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COGNITIVE DEVELOPMENT

Effects of age, reminders, and task difficulty on young children's rule-switching flexibility

Gedeon O. Deák[a,*], Shanna D. Ray[b,1], Anne D. Pick[c]

[a] Department of Cognitive Science, University of California, San Diego, La Jolla CA 92093-0515, USA
[b] Department of Psychology and Human Development, Vanderbilt University, USA
[c] Institute of Child Development, University of Minnesota, Twin Cities, MN, USA

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Abstract

To test preschoolers' ability to flexibly switch between abstract rules differing in difficulty, ninty-three 3-, 4-, and 5-year-olds were instructed to switch from an (easier) shape-sorting to a (harder) function-sorting rule, or vice versa. Children learned one rule, sorted four test sets, then learned the other rule, and sorted four more sets. In a control condition, seventy-two 3–5-year-old children learned one rule and were re-trained on that rule before the second test block. Half of each group received metacognitive reminders to "think about" the current rule before each test trial. The shape rule was easier: many 3-year-olds failed to follow the function rule, confirming findings of Deák et al. (2002). Switching rules did not reduce overall rule-following. However, reminders facilitated rule-following when rules were switched, but not when a rule was repeated (i.e., control condition). Reminders actually reduced rule-following by control children who got the easier (shape) rule. The results show (1) 4-year-olds readily switch between abstract rules, even if the second rule requires ignoring obvious, conflicting perceptual information (i.e., shape); (2) some rule-switching tasks do not impose performance costs on children, and (3) children's rule-following consistency and flexibility depend on the nature of available social support.

Keywords: Age; Reminders; Task difficulty; Cognitive flexibility; Sorting; Rule use

Preschool children are challenged by switching from one rule to another. In a widely used paradigm (the Dimensional Change Card Sort test), 3-year-olds readily adopt a simple rule for sorting cards with colored figures (e.g., "all dogs go here... [and] only flowers go

* Corresponding author. Tel.: +1 585 822 3352.
E-mail address: deak@cogsci.ucsd.edu (G.O. Deák).
[1] Current address: Department of Psychology, Lipscomb University, Nashville, TN, USA.

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there"), but when told to change to a new rule (e.g., "all blue things go here. . . only red things go there"), they do not switch responses (Zelazo, Frye, & Rapus, 1996). Instead, they perseverate, continuing to follow the first rule. Three- and 4-year-old children also perseverate more than older children in verbal response-switching or flexible inductive inference tests (Deák, 2000). Also, in task-switching tests of school aged children, 6–7-year-olds make more errors than older children (Cepeda, Kramer, & Gonzalez de Salther, 2001). Thus, the ability to switch responses as task instructions or rules change undergoes substantial improvement with age.

An open question is what circumstances make it easier for preschool children to flexibly switch responses to changing rules or instructions, and what circumstances make it harder. This question has practical importance for early childhood education (ECE) curricula design and classroom practices. More generally, it concerns age-related changes in cognitive flexibility: that is, the ability to select task-appropriate responses, then shift responses appropriately when task demands or task context changes (Deák, 2003). Recent results from rule-switching studies begin to outline some task factors that do or do not influence response flexibility in young children. For example, changing rule order, giving periodic rule reminders, leaving stimuli visible as response cues, adding more low-level rules (e.g., "Orange things go in this box."), and changing response modality (from manual to verbal), seem to have little effect on children's rule-following flexibility (see Zelazo, Müller, Frye, & Marcovitch, 2003). In contrast, rule-switching flexibility is increased if children complete other response-switching tasks first (Perner & Lang, 2002), if the rule-relevant stimulus property (and only that property) is labeled on every trial (Kirkham, Creuss, & Diamond, 2003; Munakata & Yerys, 2001; Towse, Redbond, Houston-Price, & Cook, 2000), or if stimulus-specific properties change between rules (Zelazo et al., 2003).

One general factor that might influence performance, but has not been investigated, is the prior difficulty of the rules. Most rule-switching tests use binary shape and color rules (e.g., switching from a shape-rule [e.g., cars versus flowers] to a color-rule [e.g., green versus red], or vice versa). These rules are both very easy, roughly equally so, for typically developing, middle-class 3- and 4-year-olds (Zelazo et al., 2003). A few studies (Frye, Zelazo, & Palfai, 1995, Experiment 2; Zelazo et al., 2003, Experiment 4) have explored size- and number-based rules; these seem to be harder for preschool children (see Deák, 2003).

Rule difficulty is important to consider because the literature on children's rule-switching almost uniformly uses very easy rules and very simple stimuli (i.e., monochromatic line drawings of prototypical object-shapes) that recur in every trial. This narrow task range might skew our understanding of children's flexibility. For example, young children might perseverate less if changing rules are moderately challenging, and stimuli are somewhat complex and varied (see Deák, 2000). More generally, any account of flexible cognition in children must consider not just very easy rules and stimuli, but also difficult or abstract rules and complex stimuli; at least with levels of difficulty and complexity comparable to what parents and teachers expect children to master. In a similar vein, Foulks and Morrow (1989) suggest that young children's school readiness depends largely on their social-cognitive ability to respond appropriately to rules and instructions. Because rules imposed by teachers and parents are not always simple and familiar, it is important to investigate how children shift between abstract rules, how the ability changes with age, and how it interacts with rule difficulty and with social scaffolding for rule-following flexibility. The current study is an attempt to address each of these issues.

