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Rule Selection Versus Rule Execution in Preschoolers: An Error-Detection Approach

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In 2 experiments, an error-detection approach was used to determine whether 3-year-olds' perseverative errors on the postswitch phase of the Dimensional Change Card Sort (DCCS) are due to lack of response control or representational inflexibility. In Experiment 1, 3-, 4-, and 5-year-olds watched a puppet sort perseveratively on the postswitch phase and evaluated its responses. Most 4- and 5-year-olds detected the puppet's perseverative errors, whereas most 3-year-olds failed to do so despite detecting errors on a simpler card sort. Experiment 2 revealed that 3-year-olds who failed to correctly evaluate the puppet's behavior tended to fail their own DCCS. Results imply that perseveration on the DCCS cannot be attributed to difficulty inhibiting prepotent motor responses. Instead, changes in rule use between 3 and 5 years of age are interpreted in terms of the development of representational flexibility.

Effective problem solving requires both the ability to manipulate representations (i.e., representational flexibility) and the ability to use representations to control responding (i.e., response control; Zelazo, Reznick, & Piñon, 1995; Zelazo, Reznick, & Spinazzola, 1998). Age-related changes in problem solving in the preschool period have been attributed to the development of both abilities (see Zelazo, Carter, Reznick, & Frye, 1997, for a review). DeLoache (1995), for example, argued that improvements in the ability to construe external representations (e.g., a scale model of a room) both as objects in themselves and as symbols of something else underlie changes in children's use of these representations to guide their search for hidden objects. Similar explanations have been proposed for classification (Inhelder & Piaget, 1959/1964, chap. 7), metalinguistic understanding (Bialystok, in press), memory (Harnishfeger & Bjorklund, 1993), and understanding the distinction between appearance and reality (Flavell, 1988).

In contrast, other accounts have emphasized improvements in response control (e.g., Barkley, 1997; Carlson, Moses, & Hix, 1998; Cuneo & Welsh, 1992; Diamond & Gilbert, 1989; Gladstone, 1969; Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996; Luria, 1959, 1961; Reed, Pien, & Rothbart, 1984; Tikhomirov, 1978; White, 1965). Following Luria (e.g., 1961), these accounts hold that children frequently fail to suppress overlearned, or otherwise prepotent, response tendencies despite considering an appropriate plan or rule (i.e., despite knowing what to do). Although lack of response control may seem prima facie to be associated with infancy and early childhood, it continues to be of interest even in older children, as Harnishfeger and Bjorklund (1993) pointed out. For example, Carlson et al. recently suggested that 3-year-olds have difficulties on tasks designed to assess deception because they cannot inhibit the tendency to use an overlearned motor response (viz., pointing) to reveal information that they ought to conceal.

Perseveration in any particular situation could be due either to representational inflexibility or to lack of response control (or both). In this article, we address 3-year-olds' perseverative responses in one such situation, the Dimensional Change Card Sort (DCCS; Frye, Zelazo, & Palfai, 1995; Zelazo, Frye, & Rapus, 1996), and describe a method for differentiating between representational and response-based interpretations of these responses. On the standard version of the DCCS, children are presented with two target cards (e.g., a yellow car and a green flower; see Figure 1, left panel) and test cards that match one target card on one dimension and the other target card on the other dimension (e.g., yellow flowers and green cars). In the preswitch phase, children are told a pair of rules for sorting test cards according to only one dimension (e.g., color). After sorting the test cards according to the preswitch rules, children are asked to switch and sort the cards according to the alternate dimension (e.g., shape).

Previous findings using the DCCS have revealed that the majority of 3-year-olds continue to sort according to the preswitch rules during the postswitch phase despite being told the postswitch rules on every trial (e.g., Bialystok, in press; Frye et al., 1995, Experiments 1 and 2; Zelazo et al., 1996, Experiments 1–4; see also Zelazo & Frye, 1997; Zelazo & Jacques, 1996, for reviews). In other words, they perseverate on the preswitch rules. In contrast, the majority of 4- and 5-year-olds correctly sort by the postswitch rules.

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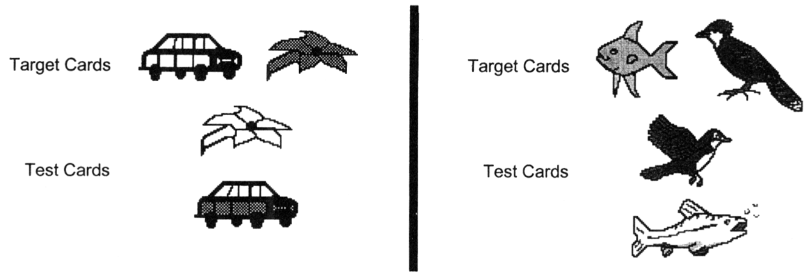

Figure 1. The left panel depicts an example of cards used in the Dimensional Change Card Sort, whereas the right panel depicts an example of cards used in the criterial sort in Experiment 1. The left panel is from "Children's Rule Use: Representation, Reflection and Cognitive Control," by P. D. Zelazo and S. Jacques, 1996, in R. Vasta (Ed.), *Annals of Child Development* (Vol. 12, p. 139), London: Kingsley. Copyright 1996 by Jessica Kingsley Publishers. Adapted with permission.

Some support for a response-control interpretation of 3-year-olds' perseverative responses on this task comes from the finding that 3-year-olds who fail to sort cards according to the postswitch rules nonetheless demonstrate knowledge of these rules. When required to indicate a specific tray in response to inquiries about each of the two postswitch rules (e.g., "Where do cars go in the shape game? Where do flowers go?"), almost all children who fail the postswitch phase indicate the appropriate trays (Zelazo et al., 1996, Experiments 1, 2, and 4). This finding appears to demonstrate that 3-year-olds consider the appropriate rules but fail to use them to control responding. However, the knowledge questions used by Zelazo et al. only assess general knowledge of the postswitch rules, and correct responding on these questions does not guarantee that children consider these rules when they are actually sorting cards during the postswitch phase. Thus, the dissociation between knowledge of the postswitch rules and the use of these rules when sorting does not, in and of itself, implicate lack of response control (see Zelazo et al., 1996, Experiment 1).

