Categorical Flexibility in Preschoolers: 
Contributions of Conceptual Knowledge and Executive Control

Agnès Blaye                                  Sophie Jacques
Université de Provence                    Dalhousie University
L.P.C., UMR 6146                 Halifax, Nova Scotia, Canada
Aix-en-Provence, France

To appear in Developmental Science

Author Note. This research was funded by a grant (AF No. 03 2 438) from the French Ministry of Research to the first author. We thank Maelle Lechevrel-Loubet and Amélie Doucet for assistance with data collection. Part of this work was presented at the XIth European Conference on Developmental Psychology, Milan, Italy, August, 2003. Send correspondences to Agnès Blaye, Université de Provence, Laboratoire de Psychologie Cognitive, 29, Av R. Schuman, 13621 Aix en Provence, cedex 1. Email: Agnes.Blaye@univ-provence.fr
Abstract

The current study evaluated the relative roles of conceptual knowledge and executive control on the development of categorical flexibility, the ability to switch between simultaneously available but conflicting categorical representations of an object. Experiment 1 assessed conceptual knowledge and executive control together; Experiment 2 differentiated conceptual knowledge from costly executive processes. In Experiment 1, 3- to 5-year-olds were given a 3-choice (taxonomic, thematic, and nonassociate) match-to-sample task and asked to match two associates. In Experiment 2, same-aged children were assessed on another match-to-sample task that reduced executive costs by presenting thematic and taxonomic associates on separate trials. By comparing performance across tasks, age-related changes resulting from conceptual knowledge and executive control indicated that conceptual knowledge of superordinate relations showed gains between 3 and 4 years, whereas gains in executive control were seen between 4 and 5 years, suggesting a décalage in the development of conceptual and executive processes underlying categorical flexibility.
Categorical Flexibility in Preschoolers: Contributions of Conceptual Knowledge and Executive Control

Objects can be considered as members of multiple categories depending on the current goal at hand: Hence, a dog can be considered an animal (taxonomic category) or as part of a hunting scene (thematic category), among many other categories. The ability to switch between simultaneously available, but conflicting categorical representations of a given object—namely *categorical flexibility*—is therefore a critical conceptual achievement. However, the question of when and how categorical flexibility emerges in development has long been neglected because early theories of conceptual development initially held that young children’s conceptual systems were based primarily on complementary relations (Inhelder & Piaget, 1959/1964; Nelson, 1977) binding objects that co-occur in time and or space. In other words, thematic categories were supposed to emerge first in development. Taxonomic\(^1\) categories were believed to emerge only later, resulting from a major conceptual reorganization instigated by developments in logic (Inhelder & Piaget) or language (Nelson). As a result, given the supposed limits in conceptual understanding, the question regarding flexible representation of different conceptual relations in young children seemed irrelevant.

However, whereas early research by Inhelder and Piaget (1959/1964) and others primarily used free-sorting tasks to assess categorical organization, contemporary research on preschool children’s categorization abilities have used match-to-sample tasks in which children are presented with series of pictured objects (or toy replicas) and asked to select the best match for a target (e.g., an animal [dog]) among competing associates (e.g., a taxonomic match [a snail] and a thematic associate [doghouse]). This approach has revealed that preschoolers can acknowledge both thematic and taxonomic pairings (e.g., Blaye & Bonthoux, 2001; Markman &
Hutchinson, 1984; Walsh, Richardson, & Faulkner, 1993; Waxman & Namy, 1997; see Murphy, 2002, for a review). Different contextual variables, however, such as instructional format (e.g., Waxman & Namy) or presence or absence of labels (e.g., Markman & Hutchinson), may orient children to select particular types of associates (thematic vs. taxonomic), suggesting that they are sensitive to both kinds of organizational networks but that they can be biased to favor one over the other.

In fact, to assess directly whether children understand taxonomic categories, a few studies have presented children with match-to-sample tasks that involved only a taxonomic option along with a nonassociate (or several nonassociates) with no competing thematic associates (e.g., Fenson, Vella, & Kennedy, 1989; Nguyen & Murphy, 2003, Exp. 2; Rosch, Mervis, Gray, Johnson, & Boyes-Braem, 1976, Exp. 8). Using this approach, researchers have found evidence of conceptual knowledge of (superordinate) taxonomic categories in preschoolers, at least with 4-year-olds. For example, Rosch et al. found that when presenting a target with a superordinate taxonomic match and a nonassociate, 96% of 4-year-olds could identify superordinate taxonomic matches correctly, although only 55% of 3-year-olds could do so.

Nonetheless, although the aforementioned studies suggest that under some conditions, preschoolers can identify superordinate taxonomic matches, other studies have revealed that the majority of 4-year-olds are unable to justify such matches (e.g., Greenfield & Scott, 1986; Lucariello, Kyratzis, & Nelson, 1992; Tversky, 1985), indicating that conceptual knowledge of taxonomic categories might still undergo important developments during the preschool years or that verbal requirements in justification studies may be especially demanding. However, in most justification studies, children were required to activate successively two representations of the same target objects: one that they spontaneously chose first (usually the thematic option) and
then the second (the taxonomic option), which they did not favor, but were asked to justify. Moreover, their justifications were required while the favored and more salient (thematic) option was still present. Consequently, existing justification studies might have underestimated conceptual knowledge because they inadvertently also required categorical flexibility.

