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Sources of Cognitive Inflexibility in Set-Shifting Tasks: Insights Into Developmental Theories From Adult Data

Anthony Steven Dick
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Two experiments examined processes underlying cognitive inflexibility in set-shifting tasks typically used to assess the development of executive function in children. Adult participants performed a Flexible Item Selection Task (FIST) that requires shifting from categorizing by one dimension (e.g., color) to categorizing by a second orthogonal dimension (e.g., shape). The experiments showed performance of the FIST involves suppression of the representation of the ignored dimension; response times for selecting a target object in an oddity task immediately following were slower when the oddity target was the previously ignored stimulus of the FIST. However, proactive interference from the previously relevant stimulus dimension also impaired responding. The results are discussed with respect to two prominent theories of the source of difficulty for children and adults on dimensional shifting tasks: *attentional inertia* and *negative priming*. In contrast to prior work emphasizing one process over the other, the findings indicate that difficulty in the FIST, and by extension other set-shifting tasks, can be attributed to *both* the need to shift away from the previously attended representation (*attentional inertia*) and the need to shift to the previously ignored representation (*negative priming*). Results are discussed in relation to theoretical explanations for cognitive inflexibility in adults and children.

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Set-shifting tasks are commonly used to index the development of cognitive flexibility in preschoolers (see Cragg & Chevalier, in press, for review). In one variant, the Dimensional Change Card Sort (DCCS), children are explicitly told to sort test cards (e.g., blue bowls and red baskets) to target cards (e.g., blue baskets and red bowls) by one dimension (e.g., color) and then after a few trials switch to sort these same cards by another dimension (e.g., shape; Frye, Zelazo, & Palfai, 1995; Zelazo, 2006; Zelazo, Müller, Frye, & Marcovitch, 2003). Importantly, there is a high degree of conflict such that each test card can be matched to the target cards by two opposing dimensions. Even though preschoolers correctly answer questions about the rules of the task and sort correctly by the initial rule, they err by continuing to sort on the initial dimension after the rule change. Older preschoolers and adults are able to shift successfully to sort by the new rule. Another set-shifting task variant, the Flexible Item Selection Task (FIST; Jacques & Zelazo, 2001), is also a challenge for preschoolers and younger school-aged children (Dick, 2006; Jacques & Zelazo, 2001). This task is similar to the DCCS but has an additional challenge in that children are not explicitly told the sorting rule but instead must generate it from the visual display. As opposed to the DCCS, which demands explicit rule following, the FIST further demands inductive inferences (Blaye & Jacques, 2009; Jacques & Zelazo, 2005). Yet, both tasks demand cognitive flexibility, which is the focus of the present study. Specifically, of issue in the present investigation are two theoretical accounts—attentional inertia and negative priming—for the *source* of difficulty on these seemingly simple set-shifting tasks. The present study uses as a point of departure a finding by Diamond and Kirkham (2005) reporting that adults show a switch cost (i.e., slowed response time [RT]; Monsell, 2003; Wylie & Allport, 2000) on a simple variant of the DCCS. They argued that both adults and children demonstrate “attentional inertia” in set-shifting tasks. On this account, people have difficulty shifting *away* from, or redirecting, preinstantiated mind sets. That is, adults and children lack the ability to redirect focus on previously relevant features of the object (e.g., the redness of the bowl) in cases when these become irrelevant (e.g., thinking of the shape of the bowl). Further, it is the development of top-down processes of inhibition that allow successful task switching (Diamond, Carlson, & Beck, 2005; Diamond & Kirkham, 2005; Kirkham, Cruess, & Diamond, 2003).

There is, however, a different explanation: Adults and children may not be demonstrating a tendency to continue what they were doing (inertia) but instead may have difficulty returning to a dimension that was previously suppressed, a possibility that forms part of a negative priming interpretation (Müller, Dick, Gela, Overton, & Zelazo, 2006; Zelazo et al., 2003). In the visual attention literature, negative priming refers to the finding that when a distractor object is ignored on one trial (the prime trial), responses to this object on the subsequent trial (the probe trial) are impaired relative to a neutral control stimulus (Fox, 1995; May, Kane, & Hasher, 1995; Neill, 1977; Tipper, 1985). When applied to set-shifting tasks such as the DCCS or the FIST, a negative priming interpretation suggests a bottom-up process of interference in which the problem is one of engaging attention *to* the formerly irrelevant dimension or stimulus value. Thus, children and adults show a switch cost because they have difficulty returning to what had previously been the distractor (e.g., the basket or bowl when color is relevant) when it becomes the target on the switch trial (e.g., the basket or bowl when shape is relevant). This interpretation is quite different from the inertia account because it argues that the source of difficulty is not in suppressing a now-irrelevant rule or association but in returning to (or reinstantiating) a previously ignored rule or association. The implication, then, is that past representations are actively ignored rather than simply discarded and as a result directly affect the present problem-solving situation.

Developmental studies of the DCCS have been designed to adjudicate between these two theories. For example, in support of attentional inertia, Diamond and colleagues (2005; Kirkham et al., 2003) showed that manipulations that increase the saliency of the previously relevant stimulus features impair performance (e.g., leaving the test cards face up in the sorting box), while those that decrease the saliency of the previously relevant dimension improve performance (e.g., allowing the child to verbally label the relevant dimension following the rule switch, removing the target cards or replacing them with target puppets, hiding test cards in a sleeve, or physically separating the features of the test card; Kloo & Perner, 2005; Kray, Kipp, & Karbach, 2009; Perner & Lang, 2002; Towse, Redbond, Houston-Price, & Cook, 2000; see Müller, Zelazo, Lurye, & Liebermann, 2008, and Yerys & Munakata, 2006, for findings where labeling either fails to improve or negatively impacts performance). Three-year-old children also have difficulty on a *Partial Change* version of the DCCS, in which only relevant values of the preswitch phase are retained during the postswitch, but the majority of 3-year-olds pass a *Total Change* version, in which the values of both preswitch dimensions are changed (Zelazo et al., 2003). These findings together provide support for the idea that difficulty in the DCCS stems from the need to shift away from previously relevant aspects of the task situation. However, there is also evidence in support of negative priming at the stimulus level. Zelazo, Müller, and colleagues (Müller et al., 2006; Zelazo et al., 2003) found that children still have difficulty even when the previously relevant values are removed in the postswitch so that it is impossible to direct attention to them (i.e., in this *Negative Priming* version, children sort red and blue boats and rabbits by color in the preswitch phase, and then sort green and yellow boats and rabbits by shape in the postswitch phase). Notably, this only occurs in cases where conflict between the stimulus values is present in the preswitch or prime phase (Malley & Strayer, 1995; Müller et al., 2006, Experiment 2). Similar experiments by Chevalier and Blaye (2008) using a novel task-switch paradigm with 3-year-olds have also pointed to difficulty in activating the previously ignored representation.