Indeed, Zelazo and Frye (1997) favor a kind of representational-inflexibility account of perseverative responding on the DCCS. According to the cognitive complexity and control (CCC) theory (Frye, Zelazo, & Palfai, 1992; Zelazo & Frye, 1997), 3-year-olds have difficulty deliberately selecting the postswitch rules and considering them in relation to the incompatible preswitch rules. An age-related increase in self-reflection between 3 and 5 years of age permits children to formulate and use a higher order rule for choosing which lower order rules to use on a particular trial. Without the ability to formulate a higher order rule, children will automatically select the rule pair that seems most salient to them. On the DCCS, the preswitch rules will be automatically selected when children are asked to sort on the postswitch phase because children will have just used them in response to sorting requests during the preswitch phase (see Zelazo & Jacques, 1996, for other variables that influence the relative salience of rules). In the case of the DCCS, the higher order rule serves to integrate the pre- and postswitch rules into a single system whereby children first determine the relevant dimension (shape or color) and then determine which particular rule pair applies.

CCC theory emphasizes representational flexibility rather than response control, in part because of evidence that argues against the role of response control. For example, Zelazo et al. (1996, Experiment 2) found that 3-year-olds still perseverate during the postswitch phase after only one preswitch trial and when asked to respond verbally rather than manually (i.e., by labeling the box where a particular card should be sorted; Experiments 3 and 4). The former finding indicates that perseveration on this task does not result from a failure to inhibit overlearned responses. The fact that children perseverate on verbal responses is also suggestive of representational inflexibility in light of Luria's (1961, p. 45) claim that verbal responses are less susceptible to inertia than manual responses in 3–4-year-olds (see also Konow & Pribram, 1970).

However, because even one preswitch trial may be sufficient to produce response-control difficulties (Diamond, 1985), and because Luria (1961) may have been wrong about the relative flexibility of verbal versus manual responses, a more compelling way to differentiate between alternatives is to use an error-detection approach. Error-detection paradigms provide researchers with an important tool for uncovering the source of difficulties on problem-solving tasks (e.g., Briars & Siegler, 1984; Gelman & Meck, 1983; Konow & Pribram, 1970). If participants are capable of detecting someone else's errors on tasks that they themselves fail, this suggests that their failure results from a lack of response control because the execution requirements of the task are minimized during error detection. Conversely, if participants are incapable of detecting someone else's errors on such tasks, this suggests that their own errors on these tasks result from a kind of representational inflexibility. Thus, comparing participants' ability to detect errors on problem-solving tasks with their own performance on these tasks potentially permits one to determine where in the process of problem solving performance breaks down.

Several researchers have reported that patients with prefrontal cortical damage are able to detect errors on tasks that they themselves fail (e.g., Konow & Pribram, 1970; Luria, Pribram, & Homskaya, 1964; Milner, 1963). For example, Konow and Pribram instructed a patient with damage to the left frontal cortex to draw a symbol (e.g., a square), but she repeatedly drew another symbol (e.g., an *A*). However, when one experimenter executed tasks based on the other experimenter's instructions, the patient generally detected the errors that the first experimenter made. Hence, despite her inability to respond nonverbally to verbal instructions, she was able to detect incorrect responses. These findings suggest that her difficulty could not be attributed to a failure to comprehend the instructions but instead involved a failure to act on the basis of these instructions.

More recently, error-detection abilities also have been investigated in children (e.g., Briars & Siegler, 1984; Bullock & Lütkenhaus, 1988; DeLoache, Sugarman, & Brown, 1985; Gelman & Meck, 1983; Gelman, Meck, & Merkin, 1986; Wilkinson, 1982). For example, Gelman and Meck used error detection as a technique for uncovering children's underlying numerical competencies. These authors found that both 3- and 4-year-olds detected a puppet's errors at rates that were consistently above chance, even with set sizes that were larger than those on which children in this age range successfully count, and even when the puppet erred in ways that 3- and 4-year-olds typically err. The authors suggested that the children possessed the underlying numerical competence but suffered from performance limitations (but see Briars & Siegler, 1984; also see the GENERAL DISCUSSION section for further discussion of these findings).

In Experiment 1, we gave 3-, 4-, and 5-year-olds an error-detection version of the DCCS in which a puppet sorted perseveratively in the postswitch phase and the children were required to evaluate its sorting behavior instead of sorting cards themselves. In Experiment 2, we gave 3-year-olds a standard version of the DCCS along with one of three error-detection versions: one in which the puppet sorted perseveratively, one in which it sorted correctly, and one in which it sorted incorrectly but nonperseveratively in the postswitch phase. In the standard version of the DCCS, children needed to select the appropriate rules and apply them to particular cards in order to sort the cards into the correct tray. In the error-detection version of the task, the puppet applied the rules to particular cards, and the children only needed to select the appropriate rules in order to evaluate the puppet's behavior. Thus, we reasoned that if 3-year-olds were able to evaluate correctly the puppet's perseverative (and correct) responses on the postswitch phase of the DCCS, despite failing this phase of the task themselves, this would provide strong evidence in favor of a response-control account. However, if 3-year-olds failed to evaluate accurately the puppet's perseverative (and correct) responses, this would provide support for the claim that 3-year-olds fail the postswitch phase because they have difficulty selecting the appropriate rules. In the context of the DCCS, then, representational flexibility and response control may be referred to as rule selection and rule execution, respectively.

EXPERIMENT 1

The procedure for the error-detection version of the DCCS (referred to as the puppet DCCS) differed from that of previous experiments (e.g., Frye et al., 1995; Zelazo et al., 1996) in that the task was presented simultaneously to children and to a puppet. However, only the puppet was asked to sort cards; children simply were asked to say whether the puppet sorted correctly on each trial. In addition, to ensure that children could detect nonperseverative sorting errors, they first watched the puppet correctly and incorrectly sort cards on a basic-level sort (the criterial sort). Previous studies have shown that 3-year-olds perform well when asked to sort cards that differ at the basic level (e.g., Zelazo & Reznick, 1991).

Method

Participants

Twenty-four 3-year-olds (M = 3 years 7 months, SD = 3 months, range = 3 years 3 months to 3 years 11 months), sixteen 4-year-olds (M = 4 years 6 months, SD = 3 months, range = 4 years 2 months to 4 years 11 months), and sixteen 5-year-olds (M = 5 years 5 months, SD = 4 months, range = 5 years 0 months to 6 years 0 months) participated in the experiment. The sample consisted of 26 girls (thirteen 3-year-olds, eight 4-year-olds, and five 5-year-olds) and 30 boys (eleven 3-year-olds, eight 4-year-olds, and eleven 5-year-olds). Three 3-year-olds were dropped from the final sample because of procedural difficulties. Specifically, 1 girl was excluded because of experimenter error (the experimenter inadvertently placed the first card of the postswitch phase in the correct tray instead of the incorrect tray), 1 girl was excluded because she refused to finish the puppet DCCS in one sitting, and 1 boy was excluded because of parental interference.