To investigate how rule difficulty influences rule-following flexibility, children in the current paradigm were instructed to follow two abstract rules, one harder than the other. By abstract we mean are rule that is not tied to specific, recurring stimulus properties (e.g., a shade of red and a shade of blue), unlike in card-sorting tasks (e.g., Frye et al., 1995). We consider this an important broadening of the existing literature, because children in everyday settings probably are seldom asked to switch from one rule to another with respect to exactly the same, recurring stimulus or situation. Rather, children are expected to generalize rules to new circumstances, and to switch rules when the situation changes somewhat.

The specific question of interest is whether it is especially difficult for children to switch from an easier to an harder rule, than the reverse. Intuition suggests that switching to a harder rule should be more challenging, but the adult task-switching literature (see Wylie & Allport, 2000) is equivocal: some studies find a paradoxical effect wherein adults suffer larger efficiency costs when switching to an easier task (Monsell, Yeung, & Azuma, 2000; Yeung & Monsell, 2003). We know nothing about how preschool children's perseverative errors—taken as an age-appropriate measure of "switch costs"—are affected by switching to easier or harder rules. Zelazo et al. (2003, Experiment 4) found 3–4-year-olds were more flexible when switching from a number rule to a size rule than vice versa, and Deák (2003) found it especially hard for preschool children to switch from (easier) shape or color rules to a harder size rule, compared to other rule orders. Also, Cepeda et al. (2001) found that older children suffer relatively large switch costs (in response time) when switching to harder, incongruent trials compared to switching to easier, congruent trials (see also Rubenstein, Meyer, & Evens, 2001). These findings are consistent with the intuition that switching to a harder rule is especially difficult. However, no studies have tested this in preschool children, using rules that have been shown to differ a priori in difficulty.

To test whether young children's rule-switching flexibility is affected by the direction of change in rule difficulty (i.e., easy → hard or hard → easy), we adapted a rule-generalization paradigm from Deák et al. (2002). Deák et al. (2002) address a long-standing debate about whether, and when, young children classify and name artifacts by function or by shape (see, e.g., Kemler Nelson, 1995, 1999; Kemler Nelson, Frankenfield, Morris, & Blair, 2000). In the rule generalization paradigm, children are shown triads of real objects. In each trial a hybrid object (e.g., penlight) matches the shape of one object (i.e., pen), and function of another (i.e., L-shaped flashlight). After seeing each object's function demonstrated, children decide whether to sort the hybrid with the same-shape or the same-function object. Specific shapes and functions differ across triads, so to comply with a rule children must understand it as an abstract conditional rule, not a specific memory cue that links a specific action with a specific stimulus property (see Munakata & Yerys, 2001, for relevant arguments). Deák et al. (2002) found that 4-year-olds readily adopt and generalize either a shape- or a function-sorting rule in a between-subjects design, from an instruction given at the beginning of the test session. In contrast, 3-year-olds will adopt a shape rule (not merely as a default preference for shape; see Deák et al., 2002, for detailed evidence), but will not readily adopt a function rule. Three-year-olds are above chance in following a function rule only in very supportive conditions: when extra training trials are provided, and the hybrid object's function is demonstrated a second time while the child decides how to sort it, and the child is reminded on every trial to think about the sorting rule. This last form of support was conceived as metacognitive, rather than rule-specific, reminders, because the rule was never actually re-stated by the experimenter during test trials.

In sum, the function-sorting rule was found to be harder than the shape-sorting rule for preschool children. These rules thereby offer a potentially challenging test of flexible rule-switching. Both rules should be more difficult than standard card-sorting rules (Frye et al., 1995), partly because shapes and functions change on every trial, and partly because shape and function are correlated. That is, things that work the same tend to look alike, though form and function are partly separable (as in representational objects like novelty fridge magnets that look like food items). Adults can flexibly shift attention between shape and function, given appropriate instructions or tasks (Ward, 1995). Preschool children also can sort objects by shape or function, depending on contextual factors (Deák et al., 2002; Kemler Nelson et al., 2000). The current study examines whether, and how, children switch between sorting rules that are truly abstract (i.e., non-repetitive) and potentially difficult (because shape and function are usually correlated), when one rule (i.e., function-sorting) is harder than the other (shape-sorting). Three-, 4-, and 5-year-old children were tested. The youngest group is only at the cusp of being able to use the harder rule, and therefore, perhaps, catastrophically sensitive to the added demand of switching from one rule to another. The middle group (4-year-olds) readily follows either rule alone, and therefore is a barometer of added difficulty due to switching to a harder rule. The 5-year-olds are included in case switching demands exceed 3- and 4-year-olds' abilities.

To test preschoolers' ability to flexibly switch between shape- and function-sorting rules, test trials from Deák et al. (2002) were divided into two blocks, with rule instructions given before the first test block, and again before the second test block. In an experimental switch condition, between-block instructions specified a different rule than the initial instructions. Rule order was counterbalanced between-subjects, to test the relative difficulty of switching to an easier or harder rule. In the control condition, the initial rule was reiterated between blocks (i.e., re-instruction). This gives a between-groups test of switch costs (i.e., change in accuracy from test block 1 to block 2). It also tests for sampling bias, because the control group should perform like the same-age groups in Deák et al. (2002), who also followed only one rule.