Although compelling, these developmental findings are theoretically inconclusive: The findings are consistent with both attentional inertia and negative priming, and they are consistent with a third possibility that accepts both explanations, on which difficulty in these tasks might in some cases be codetermined by the need to *both* a) shift away from previously relevant representations and b) shift to previously ignored representations. Indeed, it is hard to find convincing evidence that one *or* the other process is at work because in all aforementioned studies, the task design confounds both possibilities. In the standard task-switching manipulations, children almost always either succeed or fail to shift dimensions, and thus, it is impossible to simultaneously investigate the contribution of the two opposing processes in cases where both processes could be taking place. To illustrate, the fact that children fail the *Negative Priming* version of the DCCS supports negative priming but does not preclude the possibility that attention to the previously relevant dimension is also a source of difficulty when the standard version is used. Similarly, verbal labeling of the relevant dimension, in addition to reducing inertia, could also help in shifting to the previously irrelevant dimension.

To summarize, the central question, for the two experiments to be reported here, is to what extent the difficulty in cognitive flexibility tasks can be attributed to the failure to suppress the previously relevant stimulus, to failed activation of previously ignored information, or to both. We also assessed a corollary issue: whether negative priming occurs at the level of the stimulus values or at the level of the dimension. It is necessary to understand the sources of cognitive inflexibility, but absent in the literature is a developmentally relevant paradigm that can reveal the cognitive processes occurring during task switching. In this article, we developed a novel paradigm to overcome the limitations of prior developmental investigations. This choice RT paradigm measures response latency in a more sensitive parametric manner, and it includes a neutral control condition as a comparison. We start here with adults because they represent the end state of the target competence, and we can take advantage of the sensitivity of RT measures to investigate this competence. We also aimed to investigate other task-switching methodologies, as the majority of work in this area has concentrated on DCCS performance and this task is only effective for assessing executive function development in the preschool period. As a consequence, we focused on the FIST because it has been shown to be valuable for assessing the development of cognitive flexibility across a more expansive age range using a single task methodology, from preschool (Jacques & Zelazo, 2001) through early-to-middle childhood (Dick, 2006). However, it is somewhat limited in explanatory value because no research to date has investigated factors that make the FIST difficult for children. The findings we present provide insight into the cognitive processes necessary for success or failure on these tasks, and at the same time, they establish a novel method for investigating sources of cognitive inflexibility in set-shifting tasks appropriate for use in children.

PARADIGM AND SUMMARY OF EXPERIMENTS

To investigate processes underlying cognitive flexibility in dimensional shifting tasks, we chose to develop and validate a novel task paradigm beginning first with adult participants. Adults were tested on two tasks: the FIST (Jacques & Zelazo, 2001) and a dimension abstracted oddity task (Chalmers & Halford, 2003). Recall that in the FIST, participants typically make one selection about which objects match (i.e., they choose from three pictures those two matching on a dimension, for example, color), and then shift to make a second selection, which applies to the same stimuli but while focusing on a different dimension. In the present study, participants were only required to make the first selection. We then assessed the effect of the task by immediately following the FIST selection with an oddity task. In the oddity task, participants were presented with four objects, and they determined the ‘‘odd’’ object that did not match the other three objects on a dimension. In this oddity trial, a single stimulus unequivocally served as the target on the switch trial, negating the possibility of making the same selection on the FIST trial if that trial had been repeated.

The principle, then, was to use the RT measure in the oddity task as an index for processes occurring during FIST selection. The key manipulation was how the target in the oddity trial related to the preceding FIST trial features in terms of the selected dimension and stimulus values. Thus, referring to Figure 1A, if on the FIST trial, the participant selects the two stimuli as matching based on color rather than shape, they are assumed to be ‘‘set’’ to color *and* to have suppressed shape. We assume the constant or nonvariable dimension (e.g., size) is neither attended nor suppressed.

Several reasons motivated the use of the FIST and oddity tasks in lieu of a task such as the DCCS, which was successfully used with adults by Diamond and Kirkham (2005): 1) To eliminate any biasing effects of overt language and to eliminate any memory load to remember the cued dimension, the participant is free to choose the matching dimension; 2) both tasks share several properties with the DCCS and other set-shifting tasks commonly used

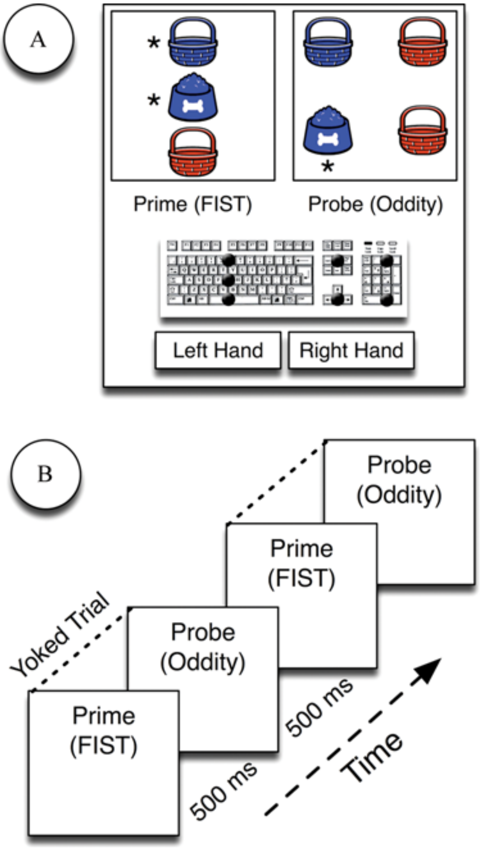

FIGURE 1 Illustration of the paradigm. A) On a computer screen, a FIST trial was presented requiring participants to choose two objects *that match in a way that is not like the third object*. Immediately following the selection, an oddity trial was presented requiring participants to select the odd object (three objects match on a single dimension, while the fourth "odd" object does not match on that dimension). Asterisks denote selections. Participants responded using buttons attached to a standard keyboard that corresponded spatially to the objects on the screen. B) Yoked prime-probe trials were presented with a 500-ms response-stimulus interval. (Color figure available online.)