Children were recruited from local day-care centers and through a database of parents who had expressed an interest in participating in research. Informed consent was obtained from all parents of children who participated in the experiment.

Design and Overview

Children first received a criterial sort that consisted of a puppet sorting basic-level cards (birds vs. fish) into separate trays. The puppet sorted correctly on half of the trials and incorrectly on the other half. Children were asked to evaluate the puppet's performance on each trial. This card sort served as a criterial measure designed to eliminate children who had a tendency to state that the puppet was always correct or always incorrect, regardless of its performance. Data from children who failed this card sort (n = 5) were excluded from the final sample (see the Results section), and these children were replaced until 16 children at each age had passed the criterial sort.

After the criterial sort, the children watched the puppet sort cards on the puppet DCCS. In the preswitch phase of this task, the puppet was told the rules for sorting cards according to one dimension (e.g., color). The puppet sorted correctly on all preswitch trials. After six preswitch trials, the experimenter announced that the puppet would play a new game and asked the puppet to sort cards according to the alternate dimension (e.g., shape). In this postswitch phase, however, the puppet sorted perseveratively, according to the preswitch rules. For both phases of this card sort, children evaluated the puppet's performance on each trial.

Age was the major variable of interest in this experiment. Half of the children at each age watched the puppet first sort cards by color on the puppet DCCS, and the other half watched the puppet first sort cards by shape. In addition, half of the children watched the puppet sort yellow flowers and green cars, whereas the other half watched the puppet sort red boats and blue rabbits. Dimension order and card set were crossed and counterbalanced within age but were not considered in the main data analyses; they served primarily as counterbalancing variables. Sex of children was not counterbalanced in this experiment.

Materials

Two unpainted wooden trays with a 12-cm × 7.5-cm base served as sorting trays for placing test cards. Each tray had a 12-cm × 11.5-cm back wall that was used to display target cards. A dinosaur hand puppet ("Barney") was used by the experimenter to sort cards. Three separate sets of 16 laminated cards (11 cm × 7 cm) were used: Each card depicted one item. In the criterial sort, 2 target cards and 14 test cards displayed different exemplars of birds and fish (eight bird exemplars and eight fish exemplars; see Figure 1, right panel, for an example of the cards used in this task). In the puppet DCCS, one of two sets of cards was used. For one set, target cards depicted a yellow car and a green flower, and test cards depicted yellow flowers and green cars (seven of each). For the other set, target cards depicted a red rabbit and a blue boat, and test cards depicted red boats and blue rabbits.

Procedure

A female experimenter tested children individually in one testing session that took approximately 10 min to complete. Testing occurred either in a quiet area at the children's day-care centers or at the laboratory.

Criterial Sort

Once children were comfortable with the experimenter, the experimenter asked them to sit at a table. The experimenter then introduced the children to the puppet as follows:

> This is my friend Barney. Barney wants to play a card game. But this game is a bit hard for Barney. Sometimes he makes mistakes. So you have to help him, OK? I'm going to show Barney how to play this card game. Then he's going to take a turn and try it. Your job is to tell Barney if he's right. Do you think you can help Barney?

The experimenter then showed the children the two sorting trays and brought out each of the two target cards individually. For each target card, the experimenter asked the puppet to label the card and then asked the children if the puppet had labeled it correctly, to provide children with practice at reporting the puppet's errors. The puppet always labeled the first target card (a bird) correctly and labeled the second (a fish) incorrectly. All but two 3-year-olds responded correctly on both of these labeling trials. Both of these 3-year-olds responded incorrectly on the second labeling trial (i.e., they claimed that the puppet had labeled the card correctly). For both of these children, the experimenter repeated the puppet's response and prompted them until they agreed that the puppet had erred.

After the children responded, the experimenter affixed each target card onto the back wall of a sorting tray. The target cards remained visible throughout the task. The experimenter then gave the puppet (and the children) the rules for sorting test cards in a number of semantically equivalent ways. More precisely, the experimenter said,

> In this game, Barney, you put all the fish in this box and you put all the birds in that box [the experimenter simultaneously pointed to the sorting tray that displayed the appropriate target card]. Fish go in this box and birds go in that box. If it's a fish it goes here and if it's a bird it goes there. I'll take a couple of turns first, then you get to try, Barney, and [child's name] is going to help you.

The experimenter subsequently modeled two test cards (one of each type) to show the puppet how to sort the cards. The task proper was comprised of four training trials and eight test trials. On each trial, the experimenter repeated the rules (e.g., "Remember, Barney, put the fish in this box and put the birds in that box."), labeled a test card at the basic level (e.g., "Here's a bird."), and gave it to the puppet, who then placed it face down in one of the trays according to a predetermined location. The experimenter then asked the children, "Is Barney right?" or "Did Barney put it in the right box?" and recorded whether children responded "yes" or "no." On the training trials, children were provided with extensive feedback on their responses (e.g., "You're right. Barney put it [did not put it] in the right box because birds go in this box in this game." or "No. Barney's wrong. See, he put the bird in this box, but birds go in that box. So Barney made a mistake! Let's try another one."). The puppet sorted correctly on two of these training trials (one trial with a bird exemplar and one trial with a fish exemplar) and sorted incorrectly on the other two trials (one bird and one fish). The experimenter then gave the children eight test trials: four trials on which the puppet sorted correctly (two birds and two fish) and four trials on which it sorted incorrectly (two birds and two fish). These test trials were exactly like the training trials except that the experimenter did not give the children feedback on their responses.

All children received the same pseudorandom order of card presentation. The pseudorandom order was determined with the restrictions that (a) no more than two cards of the same category (e.g., birds) be presented consecutively, (b) the puppet sorted correctly or incorrectly on no more than two trials in a row, and (c) no more than two consecutive cards be placed in the same tray.

