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The Role of Negative Priming in Preschoolers' Flexible Rule Use on the Dimensional Change Card Sort Task

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Four experiments examined the development of negative priming (NP) in 3–5-year-old children using as a measure of children's executive function (EF) the dimensional change card sort (DCCS) task. In the NP version of the DCCS, the values of the sorting dimension that is relevant during the preswitch phase are removed during the postswitch phase. The experiments showed that the NP effect observed in the DCCS decreased during the preschool years, and they clarified the circumstances in which NP occurs. Taken together, the findings suggest that the development of EF in early childhood consists in part in disinhibiting attention to information that has previously been suppressed.

Executive function (EF) and its development have recently received considerable attention in developmental psychology (e.g., Diamond, 2002; Zelazo & Müller, 2002). Several studies have established that EF develops rapidly during childhood, with substantial changes occurring between 3 and 5 years (Diamond, 2002; Zelazo & Jacques, 1996). However, the exact nature of these changes remains unclear. As Hughes and Graham (2002, p. 131) note, EF is ''an umbrella term for all of the complex set of cognitive processes that underlie flexible goal-directed responses to novel or difficult situations.'' In order to deal more precisely with the particular processes underlying EF and its development, some investigators have suggested a theory-guided experimental manipulation of features of EF tasks (Ozonoff, 1997; Roberts & Pennington, 1996). We applied this approach to a widely used measure of EF in preschoolers, the dimensional change card sort (DCCS) task (Zelazo, Müller, Frye, & Marcovitch, 2003).

In the standard version of the DCCS, children are presented with two target cards (e.g., a red rabbit and a blue boat) and are told a pair of rules for sorting bivalent test cards (e.g., blue rabbits and red boats) according to only one dimension (e.g., color). After children sort several test cards according to the color dimension, they are told to switch and sort the same cards according to another dimension (e.g., shape). It is now well established that there are systematic, age-related changes in children's performance on the standard version of this task. Whereas the majority of 3-year-olds continue to sort according to the preswitch rules during the postswitch phase, the majority of 4- and 5-year-olds correctly sort by the postswitch rules (for a review, see Zelazo et al., 2003).

Theoretical explanations of age-related changes in performance on the DCCS have focused on the mechanisms whereby children come to inhibit a tendency to sort by the preswitch rules. According to the cognitive complexity and control (CCC) theory (Zelazo & Frye, 1997, 1998), in order to avoid perseverating during the postswitch phase of the DCCS, children must first realize that pre- and postswitch rules apply to the same situation, and then construct a higher order, embedded ''if–if–then'' rule for selecting the postswitch rules as opposed to the preswitch rules. Three-year-olds perseverate on the DCCS because they fail to formulate and use a higher order rule. By 4 years of age, children represent and use this higher order rule deliberately to select between two different pairs of rules (''If we're playing by color, then if red . . . here, if blue . . . there, but if

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we're playing by shape, then if rabbit . . . here, if flower . . . there'').

By contrast, Kirkham, Cruess, and Diamond (2003) have attributed 3-year-olds' perseveration to deficits in inhibitory control per se. That is, 3-year-olds fail to suppress attention to the preswitch dimension in order to shift attention to the postswitch dimension. As they put it, ''Having focused their attention on a particular dimension, their attention gets stuck, and they have extreme difficulty redirecting it'' (Kirkham et al., 2003, p. 451). They characterize this failure as a problem of ''attentional inertia'' and suggest that this inertia is eventually overcome by the development of a stronger ability to inhibit attention to the aspect of the stimulus (e.g., redness) that was relevant during the preswitch phase.

Whereas CCC theory and attentional inertia theory differ in terms of the mechanisms they invoke to explain 3-year-olds' perseveration on the DCCS (i.e., reflection and higher order rule use vs. inhibitory control), they share the assumption that the main reason for perseveration is that children fail to shift attention away from aspects of a situation that were previously relevant. This assumption is supported by several findings. For example, Zelazo et al. (2003) found that children often perseverated on a partial change version in which only the values of the dimension that was relevant on the preswitch phase were retained during the postswitch phase (e.g., children sorted red and blue rabbits and boats by shape during the preswitch phase, and yellow and green rabbits and boats by color during the postswitch phase). By contrast, most children (approximately 75% of 3-year-olds; Zelazo et al., 2003, Experiments 7–9) performed well in a total change version of the DCCS, in which the values of both dimensions were changed between pre- and postswitch (i.e., children were given a different set of cards involving different colors and different shapes). These findings are consistent with the hypothesis that for most 3-year-olds, the preswitch rules or values (but not the preswitch dimension per se) are activated when selected during the preswitch phase and that this activation persists during the postswitch phase, creating a bias toward their selection and use in the absence of a higher order rule (CCC theory) or in the absence of sufficient inhibitory control (attentional inertia theory).

In addition, however, there is evidence that children fail the DCCS because they have difficulty engaging attention to the values of the formerly *irrelevant* dimension when these values become relevant in the postswitch phase of the task. Zelazo et al. (2003) administered a version of the DCCS in which the values of the preswitch sorting dimension were removed after the preswitch phase and replaced by different values from the same dimension (e.g., children were required to sort red rabbits and blue boats according to shape in the preswitch phase, and they were required to sort red flowers and blue cars according to color in the postswitch phase; see Figure 1a). Notice that, in this version, referred to as the negative priming (NP) version, activation of the values of the preswitch dimension (e.g., rabbits and boats) cannot interfere with postswitch performance because it is no longer possible to sort by these values. Three-year-olds performed equally poorly on the standard version and this NP version, suggesting that perseveration in the DCCS is partly due to the failure to engage attention to the values of the formerly irrelevant dimension (e.g., red and blue). At the same time, 3-year-olds performed significantly better on the total change version than on the NP version (Zelazo et al., 2003, Experiments 8 and 9), so it seems likely that any tendency that children may have had to get stuck on the preswitch sorting dimension (e.g., shape) cannot account for children's difficulty on the NP version.

As the name of the version indicates, suppression of preswitch values in the DCCS constitutes an instance of NP (Müller, 2001). NP is a complex phenomenon that lends itself to different interpretations (Fox, 1995). It generally refers to the apparent disruption or slowing of a response to a stimulus that has previously been ignored (Tipper, 2001). In the DCCS, NP may occur because each test card matches one target card on one dimension (relevant) and the other target card on the other dimension (irrelevant). In the process of focusing their attention on the values of the relevant dimension during the preswitch phase, children may need to inhibit the pull that is exerted by the values of the irrelevant dimension because there is a visual match between target cards and test cards on this dimension (Müller, 2001; Perner & Lang, 2002). When sorting correctly on the preswitch phase, children may suppress attention to the values of the competing dimension, and this suppression of attention may be carried over into the postswitch phase. As a result, NP in this task would decrease the probability that these values would be selected during the postswitch phase when they became relevant.

Children's performance in the NP version is not consistent with either CCC theory or attentional inertia theory, both of which emphasize the activation of aspects of the situation that were relevant during the preswitch phase. For example, in line with its emphasis on inhibition, attentional inertia theory explicitly claims that "children should be able to succeed if the previously relevant values on the now irrelevant dimension are no longer present in the stimuli (and they do)" (Kirkham et al., 2003, p. 451). Clearly, the results of the NP version contradict this claim. In the NP version, the children's problem cannot be that they have deficits inhibiting attention to the values of the preswitch dimension because these values are no longer present in the postswitch phase. Instead, the problem would seem to be one of disinhibiting attention to the values of the formerly irrelevant dimension.

On the basis of the pattern of findings with the different versions of the DCCS, Zelazo et al. (2003) proposed a revised version of the CCC theory (cognitive complexity and control–revised; CCC-r). According to CCC-r, 3-year-olds perseverate on the standard version of the DCCS because of both activation of the rules that were relevant during the preswitch phase and suppression of attention to the rules that were irrelevant. The interfering effect of suppression is seen as an example of NP (Müller, 2001; Zelazo et al., 2003), and a higher order rule is required not only to overcome the activation of the preswitch rules but also to overcome this NP.