to assess the development of cognitive flexibility—in particular a high degree of conflict exists between the dimension deemed to be relevant and that deemed to be irrelevant; and 3) finally, as noted above, very little developmental research has investigated the sources of cognitive inflexibility on set-shifting tasks other than the DCCS. The same general design was followed for both Experiments 1 and 2. Adult participants were presented with a FIST trial (i.e., the *prime*), followed by an oddity problem (i.e., the *probe*). This yoked FIST-oddity pairing repeated for 175 trials (Figure 1B). Five FIST-oddity conditions were presented in which the primary manipulation was the relation between each yoked FIST-oddity pair. In what follows, "dimension" denotes the category (e.g., color, shape, size) and "stimulus value" denotes the specific value (e.g., blue, basket, small). Prime target refers to the selected category of the prime, and prime distractor refers to the ignored category. Probe target refers to the category of the odd object of the oddity trial.

EXPERIMENT 1

Experiment 1 used five conditions to investigate processes contributing to difficulty in task switching. All of the specific examples reference Figure 2. The conditions were:

1. *Neutral Control (NC)*: The prime target (color) was *unrelated* to the probe target (size), and none of the prime stimulus values were used during the probe.
2. *Attended Repetition (AR)*: The prime *target* (color) was also the probe target (color), and all stimulus values from the prime were used in the probe.
3. *Ignored Repetition (IR)*: The prime *distractor* (shape) was the probe target (shape), and all stimulus values from the prime were used in the probe.
4. *Total Change (TC)*: As in *NC*, none of the prime stimulus values were used during the probe, but both dimensions (color and shape) that varied on the prime also varied during the probe. As in *IR*, the prime distractor was the probe target.
5. *Negative Priming (NP)*: The prime target stimulus values (red and blue) were removed during the probe, but the stimulus values for the prime distractor (basket and bowl) were repeated in the probe. As in both *IR* and *TC*, the prime distractor (shape) was the probe target. The *TC* and *NP* conditions were based on two DCCS manipulations of the same name (Zelazo et al., 2003).

Support for attentional inertia as an alternative to negative priming would be provided if the *AR* condition revealed a facilitation effect. For *AR*, the oddity target is consistent with the FIST "mind set." Thus, although the attentional inertia theory as currently developed in the literature only specifies conditions that impair responding, a prediction that RT will be faster relative to a neutral stimulus ($AR < NC$) would be consistent with the theory.

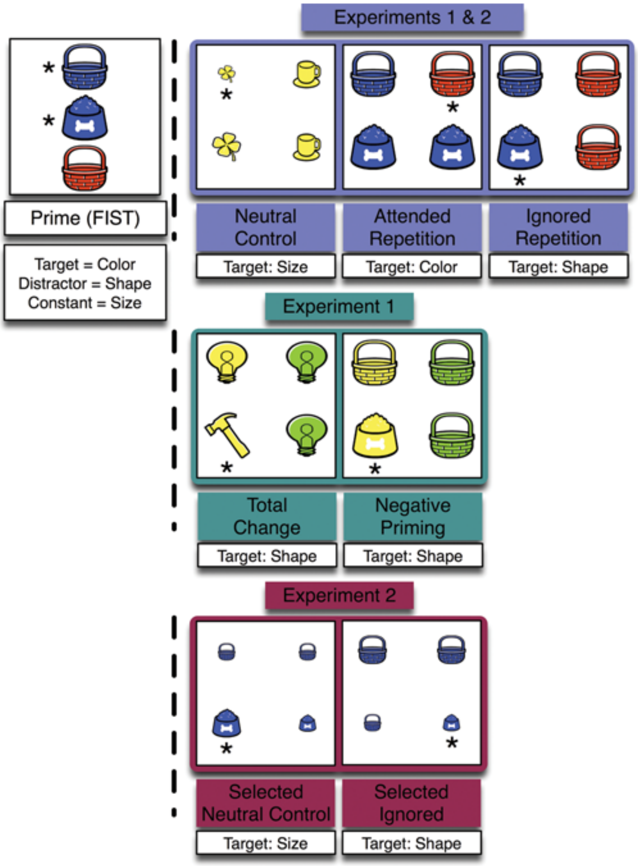

FIGURE 2 Sample stimuli are given for all conditions. To facilitate comparison across conditions, Screen 2 examples are all related to the same example FIST trial in which color (blue) is the selected dimension or target and shape (basket) is the irrelevant dimension or distractor. The odd dimensions for the oddity trials are: *Neutral Control* (NC; size), *Attended Repetition* (AR; color), *Ignored Repetition* (IR; shape), *Total Change* (TC; shape), *Negative Priming* (NP; shape), *Selected Neutral Control* (SNC; size), and *Selected Ignored* (SI; shape). (Color figure available online.)

Alternatively, support for negative priming would be provided if the oddity response in the *NP* condition was slower than in the *TC* condition. This is because specific values of the distractor dimension are maintained in *NP* but not *TC*; these values will be negatively primed, and RT will be slowed ($NP > TC$). This prediction is inconsistent with attentional inertia because relevant values of the preshift dimension (e.g., red and blue) cannot interfere with responding if they are removed in the *NP* oddity trial. Thus, attentional inertia predicts $NP = TC$.