In the current study we investigated the development of categorical flexibility directly by examining whether preschool children can switch successively between representing objects as part of schemas (henceforth, members of thematic categories) or as members of superordinate taxonomic categories (or visa versa) within the same context. To achieve categorical flexibility, one must have developed sufficient conceptual knowledge of thematic and taxonomic representations. As mentioned above, it is possible that in existing justification studies, children were unable to justify taxonomic categories because they did not have sufficient conceptual knowledge. However, a lack of categorical flexibility does not necessarily imply deficient conceptual knowledge because switching between competing representations as is required in categorical flexibility also requires sufficient executive control, and more specifically cognitive flexibility, both of which are known to develop drastically during the preschool years.

Executive control (Miller & Cohen, 2001) is an ill-defined construct “that refers generally to the psychological processes involved in the conscious control of thought and action” (Zelazo & Müller, 2002, p. 445). Executive processes are hence specifically involved when top-down control is required instead of stimuli-driven processing. Important components of executive control that have been proposed include cognitive flexibility, inhibition, and working memory (Diamond, 2006; Garon, Bryson, & Smith, 2008; Hughes, 2002). Cognitive flexibility can be defined as “the ability to flexibly switch perspectives, focus of attention, or response mappings” (Diamond, 2006, p. 70); inhibition refers to the ability to exert inhibitory control on
dominant prepotent responses (Carlson & Moses, 2001); and working memory refers to “a system for the temporary holding and manipulation of information during the performance of a range of cognitive tasks” (Baddeley, 1986, pp. 33-34). Thus, because categorical flexibility requires that children be able to switch flexibly between different categorical representations of the same object, it is one manifestation of cognitive flexibility when representations are categorical in nature.

Like conceptual knowledge, there are significant age-related changes in executive control during the preschool years and more specifically, a drastic increase in cognitive flexibility (e.g., Carlson & Moses, 2001; Chevalier & Blaye, 2008; Frye, Zelazo, & Palfai, 1995; Gerstadt, Hong, & Diamond, 1994; Jacques & Zelazo, 2001; Luria, 1961; Müller, Zelazo, Hood, Leone, & Rohrer, 2004; Smidts, Jacobs, & Anderson, 2004; Zelazo, 2006; see also Diamond, 2006, Jacques & Zelazo, 2005, for recent reviews). A commonly used task to assess cognitive flexibility in this age range is the Dimensional Change Card Sort (DCCS) designed by Zelazo and Frye (Frye et al.; Zelazo, 2006; Zelazo, Müller, Frye, & Marcovitch, 2003). In this task, children are presented with cards that vary on two dimensions (color and shape) that they have to sort first according to one dimension (for instance shape) for a given number of trials and then by a second dimension (for instance color) requiring opposite responses to be applied to the same stimuli. Many studies have revealed that whereas 3-years-olds can sort correctly according to the first dimension, most of them fail to switch to the other dimension. In clear contrast, most 4-year-olds experience no switching difficulties.

The DCCS is a deductive task (Jacques & Zelazo, 2005) in that children are explicitly told which matching to perform for a given picture. Other tasks provide less explicit instructions (see Deák’s Flexible Induction of Meaning task, for instance in Deák, 2003) and others still are
clearly inductive in that children must identify for themselves more than one match for each object successively. The Flexible Item Selection Task (FIST) designed by Jacques and Zelazo (2001) is one such task. On each trial, participants are shown three items that vary on two of three dimensions (shape, color, and size) and a pivot item matches one of the other items on one dimension and the remaining item on the other dimension. Participants are then asked to find two pairs of matching items, and as a result, they have to select the pivot item twice. Jacques and Zelazo found that 3-year-olds have relatively more difficulty than 4- and 5-year-olds on their first selection, suggesting that they have difficulty detecting a similarity between items when these are nonidentical. In contrast, both 4- and 5-year-olds do well on their first selection. However, 4-year-olds have relatively more difficulty than 5-year-olds on their second selection, suggesting that they have difficulty selecting the pivot item flexibly (see Jacques, Zelazo, & Lourenco, 2008, for additional findings with this task). Thus, both the DCCS and the FIST, as well as many other similar tasks, reveal important changes between 3 and 5 in cognitive flexibility, although successful performance on inductive tasks like the FIST are generally delayed compared to the DCCS and other deductive tasks (see Jacques & Zelazo, 2005, for a review).

In recent years, research has begun on flexible categorical representations in both infants (e.g., Ellis & Oakes, 2006; Mareschal & Tan, 2007) and preschool children (e.g., Blaye & Bonthoux, 2001; Deák, 2003; Nguyen & Murphy, 2003; Waxman & Namy, 1997). However, most of these studies have not assess categorical flexibility per se because they compared (a) categorical choices of independent groups of children placed in different setting conditions, (b) the performance of the same children on different sets of objects, or (c) the performance of the same children on the same set of objects, but only after a delay. Although suggestive, findings
using these methodologies do not inform us about whether children are able to alternate successively between different categorical representations of the same objects at any given moment.

Hence, the current research had two broad aims. First, in Experiment 1, we developed a categorization task that allowed us to assess categorical flexibility directly in conditions of conflict between two potentially correct response options. One could argue that both the DCCS and the FIST can be construed as measures of categorical flexibility per se; however, they only assess perceptual categories (e.g., colors, sizes, or shapes) and as such, they do not assess children’s ability to switch between different semantic representations. Therefore, we used a three-choice match-to-sample task (hereafter, the Double Categorization Task) that included a superordinate taxonomic associate, a thematic associate, and a nonassociate. To assess categorical flexibility, we asked children to identify two matches for the target. The first selection was assumed to correspond to participants’ most salient match in the context of another potential match, whereas the second selection, presumably a less salient match, had to be identified while the first salient selection was still present, thereby requiring categorical flexibility.