Although NP has received considerable attention in adult cognition (Fox, 1995; May, Kane, & Hasher, 1995; Milliken & Tipper, 1998; Tipper, 2001), few studies have explored NP in children (Amso & Johnson, 2005; Houdé & Guichart, 2001; Perret, Paour, & Blaye, 2003; Pritchard & Neumann, 2004; Tipper, Bourque, Anderson, & Brehaut, 1989; Tipper & McLaren, 1990). On the basis of an early finding that, compared with adults, evidence of NP was weak in 7-year-olds in a Stroop task (Tipper et al., 1989), it has been claimed that the "negative priming effect develops inconsistently in early childhood up to first grade" (Nigg, 2000, p. 227). However, subsequent research found evidence that NP is already present in preschoolers (Tipper & McLaren, 1990) and even in infants (Amso & Johnson, 2005), under some circumstances.

In developmental research, NP has been taken as evidence of inhibitory control, with more NP indicating better inhibitory control (e.g., Houdé & Guichart, 2001; Perret et al., 2003). However, the findings from the NP version of the DCCS raise the interesting possibility that the NP effect may actually decrease during childhood—although this possibility remains to be tested. Given the paucity of developmental studies on NP, four experiments were designed to examine the conditions under which NP occurs in the DCCS by experimentally manipulating features of the DCCS. The first experiment aims to replicate the finding that 3-year-olds show considerable NP in the DCCS, and assess directly whether the NP effect actually decreases with age. The second experiment explores whether the phenomenon of NP observed in the DCCS is qualitatively similar to the NP that is observed in adults in other situations. This last aim was addressed by examining whether NP in the DCCS occurs regardless of whether there is a conflict between alternative ways of matching test and target cards during the preswitch phase. There is some empirical evidence that conflict of this type is not necessary for NP in adults (Milliken, Joordens, Merikle, & Seiffert, 1998), but it is unknown whether this is also the case for preschool children. The third and fourth experiments explore the extent to which NP in the DCCS is influenced by the frequency and the recency of conflicting stimuli. Frequency and recency of conflicting stimuli have been shown to influence NP in adults (Allport & Wylie, 2000; Lowe, 1998; Waszak, Hommel, & Allport, 2003), but it is unknown whether these factors have any effect on NP in children. Experiment 4 also examines whether the task set and perseveration can survive intervening events that last for several minutes.

Experiment 1

Experiment 1 examined whether children's performance on the NP version of the DCCS follows the same developmental trend as on the standard version. On the standard version, children's performance improves significantly between the ages of 3 and 5 years (Zelazo, Frye, & Rapus, 1996). On the NP version, the majority of 3-year-olds (approximately 75%) fail the postswitch phase (Zelazo et al., 2003, Experiments 8 and 9). It is currently unknown whether performance on the NP version improves between the ages of 3 and 5 years.

If children's performance on the NP version were entirely determined by inhibitory control and by the bottom-up dynamic interplay of relative activation levels of pre- and postswitch values, then children's performance on this version would be expected to get worse with age as children's inhibitory control (exercised during the preswitch phase) improves. That is, as children get older and exercise more inhibitory control during the preswitch phase, there should be more NP of the preswitch values. This pattern of results would be consistent with the observation of age-related increases in NP in other paradigms (e.g., Perret et al., 2003; Tipper et al., 1989; but see Pritchard & Neumann, 2004). According to CCC-r theory, however, children's performance on the DCCS is not entirely determined by inhibitory control, bottom-up processes, and task dynamics. Rather, children pass the DCCS because they become capable of reflecting on and distancing themselves from the preswitch rules. As a consequence, children become capable of constructing and using a higher order rule that allows them consciously to contrast pre- and postswitch rules and to control their behavior in a relatively top-down fashion (Zelazo et al., 2003). CCC-r theory thus predicts that children's performance on the NP version should follow the same developmental pattern as the standard version of the DCCS.

Method

Participants. Twenty-eight children between the ages of 37 and 48 months (14 boys; $M = 44.07$ months, $SD = 3.11$) and 28 children between the ages of 49 and 60 months (14 boys; $M = 55.43$ months, $SD = 3.65$) participated in this study. An additional boy (49 months) was dropped from the final sample because he refused to comply with the experimenter's instructions. Participants were recruited through local day cares in Victoria. The large majority of participants in this and the following experiments were from a White, middle-class background; however, this information was not systematically recorded. The entire procedure was videotaped.

Procedure. Each child was tested individually. For each session, the child and experimenter were seated across from each other at a small table. Each child took approximately 10 min to complete the task.

Two sorting trays were placed on the table, each tray 11.5 cm long, 9.5 cm wide, and 2 cm deep. Target and test cards were 10.75 cm × 7 cm color drawings on laminated cards. Target cards were affixed to the trays and remained visible during task administration. The NP version of the DCCS was comprised of two phases: a preswitch and a postswitch phase. Because previous studies using the NP version had not found any effect of sorting dimension (Zelazo et al., 2003, Experiments 8 and 9), all children were asked to sort cards according to shape during the preswitch phase (e.g., ''We are going to play the shape game. In the shape game, all of the rabbits go in this box, and all of the boats go in this box.''). Two demonstration trials were administered, in which the experimenter sorted two test cards (e.g., one rabbit and one boat) face down into the trays. Children then sorted six test cards. On each preswitch trial, the experimenter repeated the rules and labeled the test card by the relevant dimension only (''Here is a boat''), and asked the child, ''Where does it go in the shape game?'' Children were asked to place the cards face down into the sorting trays. No feedback was given as to whether or not children sorted the test cards correctly.

Following the preswitch phase, the target cards used during the preswitch phase were removed and new target cards were affixed to the sorting trays. Children were given new sorting rules. They were told, ''We are not going to play the shape game any more, no way. Now we are going to play the color game. In the color game, blue ones go in this box, and red ones go in this box.'' After each postswitch trial, the sorting rules were restated; children received no feedback during the postswitch phase about whether or not they sorted correctly. Test and target cards for the NP version are shown in Figure 1a.

Results

In the postswitch phase, 89% (50 out of 56) of the children either sorted all six cards or none of the cards correctly. Because responses were not normally distributed, chi-square tests were used to analyze the data. For that purpose, children who sorted five or more cards correctly (out of six) during postswitch were classified as passing. Chi-square tests established that there were no significant effects for gender.

Table 1 shows the distribution of pass–fail performances in the NP version by age group. Significantly more 4-year-olds passed the NP version than did 3-year-olds, $\chi^2(1, N = 56) = 5.85$, $p < .05$. The difference between age groups amounts to a medium effect size ($\varphi = .32$).

Discussion

Experiment 1 replicates the previous finding (Zelazo et al., 2003, Experiments 8 and 9) that most 3-year-olds fail the NP version of the DCCS, and it extends previous research by demonstrating that 4-year-olds were significantly less likely to do so. This finding suggests that performance on the NP version follows the same developmental progression usually observed on the standard version of the DCCS, which raises the interesting possibility that the NP effect—typically taken to reflect inhibitory control of attention—actually declines between 3 and 5 years of age. This finding is consistent with CCC-r theory, which predicts that older preschoolers are better able to construct higher order rules that allow them to regulate their actions and thoughts in a top-down fashion.