Finally, two additional comparisons provide information about processes at work during FIST selection. The first assesses whether interference during the probe might stem from both the prime distractor and prime target values. In *IR*, both the prime distractor and prime target values are repeated, while *NP* only repeats the prime distractor stimulus values. If both the previously relevant and previously irrelevant stimulus values contribute to impaired responding, then *IR* should be slower than *NP* ($IR > NP$). If there is no difference, this would suggest that shifting attention to the prime distractor values (negative priming) contributes to impaired responding more than shifting attention away from the prime target values (attentional inertia).

The final comparison speaks to an issue that has been difficult to assess in previous developmental investigations. The issue is whether negative priming occurs at the level of task set or dimension (e.g., color) or at the level of individual stimulus values (e.g., red). Comparing the *NC* and *TC* conditions can assess this. If there is negative priming of the distractor task set (e.g., suppression of "categorize by shape" when "categorize by color" is the relevant task set), then when all stimulus values are removed during the probe, it should be easier to shift to a neutral dimension (as in *NC*) than to a dimension in which the prime distractor dimension is the probe target dimension (as in *TC*; i.e., $NC < TC$). If there were no difference ($NC = TC$), this would provide some suggestion that negative priming, if it occurs at all, does not occur at the level of the task set.

Method and Design

Participants. Participants were 24 Temple University adult undergraduate students (9 males, $M = 19;0$, $SD = 15.91$ months). Two additional participants were not analyzed due to equipment error. The Temple University Institutional Review Board approved the study. All participants provided informed consent and were debriefed.

Materials and task design. Stimuli were presented on a PC using Presentation® (Neurobehavioral Systems). Response buttons were attached to a standard keyboard and corresponded spatially to the objects on screen (inset Figure 1A). FIST-oddity trials were constructed using the following stimulus attributes: a) *shape*: bag, basket, dog bowl, light bulb, clover, coffee mug, hammer, pig, pin, and scissors; b) *color*: red, orange, yellow, green, blue, and purple; c) *size*: large (160^2 pixels), medium (80^2 pixels), and small (40^2 pixels). Pilot testing revealed that sizes were easily distinguishable, but orange and red were difficult to distinguish quickly and thus were never paired together. Although *NP* and *TC* utilized the same stimuli as the other conditions, size only had three stimulus values and could not be used as a varying stimulus on the *TC* condition. Thus, for *NP* and *TC* only, color and shape, but not size, were potential matching dimensions.

There were 175 paired prime-probe trials. The first 25 trials (5 trials for each condition) were designated practice trials to allow participants to perform at a steady state level, leaving 30 test trials available for analysis from each condition. The probe (oddity) followed the prime (FIST) with a response-stimulus interval (RSI) of 500 ms (Figure 1B). Prime-probe pairs were prespecified for all possible selections, but the presentation of the probe stimulus was determined conjointly by both the participant's prime response and by the condition. For example, in a prerandomized fashion, the program determined the order of the presentation of conditions. Then, if the trial was an *IR* trial with shape and color as possible FIST selections, the program prepared two oddity trials but determined which one of these two oddity trials to present based on the participant's FIST selection. The order of conditions and pairing of dimensions (shape, color, size) were prerandomized across trials, and order of presentation was identical across participants.

Procedure. The design was a within-subjects design. All participants were given a demonstration in which they were told that there were two screens to be presented consecutively and that the response buttons corresponded to each of these screens. For FIST trials, participants were instructed to choose two objects *that match in a way that is not like the third object*, and it was explained that there were only two possible ways for this to occur. They were also shown that there was an incorrect way to respond (i.e., objects could be matched on the constant dimension—e.g., size, when all objects are the same size—but this violated the matching rule). The program provided feedback ("Correct!" or "Incorrect!" when subjects matched on the constant dimension), and asterisks were placed on screen next to the selected objects when the buttons were pressed. The oddity trial only appeared following correct FIST responses. Incorrect FIST responses occurred very infrequently, but when they did, the screen reset and participants were allowed to respond correctly before moving onto the oddity trial.

In the demonstration, the experimenter used the FIST response buttons to indicate one of the two possible choices, at which point the oddity task appeared. For oddity, the participant saw four objects and was told that three of the objects shared some attribute that the other did not share. This fourth object was the odd object to be selected. The demonstration continued for five trials, and participants were told to respond as quickly and as accurately as possible, that mistakes were okay and to continue on to the next trial. Because participants were to respond quickly, they kept their hands above the keyboard throughout the experiment. Participants responded to the prime trial pressing buttons sequentially (to select the two matching objects) with their finger of choice. No feedback was given for the oddity task. In summary, a complete test trial was as follows: a) For the prime, a FIST trial was presented, and the participant selected two matching objects; b) 500 ms RSI; c) for the probe, an oddity trial was presented, and the participant selected the odd object; d) 500 ms RSI until the next trial (Figure 1B).

Results and Discussion

After removing practice trials, there were 30 trials available for analysis in each condition. We first analyzed error rates. Incorrect responses (i.e., participants picked a non-odd object during the probe) accounted for about 4% of test trials. There were significant differences in error rates among the conditions (Friedman's $\chi^2_{df=4} = 23.7$, $p < .001$). Post-hoc Wilcoxon signed-rank tests revealed that significantly more errors occurred in the *NC* condition compared with all other conditions (corrected for multiple comparisons using the false discovery rate [FDR] procedure, $i = 5$, $q^* = .05$; Benjamini & Hochberg, 1995; largest value of corrected results, $p < .007$). Error rates were low. Means (and standard deviations) for each condition were as follows: $NC = 2.04$ (1.12); $AR = 1.13$ (0.99); $IR = 1.04$ (1.08); $TC = 0.92$ (1.01); and $NP = 0.67$ (0.96). The effect sizes were small (out of 30 trials, the *NC* condition elicited, on average, one more error than the other conditions; probability of superiority values for significant differences ranged from .58 to .70, with .50 indicating no difference; Sheskin, 2007). Because the *NC* condition elicited fast RTs, this possibly reflects a speed–accuracy trade-off (i.e., the phenomenon that faster responses tend to produce more errors; Liu & Smith, 2009; Miller, Sproesser, & Ulrich, 2008; Thorpe, Fize, & Marlot, 1996). Notably, though, errors on the *TC* condition were not different from the other conditions, and this condition was comparable to the *NC* condition in that it also elicited fast RTs. Therefore, evidence for a speed–accuracy trade-off is equivocal. When errors are infrequent, as they are here, they are often removed from the analysis of RT data (Ratcliff, 1993). Thus, in the subsequent analysis, we focus on correct responses and delay discussion of the results of the analysis of error rates, and potential explanations for the condition differences, for the General Discussion.