In addition to investigating rule order and difficulty, the study addressed a question about social scaffolding of rule-switching. Because preschool children are probably inexperienced with tasks that require switching between discrete, explicit rules, their tendency to perseverate might be due to a failure to interpret unfamiliar pragmatic or social demands (see Siegal, 1991). For instance, Deák (2003) suggests that in standard rule-switching tests, after children master an easy (pre-switch) rule, they feel highly confident they have succeeded, and thereafter tend to ignore (or fail to analyze) instructions, even instructions that specify a new rule. This is a pragmatic failure, but not necessarily indicative of inability to inhibit prior responses. Also, 3-year-olds in everyday settings probably receive scaffolding from adults to help them follow rules. For example corrective feedback, demonstrations by an adult, or implicit exhortation to recall rules (e.g., "Is that how we put away our clothes?") might provide useful information to children. However, past findings are mixed. Zelazo, Resnick, and Piñon (1995) showed that simply re-stating a rule did not help 30–36-month-old toddlers follow rules. However, other studies have shown that social scaffolding can help children flexibly switch rules. Bohlmann (2001) found that a single presentation of corrective feedback helped almost all 3-year-olds switch to a new sorting rule. Sweet and Deák (in preparation) found that letting 3-year-olds choose when to begin using a new rule significantly increased correct rule switching. Finally, Perner and Lang (2002) found that 3-year-olds performed well in a response-switching task when sorting was framed in terms of characters' preferences (e.g., "Mickey likes cars. . . and Donald likes flowers" and "Mickey likes red things... and Donald likes blue things"). The premise that two individuals could like different colors *and* different toys is more familiar and understandable to children than a spontaneous, unexplained, switch from one arbitrary rule to another. Thus, there is some evidence that scaffolding might help children flexibly switch rules.

Perhaps other kinds of scaffolding could clarify rule-switching demands for children. The very possibility of this imples that cognitive flexibility is in part socially learned, perhaps as set of executive cognitive strategies. The effect of scaffolding was tested by giving half of children a rule-use reminder, exhorting them on every trial to recall or "think about" the last rule. The rule was not actually re-stated, because our goal was not to test children's ability to remember the current rule (Zelazo et al., 2003, found rule memory limits do not explain 3-year-olds' switching problems). Rather, our goal was to determine whether social input can get children to reflect upon the current rule. If this manipulation is effective, it would suggest that (1) children's rule-switching failures are more likely to be avoidable responses than to be responses they simply cannot suppress; and (2) in young children, social input can compensate for lack of spontaneous metacognitive activity (e.g., covert self-reminders) that might be necessary for flexible rule-switching.

To summarize, this study examined the development of rule-switching flexibility between 3 and 5 years, using a task in which children were instructed to switch between an easier and a harder rule. Rule order was varied, to test how order of rule difficulty impacts switching. Some children were re-trained on the first rule, as a control condition. Some children were reminded to "think about the rule" as a metacognitive scaffold to prompt them to retrieve the last rule before making a sorting response.

1. Method

1.1. Participants

One hundred and sixty-eight young children, mostly Caucasian and middle-class, were recruited from preschools in a city in the Southeastern United States. Ninty-six were randomly assigned to a Switch group: thirty-two 3-year-olds (13 girls; mean age = 3.6; range 3.0–3.11), thirty-two 4-year-olds (13 girls; mean = 4.6; range 4.1–4.11), and thirty-two 5-year-olds (13 girls; mean = 5.6; range 5.0–5.11). The rest were a control group, including twenty-four 3-year-olds (9 girls; mean age = 3.6; range 3.0–3.l 1), twenty-four 4-year-olds (8 girls; mean = 4.6; range 4.0–4.11), and twenty-four 5-year-olds (11 girls; mean = 5.6; range 5.1–5.11).

Table 1
Objects in instruction and test triads

Hybrid	Same-shape, different-function	Same-function, different-shape
Instruction trios		
Large light bulb	Bulb-shaped bottle	Ornamental light bulb
Heart-shaped pencil sharpener	Heart-shaped bracelet	Pencil sharpener
Test trios		
Lyre-shaped drum	Lyre	Drum
Plush jingling cube	Wood cube	Plush jingling sphere
Flour sifter	Pewter mug	Potato ricer
Football-shaped telephone	Toy football	Telephone
Egg-shaped tea infuser	Egg-shaped timer	Tea infuser with handle
Disk-shaped pitch pipes	Disk-shaped tape measure	Corn-shaped harmonica
Rectangular magnet	Rectangular eraser	Round magnet
Penlight	Pen	L-shaped flashlight

1.2. Materials

Stimuli were 10 object triads (see Table 1), each including a "hybrid", a same-shape/different-function object, and a same-function/different-shape object. Note that hybrid denotes a blend of one object's shape and the other's function, and that "function" denotes a designated function demonstrated by the experimenter and copied by the child. Other properties (e.g., color; size) were controlled either by differing across all three objects (e.g., football-telephone, football, and telephone were brown, red, and blue, respectively), or by being the same in all three (e.g., the penlight, pen, and flashlight all were black plastic). Two trios were designated instruction sets to be used for initial rule instruction and block 2 re-instruction trials.