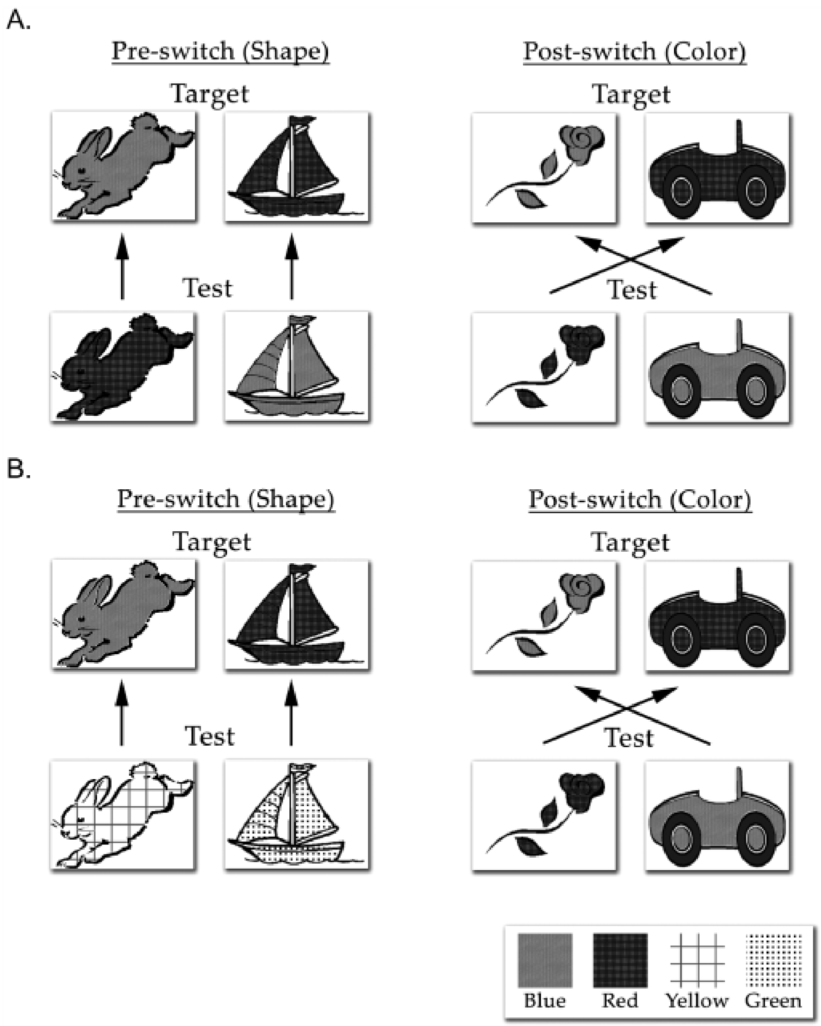

Figure 1. (a) Test and target cards for the negative priming version of the dimensional change card sort (DCCS). (b) Test and target cards for the absolute negative priming version of the DCCS. Shape is the preswitch sorting dimension for both examples.

Experiment 2

Experiment 2 was designed to explore the circumstances in which NP is elicited in the DCCS. One possibility is that NP occurs only when there is a conflict between (at least) two possible ways of matching test and target cards. One might call this the *relational* NP hypothesis. Another possibility is that all stimuli that are not in the focus of attention are negatively primed. This latter possibility, which might be called the *absolute* negative priming (ANP) hypothesis, implies that irrelevant values (e.g., the specific values of shape that appear on the test and/or target cards when color is the preswitch sorting dimension) should be negatively primed even in the absence of a conflict between ways of matching target and test cards.

Empirical evidence consistent with the idea that NP depends on conflict comes from a study by Zelazo et al. (2003, Experiment 9). They found that, compared with the NP version, children performed significantly better in a version of the DCCS (the NP [redundant preswitch] version) in which the test cards were identical to the target cards during the preswitch phase, and the values of the formerly relevant dimension were replaced during the postswitch phase. As in the NP version, activation of the relevant preswitch rules would not affect postswitch performance in this version. Unlike in the NP version, however, children did not need to select the preswitch rules as opposed to a competing alternative during the preswitch phase.

However, this finding is open to alternative interpretations. In particular, because the test cards were identical to the target cards during the preswitch phase, this phase may not have required selective attention at all. That is, in the preswitch phase, children could have simply matched target

Table 1
Number of Children Passing and Failing the Different Versions of the DCCS in Experiments 1–3

	Pass	Fail
Experiment 1		
NP (3–4 years)	11 (39)	17 (61)
NP (4–5 years)	20 (71)	8 (29)
Experiment 2		
NP (3–4 years)	4 (33)	8 (67)
ANP (3–4 years)	9 (75)	3 (25)
Experiment 3		
Standard	3 (20)	12 (80)
Random-NP	7 (47)	8 (53)
Recency-NP	0 (0)	15 (100)
Partial–partial	5 (33)	10 (67)

Note. Percentages in parentheses. NP = negative priming; ANP = absolute negative priming; Random-NP = negative priming-random; Recency-NP = negative priming recency; Partial–partial = partial–partial change-random. Experiments 1 and 2: passing = 5 or 6 postswitch sorts correct; Experiment 3: passing = 7 or 8 postswitch sorts correct.

and test cards holistically on the basis of values from both dimensions. If this were the case, then this version may have failed to elicit NP either because children did not need to selectively ignore the values of the irrelevant preswitch dimension, or because children did not attend selectively at all and simply sorted the test cards by global features.

If NP is an absolute phenomenon and occurs regardless of whether there is a conflict between possible ways of matching target and test cards, then 3-year-olds' performance should be similarly poor on the NP version and on a new version of the DCCS (ANP version) in which (a) the test and target cards are not redundant during the preswitch phase, (b) there is no conflict between target and test cards during this phase, and (c) the values of the preswitch sorting dimension are removed after the preswitch phase and replaced by different values from the same dimension. To illustrate, 3-year-old children should perform similarly poorly on the NP version and an ANP version in which (a) during the preswitch phase they sort yellow rabbits and green boats according to shape, and a blue rabbit and a red boat serve as target cards, and (b) during the postswitch phase they sort blue cars and red flowers according to color, and a red car and a blue flower serve as target cards (see Figure 1b). Like the NP version, this ANP version removes the possibility of interference because of persistent activation of the values of the dimension that was relevant during the preswitch phase. However, if NP is a relational phenomenon, then children should do better on this version than on the NP version because, although the test cards are not identical to the target cards during the preswitch phase (and hence selective attention to the relevant dimension is required), there is no possibility of matching test cards and target cards according to the irrelevant dimension.

Method

Participants. Twenty-four children between the ages of 37 and 48 months participated in this study. An additional 5 children were dropped from the final sample (median age = 38 months) because they failed to pass the DCCS preswitch phase (i.e., these children sorted fewer than five out of six cards correctly). Twelve children were randomly assigned to one of two conditions (NP, ANP). The mean ages in these conditions were as follows: NP mean age = 42.50, $SD = 3.12$ (7 girls); ANP $M = 42.67$, $SD = 3.11$ (7 girls). Participants were recruited through a database compiled from birth announcements, or through local day cares in State College. The entire procedure was videotaped.

Procedure. Each child was tested individually in the same manner as in Experiment 1. However, because the ANP version had not been used previously and it was thus unknown whether preswitch sorting would influence performance, in both DCCS versions, half the children received color as the preswitch sorting dimension, and the other half received shape as the preswitch sorting dimension. In the NP version, a blue rabbit and a red boat served as target cards, and three red rabbits and three blue boats were the test cards during the preswitch phase. When shape was the preswitch sorting dimension in the NP version, then a blue flower and a red car were the target cards, and three red flowers and three blue cars were the test cards during the postswitch phase. When color was the preswitch sorting dimension in the NP version, then a green rabbit and a yellow boat were the target cards, and three yellow rabbits and three green boats were the test cards during the postswitch phase. In the ANP version, a blue rabbit and a red boat served as target cards during the preswitch phase. When shape was the preswitch sorting dimension, then test cards were three yellow rabbits and three green boats, the target cards during the postswitch phase were a blue flower and a red car, and the test cards during the postswitch phase were three red flowers and three blue cards. When color was the preswitch sorting dimension, then test cards were three red cars and three blue flowers, the target cards during the postswitch phase were a green rabbit and a yellow boat, and the test cards during the postswitch phase were three yellow rabbits and three green boats. Exemplars of the test and target cards used for the NP version and the ANP version are shown in Figure 1.

Results

In the postswitch phase, 83% (20 out of 24) of the children sorted either all six cards or none of the cards correctly. As in Experiment 1, children who sorted five or more cards correctly (out of six) during postswitch were classified as passing. Chi-square tests established that there were no significant effects for either gender or the order in which the dimensions (shape, color) were presented.

Table 1 shows the distribution of pass–fail performances in the NP and the ANP. Significantly more 3-year-olds passed the ANP than the NP, $\chi^2(1, N = 24) = 4.20$, $p < .05$ ($\varphi = .42$).