Second, in Experiment 2, we used another match-to-sample task that allowed us to measure conceptual knowledge independent of executive control involved in the Double Categorization Task. In this Simple Categorization Task, we reduced executive costs by presenting children thematic and taxonomic associates on separate trials (cf. Nguyen & Murphy, 2003, Experiments 1 and 2). On thematic trials, children were shown targets with a thematic associate and two nonassociates, whereas on taxonomic trials, they were shown the same targets with a superordinate taxonomic associate and two nonassociates. Consequently, by comparing
performance on the Double and Simple Categorization Tasks, we were able to determine whether age-related changes in categorical flexibility measured in the Double Categorization Task result from increases in conceptualization abilities, efficient executive control, or both.

In short, the purpose of the current experiments was to evaluate the relative role of both conceptual knowledge and executive control involved in the development of categorical flexibility. On their own, adequate conceptual knowledge and executive control skills are both necessary but not sufficient conditions for categorical flexibility. For categorical flexibility to emerge, both need to be operational. Experiment 1 assessed conceptual knowledge and executive control together, whereas Experiment 2 differentiated conceptual knowledge from costly executive aspects.

Experiment 1

In this experiment, we examined the performance of 3-, 4-, and 5-year-old children in a match-to-sample task that required children to match a target successively with both thematic and taxonomic associates. This was done to determine whether children could identify two matches for a given target, providing evidence of categorical flexibility. In addition, it allowed us to determine whether age-related differences in categorical flexibility emerge at the same time during the preschool period as they do in research on cognitive flexibility in the executive function literature (e.g., Deák, 2003; Jacques & Zelazo, 2001; Zelazo et al., 2003).

Method

Participants. Participants were twenty 3-year-olds ($M = 44$ mos., range 38 to 47 mos.), twenty 4-year-olds ($M = 54$ mos., range 48 to 59 mos.), and twenty 5-year-olds ($M = 66$ mos., range 60 to 71 mos.). Approximately equal numbers of boys and girls participated at each age. Children were recruited from preschools in a middle-sized city in the south of France and were
predominantly from middle-class backgrounds. Parents were provided with a short written description of the experiment and they granted informed consent allowing their children to participate.

**Stimuli.** Black and white line drawings of familiar objects were used. Each trial was presented on an A4 sheet displayed horizontally with a target (e.g., a dog) positioned at the top and centered, and three potential associates positioned together on the same line below the target (see Figure 1, Panel A). Among these three associates, one was a thematic associate (e.g., a doghouse), another was a superordinate taxonomic associate (e.g., another animal, a snail), and the remaining one was semantically unrelated to the target (e.g., a telephone). Sixteen item sets were used in test trials including eight artifacts and eight natural objects as targets. Two additional item sets were used in demonstration trials. The placement (left, middle, or right) of the three types of associates (thematic, taxonomic, or nonassociate) was counterbalanced across the 18 item sets.

Eleven adults aged between 23 and 48 years were asked to participate in a judgment task to ensure that they agreed with our pairings of the targets and the three potential types of associates (taxonomic, thematic, or unrelated). Participants were initially presented with three example trials in which they were shown three types of pairs of pictures (i.e., one thematic, one taxonomic, and one nonassociate pair of pictures) in order to define the three categories in which they were expected to classify test pairs. The three categories were defined as (a) “the two objects belong to the same category, they are the same sort of things”, (b) “the two objects can often be seen together in a common scene or event”, and (c) “the two objects have no links whatsoever”. Adults were then shown 64 test pairs of pictures involving each of the 16 targets presented four times, once paired with its thematic associate, once paired with its taxonomic
associate, and once paired with each of two nonassociates. The 64 pairs were presented in a constant random order on computer using PowerPoint SlideShow mode and participants saw each pair successively in a self-paced manner. They had to decide to which of the three types of associations (thematic, taxonomic, or unrelated) each pair of pictures belonged.

Across all pairings, the average degree of agreement between participants’ pairings and our own *a priori* pairings was 98.5% (range 95.3% [1 participant] to 100% [4 participants]). For individual pairings of nonassociates, there was 100% agreement on all pairs but one, which produced only one disagreement. For the taxonomic pairings, 15 pairs produced 100% agreement and 1 pair produced one disagreement. Similarly, for the thematic pairings, 11 pairs produced 100% agreement and 4 produced only one disagreement. The remaining thematic pairing, however, did produce some disagreement with only 45.5% of the adult sample agreeing with our pairing. This particular thematic pairing involved a screwdriver (the target) and a child’s bicycle (the thematic match). The remaining adults considered this pair to be unrelated. Despite the low agreement from our adult participants, it is worth considering that children’s performance in the Simple Categorization Task in Experiment 2 on this item was high: 44 out of 53 children (83%) selected the bicycle from among the other two nonassociates. This discrepancy between adults’ and children’s judgments may be due to recent personal experience: Many young children may have had their bicycle repaired recently (e.g., many children within this age range have had the training wheels removed from their bicycle), whereas many of the urban adults in our sample may not have even owned a bicycle. Overall, then, the data overwhelmingly confirmed our *a priori* associations for the different pairs (see list of stimuli in the Appendix).