1.3. Procedure

Children were seated facing the experimenter (E) in a preschool classroom, with objects piled haphazardly nearby. After establishing rapport, E suggested, "let's look at these things, and play with them. . . [then] clean them up." The general procedure in each trial was to place a triad before the child, demonstrate each of the three objects' functions (in counterbalanced order, as described by Deák et al., 2002), and encourage the child to try each function. E then suggested, "Let's put these away so we can look at some more." The same-shape and same-function objects were placed in different boxes (side counterbalanced). E then asked the child to sort the hybrid by grouping it with one of the two objects. The child's choice was recorded as shape-based or function-based, and scored as either consistent or inconsistent with the given rule (see further).

1.3.1. Instruction trials

Before each test block, children completed two instruction trials. Both instruction trials focused on the same rule, either shape or function. The instruction was framed by E as "the rule of the game." In shape instruction trials E demonstrated each object's function and said, "Put this one [hybrid] with the one that's the same shape. . . the one that's shaped the same.” Children received feedback (i.e., “That’s right, these are the same shape, so we put them together in this game.” or “Actually, these are the same shape, so we put it with this one”). In function instruction trials E said “Put this one with the one that works the same... .the one that does the same thing,” and provided analogous feedback. In each condition the rule was repeated several times per trial. The same two triads were used in the instruction trials for blocks 1 and 2.

Half of Switch condition children received shape instructions trials before the first test block and function instructions before the second block; the other half received the opposite order. Half of the Control group children heard shape instructions before each block; the other half heard function instructions before each block.

1.3.2. Test trials

After each pair of instruction trials, children completed four test trials. On each trial, after seeing the objects’ functions demonstrated and two objects placed in boxes, children were asked, “Which one does this [hybrid] go with?” No feedback or reinforcement was given. Triad order was randomized for every child, so different combinations of triads were presented in the first and second blocks, and in different orders. Thus, unintended order effects, such as having two triads with related functions presented in sequence, would be randomly distributed.

1.3.3. Rule reminder

Half of each group was randomly assigned to a rule-reminder support condition. During the instruction phase, these children were told they would learn a new game, and were cautioned to “remember the rule [of the game].” On each test trial, before the child matched the hybrid, E suggested, “Wait a minute. . . think about the rule. What’s the rule of [our] game?” For children in the switch condition, the new instruction was described as a “new game,” and in each block two trial the child was told, “Wait a minute. . . think about the rule. What’s the rule [of our game] now?” (or, “What are we supposed to put it with now?”). This was to encourage children to retrieve the last rule, but without re-stating it. Control children who received rule reminders also were exhorted, “Wait. . . think about the rule. . . [etc.]” on every trial. Children who did not receive rule reminders heard no extra instructions on test trials.

1.3.4. Design summary

By crossing condition (switch or control) with first rule (easy [shape] or hard [function]), we derive four groups with the block orders: easy → easy, easy → hard, hard → easy, and hard → hard. Samples of three age groups (3-, 4-, and 5-year-olds) each are randomly assigned to these four groups. Half of the children in each of these 12 age-by-conditions groups received reminders on every trial to think about the rule.

2. Results

A preliminary ANCOVA showed no significant gender effect in total rule-consistent sorting choices (with age, reminder, and block 1 rule covaried), $F(1,162) = 2.4$, $P > .12$. All further analyses therefore combine boys and girls.

Our first question was whether switching to an easier rule facilitates rule-shifting more than switching to a harder rule. Put differently, we can ask whether a rule's difficulty depends on its context in a sequence of rules or conditions. To address this, two analyses were conducted. The first was a mixed-measures ANOVA of rule-consistent responses (range = 0–4), with age (3-, 4-, or 5-year-olds) and rule order (easy → hard or hard → easy) between-subjects, and block (1 or 2) within-subjects. The main effect of age was significant, $F(2,90) = 11.1$, $P < .001$ ($\eta = .20$). Mean rule-consistent block 1 responses increased from 2.5 (S.D. = 1.5) in 3-year-olds to 3.3 (1.1) and 3.2 (1.3) in 4- and 5-year-olds, respectively. Mean rule-consistent block 2 responses increased from 2.5 (S.D. = 1.5) in 3-year-olds to 3.1 (1.1) and 3.7 (0.9) in 4- and 5-year-olds, respectively. The rule order effect was not significant, $F(1,90) = 1.9$, $P = .171$. Children who began with the shape rule made a mean of 6.3 (S.D. = 1.7) rule-consistent sorts (out of 8); those who began with the function rule made a mean of 5.9 (1.9). There was no interaction of age and order. The within-subjects effects show a non-significant effect of block (1 versus 2), $F(l,90) < 1$. Overall, the rule switch did not reduce rule-following responses. There was a significant block-by-rule-order interaction, $F(, 90) = 47.5$, $P < .001$ ($\eta^2 = .35$). Children who began with the shape rule correctly sorted means of 3.6 (S.D. = 0.9) in block 1 and 2.7 (1.5) in block 2; children who began with the function rule sorted 2.4 (1.5) in block 1 and 3.5 (0.9) in block 2. Thus, rule-followed depended solely on a priori rule difficulty. Finally, there was a significant 3-way, age X block X rule-order interaction, $F(2, 90) = 16.4$, $P < .001$ ($\eta^2 = .27$). The order-by-rule effect just described was due mostly to 3-year-olds, and less by 4-year-olds and 5-year-olds, who followed either rule in either order. This is shown in Fig. 1: children performed relatively well on all pre- and post-switch rules, except 3-year-olds on the function-sorting rule.