Discussion

Experiment 2 demonstrated that 3-year-olds performed significantly better on the ANP version of the DCCS than the NP version. This finding extends previous research in an important way by clarifying the role of conflict during the preswitch phase of the DCCS. Specifically, this finding shows that the absence of conflict during the preswitch phase significantly reduces NP of the values of the irrelevant dimension, which then facilitates sorting by those same values during the postswitch phase. In contrast to the NP (redundant preswitch) version used in Zelazo et al. (2003), selective attention was required during the preswitch phase of the ANP version, so the results demonstrate more convincingly that NP depends on the presence of two possible ways of matching test and target during the preswitch phase and on the selection of specific rules or values in the context of competing distractors. Still, because 25% of 3-year-olds failed to switch in the ANP version, this version may not have completely eliminated NP, and some NP of the values of the target cards may have carried over into the postswitch phase. Nonetheless, NP, at least in 3-year-olds, and at least in the DCCS, is significantly weaker when test and target cards are not in conflict during the preswitch phase than when they are in conflict.

Alternatively, some children (i.e., those few who would fail the total change version) may fail the ANP version because they perseverated on the preswitch dimension (and not on the specific values of the preswitch dimension). Even if this explanation is correct, however, it still needs to be explained why significantly fewer children perseverated on the preswitch dimension in the ANP version than in the NP version, and it is not clear how this difference in performance could be explained without invoking the absence versus presence of conflicting test–target card pairings.

Three alternative explanations of children's better performance on the ANP version should be considered, however. First, by design, the preswitch phase of the NP version involved conflict whereas the preswitch phase of the ANP version did not, and for this reason the NP version may also have had greater processing demands. This alone may have caused children in the NP version to have greater difficulty switching to the values of the formerly irrelevant dimension. Although this explanation may explain why children perform better in the ANP version than in the NP version, it cannot explain why the majority of children perform well in the total change version (Zelazo et al., 2003), because in the total change version children encounter conflict on every trial during the preswitch phase. Indeed, children's good performance on the ANP version provides additional, converging evidence that the majority of 3-year-old children do not perseverate in responding to a dimension in the DCCS (i.e., because it would have been possible in this version for children to continue sorting by the preswitch dimension). Thus, a more parsimonious and inclusive account of the current pattern of findings is to attribute poor performance on the NP version to the presence of NP arising from the conflict between multiple ways of matching test and target cards during the preswitch phase, and to attribute good performance on the ANP version to the absence of NP when there is no conflict between test and target cards during the preswitch phase.

Second, it is possible that children's better performance in the ANP version than in the NP version was due to novelty and not to reduced conflict. Specifically, in the ANP version the values of the test cards were changed for the dimension to which children were asked to switch, which was not the case for the NP version. The change in the values of the test cards could have attracted children's attention, which, in turn, could have facilitated sorting by the values of the postswitch dimension. Although novelty likely moderates preschooler's performance on the DCCS (Zelazo et al., 2003), and on their sorting abilities more generally (Esposito, 1975), it is unlikely that novelty alone can explain children's good performance on the ANP version because in the postswitch phase of the ANP version novel stimulus values were also introduced for the irrelevant dimension of the test cards, and children had to suppress sorting by these stimulus values. Thus, in the ANP version novelty partly counteracted sorting by the postswitch dimension, and yet the majority of children passed the ANP version. Furthermore, findings from the partial change version of the DCCS are inconsistent with the claim that novelty explains children's good performance in the ANP version. In the partial change version, novel stimulus values are introduced in the postswitch phase, and children are asked to sort by these novel stimulus values. If novelty alone were sufficient to switch children's attention to the postswitch rules, then children should perform well on the partial change version. Yet, about 50% of 3-year-old children perseverated in the partial change version (Zelazo et al., 2003, Experiments 7 and 8). This pattern of findings suggests that novelty of the relevant values of the postswitch sorting dimension alone is not sufficient to enable children to switch sorting by this dimension.

A third alternative explanation of the better performance in the ANP version is that greater variability in the stimulus exemplars aids children in the performance in the postswitch phase. For example, greater variability in the values of the irrelevant dimension during the preswitch phase might draw children's attention to this dimension, and thus make it easier to switch to this dimension during the postswitch phase. Alternatively, the greater variability in distractors during the preswitch phase could also lead to a dispersion and thus weakening of inhibition (Fox, 1995), which, in turn, could facilitate switching to the values of the postswitch dimension during the postswitch phase. The question of variability is addressed in Experiment 3.

Experiment 3

NP in the DCCS appears to be a relational phenomenon that occurs in the context of selective attention to relevant values as opposed to conflicting values. However, it is unclear whether and how different factors related to NP in adults (Fox, 1995) influence NP in preschoolers. One factor is the relative frequency of interfering trials: the larger the proportion of interfering trials, the greater the NP (Lowe, 1998).

In addition, research on task switching has found that switch costs are affected by the recency of the interference. Allport and Wylie (2000), for example, found that the further away the alternate response was either in time or number of trials from the competitor response, the smaller the switch costs. Summarizing the findings from a series of experiments, Allport and Wylie (2000, p. 65) conclude that "the relative frequency and recency of competing S-R mappings strongly affect the size of RT interference costs." Thus, both the relative frequency of conflict trials and the recency of these trials may affect children's performance in the NP version of the DCCS.

Experiment 3 examined the roles of relative frequency and recency of conflict trials in producing NP in the DCCS by varying the number of times incompatible test cards were paired with the target cards during the preswitch phase (which consisted of a fixed number of preswitch trials). In the standard version of the DCCS, test cards (e.g., blue rabbits, red boats) are mismatched with target cards (e.g., red rabbit, blue boat) on every trial. If the presence of conflict trials is responsible for NP in the DCCS, as indicated by the results of Experiment 2, then reducing the number of such pairings during the preswitch trials should decrease NP. For example, if children are asked to sort by shape during the preswitch phase, then the magnitude of NP could be reduced by using test cards with a color (e.g., yellow) that does not conflict with the color of the relevant target card (e.g., blue).

In order to reduce the amount of NP in the preswitch phase of the DCCS, two new versions of the DCCS were designed: random negative priming (Random-NP) and recency negative priming (Recency-NP). Both versions were similar in that mismatching target–test card pairings were presented on only half of the eight preswitch trials. However, these versions differed in how mismatching target–test card pairings were distributed over the preswitch trials. In the Random-NP version, mismatching target–test card pairings were randomly distributed over the preswitch trials; in the Recency-NP version, the mismatching target–test card pairings were presented en bloc at the end of the preswitch phase, and so were relatively recent when the postswitch phase commenced.

In order to examine the effect of relative frequency on NP, we compared performance on the Recency-NP and Random-NP versions with performance on the standard version. We expected that the Recency-NP and Random-NP versions would be easier than the standard version of the DCCS because, compared with the standard version, the frequency of mismatching test–target card pairings was reduced in these versions.

In order to examine the role of recency on NP, we compared the Recency-NP version with the Random-NP version. Both versions had the same total number of mismatching target–test card pairings during the preswitch trials, but the distribution of these trials differed over the preswitch phase. We expected that the massed presentation of mismatching target–test card pairings at the end of the preswitch trials (vs. the random presentation in the Random-NP version) should make the Recency-NP version more difficult than the Random-NP version.

A further question addressed by Experiment 3 concerned the specific stimulus properties of noninterfering information that reduce NP. In both the Recency-NP version and the Random-NP version, the noninterfering preswitch trials were constructed by presenting test cards with values on the irrelevant dimension that were noninterfering but positive in the sense of present as opposed to absent (e.g., in the Recency-NP version, target cards were a blue rabbit and a red boat, and test cards were yellow and green rabbits and boats in the shape game). It remains unclear as to what extent NP depends on the characteristics of the noninterfering values on the irrelevant dimension.

In order to investigate this, a partial–partial change–random version was designed. In the partial–partial change–random version, interference was removed on half of the preswitch trials by introducing neutral values for the irrelevant dimension of the test cards. For example, when the preswitch sorting dimension was shape, half of the test cards were uncolored (black and white) rabbits and boats and target cards were blue rabbits and red boats. These neutral values of the irrelevant dimension were randomly distributed over the preswitch trials (the other half of the trials involved standard test cards: red rabbits and blue boats). In the postswitch phase, all test cards were the standard red rabbits and blue boats. The critical comparison for the effect of the partial–partial change–random version was with the Random-NP version because both versions had the same number of randomly distributed noninterfering preswitch trials. If NP is reduced only when noninterfering but positive values on the irrelevant dimension are used, then performance on the Random-NP version should be better than on the partial–partial change–random version. However, if NP is reduced whenever there are fewer conflict trials, regardless of the characteristics of the noninterfering values, then success rates on the partial–partial change–random version and the Random-NP version should be similar.