Puppet Dimensional Change Card Sort

In the puppet DCCS, the experimenter affixed new target cards (e.g., a yellow car and a green flower) onto the sorting trays. The puppet was not asked to label these cards, because for half of the children, color, and not shape, was the relevant dimension in the preswitch phase. Children who were randomly assigned to watch the puppet sort yellow flowers and green cars by the color dimension first, for example, were then told,

> Now, Barney is going to play another game. This is the color game, Barney. The color game is different from the shape game. In the color game, all the yellow ones go in this box and all the green ones go in that box. If it's yellow it goes here, but if it's green it goes there.

Analogous instructions were devised for each combination of card set and dimension order. As in the criterial sort, the experimenter introduced the game by stating the rules in several semantically equivalent ways and modeled sorting two test cards (one of each type). The puppet was then asked to sort six test cards (three of each type) according to the preswitch rules. The experimenter repeated the rules on each trial (e.g., "Yellow ones go here and green ones go there.") and labeled test cards by the relevant sorting dimension only (e.g., "Here's a green one. Where does it go, Barney?"). The puppet sorted correctly on all trials in the preswitch phase. After the puppet sorted each test card, the experimenter asked, "Is Barney right?" Children did not receive feedback on their performance.

After the puppet had sorted by the preswitch rules for six trials, the experimenter asked the puppet to play a new game (i.e., the postswitch phase), although the experimenter did not remove the target cards and test cards from the sorting trays. For example, children who watched the puppet sort yellow flowers and green cars by color in the preswitch phase were told,

> OK, now we're going to switch, Barney. We're not going to play the color game anymore; we're going to play the shape game. The shape game is different from the color game. In the shape game, all the cars go in this box and all the flowers go in that box. This is the shape game. You put all the cars here and you put all the flowers there. If it's a car, you put it in this box, but if it's a flower, then you put it in that box, Barney. Here's a flower; where does it go, Barney?

Six postswitch trials were then administered exactly like those in the preswitch phase. However, unlike the preswitch phase, the puppet sorted incorrectly on all trials in this phase. That is, the puppet perseverated by sorting according to the preswitch rules instead of the postswitch rules. Hence, to respond correctly, children had to say "no" to the experimenter's question on all trials in this phase.

Analogous pseudorandom orders of card presentation (making allowances for card set and dimension order) were used for all children across both phases of the puppet DCCS. The orders were determined with the restriction that no more than two identical cards (e.g., yellow flowers) be presented consecutively.

Scoring Reliability

Testing sessions were videotaped except in 10 cases of equipment failure and 2 cases in which the videotape ran out before the end of the session. To assess reliability, performance was rescored from the videotape by a second experimenter. Reliability was calculated as the number of trials on which the two scorers agreed divided by the total number of trials on videotape. Scoring reliability was 99%. In addition, for 3 of the children for whom videotapes were not available, performance was double scored at the time of testing by a second experimenter who was present during the testing session (in these cases, agreement was 100%).

Results

Criterial-Sort Performance

Passing the criterial sort was defined as responding correctly on at least seven of the eight test trials ($p < .04$ on the basis of the binomial distribution). Five 3-year-olds (2 girls and 3 boys) failed this task (3 children erred by making too many "yes" responses, and 2 children erred by making too many "no" responses), whereas no 4- or 5-year-olds did so. A Fisher's exact test revealed that performance on the criterial sort was dependent on age ($p < .01$).

Puppet Dimensional Change Card Sort Performance

The final sample included only children who passed the criterial sort ($N = 48$; 16 children at each age). Inspection of the raw data revealed that 75% of 3-year-olds, 94% of 4-year-olds, and 88% of 5-year-olds (i.e., 85% of the total sample, or 41 of 48 children) either succeeded on all trials or erred on all trials within a given phase. Consequently, we used nonparametric categorical analyses (i.e., chi-square tests of independence and Fisher's exact tests) to analyze the data. Children at each age were classified as having passed neither phase, one phase, or both phases. To pass a given phase, children needed to respond correctly on at least five out of the six trials (binomial, $p < .11$).[1] All children passed the preswitch phase, and preliminary analyses confirmed that the pattern of results on the postswitch phase was identical for children who received color or shape in the preswitch phases. As a result, a chi-square test of independence was performed on the number of children who passed or failed the postswitch phase as a function of age (but regardless of dimension order). The chi-square test confirmed that performance on the postswitch phase was dependent on age, $\chi^2(2, N = 48) = 15.27, p < .001$ (see Table 1). Moreover, the magnitude of association between age and performance (or effect size) was large ($w = .56$; see Cohen, 1988, chap. 7). We also conducted separate Fisher's exact tests on each pair of age groups to determine which age groups differed. The comparison between 3- and 4-year-olds did not reach statistical significance ($p < .07$), and neither did the comparison between 4- and 5-year-olds ($p > .10$). However, the comparison between 3- and 5-year-olds was significant ($p < .001$).

To determine whether children who failed the postswitch phase generally failed by responding randomly or systematically, we classified children as having responded perseveratively if they succeeded on only one trial or zero trials out of six ($p < .11$). Of the 22 children who failed the postswitch phase, 12 (out of 13) 3-year-olds, 6 (out of 7) 4-year-olds, and 1 (out of 2) 5-year-olds were classified as having responded perseveratively. More 3- and 4-year-olds responded perseveratively than would be expected by chance alone (binomial, $p < .0001$ and $p < .01$, respectively).

Table 1
Number of Children in Experiment 1 Who Passed or Failed the Postswitch Phase of the Puppet Dimensional Change Card Sort (DCCS) as a Function of Age

	Performance	
Age group	Failed	Passed
3-year-olds	13	3
4-year-olds	7	9
5-year-olds	2	14

Note. To pass the postswitch phase of the puppet DCCS, children had to respond correctly on at least five of the six trials (binomial, $p < .11$).

Discussion

In the puppet DCCS, response-control requirements of the DCCS were minimized by having children evaluate someone else's sorting behavior. However, most 3-year-olds failed to detect the puppet's perseverative errors, suggesting that they had difficulty deliberately selecting the appropriate rules during the postswitch phase and consulting them as the standard of evaluation. Furthermore, the finding that 3-year-olds could reliably detect the puppet's sorting errors on the criterial sort indicates that their difficulty in detecting perseverative errors on the puppet DCCS did not result from a preexisting bias to respond affirmatively (or negatively) to the puppet's sorting behavior, regardless of its performance.