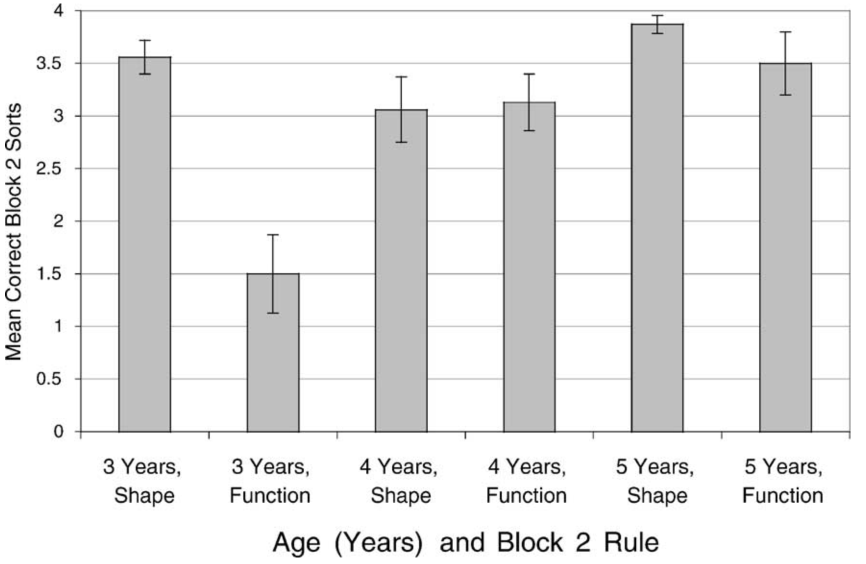

Fig. 1. Mean rule-compliant responses to a post-switch (block 2) rule that is easier (i.e., shape-sorting) or harder (i.e., function-sorting), by age.

Table 2
Numbers (and percentages) of Switch condition 3-, 4-, and 5-year olds who either switched or did not switch to the block 2 (post-switch) rule after complying with the block 1 (pre-switch) shape- or function-matching rule

	Age		
	3-year-olds	4-year-olds	5-year-olds
Block 1 easy rule (shape-match) compliant			
Switched to function rule in Block 2	5 [31%]	13 [87%]	14 [87%]
Did not switch in Block 2	11 [69%]	2 [13%]	2 [12%]
Total	16 of 16	15 of 16	16 of 16
Block 1 hard rule (function-match) compliant			
Switched to shape rule in Block 2	3 [100%]	10 [83%]	13 [100%]
Did not switch in Block 2	0	2 [17%]	0
Total	3 of 16	12 of 16	13 of 16

Compliance criterion = 3 or 4 rule-consistent sorts per block. Totals are the number of children who complied with the block 1 rule.

This pattern is confirmed by non-parametric analyses. We considered 73 children in the switch condition who sorted 3 or 4 triads according to the block 1 rule: ($n = 19$) 3-year-olds, ($n = 27$) 4-year-olds and ($n = 21$) 5-year-olds. They were divided by post-switch performance: 0–2 correct (designated inflexible) or 3–4 correct (designated flexible). Number of children in each group are shown in Table 2. Fewer children, especially 3-year-olds, met criterion when the first rule was harder. Most 4- and 5-year-olds followed either rule. The difference across age groups in number of children who followed a block 2 function rule is significant, χ^2 (2, $n = 45$) = 14.0, $P < .001$. Only three of sixteen 3-year-olds followed a block 1 function rule, and all of them correctly switched to the shape rule. Similarly, all five of sixteen 3-year-olds who followed a block 1 shape rule correctly switched to the function rule. Thus, the proportion of 3-year-olds who followed a function rule did not depend on which block that rule was in. Overall, only 25% of 3-year-olds met this criterion of flexibility. Is this more than expected by chance? The binomial probability of making at least 3 of 4 rule-consistent sorts in block 1 is .312; thus the conjoint probability of doing this in both blocks is .098. The binomial probability of at least 3 of 16 children meeting this criterion is marginal, $P = .098$; the probability of 5 or more meeting it is significant, $P = .016$. Overall, then, only marginally more 3-year-olds than expected by chance flexibly switched rules.

Using a stricter criterion for flexibility of 3 or 4 correct in both blocks, and at least 7 of 8 total correct (binomial $P = .035$), there were $n = 2$, 7, and 13 children aged 3, 4, and 5 years who flexibly switched to the shape rule, and $n = 3$, 12, and 12 children aged 3, 4, and 5 years who flexibly switched to the function rule. The binomial probability of at least 2 of 16 children meeting this criterion is not significant, $P = .107$; the probability of at least 3 meeting it is significant, $P = .017$. Thus, evidence that a substantial proportion of 3-year-olds can meet a stringent standard of flexibility is equivocal. Note that 59% of 4-year-olds met the stricter criterion, suggesting some individual differences in 4-year-olds' ability to consistently switch between rules. The numbers of children who meet the stricter criterion across six age (3) by order (2) groups does not different from the expected distribution, χ^2

(2, $N = 49$) = 1.1, ns. Thus, non-parametric analyses confirm the finding that age and a harder rule, but not rule order, limit childrens' flexible rule-switching.