By comparing performance on the partial–partial change–random version and the Random-NP version, it is also possible to gauge the effect of the variability in stimulus material on performance. The Random-NP version provides children with greater variability in the values of the irrelevant dimension during the preswitch phase than does the partial–partial change–random version. If greater variability facilitates switching (e.g., by directing attention to the values of the dimension that will become relevant during the postswitch), then children should perform better in the Random-NP version than in the partial–partial change–random version. Similarly, if greater variability facilitates performance, then children should perform better in the Random-NP and Recency-NP versions than in the standard version because the former versions consist of more variable stimulus materials than the latter version.

Method

Participants. Sixty-eight preschool children between the ages of 36 and 54 months were recruited from preschools (35 boys and 33 girls) in suburban Philadelphia. To ensure equality of age across conditions despite the large age range, children were matched based on age in months. A child in one condition was matched to one child (within 2 months) in each of the other three conditions. Six children were dropped from the analysis because they did not match another child in another condition for the age criteria. Two additional children were dropped because they failed the preswitch phase of the DCCS (i.e., they sorted fewer than seven of eight preswitch cards correctly). The final sample consisted of 15 children in each of four conditions (mean age standard = 46.00 months, $SD = 5.95$; Random-NP = 46.07 months, $SD = 5.90$; Recency-NP = 46.40 months; $SD = 5.75$, partial–partial change–random = 46.20 months, $SD = 5.28$).

Procedure. Each child was tested individually in the same manner as in Experiment 2. The dimension that was relevant in the preswitch phase (color or shape) was counterbalanced and crossed with sex. Half of the children received the shape rules first, and half received the color rules first.

Children were assigned to one of the four conditions: standard, Random-NP, Recency-NP, and partial–partial change–random. In each condition, children received two demonstration trials (in each condition, the experimenter sorted a red rabbit and a blue boat), eight preswitch trials, and eight postswitch trials. Eight trials per phase were used (vs. six in Experiments 1 and 2) in order to allow additional opportunities for the manipulation of trial types within each phase. For all conditions, a blue rabbit and a red boat served as pre- and postswitch target cards, and four red rabbits and four blue boats served as test cards in the postswitch phase. Conditions differed in the test cards used during the preswitch phase and in the order in which the test cards were presented. In the standard version, children received mismatching target–test card pairs for each preswitch trial. In the Random-NP, Recency-NP, and partial–partial change–random versions, mismatching target–test card pairs were presented during half (i.e., four) of the preswitch trials. The Random-NP and Recency-NP versions differed in that mismatched target–test card pairs were randomly distributed across preswitch trials in the Random-NP version, but they were presented as the last four preswitch trials in the Recency-NP version. In the partial–partial change–random version, children received mismatching and nonmismatching target–test card pairings that were randomly distributed across preswitch trials. On shape trials with nonmismatching test cards, children received uncolored (''black and white'') cards; on color trials with nonmismatching test cards, children received colored ''squiggles'' (i.e., colored, wavy lines on a blank card).

The procedures were the same as in Experiment 2 with the following exceptions. First, test cards were labeled by both dimensions (e.g., ''Here is a yellow boat'') during both pre- and postswitch phase. This was done to increase the likelihood that children would attend to both relevant and irrelevant values on each trial. Second, children received feedback after each preswitch trial (but, as in Experiment 1, children did not receive any feedback during the postswitch phase). Previous research has found that these aspects of the procedure have no effect on performance (Zelazo et al., 2003). Figure 2 displays the test and target cards used in Experiment 3.

Results

In the postswitch phase, 95% of the children (57 out of 60) either sorted all eight cards or none of the cards correctly. Children were scored as having passed the post-switch phase if they sorted at least seven out of eight cards correctly. Chi-square tests showed that passing the postswitch was not associated with either gender or the order in which the dimension (color or shape) was presented.

Table 1 shows the percentage of children who passed the postswitch phase for each condition. Fisher's exact test (with Bonferroni correction .05/5 = .01) was used to examine group differences. Because directional predictions had been made, one-tailed significance tests were conducted for these comparisons.

To examine the role of recency, we first compared performance on the Recency-NP version with performance on the Random-NP version. Fisher's exact test revealed that significantly fewer children passed the Recency-NP version than the Random-NP version, $p < .003$, which is a large effect (effect size $\varphi = .50$). Surprisingly, no child passed the Recency-NP version.

In order to explore the role of relative frequency, performance on the Random-NP and Recency-NP versions was grouped together and compared with the performance on the standard version. There was no significant difference between these conditions, $p < .57$ ($\varphi = .02$). When performance in the individual versions was compared, it was found that neither performance on the Random-NP version nor performance on the Recency-NP version significantly differed from performance in the standard version, $p < .12$ ($\varphi = .22$) and $p < .13$ ($\varphi = .20$), respectively.

To examine the role of variability of stimulus material (i.e., interfering vs. noninterfering values during the preswitch phase), we compared performance on the Random-NP version with performance on the partial–partial change–random version, which revealed no significant differences between these conditions, $p < .70$ ($\varphi = .10$).

In order to explore further the role of recency, we grouped the performance on the standard version and the Recency-NP together because children in these conditions received interfering test–target card pairs during (at least) the last half of the preswitch trials. We also grouped the performance on the Random-NP and the partial–partial change–random together, because children in these conditions received randomly distributed interfering test–target card pairings during the preswitch trials. In order to examine developmental trends in the recency and random conditions, two age groups were created by using the median age to split the sample in a group of younger (<48 months) and older (48 months and older) participants. A loglinear analysis with condition (random, recency) and age group as independent variables, and postswitch performance as dependent variable revealed a significant effect for condition, $z = 2.05$, $p < .05$, and a marginally significant effect for age group, $z = 1.82$, $p < .07$, but no significant effect for the interaction between condition and age group, $z = 0.34$, $p > .70$. Interestingly, all children who passed the recency conditions were older than 48 months. Similarly, of the 12 children who passed in the random conditions, 9 (75%) were older than 48 months.

Discussion

Experiment 3 yielded four main findings. First, the relative frequency of interfering stimuli did not

