identical to that of the previous study. On each trial, the child was presented with 2 target cards and told that these objects had been put together because they were the "same kind of things", they belonged to the "same family". Then 3 choice cards were offered and the child had to pick the one of the "same kind", the "same family" as the 2 target cards.

The materials used in the training sessions were identical in both interventions. They consisted of black and white drawings of familiar objects presented either on little cards individually or on bigger cards in sets of 5 objects sharing a particular function or visual feature. The objects that shared a particular function or visual feature did not belong to the same category (for instance the 5 objects corresponding to the function “can light” were a fire, a candle, sun, a light bulb, and a car on full beam). In this way, the potential effect of interventions on superordinate categorization would not be due to the acquisition of specific categories but would truly refer to an object processing mode. There were also boxes to sort the cards into and exercise sheets, one per child per training session.

Each intervention took place in small groups (4-5 children) over 3 training sessions of approximately 30 minutes each. In the “function” intervention, children were required to look for common functions: for example “objects which can light” or “objects which can roll”. In the “perception” intervention, they were asked to look for common visual features: for example “peaked objects” or “objects which have a door”. The same 6 functions or 6 visual features were used during the 3 training sessions. The games and exercises were of the type children are used to doing at preschool. For instance, they were asked to find and tell what was common to a set of objects, to sort cards into boxes, to find the add-one-out in a set of objects, or to circle each object having the same property. Most of these were performed collectively, but the paper and pencil exercises were done individually.

The number of correct responses, namely superordinate taxonomic choices, was measured for each child before and after the specific intervention. Both groups were equivalent at the pre-test (10.4 correct taxonomic choices out of 16 in the “function” intervention group and 10.7 in the “perception” intervention group).

The difference between the correct responses pre- and post-intervention was analyzed as a function of the type of intervention (“function” or “perception”) and the domain of objects (natural objects or artifacts). There was no main effect: the "function" and "perception" interventions led to equivalent progress in the whole superordinate categorization task [$F(1,30) < 1$] and the global performance improved in the same way for natural objects and artifacts [$F(1,30) < 1$]. However, the expected interaction between these 2 factors was significant in both the by-subjects [$F_1(1,30) = 7,77$; $p < 0,01$] and by-items analyses [$F_2(1,14) = 6,08$; $p < 0,05$]. The type of intervention thus appeared to modulate superordinate categorization performances between natural objects and artifacts. More particularly, the “function” intervention facilitated the superordinate categorization of artifacts

more than natural objects and conversely, the “perception” intervention facilitated the categorization of natural objects more than artifacts.

Discussion

Despite a short training period, the results were clear-cut. Training the children to look for common visual properties helped them to categorize natural objects at the superordinate level, whereas asking them to seek common functions improved their categorization of artifacts. This result adds further support to the idea that developmental mechanisms of concept formation differ according to the objects involved. It is worth noting that the children were trained to look for visual or contextual commonalities which differed from those involved in the superordinate categorization task. Thus, the training sessions oriented the children toward a given mode of processing objects, which helped them to better understand some global concepts, but not others.

General Discussion

Overall, the experiments reported here can help to understand concept formation more precisely. First of all, we have shown that superordinate categorization is more or less facilitated depending on the available similarity (Scheuner & Bonthoux, 2004). Visual similarity was a more efficient cue for categorizing natural objects than artifacts, at least from 4 ½ years. Next, we found that 3-year-old children most sensitive to basic level taxonomic relations perform better superordinate categorization of natural objects than artifacts (Kalénine & Bonthoux, 2006). Finally, we have demonstrated that when older children are trained to seek visual commonalities, they also better categorize natural objects than artifacts at superordinate level (Kalénine et al., 2007). It is thus likely that basic level taxonomic sensitivity is linked to an orientation toward visual comparisons, which facilitates the process of more abstract similarity relations (Gentner & Namy, 2002; Namy & Gentner, 1999), this process being particularly efficient for natural object categorization.