However, although children may not have come into the experiment with a preexisting bias, the order in which the card sorts were presented may have induced such a bias by the time the postswitch phase of the puppet DCCS was presented. First, in the criterial sort, trials on which the puppet responded incorrectly were interspersed with trials on which it responded correctly. This may have forced children to attend closely on every trial. This was not the case for the puppet DCCS, in which the puppet sorted correctly on six consecutive trials and then sorted incorrectly on the remaining six trials. After having watched the puppet sort correctly on the preswitch trials, children may have falsely concluded that the puppet was finally "getting it right" and failed to attend closely to its performance. Second, because the postswitch phase was presented at the end of the testing session, results for this phase may have been affected by age differences in attention span.

However, the proportions of children across the three age groups who failed to detect the puppet's errors were similar to the proportions of children who have been found in previous studies to perseverate on the standard version of the task (e.g., Frye et al., 1995; Zelazo et al., 1996), suggesting that error detection and sorting behavior on the DCCS require the same underlying processes. In Experiment 2, this hypothesis was tested more directly.

EXPERIMENT 2

In Experiment 2, 3-year-olds were asked to sort cards on their own DCCS (referred to as the child DCCS) in addition to receiving

[1] Although it might have been prudent to use more trials within each phase, we opted to use six trials to ensure that children maintained their interest in the task. In any case, children typically succeed on all trials or err on all trials within a phase. The probability associated with obtaining all trials correct is $p < .02$.

the puppet DCCS. The investigation was limited to 3-year-olds because it was their performance in particular that raised questions in Experiment 1. To address the possibility that the puppet's correct responses on the preswitch phase of the puppet DCCS in Experiment 1 may have led 3-year-olds to adopt an affirmative response bias during the postswitch phase, we introduced two other puppet DCCS conditions in addition to the perseverative condition: namely, the correct-switch and incorrect-switch conditions. In the correct-switch condition, the puppet sorted correctly during both the pre- and postswitch phases. The incorrect-switch condition differed from both the perseverative and correct-switch conditions in that the rules did not change between the phases. However, the puppet spontaneously switched and began to sort according to the alternate dimension during the postswitch phase.

If 3-year-olds failed the postswitch phase of the puppet DCCS in Experiment 1 because they were experimentally induced to have an affirmative response bias, then they should fail the postswitch phase of both the perseverative and incorrect-switch conditions (both of which required negative responses) but succeed on the postswitch phase of the correct-switch condition (which required affirmative responses). If, however, 3-year-olds failed the postswitch phase of the puppet DCCS in Experiment 1 because of difficulties deliberately selecting the postswitch rules in order to evaluate the puppet's postswitch performance, then they should fail the postswitch phase of both the perseverative and correct-switch conditions but succeed on the postswitch phase of the incorrect-switch condition, which only required selecting the preswitch rules. Furthermore, we introduced a basic-level puppet confirmation sort at the end of the testing session to detect and eliminate children whose performance on the puppet DCCS may have been influenced by an acquired response bias due to fatigue or lack of attention.

Method

Participants

Sixty-nine 3-year-olds (M = 3 years 7 months, SD = 3 months, range = 3 years 0 months to 4 years 0 months; 34 girls and 35 boys) participated in this experiment. These children were recruited in the same manner as were those in Experiment 1. Data from 13 of these children were subsequently dropped, and these children were replaced with other children. Nine children (6 girls and 3 boys) were excluded because of experimenter error,[2] 2 boys (both of whom failed the criterial sort) were excluded because they failed to complete all tasks, and 2 children (1 girl and 1 boy) were excluded because of parental interference. Testing occurred either in a quiet area at the children's day-care centers or at the laboratory.

Design and Overview

All children received four tasks, with a 2-min delay between each task. The first task was the criterial sort, a basic-level sort (birds vs. women) similar to the one used in Experiment 1. The last task, the confirmation sort, also consisted of a basic-level sort (fish vs. men). Two DCCS tasks (a child DCCS and a puppet DCCS) were presented between the criterial and confirmation sorts in a counterbalanced order (child vs. puppet first). The child DCCS consisted of a standard version of the task (e.g., Frye et al., 1995, Experiment 2). However, children were randomly assigned to one of three versions of the puppet DCCS (perseverative, correct-switch, or incorrect-switch condition). These puppet-sort conditions resulted from crossing two variables: (a) whether the puppet was incorrect or correct in the postswitch phase and (b) whether the rules did or did not change during the postswitch phase. This yielded four possible conditions, only three of which were used in this experiment. One condition (puppet correct, rules did not change) was not included because it was equivalent to administering 12 preswitch trials instead of 6.

For each child, dimension order (color vs. shape first) was constant across both DCCS tasks, although dimension order was counterbalanced across children. The card set used in each task was also counterbalanced, with yellow flowers and green cars used for one DCCS and red boats and blue rabbits used for the other. In an attempt to have children of both sexes better represented across conditions than they were in Experiment 1, sex was also counterbalanced. All variables that were counterbalanced (i.e., puppet-sort condition, DCCS order, dimension order, card set, and sex) were crossed with each other. In addition, two pseudorandom orders of card presentation were generated across the four tasks. These orders were based on the same restrictions used in Experiment 1. Half of the children were randomly assigned to one order and half to the other.

As in Experiment 1, only variables of interest were used in the main analyses. That is, only puppet-sort condition (perseverative vs. correct-switch vs. incorrect-switch condition) and DCCS (child vs. puppet) were examined. Children who did not pass both the criterial and confirmation sorts (n = 8) were not included in the final sample and were replaced with other children until 16 children in each puppet-sort condition passed these tasks.

Materials

The materials were the same as those used in Experiment 1, except for the cards used in the criterial sort and the new confirmation sort. For the criterial sort, the 2 target cards and 10 test cards displayed different exemplars of women and birds (six of each). For the confirmation sort, the 2 target cards and 6 test cards displayed different exemplars of men and fish (four of each).