For the valid RTs (i.e., correct responses), all responses with latency more than 2.5 standard deviations from the condition mean (about 3% of test trials) were excluded. The remaining oddity RTs were averaged for each condition, and these served as the dependent variable. We first assessed interactions with repeated-measures condition (5) × sex (2) analyses of variance (ANOVAs), which revealed no significant effect of sex ($p = .37$, $\eta_p^2 = .04$)

and no significant condition × sex interaction ($p = .13$, $\eta_p^2 = .08$). We next proceeded to examine four planned nonorthogonal repeated-measures contrasts (Rosenthal, Rosnow, & Rubin, 2000) focused on specific hypotheses: 1) $AR < NC$ predicted by attentional inertia; 2) $NP > TC$ predicted by negative priming; 3) $IR > NP$ assessing the contribution of both negative priming and attentional inertia; and 4) $TC \neq NC$, assessing whether negative priming occurs at the level of stimulus dimension. A fifth comparison, $IR > NC$, was also tested, but the results are not informative with respect to adjudicating between the two competing theories (i.e., due to the similarity of *IR* to the standard FIST and DCCS tasks, both negative priming and attentional inertia would predict longer RT during the *IR* condition). The results of this comparison are, however, generally informative, and we report them as a validation of the method. All significant contrasts survived a correction for multiple comparisons using the FDR procedure ($i = 5$; $q^* = .05$). With the exception of $TC \neq NC$, hypothesis tests were directional.

Results of the comparisons are reported in Figure 3A. First, two findings supported the negative priming hypothesis; RTs were slower for the conditions in which the distractor became the target: a) $IR > NC$, $t(22) = 5.12$, $p < .001$, $d = .59$[1]; b) $NP > TC$, $t(22) = 4.04$, $p < .001$, $d = .64$. Most importantly, the result $NP > TC$ would not be predicted by attentional inertia because the prime target stimulus values are removed, yet negative priming would predict this result because the prime distractor becomes the probe target.

Second, the results of the contrast comparing $AR < NC$ failed to support attentional inertia as an alternative to negative priming. There was no facilitation effect; participants were actually slightly *slower* in *AR* than in the *NC*, although this difference was not significant, $t(22) = -1.63$, $p > .05$ (two-tailed, opposite the expected direction), $d = .17$. This is an unexpected finding, according to attentional inertia, because repetition of the prime target dimension (i.e., the maintenance of the previously relevant "mind set" during the probe trial) should have facilitated performance relative to a neutral condition.

The comparison $IR > NP$ was significant, $t(22) = 2.33$, $p < .05$, $d = .20$, suggesting that both the previously relevant and previously irrelevant stimulus values contribute to impaired responding during the probe trial. That is, while *NP* only contributes interference from the prime distractor, *IR* contributes interference from both the prime distractor and the prime target, rendering the *IR* condition more difficult. This result actually suggests both attentional inertia and negative priming contribute to impaired responding.

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[1] All Cohen's *d* effect sizes were calculated using the pooled standard deviation of the conditions (Dunlap, Cortina, Vaslow, & Burke, 1996).

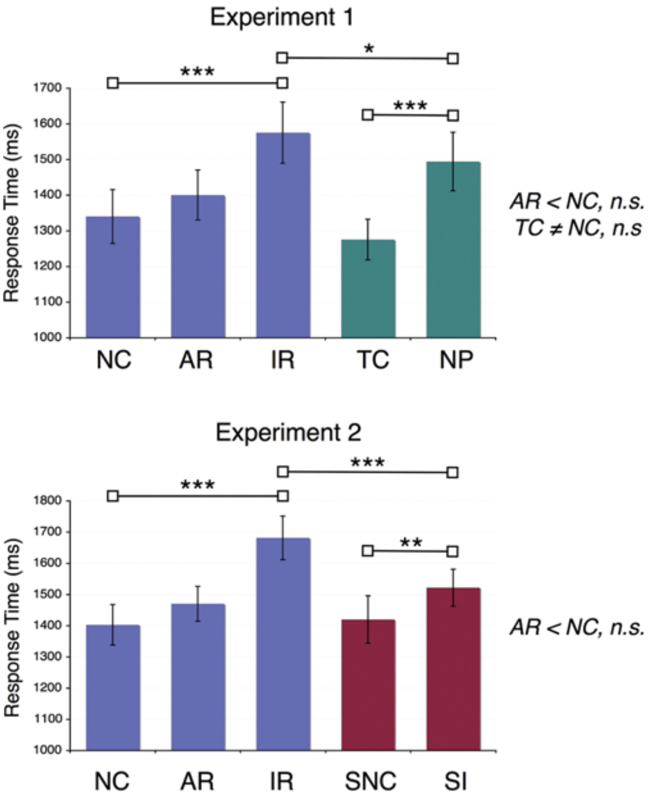

FIGURE 3 Mean response time to select the odd object for each condition for both Experiment 1 (top) and Experiment 2 (bottom). Nonsignificant comparisons are reported to the right of each figure. *n.s.* = nonsignificant. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$. Error bars represent ± one standard error. (Color figure available online.)

Finally, we found *TC* was not significantly different from *NC*, $t(22) = -1.15$, $p > .05$, $d = .20$. In both cases, the prime target and distractor values are removed, but in *TC*, the prime distractor dimension becomes the probe target. This was, however, not sufficient to impair responding relative to a neutral stimulus, suggesting that negative priming does not occur at the level of the dimension.