**Procedure.** Children were tested individually in their preschool. The task began with two demonstration trials. In each demonstration (and test) trial, children were asked to select two
matches for each target. For Selection 1, children were told (in French), “Look at this one [Experimenter pointed to the target]. Can you show me, among these three, the one that goes best with this one? To show me, put this token beneath the one you choose.” For Selection 2, they were told, “Ok, now there are only two left. Can you show me the one that goes best with this one [Experimenter pointed to the target] among these two? [Experimenter pointed to the two remaining items] Here is another token to indicate your choice.” If children selected the nonassociate for either selection in the demonstration trials, they received corrective feedback in that the token was moved to the correct associate. Order of the two demonstration trials was counterbalanced across participants. After the 2 demonstration trials, 16 test trials were presented in which a shortened version of the instructions was used with no corrective feedback. Two random presentation orders for test trials were devised and counterbalanced across participants.

Results and Discussion

For each target, there were three possible response options (thematic, taxonomic, and nonassociates), only two of which were correct (thematic and taxonomic ones). On each trial, each of the two selections was scored as correct only if children selected the thematic or taxonomic choice. Although categorical flexibility is demonstrated only in children’s ability to select both associates (thematic and taxonomic) for a given target correctly, we first considered Selection 1 performance alone to ensure that children understood the task and to examine patterns of performance on Selection 1 that might influence categorical flexibility.

Selection 1 Performance. Although the type of target objects (artifacts vs. natural objects) was controlled across trials, we first analyzed whether there were any potential effects of this variable on performance. No main effect or interaction with age or type of associate was found in this experiment or in Experiment 2. Therefore, this variable was not included in any further
analyses. A 3 (Age Group: 3-, 4-, vs. 5-year-olds) x 2 (Associate Type: taxonomic vs. thematic associates) mixed analysis of variance (ANOVA) with repeated measures on associate type was then conducted on the proportion of correct choices on Selection 1. The ANOVA detected no reliable effect of associate type, nor an interaction between associate type and age group, although descriptively the proportion of thematic first selections (\(M = .48, SD = .22\)) was higher than taxonomic ones (\(M = .40, SD = .19\)). However, a significant main effect of age group was detected, \(F(2, 57) = 8.80, p < .0005, \text{partial } \eta^2 = .24\), revealing that 5-year-olds (\(M = .97, SD = .07\)) differed significantly from both other age groups (\(M = .80, SD = .15\), for 3-year-olds; \(M = .87, SD = .14\), for 4-year-olds), Tukey’s HSD tests, \(ps < .005\), who did not differ from each other.

The proportion of correct trials expected on the basis of chance alone was .67 (2 out of 3 response options), and according to this criterion, all age groups performed above chance on Selection 1, all \(t(19) > 4.00, p < .0005\). Together, these results suggest that children have sufficient conceptual knowledge and control capacities to select at least one relevant match for a target by 3 years of age.

The design of the match-to-sample task allows one to examine if children approach the task on a trial-by-trial basis providing evidence for a bottom-up, stimulus-based approach or if they approach the task using a controlled approach and systematically select the same kind of associate across trials providing evidence for a top-down approach. Indeed, Scheuner, Bonthoux, Cannard, & Blaye (2004) found evidence that children’s selections are partly determined by the relative strength of particular associations among potential associates of a given target. Such a stimulus-driven approach can result in intra-individual variability in categorical matching across trials (Walsh et al., 1993). However, Waxman & Namy (1997) observed that intra-individual variability tends to decrease between 3 and 4 with older children showing more consistent
patterns of selections across trials. On our account, an interesting aspect of executive control may be revealed by considering the consistency of Selection 1 responses across different targets. Specifically, our contention is that to approach the task using top-down processes, despite uncontrolled variability in the relative strength of associations of particular matching candidates, provides evidence of executive control (cf. Kendler, 1995), which might in turn be a precursor to categorical flexibility itself. To test this prediction, we defined a consistent pattern of Selection 1 responses as one in which children selected twice as many correct matches of one type or another, whether these were thematic or taxonomic matches. According to this definition, we found that 40% of 3-year-olds, 60% of 4-year-olds, and 70% of 5-year-olds produced a consistent selection pattern for Selection 1. Although there was an increase in systematicity with age as reported by Waxman and Namy, only the difference between 3- and 5-year-olds was significant, $\chi^2(1, N = 40) = 3.63, p < .057$. Alternatively, if we considered the exact dominance ratio between the frequencies of the two kinds of responses (ABS [(THfreq - TXfreq) / (THfreq + TXfreq)]) on Selection 1, a one-way ANOVA also revealed a significant effect of age, $F(2, 57) = 4.67, p < .02$, partial $\eta^2 = .14$. Post hoc comparisons indicated that this effect was again only significant when contrasting the youngest and oldest age groups, $p < .01$.