Procedure

A female experimenter tested children individually in one testing session that took approximately 20–25 min to complete. The procedure for administering the card sorts was similar to that used in Experiment 1, except that four procedural changes were introduced with the purpose of maintaining children's interest despite the inclusion of two additional tasks. First, 2-min delays were included between each task. Second, fewer trials were used in the criterial sort (see *Criterial and Confirmation Sorts* section below). Third, as in Experiment 1, the experimenter modeled two test cards at the beginning of the criterial sort. However, the experimenter did not model test cards at the beginning of the other card sorts, thereby eliminating six (experimenter) trials. The purpose of modeling trials in Experiment 1 and in previous studies (e.g., Frye et al., 1995; Zelazo et al., 1996) was to show children how to place test cards face down into the appropriate sorting tray. Thus, having the experimenter model two test cards in the first

[2] Seven of these children were excluded because of the same procedural error. More specifically, the experimenter removed test cards from the sorting trays between the pre- and postswitch phases of the DCCS task (child or puppet) in which boats and rabbits were being used. Because this change was introduced in only one of the DCCS tasks, we opted to exclude the data from these children. Moreover, we were unable to determine if the change affected performance because only 4 children were exposed to this change in the child DCCS whereas the other 3 children were exposed to this change in the puppet DCCS. The remaining 2 children were excluded because the experimenter stopped testing these children when they were failing the criterial sort.

task only seemed sufficient. Finally, on the three card sorts in which the puppet sorted test cards (i.e., the criterial sort, the puppet DCCS, and the confirmation sort), the puppet itself asked the children whether it had sorted correctly (i.e., "Am I right?"). Pilot testing suggested that children particularly enjoyed being addressed by the puppet.

Criterial and Confirmation Sorts

The procedure for the criterial sort was similar to that used in Experiment 1. However, the experimenter gave children feedback only on the first two trials (as opposed to four in Experiment 1), one on which the puppet was correct and the other on which it was incorrect. Children then received six test trials (as opposed to eight) on which they did not receive feedback. In addition, after the puppet sorted each card, the puppet asked the children whether it had sorted correctly (i.e., "Am I right?"). The last task, the confirmation sort, was administered in an identical manner as the test trials in the criterial sort, except that the puppet sorted men and fish (instead of women and birds).

Child Dimensional Change Card Sort

In the child DCCS, the experimenter presented instructions as had been presented in the puppet DCCS of Experiment 1, except that the children sorted test cards themselves. In half of the cases, the children sorted by color in the preswitch phase. For example, the experimenter said, "You helped Barney so much in the other game(s), now it's your turn to play a card game! This game is called the color game." On each trial, the experimenter told the children the relevant rules, labeled the test card by the relevant dimension only, and asked the children to place the test card face down into the appropriate tray. Children sorted six test cards according to the first pair of rules. After they completed the preswitch phase, the experimenter introduced the postswitch rules, and the children were asked to sort an additional six test cards according to the alternate dimension.

Puppet Dimensional Change Card Sort

Children received one of three versions of the puppet DCCS: a perseverative, a correct-switch, or an incorrect-switch condition. In all conditions, the puppet sorted correctly in the preswitch phase (as in Experiment 1). However, in the postswitch phase, the puppet sorted differently depending on the condition (see below). The experimenter administered the preswitch phase of the puppet DCCS in the same manner as the child DCCS except that the puppet, instead of the children, sorted each test card.

Perseverative condition. In the postswitch phase of the perseverative condition, the experimenter switched the rules so that the puppet was required to sort by the alternate dimension. In this condition, as in the puppet DCCS in Experiment 1, the puppet perseverated. Hence, successful responding in this condition required the children to say that the puppet sorted correctly on each trial of the preswitch phase but sorted incorrectly on each trial of the postswitch phase.

Correct-switch condition. The experimenter administered trials in the postswitch phase of this condition in a manner identical to that in the perseverative condition. However, the puppet sorted correctly. Thus, children were required to state not only that the puppet was correct on each trial of the preswitch phase (as in the perseverative condition) but also that it was correct on each trial of the postswitch phase (unlike the perseverative condition).

Incorrect-switch condition. The procedure for the postswitch phase of the incorrect-switch condition differed slightly from the procedure for the perseverative and correct-switch conditions. The experimenter administered six preswitch trials (as in the other conditions), but then instead of switching and introducing postswitch rules, the experimenter simply reminded the puppet of the preswitch rules (i.e., "Remember, Barney, we're playing the color game. The color game is different from the shape game. Remember in the color game. . ."). These reminders were analogous in length and format to the instructions that preceded the postswitch phase in the other conditions. Immediately after this elaborated reminder, however, the puppet spontaneously switched and began sorting according to the alternate dimension. Hence, to succeed children were required to respond that the puppet was correct in the preswitch phase but that it was incorrect during the postswitch phase (as in the perseverative condition).

Scoring Reliability

As in Experiment 1, testing sessions were videotaped. However, the testing sessions of 3 children were not videotaped, and only partial videotapes of 3 other children were available because the videotape ran out before their sessions were completed. A second experimenter rescored the testing sessions of all children for whom videotapes were available. Scoring reliability (calculated as it was in Experiment 1) was 99%.

Results

Criterial and Confirmation Sorts

To pass each of the basic-level sorts, children had to respond correctly on at least five of the six test trials in the criterial sort (binomial, $p < .11$) and on five of the six trials in the confirmation sort ($p < .11$). The joint probability of passing both of these tasks by chance alone was $p < .02$. Eight children (3 girls and 5 boys) failed at least one of the two tasks (6 children failed both card sorts, and 2 children failed only the confirmation sort). Six of these eight children failed one ($n = 1$) or both ($n = 5$) of these tasks by making too many "yes" responses, 1 child failed the confirmation sort by making too many "no" responses, and 1 child failed both card sorts by making too many "yes" responses or by not responding at all. The number of children who failed one or both of these tasks did not differ across conditions (Fisher's exact test, $p > .10$). Specifically, 4 children in the perseverative condition and 2 children in both the correct-switch and incorrect-switch conditions failed one or both of these card sorts.

Child and Puppet Dimensional Change Card Sort Tasks

Children who failed one or both of the basic-level sorts were omitted from the analyses. For both DCCS tasks, children were classified as having passed a phase if they responded correctly on at least five of the six trials. Four children failed both phases of one of the DCCS tasks (2 children failed both phases in the child DCCS, and 2 other children failed both phases in the puppet DCCS), and 1 child in the correct-switch condition of the puppet DCCS failed the preswitch phase but passed the postswitch phase. (Of the 4 children who failed both phases, 1 child failed by always claiming that the puppet was correct when it sorted test cards into one tray and incorrect when it sorted cards into the other tray, 2 children responded in a manner that suggested that they were purposely responding incorrectly to tease the experimenter, and 1 child sorted cards according to rules that were opposite to those given by the experimenter.) Because performance on the postswitch phase of the DCCS is meaningful as an index of flexibility only if children pass the preswitch phase, all 5 children who failed the preswitch phase of either DCCS task were eliminated from further analyses.