EXPERIMENT 2

The absence of facilitation in the *AR* condition was surprising and might suggest that attentional inertia does not play a role in task switching during the FIST. This finding, however, is open to an alternative explanation. Evidence from the adult task-switching literature suggests that stimulus values that form an association with one task might then cause interference when these stimulus values are used with another task (Allport, Styles, & Hsieh, 1994; Allport & Wylie, 1999, 2000). In this case, it is possible that repeating the stimulus values during the probe could have helped maintain activation of the prime distractor, causing interference during the probe task and leading to *slowed* responding when the same stimulus values are re-presented. In the same fashion, repeated stimulus values could have maintained activation of the prime target dimension leading to facilitation (as predicted by attentional inertia), which might offset the interference from the distractor. Thus, one might predict no difference ($AR = NC$) due to the offsetting contributions of the target and distractor task pairings. This would indicate that both attentional inertia and negative priming contribute to difficulty in task switching. Another finding from Experiment 1 also supports this possibility: *IR* (which contains both the prime target and distractor values) was more difficult than *NP* (which contains only the distractor values).

In Experiment 2, we had two goals. First, we wanted to rule out the possibility that the slightly slower responding in the *AR* condition relative to *NC* was a spurious finding, and thus, we conducted a replication of the *NC, AR*, and *IR* conditions on a new sample of participants. Second, we wanted to investigate further the role of negative priming and the conditions under which negative priming occurs. In Experiment 1, we found no negative priming at the level of the task set (or dimension), and we wanted to determine if varying just one of the prime stimulus dimensions (in this case the prime distractor dimension) is sufficient to instantiate negative priming. To this end, we created two new conditions to assess the effect of holding constant the selected stimulus dimension of the prime on probe target selection when the probe target is a) neutral with respect to the prime, or b) when the probe target is the distractor dimension of the prime. The two new conditions replaced *TC* and *NP* (from Experiment 1) and were:

1. *Selected Neutral Control (SNC)*: The prime target dimension (color) did not vary during the probe, and as in *NC*, the prime target (color) was *unrelated* to the probe target (size). The prime constant dimension (size) was the probe target.
2. *Selected Ignored (SI)*: The prime target dimension (color) did not vary during the probe, and as in *IR*, the prime *distractor* (shape) was the probe target (shape). The prime constant dimension (size) was the probe distractor.

In both conditions, the stimuli of the oddity trial did not vary on the prime target dimension (i.e., on the previous "mind set," reds and blues).

Attentional inertia would predict the conditions should not differ. Whereas attentional inertia is silent with respect to the effect of the previously irrelevant dimension and stimulus values on current selection, negative priming predicts that RT is slower when the distractor becomes the target. Negative priming, therefore, would predict a slowed response in the *SI* condition ($SI > SNC$).

It is also informative to investigate the difference between *IR* and *SI*. Similar to the comparison of *IR* and *NP* reported earlier, the comparison of $IR > SI$ tells us whether there is additional interference from the previously relevant stimuli. Again, in *IR*, interference during the probe potentially stems from both the prime distractor and prime target stimulus values. *SI* only varies the prime distractor stimulus values. Thus, if both the previously relevant and previously irrelevant stimulus values contribute to impaired responding, then *IR* should be slower than *SI* ($IR > SI$). As with the comparison $IR > NP$, if there was no difference, this would suggest greater interference from the prime distractor values (negative priming) than from the prime target values (attentional inertia).

Method and Design

Participants. Participants were 30 Temple University adult undergraduate students (17 males, $M = 19;1$, $SD = 13.35$ months). Three additional participants were removed due to equipment error. The Temple University Institutional Review Board approved the study. All participants provided informed consent and were debriefed.

Materials and task design. Participants were tested in the same manner as in Experiment 1, except that in Experiment 2, the *SI* and *SNC* conditions replaced the *NP* and *TC* conditions. The *NC, AR*, and *IR* conditions were presented as in Experiment 1.

Results and Discussion

There were 30 trials available for analysis in each condition. Incorrect responses only accounted for about 6% of test trials. As in Experiment 1, there were significant differences in error rates among the conditions (Friedman's $\chi^2_{df=4} = 21.8, p < .001$). Post-hoc Wilcoxon signed-rank tests revealed significantly more errors occurred in the *SNC* condition compared with the *AR, IR*, and *SI* conditions, and in the *NC* condition compared with *AR* (FDR-corrected $i = 10$; $q^* = .05$; largest corrected $p < .009$). Error rates were again low. Means (and standard deviations) for each condition were as follows: $NC = 1.96$ (1.38); $AR = 1.26$ (0.83); $IR = 1.44$ (1.43); $SNC = 2.97$ (2.68); and

SI = 1.97 (1.38). The effect sizes were small (out of 30 trials, the *SNC* and *NC* conditions elicited, on average, one more error than the other conditions; probability of superiority values for significant differences ranged from .53 to .63, with values of .50 indicating an equal proportion or no difference). In this case, the conditions with the fastest RTs were also those with the most errors, which is consistent with a speed–accuracy trade-off. Because errors were infrequent, as in Experiment 1, errors were removed from subsequent analysis, and we delay discussing errors until the General Discussion.

For the valid RTs (i.e., correct responses), all responses with latency more than 2.5 standard deviations from the condition mean (about 3% of test trials) were excluded. The remaining oddity RTs were averaged for each condition, and these served as the dependent variable. We first assessed interactions with repeated-measures condition (5) × sex (2) ANOVAs, which revealed no significant effect of sex ($p = .39$, $\eta_p^2 = .03$) and no significant condition × sex interaction ($p = .68$, $\eta_p^2 = .02$). We next proceeded to examine planned non-orthogonal repeated-measures contrasts (Rosenthal et al., 2000) focused on specific hypotheses. The first two contrasts were the same as that reported in Experiment 1, comparing 1) $AR < NC$ predicted by attentional inertia, and 2) $IR > NC$, validating the method. The final contrasts compared 3) $SI > SNC$, assessing whether negative priming affects responding when the prime target stimulus values do not vary during the probe; and 4) $IR > SI$, assessing the contribution of both negative priming and attentional inertia. All significant contrasts survived a correction for multiple comparisons using the FDR procedure ($i = 4$; $q^* = .05$). All hypothesis tests were directional.