**Performance Across Both Selections.** Selection 2 scores were not examined independently because the probability of correct responses on Selection 2 was entirely dependent on performance on Selection 1. Instead, we considered flexibility scores measured as the proportion of correct double selections; that is, the proportion of trials for which children made two correct selections. A one-way ANOVA with age group (3, 4, vs. 5 years) as a between-subject variable revealed a significant increase in this score with age, $F(2, 57) = 13.81, p < .0001$, partial $\eta^2 = .33$. As shown in Figure 2 (left panel), the increase was reliable between 3-
and 5-year-olds and 4- and 5-year-olds, $p < .002$, but not between 3- and 4-year-olds, $p < .33$.
The proportion of correct double selections expected on the basis of chance alone was $.33$ ($p = .67$ for Selection 1 and $p = .50$ for Selection 2, thus, $p = .33$ for both). According to this criterion, all age groups performed above chance on both selections, $t(19) > 3.39$, $p < .003$.

We then addressed the question of whether those children who showed a consistent selection pattern for Selection 1, suggesting a systematic matching strategy, also tended to be more flexible. A $t$ test contrasting children who demonstrated a consistent response pattern (either thematic or taxonomic) for Selection 1 with those who did not revealed that flexibility scores were higher among the former group ($M = .73, SD = .24$), $t(58) = 2.46, p < .02$, than among the latter one ($M = .57, SD = .26$). However, as the strategic use of categorical relations increased with age, its influence on flexibility scores might have been at least partly confounded with age. Consequently, we also calculated a correlation between the exact dominance ratio of Selection 1 responses and flexibility scores, partialing out age. This correlation was significant, $r(57) = .33, p < .011$, indicating that controlled responding on Selection 1 may be predictive of the ability to switch between two representations of the same object.

Overall, then, Experiment 1 revealed important developments in categorical flexibility during the preschool period, primarily between 4 and 5 years. However, as suggested in the Introduction, success on the Double Categorization Task depends on both access to conceptual knowledge of thematic and taxonomic associates of each target and efficient executive control, both of which are known to develop during the preschool years. Consequently, it is impossible to determine whether it is insufficient developments in one or the other that best accounts for the observed age-related changes in categorical flexibility. Therefore, Experiment 2 was designed to
assess the development of children’s conceptual knowledge in a context that minimized the need for executive control.

Experiment 2

The aim of Experiment 2 was to isolate conceptual knowledge from executive control costs involved in the Double Categorization Task used in Experiment 1. The Double Categorization Task requires selecting between two conflicting options for Selection 1 and immediately switching to a new representation of the target in the presence of the first more salient match. Hence, in Experiment 2 we examined the performance of 3- to 5-year-olds on another version of the match-to-sample task—the Simple Categorization Task—in which children were presented twice with the same set of targets. Like the Double Categorization Task, children also were asked to match targets to thematic and taxonomic associates, but thematic and taxonomic options for each particular target were presented on different trials (see Nguyen & Murphy, 2003, for a similar procedure). On thematic trials, targets were presented with three potential matches, a thematic associate and two nonassociates, whereas on taxonomic trials, the same targets were presented with a superordinate taxonomic associate and two nonassociates. For half of the targets, thematic trials were presented first, and for the other half, taxonomic trials were presented first. Consequently, Selection 2 responses were asked only after a series of other targets had been presented. In addition, the relevant associate to be identified for Selection 2 was presented in the context of two new nonassociates.

This Simple Categorization Task, then, presented three main differences with the Double Categorization Task. First, children made each of their selections in a non-conflictual context because only one associate was semantically related to the target on a given trial (the other two being unrelated). Second, the second potential match for a given target was requested only after a
delay. Third, the second potential match was requested in the absence of the first match. We hypothesized that these differences, all of which contributed to reducing the executive load of the task, might help reveal conceptual knowledge that might otherwise be underestimated on the Double Categorization Task and traditional match-to-sample tasks more generally. Moreover, a direct comparison with performance on the Double Categorization Task in Experiment 1 allowed us to examine the relative contributions of conceptual knowledge and executive control to categorical flexibility. In addition, this comparison allowed us to trace differences in developmental changes across the two tasks, highlighting potentially different critical periods for developments in conceptual and executive processes.

**Method**

**Participants.** Participants were eighteen 3-year-olds ($M = 43$ mos., range 40 to 47 mos.), eighteen 4-year-olds ($M = 55$ mos., range 51 to 58 mos.), and sixteen 5-year-olds ($M = 66$ mos., range 60 to 71 mos.). Approximately equal numbers of boys and girls participated at each age. Children were recruited in the same manner as those who participated in Experiment 1, but no child who participated in Experiment 1 participated in this experiment.

**Stimuli.** Targets and thematic and taxonomic associates were the same as those used in Experiment 1. However, because thematic and taxonomic associates were presented on different trials, two nonassociates needed to be presented on both thematic and taxonomic trials. Thus, three new nonassociates were used with each target in addition to the one used in Experiment 1. The particular pair of nonassociates presented on thematic and taxonomic trials was counterbalanced between participants.

**Procedure.** The task began with two demonstration trials consisting of a taxonomic trial in which a target was presented with a taxonomic associate and two nonassociates (see Figure 1,
Panel B) and a thematic trial in which a target was presented with a thematic associate and two nonassociates (see Figure 1, Panel C). Instructions were similar to those used in Experiment 1 except that no tokens were used: Children simply pointed to the best match for each target. Corrective feedback was given on the two demonstration trials. Participants were then presented with the two experimental blocks of 16 trials each, corresponding to the 16 targets used in Experiment 1, and each target appeared only once within each block. Moreover, within each block, approximately half of the targets were presented in thematic trials and the other half were presented in taxonomic trials. At the outset of the second block, children were informed that they were going to see the same targets as in the first block, but that new pictures were to be displayed with them. They were told that they again had to select the one that best matched the target. Two random orders of test trials were devised and counterbalanced across participants. For each order, however, targets were presented in the same order across the two blocks to keep the number of interspersed trials between first and second selections constant for all targets.