The lack of evidence of a difference between switching to easier versus harder rules raises a more general question: Were there significant switch costs in this paradigm? This question can be addressed by comparing switch to control groups. Four separate *t* tests were conducted, comparing switch and control children who received the shape rule in block 1, the function rule in block 1, the shape rule in block 2, and the function rule in block 2. The first two showed no group difference in block 1 performance: for block 1 shape rule, $t(82) = 0.7$; for block 1 function rule, $t(82) = 1.6$, $P = .12$. These results also show that the group samples were comparable. More important, the next two tests showed that block 2 performance also did not depend on whether the rule was new (switch) or repeated (control): for block 2 shape rule, $t(82) = 0.8$; for block 2 function rule, $t(82) = 0.7$. Thus, rule difficulty per se determined children's rule-following accuracy, and rule switches did not impose further accuracy costs.

The findings so far show that a priori rule difficulty and children's age jointly determined childrens' rule-following, and the added demand of switching rules did not impair accuracy. Our next guiding question was whether age and rule-difficulty effects are mediated by social scaffolding, for example meta-mnemonic reminders. Though no overall switch costs on accuracy were found, perhaps reminders had a more subtle effect on children undergoing a rule switch, because reminders encouraged children to think about the current rule. To test this, an ANOVA compared total rule-consistent sorts (range: 0 to 8), with age (3-, 4-, or 5-years), condition (Switch or Control), and support (yes or no) between-subjects. The age effect, as previously described, was significant: $F(2,156) = 18.1$, $P < .001$ ($\eta^2 = .19$). The other significant effect was a condition X support interaction: $F(2,156) = 6.0$, $P = .016$ ($\eta^2 = .04$). Switch children who heard reminders made more correct sorts (mean = 6.6, S.D. = 1.5) than those who did not (5.6, S.D. = 1.9), $P < .005$. This support effect was not significant in 3-year-olds alone (mean difference = .81, S.E. = .52). In both 3- and 4-year-olds, however, the support effect is significant (mean difference = 1.1, S.E. = .44). By comparison, Control children did not benefit from reminders (total correct means = 6.1 with reminders; 6.5 without reminders). This interaction is shown in Fig. 2. No other effects were significant (total adjusted $R^2 = .18$).

Because 3-year-olds had difficulty following the function rule, and because metacognitive reminders increased rule-following in only the switch group, we tested the relation between reminders and rule difficulty in 3-year-olds control children. The reminder-by-rule interaction was significant, $F(1,20) = 5.5$, $P = .03$: control 3-year-olds followed the function rule more when they received meta-mnemonic reminders (means = 5.3 versus 2.8), but followed the shape rule less consistently when given reminders (means = 5.0 versus 6.8).

To rule out the possibilities that sampling bias or other uncontrolled error variance unduly influenced the results accuracy of 3- and 4-year-old Control children was compared to 3- and 4-year-old in Deák et al. (2002, Experiment 1), who also heard only one rule, but no re-instruction after four test trials. Those children were recruited by a different procedure and from a different population in a different region of the United States, and were tested by a different researcher in a different setting (i.e., laboratory versus preschool). Thus, we can establish the reliability of this paradigm. Fig. 3 summarizes mean rule-consistent sorts by each group in the two experiments, and clearly shows that performance was very similar

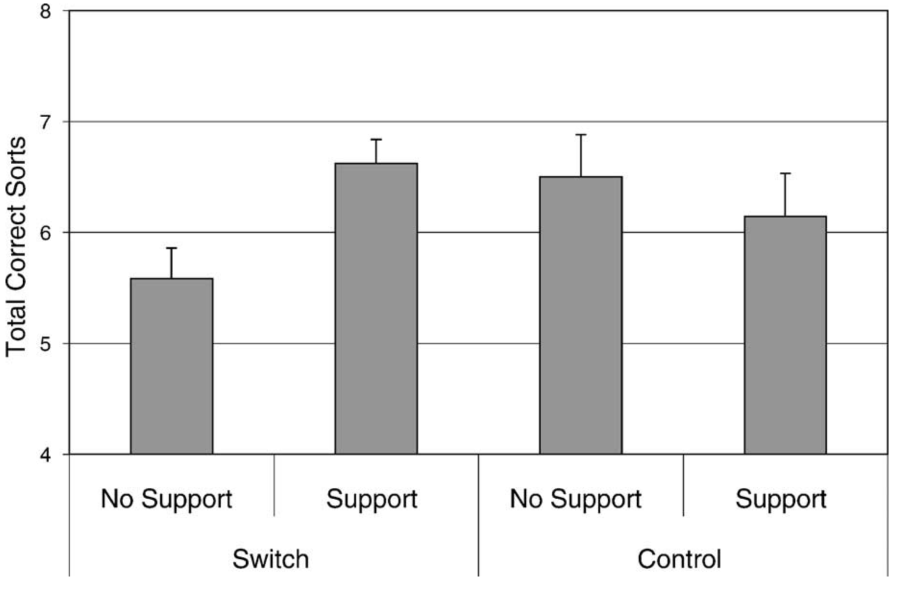

Fig. 2. Mean total rule-compliant responses by switch ($n = 96$) and control ($n = 72$) children who did or did not receive scaffolding support (i.e., meta-mnemonic reminders).