Results of the comparisons are reported in Figure 3B. The pattern of results for *NC, AR*, and *IR* replicated Experiment 1. Two findings supported the negative priming hypothesis; RTs were slower for conditions in which the distractor became the target: a) $IR > NC$, $t(28) = 9.45$, $p < .001$, $d = .75$, replicating Experiment 1; and b) the novel finding, $SI > SNC$, $t(28) = 2.43$, $p < .01$, $d = .27$. Here, the response was slower when the distractor became the target, even though the prime target dimension (e.g., color) did not vary during the probe, and thus, it was not possible to identify the odd object based on that dimension. We also replicated the absence of a facilitation effect in the *AR* condition. Again, *AR* response was slightly slower than *NC*, although again this difference was nonsignificant, $t(28) = 1.71$, $p = .10$ (two-tailed), $d = .20$. Finally, the comparison $IR > SI$ was significant, $t(28) = 5.73$, $p < .001$, $d = .45$. In Experiment 1, we found the same result for the comparison $IR > NP$; in both cases, it was more difficult to switch to a stimulus in which both the prime target and distractor stimulus values were potential probe targets. We interpret both results as suggesting that the previously relevant *and* previously irrelevant stimulus values of the prime contribute to impaired responding during the probe trial.

GENERAL DISCUSSION

Summary of Results

The present study contributes to ongoing investigations of the development of cognitive flexibility in two principal ways. First, it investigates an understudied task (i.e., the FIST), which has been shown to be useful for exploring, using a single task methodology, the development of cognitive flexibility during both preschool (Jacques & Zelazo, 2001) and early-to-middle childhood (Dick, 2006). In addition, it validates a method for investigating cognitive processes that contribute to performance on this task. Second, the results we report here provide evidence with adults that difficulty on cognitive flexibility tasks such as the FIST cannot be attributed to a single factor of attentional inertia or negative priming. According to attentional inertia, the key problem is the need for a conceptual shift *away* from a certain property of a stimulus (e.g., blueness and redness) to focusing on another property of the same stimulus (e.g., baskets and bowls). In contrast, the negative priming theory asserts that the competing distractor (e.g., baskets and bowls when focusing on color) is suppressed during initial selection of the target, resulting in difficulty shifting *to* the distractor representation when this representation becomes the target. The central findings of the two experiments reported here provide broad support that a) the source of difficulty on the FIST can be attributed to both attentional inertia and negative priming—that is, neither explanation alone is sufficient; and b) negative priming in this task occurs at the level of individual stimulus values, and not at the level of dimension or task set.

Although the findings presented here were acquired with adult participants, they are consistent with the predictions made by theories of the development of cognitive flexibility and with empirical findings in children. This could be interpreted to suggest that the cognitive processes involved in navigating problem-solving situations in childhood are similar if not identical to those we use as adults. Indeed, Diamond and Kirkham (2005) found that when assessed with sufficiently sensitive measures (i.e., RT), adults show performance deficits on the DCCS, a task that is successfully managed by most 5-year-olds. In another example, using eye tracking to supplement a behavioral measure, Keysar, Lin, and Barr (2003) showed that adults fail to routinely apply theory-of-mind knowledge that they acquired by 6 years old. Thus, under the right circumstances, some of the same problem-solving difficulties with children can be observed with adults, and it may be the case that the findings from developmental and adult studies can be brought together under the same theoretic umbrella—for example, for task switching, under a model incorporating both attentional inertia and negative priming.

The findings reported here thus aid in interpreting previous findings with children because they flesh out an explicit model of what the task is assessing and the model engenders specific predictions. Such an explicit model is difficult to derive from children per se because their data are categorical (error rates). The fleshing out of this explicit model offers new insights into the competence underlying the task and suggests new designs to evaluate this competence in children. However, we are careful to note that the pattern of results reported here may not hold for children because they may differentially weigh one attentional process over the other. Further, the domain under study may influence the development of these attentional processes. Research has addressed the latter issue and suggests that the domain under study matters for whether attentional processes such as negative priming show developmental change. For example, there is little evidence for negative priming in 7-year-old children in a Stroop task (Tipper, Bourque, Anderson, & Brehaut, 1989), but there is evidence for negative priming during spatial attention in infants (Amso & Johnson, 2005, 2008) and children (Simone & McCormick, 1999), during location-based and conceptual-level tasks in children as young as 5 (Pritchard & Neumann, 2004), and during set-shifting tasks in preschoolers (Chevalier & Blaye, 2008; Müller et al., 2006; Zelazo et al., 2003). But the former question of whether processes of attentional inertia or negative priming might be more influential to cognitive flexibility at different points in development remains unanswered, and the developmental trajectory on the way to adult competence is a matter for future work.

Fortunately, the paradigm developed here is appropriate for investigating this question. For example, Müller and colleagues (2006) showed that children improve on the negative priming version of the DCCS with age, which was taken to indicate that negative priming effects actually decline with age. We might therefore expect that if children were tested under the paradigm developed here, they would show a decrease with age in the RT difference between the *NP, IR*, and *AR* conditions and their respective neutral control conditions (i.e., *TC* and *NC* conditions). However, it might also be the case that attentional inertia influences performance on the task differently across age. For example, with adults, we found that repetition of prime target and distractor stimulus values leads to greater interference than repetition of the prime distractor values alone ($IR > NP$; $IR > SI$), which suggests attentional inertia contributes to performance on the task in addition to negative priming. If the weighting of one or both of these processes changes with development, this would be reflected in age-related changes in the difference between target–distractor repetition conditions (i.e., attentional inertia +negative priming) and distractor-only repetition conditions (i.e., negative priming only). That is, $IR > NP$ and $IR > SI$ differences should change with age. Further, if theories suggesting that attentional inertia is overcome with developing inhibitory control are correct (Diamond et al., 2005; Diamond & Kirkham, 2005; Kirkham et al., 2003), we should see a reduction in these differences with age. The paradigm developed here can potentially tease apart these processes, but obviously, these predictions need to be empirically verified with children. With this in mind, we turn to a detailed analysis of the primary experimental results and their implications for explanations of cognitive inflexibility.

Interference during the probe stems in part from the ignored stimulus values of the prime (negative priming).