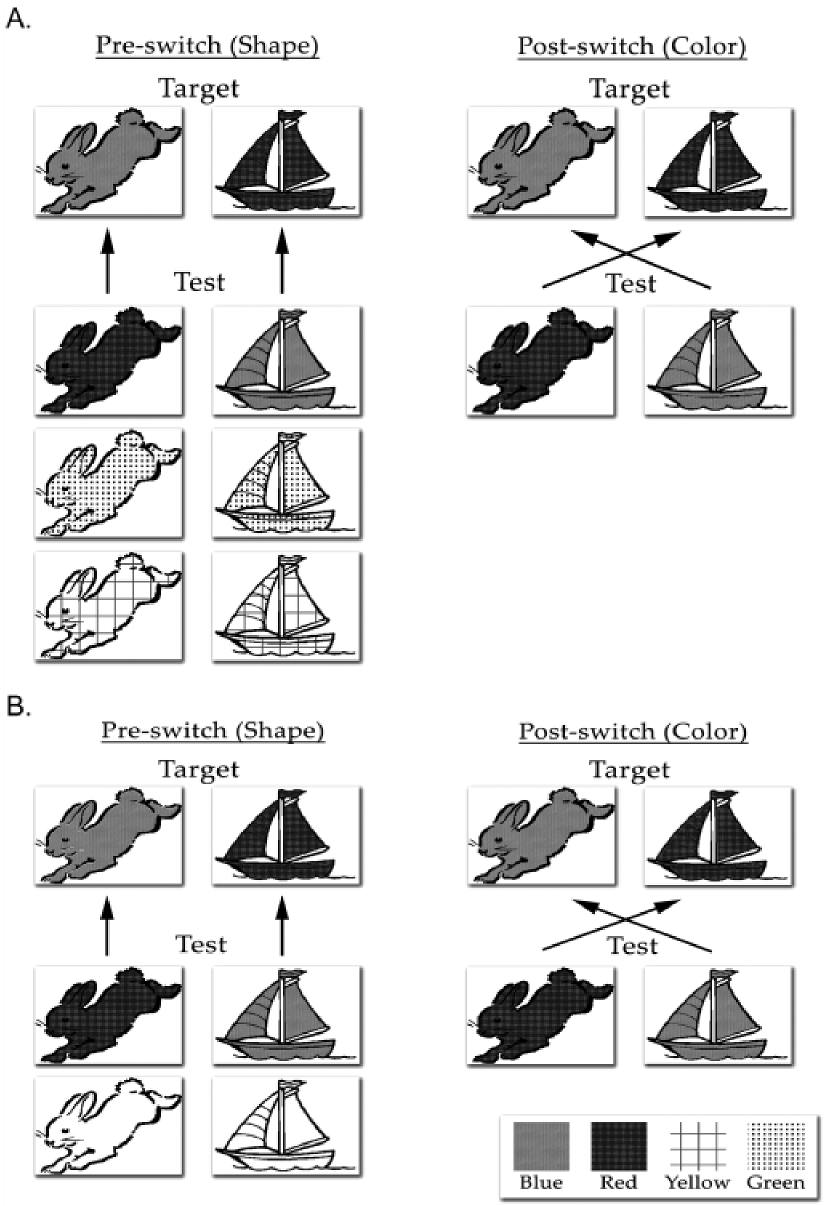

Figure 2. (a) Test and target cards for both the negative priming-random and negative priming-recency versions of the dimensional change card sort (DCCS). (b) Test and target cards for the partial – partial change version of the DCCS. Shape is the preswitch sorting dimension for both examples.

appear to affect performance on the DCCS. Children did not perform significantly better on the Recency-NP version and the Random-NP version than on the standard version, despite the fact that only half of the preswitch trials in the former versions (vs. all the preswitch trials in the latter version) consisted of mismatched target and test cards. One possible explanation for this finding is that in the presence of consistent interference, the probability of NP accrues and reaches an asymptotic maximum quickly in children such that presentation of further interfering trials (say, interfering trials in excess of four trials) has no effect.

An alternative explanation of the finding that the standard version and the Recency-NP version did not differ significantly is that the introduction of novel, mismatched values of the irrelevant dimension midway through the preswitch trials (vs. earlier, as in the Random-NP version) actually attracts attention to these values (Zelazo et al., 2003, Study 4). These novel values of the irrelevant dimension, however, must be ignored in order to follow the instructions of the experimenter. In this manner, novelty could have elicited stronger NP per trial, which could explain why performance on this version was not better than on the standard version.

The second main result of Experiment 3 is that blocking conflicting trials at the end of the preswitch phase interfered more with postswitch sorting performance than randomly distributing the trials. Children performed better on the Random-NP version (where mismatched target–test card pairings were randomly distributed over the preswitch trials) than they did on the Recency-NP version (where mismatched target–test card pairings were blocked just before the postswitch phase). The same pattern also emerged when performance on the two random versions (i.e., Random-NP and partial–partial change–random) was combined and compared with the performance on the two other versions (standard version and Recency-NP version). One possible explanation of this finding is that postswitch performance is indeed influenced mainly by relatively recent events—the last four preswitch trials. If this were the case, then children would effectively have received more conflict trials in the recency versions than in the random versions. Future research is necessary to decide whether this explanation is valid. A related possibility is that the primary determinant of NP is the relative frequency (vs. absolute number) of conflict trials during the most recent (e.g., last four) preswitch trials. Relative frequency per se did not appear to affect performance, but relative frequency may have interacted with recency.

The third main finding was that variability in stimulus material does not affect preschoolers' performance on the NP versions. None of the comparisons between versions with different amount of variability in stimulus material during the preswitch phase reached significance, and effect sizes were small. This finding supports the interpretation that conflict and not variability facilitated performance on the ANP version in Experiment 2.

Finally, Experiment 3 showed a developmental pattern that is consistent with previous studies (Zelazo et al., 2003). There was a trend for 4-year-olds to perform significantly better than 3-year-olds in the random conditions as well as in the recency conditions. However, the exception to the developmental trend was constituted by the Recency-NP version, in which even older preschoolers did not succeed. The introduction of conflicting novel values (which needed to be ignored during the preswitch phase, and switched to during the postswitch phase) may have affected older preschoolers as much as it did affect younger preschoolers.

One limitation of Experiment 3, however, is that in the Random-NP version, because the four conflict trials were distributed randomly among the eight preswitch trials, the very last preswitch trial could consist of either a matching or a mismatching (conflict) test–target card pairing. Unfortunately, we did not record whether the final trial was a conflict trial or not. It is possible that the likelihood of NP is especially influenced by the trial immediately preceding the postswitch phase. If the trial immediately preceding the postswitch phase is especially influential, then the Random-NP condition may have been easier than the standard version and the Recency-NP version only for those children for whom the last trial was not a conflict trial. Experiment 4 was designed to clarify this issue.

Experiment 4

Experiment 4 was designed to address three issues. First, the occurrence of the last mismatching test–target card pairing was systematically manipulated in Experiment 4: it occurred either in the second-to-last or in the last position. This manipulation allowed us to assess whether the effect of recency is due to relative frequency of mismatching test–target card pairings over several (say four) preswitch trials, or just to the last preswitch trial.

The second issue addressed in Experiment 4 concerned the absolute number of mismatched test–target card pairings necessary to elicit NP. Previous research has shown that 3-year-olds perseverate on the standard DCCS even after only one preswitch trial (Zelazo et al., 1996). Similarly, research on task switching with adults has shown that even one presentation of a particular stimulus item can lead to interference on the alternate task (Waszak et al., 2003). In Experiment 4, NP versions with two and eight preswitch trials were administered to examine this issue. In both versions, 50% of the preswitch trials consisted of mismatching test–target card pairings. Thus, children in the NP version with two preswitch trials received only one mismatching test–target card pairing.

Thus, two variables were manipulated in Experiment 4: (a) the position of the last mismatching test–target card pairing during the preswitch phase and (b) the number of preswitch trials. Crossing these two variables resulted in four conditions: (a) frequent-and-last trial, (b) frequent-and-not-last trial, (c) infrequent-and-last trial, and (d) infrequent-and-not-last trial.

A third question we addressed in this experiment dealt with the effect of time on the persistence of perseveration. Research on task switching in adults has shown that task set persists over a number of trials (Allport & Wylie, 2000; Waszak et al., 2003). Allport and colleagues referred to this phenomenon as task set inertia and attributed it to the combined effects of NP of the current task and positive or "competitor priming" (i.e., positive priming) of the previously relevant but now irrelevant, competing task (Allport & Wylie, 2000; Waszak et al., 2003). To test the long-term effect of task set in preschoolers, we administered two postswitch phases: the first phase was administered immediately after the preswitch and the second phase was administered after a 10-min interval that was filled with unrelated activity.

Method

Participants. Sixty-four preschool children (33 boys and 31 girls) between the ages of 36 and 57 months were recruited from preschools in suburban Philadelphia and in Victoria. Sixteen children were randomly assigned to each of four conditions. The mean ages of children in each of these four conditions were as follows: frequent-and-last-trial mean age = 45.06, $SD = 6.58$; frequent-and-not-last-trial $M = 45.69$, $SD = 6.24$; infrequent-and-last-trial $M = 45.38$, $SD = 7.14$; infrequent-and-not-last-trial $M = 45.50$, $SD = 5.97$. One 41-month-old boy was dropped from the analysis because he did not pass the preswitch phase of the frequent-and-last-trial condition, and 2 boys (36 and 38 months old) were dropped because they refused to comply with the instructions of the experimenter.

Procedure. Each child was tested individually in the same manner as in Experiment 3. The dimension that was relevant in the preswitch phase (color or shape) was counterbalanced and crossed with sex. Half of the children received the shape rules first, and half received the color rules first.