Thus, the final sample included in the analyses consisted of 43 children. Eighty-four percent of children (36 out of 43) succeeded on all trials or erred on all trials within a given phase of the child DCCS, as did 72% of children (31 out of 43) on the puppet DCCS; therefore, categorical analyses were used. As in Experiment 1, preliminary analyses confirmed that the pattern of results on the postswitch phase was identical for children who received color or shape first. A chi-square test also confirmed that passing the postswitch phase of the child DCCS was not dependent on puppet-sort condition, $\chi^2(2, N = 43) = 0.04, p > .10$. However, for the puppet DCCS, passing the postswitch phase was dependent on puppet-sort condition, $\chi^2(2, N = 43) = 14.41, p < .001$ (see Table 2). In addition, effect-size analyses revealed that the degree of association between condition and performance on this task was large ($w = .58$). Separate Fisher's exact tests were conducted on each pair of conditions to determine which conditions differed. Although the comparison between the perseverative and correct-switch conditions was not significant ($p > .10$), reliable differences were found between the perseverative and incorrect-switch conditions ($p < .001$) and between the correct-switch and incorrect-switch conditions ($p < .01$).

As in Experiment 1, children who passed only one or no postswitch trials (out of six) were classified as responding perseveratively. Of the 22 children who failed the postswitch phase of the child DCCS, 19 were classified as responding perseveratively (7 children in the perseverative condition, 6 children in the correct-switch condition, and 6 children in the incorrect-switch condition). In each condition, more children perseverated than would be expected by chance alone (binomial, $p < .001$ for the perseverative condition and $ps < .01$ for the correct-switch and incorrect-switch conditions). Likewise, the majority of children who failed the postswitch phase of the puppet DCCS failed by responding perseveratively (11 out of 17). More children in the perseverative condition responded perseveratively than would be expected by chance (7 children, $p < .001$), as did children in the correct-switch condition (4 children, $p < .058$). (Recall that no children in the incorrect-switch condition failed the postswitch phase of the puppet DCCS.)

Finally, Fisher's exact tests were used to determine to what extent children in each condition passed the postswitch phase on both DCCS tasks or failed it on both tasks. For children in the perseverative condition, the association was not significant ($p > .10$), although the effect size was moderate ($w = .47$). Eleven out of 15 children either passed the postswitch phase on both tasks or failed it on both tasks. In contrast, for the correct-switch condition, the association was significant ($p < .05$), and the effect size was large ($w = .71$). Twelve of the 14 children in this condition either passed the postswitch phase on both tasks or failed it on both tasks. No analyses were conducted on performance in the incorrect-switch condition because all children in this condition passed the postswitch phase of the puppet DCCS.

Table 2
Number of Children in Experiment 2 Who Passed or Failed the Postswitch Phase of the Child and Puppet Dimensional Change Card Sort (DCCS) Tasks as a Function of Condition

	Performance	
Puppet-sort condition	Failed	Passed
Child DCCS		
Perseverative	8	7
Correct-switch	7	7
Incorrect-switch	7	7
Puppet DCCS		
Perseverative	10	5
Correct-switch	7	7
Incorrect-switch	0	14

Note. To pass the postswitch phase of the child and puppet DCCS tasks, children had to respond correctly on at least five of the six trials (binomial, $p < .11$).

Discussion

The finding in Experiment 2 that 3-year-olds performed more poorly in both the perseverative and correct-switch conditions than in the incorrect-switch condition provides further support for the suggestion that children err on the puppet DCCS because they select the preswitch pair of rules and consider these rules when evaluating the puppet's postswitch responses. Both the perseverative and correct-switch conditions required children to consider the postswitch rules, whereas the incorrect-switch condition required them to consider the preswitch rules. In contrast to the perseverative condition, however, the correct-switch condition provided a more stringent or conservative test of 3-year-olds' rule-selection difficulties. In the correct-switch condition, children were presented with correct sorting responses that likely countered their own inclinations. This had the potential to disrupt children's problem-solving set and call attention to the need to switch.

The results of this experiment also address the possibility that 3-year-olds erred on the postswitch phase of the puppet DCCS in Experiment 1 because they were induced to acquire an affirmative response bias during the preswitch phase. All children in the incorrect-switch condition succeeded by stating that the puppet sorted incorrectly, and many children in the correct-switch condition failed by stating that the puppet sorted incorrectly. Thus, in both of these conditions, children switched from responding "yes" in the preswitch phase to responding "no" in the postswitch phase, suggesting that 3-year-olds do not acquire an affirmative bias under these circumstances. The inclusion of the confirmation sort also aided in eliminating fatigue and lack of attention as another possible interpretation for the results.

As predicted, the overall number of 3-year-olds who failed the child DCCS did not differ across conditions. The percentage (approximately half) who failed the postswitch phase appeared to be somewhat lower in this experiment than those found in previous studies (which ranged from 60% to 90% of 3-year-olds; Frye et al., 1995, Experiments 1 and 2; Zelazo et al., 1996, Experiments 1–4). However, it should be noted that several children were eliminated from the final sample because of their difficulties in accurately reporting a puppet's correct and incorrect responses on the criterial sort, the confirmation sort, or both. These children would have been included in previous studies and would likely have failed the child DCCS. Moreover, children who failed both phases of one of the DCCS tasks were also excluded from the analyses. Although these selection criteria permitted meaningful comparisons between the child and puppet DCCS tasks, they decreased the proportion of children failing the child DCCS.

Finally, we predicted that children in the perseverative condition who failed to detect the puppet's perseverative errors and children in the correct-switch condition who incorrectly stated that the puppet was wrong in the postswitch phase would also perseverate on the child DCCS. Both of these predictions were supported; although in the perseverative condition, the correlation between performance on the child and puppet DCCS tasks failed to reach statistical significance despite a moderate effect size.

GENERAL DISCUSSION

In these experiments, we used an error-detection paradigm to differentiate between rule-execution and rule-selection difficulties on the DCCS. In both experiments, 3-year-olds had considerable difficulty detecting a puppet's perseverative errors on the puppet DCCS, indicating that they perseverate on the postswitch phase of the child DCCS because they select the inappropriate preswitch rules and not because they have difficulty inhibiting prepotent motor responses.