Results and Discussion

On a given trial children had to choose among three response options: one correct (taxonomic or thematic) associate and two incorrect nonassociates. In this context, then, Selection 1 responses were those responses that children made in the first experimental block and a correct double selection involved selecting the two associated pictures presented in the first and second trial of a given target, one in the first block and the other in the second block.

Selection 1 Performance. Children’s performance was first examined on the proportion of correct Selection 1 responses using a 3 (Age Group: 3-, 4-, vs. 5-year-olds) x 2 (Associate Type: thematic vs. taxonomic) mixed ANOVA with repeated measures on associate type. It revealed a significant main effect of age, $F(2, 49) = 18.31, p < .0001$, partial $\eta^2 = .43$, with the mean
proportion of correct Selection 1 responses increasing from 0.73 ($SD = .14$) to 0.88 ($SD = .08$) to 0.94 ($SD = .08$) in 3-, 4-, and 5-year-olds, respectively. Tukey’s HSD analyses indicated that the increase in performance occurred primarily between 3 and 4 years of age: Only the youngest group’s performance differed significantly from that of the other two groups, $p < .001$.

However, with a probability of $p = .33$ of making a correct selection on Selection 1 on the basis of chance alone, even 3-years-olds performed above chance level, $t(15 \text{ or } 17) > 12.3, p < .0001$. There was also a significant main effect of associate type with children performing better on thematic selections, $F(1, 49) = 7.23, p < .01$, partial $\eta^2 = .13$, ($M = .88, SD = .14$, for thematic selections and $M = .81, SD = .17$, for taxonomic selections), although performance for both types (taxonomic and thematic) was high. There was no interaction between age and type of associate, $p > .40$.

Performance Across Both Selections. Turning to correct double selections, we used a 3 (Age Group) x 2 (Presentation Order: thematic then taxonomic vs. taxonomic then thematic) ANOVA on the proportions of correct double selections. It revealed no effect of presentation order or interaction, $p > .50$, but a significant main effect of age, $F(2, 49) = 26.85, p < .0001$, partial $\eta^2 = .52$. As suggested in Figure 2 (right panel), there was a significant improvement between 3 and 4 years ($M = .52, SD = .18$, and $M = .78, SD = .09$, for 3- and 4-year-olds, respectively), but no significant changes between 4 and 5 years ($M = .86$ and $SD = .14$, for 5-year-olds). Tukey’s post hoc tests confirmed that differences were reliable only between the youngest group and the two older ones, $p < .0001$, who did not differ from one another, $p > .32$.

However, it is noteworthy that with a mean proportion of 0.52 correct double selections, 3-year-olds’ performance was far above chance given that the proportion of trials expected to be correct
by chance alone was only .11 ($p = .33$ for Selection 1 and $p = .33$ for Selection 2, thus, $p = .11$ for both).

Comparisons Across the Double and Simple Categorization Tasks. Scores represented in Figure 2 contrasting the proportions of correct double selections in the Double and Simple Categorization Tasks, respectively, are not directly comparable because the base probability of selecting a correct double selection for a given target differed across tasks. Consequently, we examined the percentages of children in each age group who produced flexibility scores (i.e., correct double selections for each target) superior to chance as a function of task using binomial probability distributions (i.e., $x \geq 9$ for the Double Categorization Task, binomial = .05, and $x \geq 5$ for the Simple Categorization Task, binomial = .03). Whereas a large majority of children produced flexibility scores superior to chance from 3 years onwards on the Simple Categorization Task, less than half of 3-year-olds and approximately half of 4-year-olds did so on the Double Categorization Task (Figure 3). One had to wait until age 5 to observe comparable percentages on both tasks. Indeed, there was a significant effect of age group for the Double Categorization Task, $\chi^2(2, N = 60) = 11.14, p < .004$, but no effect of age group for the Simple Categorization Task, $\chi^2(2, N = 52) = 3.93, p > .13$. For the Double Categorization Task, pairwise comparisons detected a significant difference only between the two older age groups, $\chi^2(1, N = 40) = 6.14, p < .02$. For the Simple Categorization Task, a ceiling effect was obtained, even if two 3-year-olds (11% of this age group) failed to perform above chance on this task. Clearly, the difference in performance across the two tasks provides support for the hypothesis that categorical flexibility involves more than only conceptual knowledge of both kinds of associations. We return to this point in the next section.

General Discussion
We explored whether age-related changes during the preschool years in children’s categorical flexibility occur as a result of changes in conceptual knowledge or changes in executive control, as categorical flexibility depends on both. To assess categorical flexibility in Experiment 1, we used the paradigmatic match-to-sample task and adapted it: For each target, children had to select a first match presented in a conflictual context involving two potential associates and a nonassociate, and they then had to select a second match. Categorical flexibility in this context required that children access and switch successively between the two simultaneously available associates. Thus, as with research on cognitive flexibility in the executive function literature and other domains (e.g., Carlson & Moses, 2001; Chevalier & Blaye, 2008; Frye et al., 1995; Gerstadt et al., 1994; Jacques & Zelazo, 2001; Luria, 1961; Müller et al., 2004; Smidts et al., 2004; Zelazo, 2006; see also Diamond, 2006, Jacques & Zelazo, 2005, for recent reviews), categorical flexibility in our task involved successively switching between available, but conflicting representations.