Whereas children received eight preswitch trials in the frequent-and-last-trial and frequent-and-not-last-trial conditions, they received two preswitch trials in the infrequent-and-last-trial and infrequent-and-not-last-trial conditions. Furthermore, in the frequent-and-last-trial and infrequent-and-last-trial conditions, the last preswitch trial consisted of a mismatching test–target card pairing, and in the frequent-and-not-last-trial and infrequent-and-not-last-trial conditions, the second-to-last preswitch trial consisted of a mismatching test–target card pairing. In the frequent-and-last-trial condition, mismatching test–target card pairings were administered in the following order: mismatch (M), no mismatch (N), N, M, M, N, N, M. In the frequent-and-not-last-trial condition, the order was M, N, N, M, M, N, M, N. In order to control for the number of trials during which conflicting stimuli were presented, children did not receive any demonstration trials. Test and target cards used for Experiment 4 were the same as those used in the Recency-NP and Random-NP conditions in Experiment 3 (Figure 2a). Test cards used in the conditions with two preswitch trials were randomly selected, with the constraint that one test card mismatched the target cards on one dimension and the other test card did not mismatch the target cards.

In each condition, children received 16 postswitch trials and four knowledge questions. Eight of these postswitch trials were administered immediately after the preswitch phase. Next, the experimenter administered three unrelated memory tasks, and children played a puzzle. After 10 min had passed, the experimenter reintroduced the sorting trays and target cards, repeated the postswitch rules twice, and administered 8 additional postswitch trials. Finally, children received four knowledge questions (e.g., "Can you point and show me where the boats go in the shape game?"). Two questions pertained to each value of the relevant sorting dimension. Knowledge questions were asked to ensure that children were paying attention to the rules in the second postswitch phase. All children answered all four knowledge questions correctly.

Results

In the first postswitch phase, 77% (49 out of 64) of the children sorted either all eight cards or none of the cards correctly; in the second postswitch phase, 86% (55 out of 64) of the children sorted all eight or none of the cards correctly. For each postswitch phase, children who sorted seven or more cards correctly (out of eight) were classified as passing. Chi-square tests established that there were no significant effects for gender. However, children performed better in the first and second postswitch when shape was used as the preswitch dimension than when color was used as the preswitch dimension, $\chi^2(1, N = 64) = 6.35$, $p < .05$, and $\chi^2(1, N = 64) = 4.27$, $p < .05$. There was no effect of preswitch dimension in either Experiment 2 or Experiment 3, nor have these effects been discovered in other studies (Zelazo et al., 2003). A loglinear analysis showed that the interaction between dimension and condition did not account for any significant amount of variance in children's performance in either postswitch 1 or postswitch 2 (ps $< .40$). Because the

Table 2
Number of Children Passing and Failing the Different Versions of the DCCS in Experiment 4

	Pass	Fail
Postswitch 1		
FLT	6 (37)	10 (63)
FNLT	8 (50)	8 (50)
ILT	6 (37)	10 (63)
INLT	8 (50)	8 (50)
Postswitch 2		
FLT	10 (63)	6 (37)
FNLT	11 (69)	5 (31)
ILT	9 (56)	7 (44)
INLT	10 (63)	6 (37)

Note. Percentages in parentheses. FLT = frequent and last trial; FNLT = frequent and not last trial; ILT = infrequent and last trial; INLT = infrequent and not last trial. Passing = 7 or 8 postswitch sorts correct.

type of preswitch dimension did not interact with condition, we will not discuss this effect any further.

Table 2 shows the distribution of pass–fail performances in the first and second postswitch phases in the different conditions. There were no significant differences among conditions in either of the two postswitch phases, $\chi^2(3, N = 64) = 1.02$, $p < .79$, and $\chi^2(3, N = 64) = 0.53$, $p < .91$, respectively. Effect sizes were small ($\varphi = .13$ and .09, respectively). Next, we compared children's performance in conditions with frequent mismatching test–target card pairings (frequent-and-last-trial, frequent-and-not-last-trial) with their performance in conditions with infrequent mismatching test–target card pairings (infrequent-and-last-trial, infrequent-and-not-last-trial). There was no significant effect of frequency for either the first or the second postswitch, $ps < .60$ ($\varphi = .00$ for first postswitch, $\varphi = .07$ for second postswitch). Neither was there any significant effect of recency (frequent-and-last-trial and infrequent-and-last-trial vs. frequent-and-not-last-trial and infrequent-and-not-last-trial) for either the first or the second postswitch, $ps < .31$ ($\varphi = .13$ for first postswitch, $\varphi = .07$ for second postswitch).

To assess the relation between age and performance, data were pooled over conditions. Age was significantly correlated with performance on the first postswitch, $r(64) = .30$, $p < .05$, and the second postswitch, $r(64) = .35$, $p < .01$. To further examine age differences in different conditions, two age groups were created by using the median age to split the sample into a group of younger (<45 months) and older (45 months and older) participants. Two loglinear analyses were computed, with age group and condition as independent variables, and postswitch performance as the dependent variable. In the first analysis data were pooled for the two levels of frequency conditions, and in the second analyses data were pooled for the two types of last trial conditions. The loglinear analyses did not reveal significant effects for age group, condition, or the interaction between age group and condition.

Children performed significantly better during the second postswitch than during the first postswitch, McNemar ($N = 64$) $p < .001$ (binomial distribution used). However, the better performance in the second postswitch was largely carried by older children. Whereas 10 out of 17 (59%) older children (45 months and older) who had failed the first preswitch improved their performance from the first to the second postswitch, only 3 out of 17 (18%) younger children (<45 months) did so. McNemar tests showed that performance on the first and second postswitch did not significantly differ for younger children, $p < .25$ ($N = 34$; binomial distribution used), but performance on the first and second postswitch differed significantly for older children, $p < .01$ ($N = 30$; binomial distribution used).

Discussion

Experiment 4 produced three major findings. First, Experiment 4 showed that performance did not significantly differ depending on whether the mismatching test–target pairing was presented in the second-to-last or last preswitch trial. This finding suggests that the recency effect observed in Experiment 3 was due to the relative frequency of mismatching test–target card pairings over the last several preswitch trials, and not just whether the last preswitch trial was a conflict trial.

Second, there was no difference between NP versions with two and eight preswitch trials. Fifty percent (infrequent-and-not-last-trial) and 63% (infrequent-and-last-trial) of the children perseverated in the conditions with two preswitch trials, even though they received only one mismatching test–target card pairing. This finding addresses the question of whether absolute number of interference or relative frequency of interference affects NP. Specifically, this finding suggests that even a single exposure to a mismatching test–target card pairing is effective in triggering NP strong enough to impair postswitch performance.

The third finding was that task set survives a 10-min interval filled with unrelated activities. This finding mirrors the long-term effects of task set observed in the adult literature (e.g., Waszak et al., 2003), which also lasts several minutes. Consistent with previous findings (Zelazo et al., 2003), Experiment 4 showed that performance was significantly correlated with age: Older children performed significantly better on the first as well as on the second postswitch. Interestingly, older preschoolers also showed improved performance in the second postswitch phase relative to younger preschoolers. It is possible that task set inertia dissipates more quickly in older children. This explanation is consistent with the general developmental pattern that has been established for task set inertia (Cepeda, Kramer, & Gonzalez de Sather, 2001).

General Discussion

This study presents four experiments that examine NP and its development in young children. NP was assessed in the DCCS, where suppression of attention to the values of the preswitch dimension (NP) evidently affects children's ability to engage attention to and switch to sorting by these values in the postswitch phase. The experiments replicate the surprising difficulty that 3-year-olds have on the NP version. More importantly, Experiment 1 clearly established that performance on the N P version follows the same developmental pattern as performance on the standard version of the DCCS, suggesting that the NP effect seen in the DCCS actually decreases with age.

Experiments 2–4 addressed the circumstances in which NP occurs in 3-year-olds in this task, and the results raise a number of interesting questions for future research, while clarifying and sharply constraining the range of possible answers. These experiments clarify the effects of conflict, recency, and relative frequency on NP in the DCCS. Experiment 2 found that NP was only observed in a version of the DCCS where there was conflict between two possible ways of matching target and test cards during the preswitch phase. Experiment 2 therefore suggests that NP in the DCCS is a relational phenomenon that is only operative when children must actively select a pair of rules as opposed to a competing alternative. NP thus appears to reflect mechanisms that play an instrumental, inhibitory role in the selection of relevant rules in the presence of competing distractors. It is possible that in other tasks and/or at different ages NP may occur in the absence of conflicting information (see Milliken et al., 1998), but this does not appear to be the case for 3-year-olds in the DCCS.