Regarding contextual/functional information, it is more difficult to link the 3 experiments. On the one hand, contextual similarity at 4 years (Scheuner & Bonthoux, 2004) and functional similarity at 5 years (Kalénine et al., 2007) were more helpful for categorizing artifacts than natural objects at the superordinate level. On the other hand however, a strong sensitivity to thematic sensitivity at 3 years did not favour the superordinate categorization of artifacts (Kalénine & Bonthoux, 2006). Hence, thematic sensitivity which probably reflects an orientation toward an integration process (Wisniewski & Bassok, 1999) did not help children

to find more commonalities between artifacts than between natural objects. We speculated that these children were too young and thus had not had enough experience with objects to be able to extract functional commonalities from event schemas as suggested by Nelson (1983, 1985). Further studies are needed to really test whether functional properties emerge from event schemas

Nevertheless, taken together these results lend support to a pluralistic view of conceptual development. We have provided converging evidence that visual and contextual/functional similarities are unequally efficient in categorizing natural objects and artifacts. Moreover, the individual's mode of processing objects interacts with object domain. It is likely that at a given age children have several means of building object concepts at their disposal but not all of them master the processing of visual and contextual/functional similarities equally, due to their different experiences. Individual variability seems to be a cornerstone of conceptual development as it is in other areas of cognition (e.g., Fischer & Bidell, 2006; Lautrey, 2003; Siegler, 2007). This individual variability in turn combines with differences as a function of object type.

Prospective

Results reported till now refer to a broad distinction, natural objects and artifacts, the most classically considered. Yet some neuropsychological studies report more fine-grained dissociations (e.g., animals vs. fruits and vegetables; tools vs. buildings and vehicles). In addition, recent studies on both adults (e.g., Kellenbach, Brett, & Patterson, 2003; Pecher, Zeelenberg, & Barsalou, 2004) and children (e.g., Smith, 2005a, 2005b) reveal that sensorimotor experience can influence cognition and, particularly conceptual development and processing. The growing evidence in this field suggests that objects could be distinguished according to the type of interaction involved. In this perspective, object manipulability may be a crucial factor in understanding concept formation because manipulable objects are most closely linked to motor experience whereas non-manipulable objects are mainly linked to perceptual/visual experience. Thus, perceptual/visual cues and contextual/functional cues might refer to distinct sensori-motor experiences. Consequently, the classical dissociation between the domains of natural objects and artifacts could have been confounded in many studies with the distinction of object manipulability as suggested by Filliter, McMullen, and Westwood (2005). Indeed, most previous experiments have contrasted categories such as animals and tools, two categories of objects that differ in terms

of ontological domain but also of manipulability. Although the findings reported here showed different categorization behaviors according to object domains, the manipulability factor was not directly introduced in the experimental design. Further studies investigating conceptual processing in children should explore such distinctions (i.e., domain and manipulability) perhaps using finer measures (e.g., reaction times) to assess children' categorization behaviors.

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Figure 1. Example of a target picture and its taxonomic associates

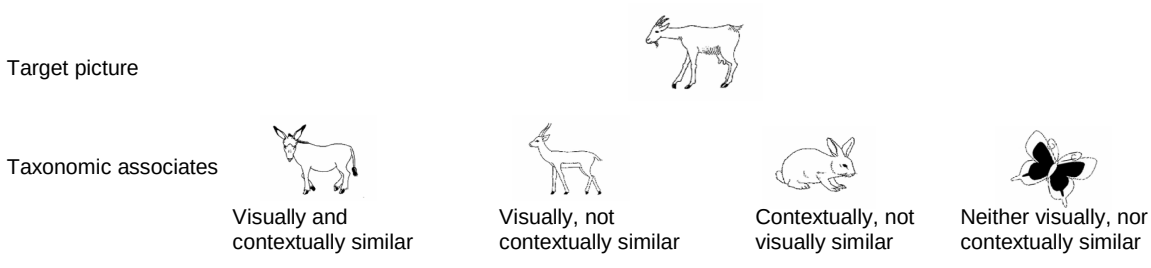

Figure 2. Mean number of correct responses in session 2 as a function of sensitivity in session 1 and object domain