Experiment 2 focused on assessing conceptual knowledge of both kinds of associations for each target independent of executive demands. That is, because the executive cost involved in the Double Categorization Task might underestimate conceptual knowledge itself, we assessed children on the Simple Categorization Task. Selecting two associates on the Simple Categorization Task did not require categorical flexibility as the two representations of the objects were not placed directly in conflict with one another. Instead, the Simple Categorization Task measured what Nguyen (Nguyen & Murphy, 2003; Nguyen, 2007) called cross-classification, namely the ability to access two representations of the same object on two separate occasions. Because accessing both representations of the same object was done on separate occasions in this task, the potential interference resulting from having represented the first
selected representation was removed. In other words, children did not need to access two conflicting representations of the same object and switch between them. Hence, performance on this task provided an index of children’s conceptual knowledge of both kinds of associations.

Both tasks revealed significant increases in performance during the preschool period, but with different developmental trajectories: Whereas correct double selections increased between 4 and 5 years of age on the Double Categorization Task, increases in correct double selections occurred earlier, between 3 and 4 years, on the Simple Categorization Task. In fact, our findings with the Simple Categorization Task replicated recent findings by Nguyen and Murphy (2003; Nguyen, 2007). For example, Nguyen (2007) identified a developmental pattern similar to ours in that she found significant changes in conceptual knowledge between 3 and 4, but not between 4 and 6 (cf. Rosch et al., 1976). Likewise, Nguyen and Murphy obtained similar findings, but these were limited to conceptual knowledge of food categories. However, Nguyen and Murphy, and Nguyen did not include a task like the Double Categorization Task.

In contrast, the period of rapid change in categorical flexibility on Double Categorization Task that we observed between 4 and 5 years coincides well with the period of rapid change in cognitive flexibility observed on other tasks, including the FIST (Jacques & Zelazo, 2001; see Jacques & Zelazo, 2005, for a review), a similar inductive task that measures cognitive flexibility using perceptual dimensions (as opposed to categorical relations). As in the Double Categorization Task, measures of cognitive flexibility in the executive function literature and other domains also involve conflicting response options and switching between two responses, although certain tasks like the DCCS are solved earlier, perhaps because of their deductive nature.
Despite these similarities with previous research, however, our findings are unique in that they are the first to document contrasting developmental pathways for conceptual and executive processes, two complementary processes that are vital for the emergence of categorical flexibility. More precisely, our findings indicate that the development of categorical flexibility occurs in two steps during the preschool years: First, children need to master conceptual knowledge of thematic and superordinate taxonomic categories, something they achieve by the age of 4. Second, they then need to acquire sufficient executive control skills, in particular cognitive flexibility, that then allows them to access alternative conceptual representations, even in circumstances when these conflict with each other. These findings might explain the relative poor performance of preschool children in existing justification studies (e.g., Greenfield & Scott, 1986; Lucariello et al., 1992; Tversky, 1985), despite findings from other studies demonstrating conceptual knowledge of superordinate relations in same-aged children (e.g., Rosch et al., 1976). Specifically, in justification studies, researchers generally asked children to first select a match (for which they often opted for the thematic match) and then justify the alternate match (the taxonomic one) in the continued presence of the first more salient match, therefore, requiring categorical flexibility. On the basis of our findings, difficulties in these justification studies may have resulted from executive control difficulties, not lack of conceptual knowledge.

In addition, we found that children who tended to select one kind of associate (either thematic or taxonomic) consistently for their first selection across trials on the Double Categorization Task also had higher flexibility scores (double correct selections) than children who were less consistent, even after controlling for age. This finding is remarkable because it suggests that children who use a top-down approach also demonstrate more categorical flexibility, providing evidence for a link between these two controlled processes. This finding is
also noteworthy because it provides additional evidence that both conceptual knowledge (i.e.,
recognizing different kinds of relations) and executive control skills (i.e., systematically selecting
particular relations and cognitive flexibility) contribute jointly to the development of categorical
flexibility. Further research is now required to gain a better understanding of exactly how
conceptual and executive aspects might support one another across development. The fact that
gains in conceptual knowledge precede gains in cognitive flexibility suggests that conceptual
knowledge is not only a prerequisite for flexibility, but that it may actually support it (see also
Blaye, Bernard-Peyron, Paour, & Bonthoux, 2006; Blaye, Chevalier, & Paour, 2007; Chevalier
& Blaye, 2008; Jacques et al., 2008; Maintenant & Blaye, 2005).