Experiment 3 further explored the circumstances in which NP occurs, and found evidence that although the relative frequency over the entire preswitch phase did not affect the amount of NP observed during the postswitch phase, NP was greater when four conflict trials were presented immediately before the postswitch phase (Recency-NP) than when the same number of conflicting trials were randomly distributed across the preswitch phase (Random-NP). Reducing the total number of conflict trials (or total amount of interference) in itself does not appear to facilitate performance because in the Recency-NP version children received only half as many preswitch conflict trials as in the standard version, and yet performance between these versions did not significantly differ.

Experiment 4 showed that the effect of massed presentation of conflict trials observed in Experiment 3 was not affected by whether the very last preswitch trial was a conflict trial. Specifically, in Experiment 4, there was no effect of whether the most recent conflict trial occurred on the second-to-last preswitch trial or on the last preswitch trial. This finding suggests that it was the relative frequency of conflict trials during the last few preswitch trials that affected performance in Experiment 3.

Experiment 4 also showed that children performed as poorly on an NP version in which they received only one mismatching test–target card pairing as on a version in which they received four such pairings. This finding is consistent with previous empirical evidence that in the standard version of the DCCS, 3-year-olds are just as likely to perseverate after a single preswitch trial as after five (Zelazo et al., 1996), and it is consistent with evidence that the presentation of a single instance of interference leads to performance costs in task switching in adults (Waszak et al., 2003). This finding again suggests that NP in the DCCS is not affected by the absolute number of conflict trials, but rather by the relative frequency of these trials. Furthermore, consistent with findings from the adult literature (Waszak et al., 2003), Experiment 4 established that the task set induced by the DCCS lasts for at least several minutes, but that task set inertia dissipates more quickly for older than for younger preschoolers.

An alternative characterization of the findings generated by the different versions of the DCCS is that children perform better on versions that reduce the similarity between (a) the test and/or target cards used in the preswitch phase and (b) the test and/or target cards used in the postswitch phase. Such a characterization would be consistent with the finding that the ANP version was easier than the NP version (Experiment 2). It is also consistent with the finding that children perform better on the partial change version than on the standard version of the DCCS (Zelazo et al., 2003). However, this characterization is not consistent with the finding that the NP version is at least as difficult as the standard version (Zelazo et al., 2003), even though the test and target cards are changed in the NP version but not in the standard version. This characterization also does not account for the recency effects observed in Experiment 3. Finally, even if this similarity characterization were correct, it does not identify the cognitive processes that account for the similarity effect, and eventually such an account may be required to draw on concepts such as NP to account for the pattern of findings generated with the DCCS.

Taken together with the previous finding that many 3-year-olds perseverate on the partial change version of the DCCS (Zelazo et al., 2003, Experiments 6 and 7), these findings suggest that performance in the DCCS involves the dynamic interplay of activation and inhibition of rules, and a corresponding activation and inhibition of attention to values of a particular dimension. Consistent with CCC-r, the activation and inhibition of rules/values affect the likelihood that children will sort flexibly in the DCCS. Increases in the ability to activate and inhibit rules/values deliberately may underlie age-related changes in performance on the DCCS and other measures of EF. Thus, on this account, during the pre-switch phase, the preswitch rules/values are selected (and hence activated), but because they are selected instead of competing values of the irrelevant dimension, these competing values are suppressed. For example, based on the experimenter's instructions, children may activate shape rules/values and inhibit attention to the competing values of the color dimension. This has the consequence that during the postswitch phase the activation levels of the shape rules/values are increased whereas the activation levels of values of the color dimension are inhibited. Performance during the postswitch phase requires that children overcome the inhibition of the values of the formerly irrelevant color dimension and, at the same time, deactivate the formerly activated shape rules. On this account, 3-year-old children fail the DCCS because they have difficulty deliberately modulating the activation values of both the relevant and irrelevant values. According to CCC-r theory, children ultimately pass the DCCS because they become better able to reflect on and distance themselves from the preswitch rules. As a consequence, children become better able to formulate and use a higher order rule that allows them consciously to contrast pre- and postswitch rules and to control their behavior in a relatively top-down fashion, so that this behavior is not entirely determined by the dynamic interplay of the relative activation levels of pre- and postswitch rules (Zelazo et al., 2003).

As noted by Zelazo et al. (2003), this account points to a reconceptualization of the concept of NP and its development. NP is often conceptualized as evidence of a developing inhibitory ability that allows successful selective attention (e.g., Houdé & Guichart, 2001; Perret et al., 2003), and it is assumed that NP will increase with age. However, the finding that children have problems engaging attention to the values of a previously irrelevant dimension suggests that the inhibition resulting in NP may also be a problem to be overcome in the course of development. This finding is not accounted for by theories that explain failure in the DCCS by drawing on deficits in response inhibition (Towse, Redbond, Houston-Price, & Cook, 2000) or conceptual inhibition (Kirkham et al., 2003).

The present experiments also raise a number of questions that should be addressed by future studies. Experiment 1 demonstrated that the performance on the NP version improved significantly with age. CCC-r theory attributes this progress to the emergence of a higher order rule. According to CCC-r theory, older children perform better on this task because they can process information more flexibly according to a higher order rule, and consequently are better able to override NP and activate resources that allow them to engage attention to the values of the irrelevant dimension. However, it is also possible that task dynamics and rule use interact with each other. The results from Experiment 4 indicate that task set inertia dissipates more quickly in older preschoolers than in younger preschoolers. The more rapid dissipation of task set inertia, in turn, may set the stage for the construction of more complex rules. Future research should examine these possibilities by, for example, using new methodologies (e.g., Amso & Johnson, 2005; Bub, Masson, & Lalonde, 2005) and training studies (e.g., providing children with override opportunities by presenting the ignored stimulus itself as a target during an interval; see Tipper, Weaver, Cameron, Brehaut, & Bastedo, 1991; Waszak et al., 2003).

Another question that needs to be addressed concerns the relations between NP and other types of inhibition. For example, it has been suggested (Nigg, 2000) that NP is a process that occurs automatically in the context of selective attention, but that other types of inhibition, such as cognitive inhibition (as might be involved in disengaging attention from the preswitch dimension in the DCCS), are more deliberate and effortful. The question of whether NP is a unitary process or whether different mechanisms underlie NP in different EF tasks and at different ages certainly warrants further investigation.

In conclusion, the present findings have broad implications for theories of the development of EF. First, they reinforce the suggestion that it is necessary to reconceptualize the difficulties children encounter in the process of selective attention. Selective attention is a dynamic, two-way process that involves both inhibition and activation (Houghton & Tipper, 1994). Children's failures in EF tasks are often attributed to the inability to inhibit attention to previously relevant stimuli (Kirkham et al., 2003; Luria, 1961; Perner, Stummer, & Lang, 1999; White, 1965). However, the present experiments suggest that children have just as much difficulty engaging attention to something they have previously ignored. The ability to overcome NP is a developmental achievement that deserves to be explored more fully. Second, the findings from the NP version of the DCCS raise the possibility that engaging attention to something previously ignored is part of the problem children experience in other EF tasks. This possibility also needs to be addressed by future research. Third, the findings highlight the importance of conflict and recency of conflicting information on eliciting NP. Future research with other measures of EF might usefully be conducted to examine how conflict and recency of conflicting information affect children's ability to activate responses to stimuli that they previously ignored. Finally, the study demonstrates the utility of an experimental approach to examining the development of EF. Many studies of EF in children rely on batteries of complex EF tasks (e.g., Brocki & Bohlin, 2004; Hughes, 1998; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Welsh, Pennington, & Groisser, 1991). Although this approach has undoubtedly yielded important findings, it generally does not allow researchers to determine precisely the specific executive processes underlying task performance. As a result, an experimental approach is in a better position to test more precisely predictions made by different theoretical models. For these reasons, studies relying on batteries of EF tasks need to be complemented by an experimental approach as applied in this study.

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