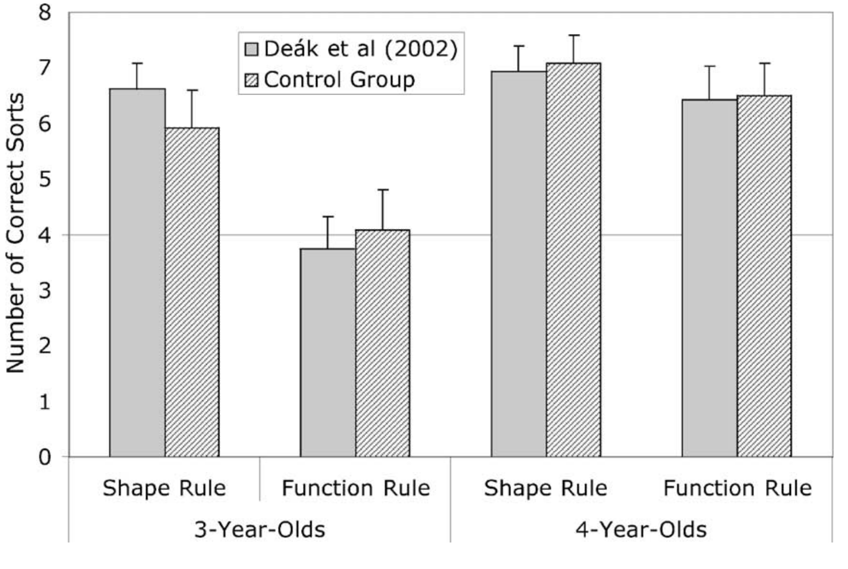

Fig. 3. Mean (and S.E.) total rule-compliant responses by 3- and 4-year-olds in the current control condition, and in Deák et al. (2002, Experiment 1), by rule (shape or function).

in the two studies. The slight apparent decrement in shape-rule following by 3-year-olds in the current study is not significant, $t(20) < 1$. However, percentages of 3- and 4-year-olds who met the stringent (≥7 out of 8 correct) criterion for shape-rule accuracy are 78% in Deák et al. (2002) and 75% in the current no-reminder control group, but only 50% in the reminder control group. This supports the previous analysis that reminders reduced consistent following of an easy rule.

3. Discussion

These results answer the original questions about rule switching, rule difficulty, and meta-mnemonic scaffolding in 3–5-year-old children. Perhaps the most surprising finding was that children's performance was not generally compromised by switching rules. The effect of rule switching demands on children's performance was mediated by social support: meta-mnemonic reminders facilitated rule-following only in children who switched rules. By contrast, age and rule difficulty had more general effects on children's performance. Most 4- and 5-year-olds could follow and switch rules nearly perfectly. Yet a minority of 3-year-olds flexibly switched rules: 16% of children met a stringent flexibility criterion; 25% met a looser criterion. Most non-flexible 3- and 4-year-olds consistently followed the shape but not the function rule. These findings are not compromised by sampling error, and they replicate previous results.

3.1. Rule switching and rule difficulty

Compared to paradigms in which 3-year-olds fail to adapt to changing rules and perseverate on the first rule (e.g., Frye et al., 1995), the current results show a significant, and sizeable, effect of rule difficulty, especially in younger children. The harder, function rule elicited more errors than the shape rule, regardless of rule-switching demands and whether on not children previously followed an easier rule.

Rule difficulty was largely age-dependent. Only 3-year-olds had trouble sorting by function; 4- and 5-year-olds were close to ceiling with either rule. This replicates the findings of Deák et al. (2002). The data go beyond previous studies, however, by showing that young preschoolers function-sorting difficulty is not due to having to suppress a previous, easier rule; indeed it is not increased by the demand to switch rules. This is intriguing because 3-year-olds' function-rule difficulty might be expected to evolve into a subtler switch costs in 4- and 5-year-olds. There are many examples of such transitional shifts in young children's acquisition of cognitive skills (see Karmiloff-Smith, 1994), but the current data showed no evidence of such a transition. The absence of switch costs to children's sorting accuracy also does not confirm reports of abulic dissociations in children's rule-following, wherein children know enough to follow a rule but fail to do so in switch tasks, presumably because they fail to update their representation of which rule should be followed. The attribution of children's switching errors to abulic dissociations has been challenged (Munakata & Yerys, 2001), and the current data suggest that in some cases young children do not make abulic errors when switching rules, even if the rules are abstract and more recently mastered or more difficult. Though this does not mean abulic dissociations do not occur, it suggests they are limited in scope, for reasons not yet understood. One clue, however, lies in the interaction between switching condition and meta-mnemonic support, as considered in detail below.

What makes a sorting rule easy or hard for children? Certainly familiarity and background knowledge are critical, but in the current task children saw all functions and got to try them, and object shapes were readily apparent. Thus, children had information about functions and shapes. Perhaps the function rule phrasing was not understood by 3-year-olds, or they could not isolate functions from other properties. Yet Deák et al. (2002) found that 3-year-olds almost perfectly copied and recalled all functions, and correctly answered questions about function.