However, recent research has suggested that categorical flexibility might even be
observed in infants (Ellis & Oakes, 2006; Mareschal & Tan, 2007). In fact, compared to
definitions of flexibility proposed by others (e.g., Blaye & Bonthoux, 2001; Deák, 2003; Nguyen
& Murphy, 2003; Ellis & Oakes; Mareschal & Tan; Waxman & Namy, 1997), we have restricted
our meaning of categorical flexibility to a very conservative and narrow one: We propose that
demonstrating categorical flexibility requires that children be exposed to simultaneously
available conflicting representations of the same object and be able to switch successively
between these. Our results clearly demonstrate that the conditions in which children are
presented with different categorical representations of the same object (i.e., simultaneously or at
different times) are instrumental in enhancing or preventing them from being able to identify all
relevant representations. Indeed, in our study, it was especially difficult for children to represent
objects flexibly within different conceptual networks in situations that were associated with high
executive control demands, but it was relatively easier for them to switch at a younger age when
these representations were not placed in conflict with each other and were presented instead at
different times. However, even though our definition of categorical flexibility may seem unnecessarily exacting, true flexibility requires that children be able to alternate between different representations at any given moment. As such, conceptual knowledge and executive control together must be considered integral parts of categorical flexibility.
References


Footnotes

1 Note that when we refer to taxonomic categories, we consider only superordinate taxonomic categories (Rosch et al., 1976). Basic-level taxonomic categories are too ambiguous to interpret, as these can be identified as a result of perceptual (i.e., high level of perceptual similarity between two exemplars; e.g., dogs) or conceptual processing.

2 As we used four nonassociates for a given target in the Simple Categorization Task in Experiment 2, half of the adults saw two nonassociates and the other half saw the remaining two.

3 An additional two item sets were presented in this experiment, but these were not considered here for the sake of comparison with Experiment 1.

4 Because we considered only the 16 items common to both experiments, the balance between the two types of associates presented first was not perfect. That is, some children received seven thematic trials as their first presentation and others received nine. However, in each age group, there were as many children with more thematic trials first as children with more taxonomic trials first. In addition, we compared proportions of correct responses instead of frequencies.
Figure Captions

*Figure 1.* Stimuli display presented in the Double Categorization Task (Experiment 1, Panel A) and the Simple Categorization Task (Experiment 2, Panels B and C).

*Figure 2.* Mean proportions (and standard errors) of correct double selections as a function of age for the Double Categorization Task in Experiment 1 (left panel) and the Simple Categorization Task in Experiment 2 (right panel).

*Figure 3.* Percentages of children with above chance flexibility scores as a function of age and task.
Appendix

List of Stimuli Used in Experiments 1 and 2

<table>
<thead>
<tr>
<th>Target</th>
<th>Thematic Associate</th>
<th>Taxonomic Associate</th>
<th>Nonassociate 1</th>
<th>Nonassociate 2</th>
<th>Nonassociate 3</th>
<th>Nonassociate 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>fish</td>
<td>fishing rod</td>
<td>fox</td>
<td>broom</td>
<td>playing cards</td>
<td>pencil</td>
<td>toothbrush</td>
</tr>
<tr>
<td>shirt</td>
<td>iron</td>
<td>swimsuit</td>
<td>kangaroo</td>
<td>fork</td>
<td>ax</td>
<td>beetle</td>
</tr>
<tr>
<td>cot</td>
<td>sleep wear</td>
<td>table</td>
<td>watch</td>
<td>helicopter</td>
<td>kettle</td>
<td>bird</td>
</tr>
<tr>
<td>frying pan</td>
<td>egg</td>
<td>pressure cooker</td>
<td>star</td>
<td>jacket</td>
<td>crib</td>
<td>teddy bear</td>
</tr>
<tr>
<td>house</td>
<td>key</td>
<td>tent</td>
<td>pear</td>
<td>frog</td>
<td>cup</td>
<td>ship</td>
</tr>
<tr>
<td>wood saw</td>
<td>logs</td>
<td>hammer</td>
<td>ring</td>
<td>horse</td>
<td>sailboat</td>
<td>cone</td>
</tr>
<tr>
<td>dog</td>
<td>doghouse</td>
<td>snail</td>
<td>telephone</td>
<td>tomato</td>
<td>hammer</td>
<td>pants</td>
</tr>
<tr>
<td>cake</td>
<td>candle</td>
<td>chicken</td>
<td>giraffe</td>
<td>truck</td>
<td>sock</td>
<td>rattle</td>
</tr>
<tr>
<td>flower</td>
<td>watering can</td>
<td>leaf</td>
<td>crash helmet</td>
<td>bed</td>
<td>sausage</td>
<td>guitar</td>
</tr>
<tr>
<td>plane</td>
<td>suitcase</td>
<td>motorcycle</td>
<td>bone</td>
<td>pig</td>
<td>violin</td>
<td>stool</td>
</tr>
<tr>
<td>apple</td>
<td>knife</td>
<td>banana</td>
<td>snowman</td>
<td>gift box</td>
<td>parasol</td>
<td>toothpaste</td>
</tr>
<tr>
<td>mitten</td>
<td>skis</td>
<td>pyjamas</td>
<td>butterfly</td>
<td>sofa</td>
<td>piano</td>
<td>lion</td>
</tr>
<tr>
<td>screwdriver</td>
<td>bicycle</td>
<td>power drill</td>
<td>pineapple</td>
<td>water jug</td>
<td>dress</td>
<td>mouse</td>
</tr>
<tr>
<td>bird</td>
<td>birdcage</td>
<td>dolphin</td>
<td>tap</td>
<td>t-shirt</td>
<td>toy robot</td>
<td>excavator</td>
</tr>
<tr>
<td>tree</td>
<td>owl</td>
<td>potted plant</td>
<td>rubber ring</td>
<td>doll</td>
<td>glass</td>
<td>dustbin</td>
</tr>
<tr>
<td>carrot</td>
<td>rabbit</td>
<td>strawberry</td>
<td>book</td>
<td>bus</td>
<td>bedside lamp</td>
<td>binoculars</td>
</tr>
</tbody>
</table>