Previous research has demonstrated that 3-year-olds do indeed know the postswitch rules on the postswitch phase of the DCCS (Zelazo et al., 1996, Experiments 1, 2, and 4). More specifically, when children are asked, for example, "Where do the red ones go in the color game?" they consistently indicate the correct tray. However, to succeed on the task, children not only must know the postswitch rules but also must select them for use and apply them in the service of guiding their behavior.

From the present perspective, a simple distinction between knowing and doing appears to be underspecified. Possessing the requisite knowledge for solving a specific problem does not guarantee that the problem solver will necessarily know how and when to apply that knowledge (see DeLoache, Miller, & Pierroutsakos, 1998, for a similar view). Reason (1990) similarly argued that Norman's (1981, 1983; as cited in Reason, 1990) distinction between mistakes and action slips (which maps onto the distinction between representational inflexibility and response control) needs further specification. Reason (1990, chap. 3) proposed that mistakes can be divided into knowledge-based errors and rule-based errors. Knowledge-based errors occur when plans are devised from inaccurate knowledge of a problem space. In contrast, rule-based errors occur when the selected plan of action is itself inadequate, such as when inappropriate rules are applied. In Reason's framework, action slips ("skill-based errors" in Reason's terminology) are viewed as resulting from execution difficulties.

Using this tripartite distinction, it becomes easier for one to reconcile existing data on the DCCS. Previous demonstrations that 3-year-olds possess the requisite knowledge of the postswitch rules (Zelazo et al., 1996) suggest that their errors are not knowledge-based. The present results also argue against the view that 3-year-olds err due to skill-based errors, because many 3-year-olds in the present experiments failed to identify perseverative and correct-postswitch responses on this task (i.e., they did not fail because of rule-execution difficulties). Instead, the findings support the hypothesis that children err on the postswitch phase of the DCCS because of rule-based errors. That is, 3-year-olds tend to select the preswitch rules on the postswitch phase whether they are asked to evaluate someone else's postswitch responses or they are asked to sort cards themselves.

Of course, the puppet DCCS also has its own response requirements, but these requirements are very different than the response requirements of the child DCCS. In the puppet DCCS, the puppet applies the rules, and the children need only consider post hoc whether the puppet's behavior conforms to the appropriate rules. If 3-year-olds fail the postswitch phase of the DCCS because they fail to suppress prepotent responses while considering the postswitch rules, then they should be able to evaluate the puppet's responses correctly.

According to CCC theory (Frye et al., 1992; Zelazo & Frye, 1997), 3-year-olds fail to construct a higher order rule for selecting among lower order rules. This failure to construct a higher order rule causes 3-year-olds to select the preswitch rules automatically (i.e., by default, they select the rules that they have already used in response to requests to sort). It should be noted, however, that although CCC theory proposes one mechanism whereby 3-year-olds fail to select the postswitch rules, difficulty with rule selection could arise for a variety of reasons. For example, 3-year-olds may fail to select the postswitch rules because they cannot inhibit consulting the preswitch rules, perhaps because of an immature or inefficient inhibition mechanism (Dempster, 1993; Harnishfeger & Bjorklund, 1993; see also Gerstadt, Hong, & Diamond, 1994). The results of the present experiments are thus consistent with a number of rule-selection explanations, and future work should attempt to differentiate between them, perhaps by using other rule-use tasks, such as the Stroop-like day–night test (Gerstadt et al., 1994), the finger-tapping task (Diamond & Taylor, 1996), or the modified Simon-Says task (Reed et al., 1984). Three-year-olds perform perseveratively on all of these tasks (see Zelazo & Jacques, 1996, for a review), and on the basis of the present findings, we would expect 3-year-olds to have difficulties on error-detection versions, too.

The error-detection approach is a useful means of determining where in the process of problem solving performance breaks down (e.g., Briars & Siegler, 1984; Gelman & Meck, 1983; Konow & Pribram, 1970). As described earlier, Gelman and Meck's findings suggest that children are able to detect a puppet's counting errors before they are able to count correctly (although they did not assess children's own counting abilities concurrently). Briars and Siegler also used an error-detection paradigm to assess preschoolers' ability to discriminate between essential and nonessential features of correct counts. In contrast to Gelman and Meck, Briars and Siegler found that although children tended to perform similarly on a counting task and on an error-detection task, some children consistently counted correctly but did not consistently detect the puppet's errors. On the basis of these findings, Briars and Siegler argued that children learn to count (perhaps by rote) before they understand counting principles. In other words, preschoolers' understanding of counting principles follows, rather than guides, their ability to execute correct counts.

The discrepancy in the numerical competency literature between Gelman and Meck's (1983) findings and those of Briars and Siegler (1984) appears to pose problems for the error-detection approach in that domain. In the case of numerical competencies, the counting task may not require a true conceptual understanding of counting. However, in the case of the DCCS, one can be reasonably certain that children use rules to solve both the child and puppet DCCS tasks because performance on both tasks is underdetermined by the stimuli alone (Zelazo & Jacques, 1996).

That is, on the DCCS, a given test card always matches one of the target cards on one dimension, but that same test card mismatches that target card on the other dimension. The only way in which children can sort correctly on the child DCCS is to consult the rules that they are told to use on a given trial. Similarly, in the puppet DCCS, children also must consult the rules that the experimenter gives them if they are to judge the puppet's sorting behavior appropriately. Thus, in the case of the DCCS, the two versions make the same conceptual demands, a claim that is supported by the correspondence between performance on the child and puppet DCCS tasks in Experiment 2.

The error-detection approach has proven to be successful in identifying the source of perseverative errors in preschoolers, as well as in neuropsychological investigations (e.g., Konow & Pribram, 1970). Although superficially similar, perseverative errors—like errors of commission and errors of omission—can occur for a variety of reasons (Reason, 1990, p. 11; Zelazo et al., 1997). The results of the present experiments help to distinguish between representational and response-based explanations of 3-year-olds' perseverative errors on the DCCS. Three-year-olds' difficulty detecting the puppet's perseverative errors indicates that 3-year-olds fail the postswitch phase of the child DCCS because they persist in consulting the preswitch rules. Age-related changes in this task, therefore, appear to reflect changes in representational flexibility rather than changes in response control. However, it would be an oversimplification to suggest that 3-year-olds are inflexible. As several authors have noted (e.g., Deák & Bauer, 1995, 1996; Zelazo et al., 1997), whether children exhibit flexibility depends not only on their age but also on the context of assessment.

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