As it stands, we do not know why a rule to sort objects by functions is difficult for 3-year-olds. One reason seems to be that functional similarities are de-emphasized in static displays (Deák et al., 2002). Another might be that functions are dynamic, temporally extended relational properties that can vary greatly in their appearance within events, and in their underlying causal relations (e.g., consider the perceivable difference between pounding a nut with a rock in a jungle, and using a remote control to turn on a television set in a living room). For this reason, "same-function" is a kind of relation that might simply be difficult to "get the idea of" enough to generalize to new cases. Consistent with this, note that half of 3-year-olds can adopt a function rule if they receive extra instruction, rule-use reminders, and repeated demonstrations of objects' functions (Deák et al., 2002, Experiment 3). That these multiple aids are necessary to obtain rule compliance at a group level implies that multiple cognitive demands make the function rule difficult. Meta-mnemonic reminders increased function-rule following in the current study, suggesting that 3-year-olds' difficulty lies partly in suppressing their response long enough to retrieve the current rule.

However we eventually answer questions of rule difficulty, the critical fact, for the current project, is that one rule is more difficult than another. The results show that this situation does not necessarily make switching responses harder for preschool children. The fact that even direction of the switch does not matter in this paradigm goes contrary to some findings in the adult task-switching literature (Monsell et al., 2000). We do not yet know why in some tests switch costs do not depend on the direction of rule-change, but in other tests they do.

3.2. Scaffolding and switching

An unexpected finding is that reminding children to "think about the rule" while sorting hybrid objects helped children who switched rules, but did not help—and even hindered—children who were re-instructed on the same rule. Thus, young children are not simply unable to flexibly follow abstract rules. Rather, they are influenced by social information that contextualizes rule-following requests. Why did the reminders have such an effect? Zelazo et al. (1995) found that multiple reminders do not help 2.5-year-olds in a card-sorting task: simply repeating rules does not appear to be effective. With respect to the rules used here, Deák et al. (2002) also found that repeating the function-sorting rule on every trial did not help 3-year-olds. These findings, we believe, offer a clue to the current effect. As any parent knows, simply repeating a request or rule will not win a child's compliance. The reminder we used was a nonspecific exhortation: vague with respect to the specific desired response, and designed to compel children to retrieve or contemplate the current rule: in essence a meta-mnemonic prompt like one might give oneself (e.g., "Let's see, what should I be doing now?"), only provided by an external agent. Such a reminder is akin to adults in some cultures asking children elliptical questions such as "How are we supposed to sit at the dinner table?" We know of no systematical tests of the effects of such reminders on children's performance. The intriguing finding here is that these reminders helped children who switched rules, but not children who stayed with one rule. We believe the reminders did not strengthen children's memory of the rule, but rather discouraged impulsive responding and clarified the demand to retrieve the last rule. Consider that younger children are slow to process signals to suppress a practiced response (Logan & Cowan, 1984). Reminders (or even the word "Wait. . . " which began the reminder) might help children delay their responses while retrieving the last rule, thus helping to "filter out" impulsive sorting responses based on the previous rule. Further research would be desirable to unravel the effects of specific social messages on impulsive or adaptive response patterns in preschool children.

Children's performance, however, declined with reminders in the control condition. We interpret this as a "reminder overkill" effect: beyond some threshold, reminders and instructions do not help, and even impair performance. This belies any simple hypothesis that memory cues and scaffolding monotonically improve children's performance. For example, adults sometimes repeat instructions as subtle corrective feedback, and preschoolers may consequently change their initial correct responses (Rose & Blank, 1974). Meta-mnemonic reminders caused control children, particularly those following the shape rule, to change responses. This could be a paradoxical response to hearing a rule repeated when already complying with the rule. Reminders, after all, are not neutral recall cues. The intention to remind carries social meaning: urgency, vigilance, or subtle correction of erroneous actions. Adults can influence children by repeating an instruction, or by posing subtler elliptical questions (e.g., "what are you supposed to be doing now?"). However, it is probably unusual to do so if children are already complying with the current rules or instructions. Therefore, for children already following a stable shape rule, the reminders did not fit their prior social experience. Children's responses reveal their social knowledge about such messages. In short, the interaction between reminders and condition suggests that social support must be tailored to the child's ongoing task performance. Giving too much help for a task that a child has already mastered is not helpful, and possibly detrimental.

3.3. Summary

The current study confirms that children as young as 3 years can generalize an abstract sorting rule from one to two examples, use that rule to make decisions over some unspecified number of problems with different surface features or details, and then switch to a new abstract rule after a brief period of re-instruction. They can do this even if the two rules are confusable because the attributes defined by the rules are correlated and can only be artificially separated, as is the case with shape and function.

In this study perseveration on a previous rule did occur, but mostly in 3-year-olds who heard no meta-mnemonic reminders. There were not, however, across-the-board switch costs. The results show that if children can independently follow each of two abstract rules, in some situations they can switch between rules without any decline in accuracy. This belies theories (Inhelder & Piaget, 1964; Kendler & Kendler, 1975; Vygotsky, 1986) that portray preschool children as "unidimensional thinkers" incapable of abstract thought until 6–8 years. It also qualifies claims that preschoolers' "executive functions" are categorically limited by immaturity of prefrontal cortex (e.g., Passler, Isaac, & Hynd, 1985). Children do not always suffer from rule or task switches: their flexibility depends on how they interpret tasks and task-specifying instructions.

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