1. Shifting to the previously irrelevant dimension of the prime was more difficult when the stimulus values from the prime distractor were repeated during the probe compared with when neither the prime target values nor the prime distractor values were repeated during the probe ($NP > TC$).
2. Shifting to the previously irrelevant dimension of the prime was more difficult than shifting to a neutral dimension, even when the previously relevant dimension did not vary during the probe and thus could not be a basis for selection ($SI > SNC$).

These two findings suggest that negative priming of the prime distractor is occurring and extend prior findings that negative priming is a source of difficulty during set-shifting tasks (Chevalier & Blaye, 2008; Müller et al., 2006; Zelazo et al., 2003). The *NP* condition was more difficult than the *TC* condition, which is compatible with work showing that younger preschoolers fail the *Negative Priming* version of the DCCS, but they pass the *Total Change* version (Müller et al., 2006; Zelazo et al., 2003). Shifting to the prime distractor dimension is even difficult when it is impossible to identify the odd object based on the previously relevant dimension because this dimension does not vary (e.g., when all objects are the same color), suggesting negative priming of the distractor is a source of interference over and above interference from the prime target. The fact that *SNC* was faster than *SI* also suggests the constant dimension of the prime trial (e.g., size) does not contribute to interference during the probe trial, indicating that it is not processed in the same way as the attended to and ignored stimulus dimensions (i.e., those dimensions in direct conflict). Thus, conflict between competing perceptual representations, requiring selective attention/ignoring of one stimulus over the other, appears to be necessary for interference to occur on the probe trial. This would explain why shifting tasks containing no direct perceptual conflict, such as the Reversal Version of the DCCS (Perner & Lang, 2002), are easy even though the complexity of the rules is similar to that of more difficult conflict-containing shifting tasks (also see Müller et al., 2006, Experiment 2).

Negative priming does not occur at the level of abstract task set.

3. When the specific values of both the prime target and distractor were removed during the probe, shifting to the previously ignored dimension was *not* more difficult than shifting to a neutral dimension (*TC* was not significantly different from *NC*).

This finding suggests negative priming is not associated with a particular dimension, a finding we return to later in the discussion.

Interference during the probe stems from both the attended-to and ignored stimulus values of the prime (attentional inertia and negative priming).

4. When the stimulus values of both the target and distractor dimensions of the prime were repeated during the probe, shifting to the previously irrelevant dimension was more difficult than switching to a neutral dimension ($IR > NC$).
5. When the stimulus values of both the target and distractor dimensions of the prime were repeated during the probe, shifting to the previously relevant dimension was *not* easier than switching to a neutral dimension (i.e., there was no facilitation effect when the prime target was also the probe target; *AR* was not significantly different from *NC*).
6. When the stimulus values of both the target and distractor dimensions of the prime were repeated during the probe, shifting to the previously irrelevant dimension of the prime was more difficult than a) shifting to the previously irrelevant dimension of the prime when the stimulus values from only the prime distractor were repeated during the probe, and the prime target values were removed ($IR > NP$); and b) shifting to the previously irrelevant dimension of the prime when the stimulus values from only the prime distractor were repeated during the probe, and the prime target dimension did not vary ($IR > SI$).

Both attentional inertia and negative priming predict the finding that shifting to the previously irrelevant dimension is more difficult than shifting to a neutral dimension ($IR > NC$), but for different reasons. Indeed, the *IR* condition is isomorphic to the standard DCCS and FIST tasks, which pose a problem for both preschoolers (Jacques & Zelazo, 2001; Zelazo et al., 2003) and adults (Diamond & Kirkham, 2005). The finding is not surprising, then, as this condition presents interference from both the previously relevant and irrelevant stimulus values, and shifting to the distractor dimension is particularly difficult. The surprising finding here is that there was no facilitation effect for *AR* compared with *NC*. It is well known that attending to a particular stimulus can facilitate responding to that stimulus on subsequent trials (known as "positive" or "repetition" priming; Schneider & Logan, 2005; Tulving & Schacter, 1990; Wiggs & Martin, 1998), and because attentional inertia emphasizes the maintenance of a preshift "mind set," a facilitation effect would be consistent with the theory. Further, the lack of facilitation is not likely due to a floor effect, as the responses during *NC* were faster than *AR* in both experiments. Due to the fact that in *AR*, the target of the prime and target of the probe are the same, it is difficult to see this result would be predicted by attentional inertia without taking into account negative priming of the distractor stimulus. However, it may also be the case that repetition priming of the prime target offset negative priming of the prime distractor, which explains why *AR* was not significantly slower than *NC*. Another finding supports the notion that both attentional inertia and negative priming contribute to task difficulty; repetition of prime target and distractor stimulus values leads to greater interference than repetition of the prime distractor values alone ($IR > NP$; $IR > SI$). These findings suggest that difficulty in set-shifting tasks stems from interference from the stimulus values of both the previously relevant and previously irrelevant dimensions.

Analysis of errors. Analysis of the pattern of errors showed that participants made more errors on neutral control conditions (i.e., *NC* in both experiments and *SNC* in Experiment 2) than they did during the experimental conditions. However, errors themselves were infrequent, and although reliable, the effect sizes for the differences were small (neutral conditions elicited one additional error, on average, than experimental conditions). Despite this, it is important to note that the error analysis appears inconsistent with the analysis of RT differences—conditions eliciting fast RTs also elicited more errors. Further, although the outcomes are consistent with a speed–accuracy trade-off (i.e., the phenomenon that faster responses tend to produce more errors; Liu & Smith, 2009; Miller et al., 2008; Thorpe et al., 1996), we cannot rule out additional factors that may have led to errors on these conditions (e.g., fast guesses, guesses based on the habitual response over trials, multiple runs of the process under study, and inattention). In fact, it is possible that the increase in errors for neutral conditions in the present design is a function of the fact that the *NC* and *SNC* conditions are the only two conditions in which the probe target dimension does not appear as a possible matching dimension in the prime (see Figure 2).

The inconsistency of errors and RT findings is significant given the fact that investigations of cognitive inflexibility in children often rely on error rates and not RT (thus, from an error analysis point of view alone, one might have drawn the conclusions that the *NC* condition is most difficult, even though it is associated with accuracy at near ceiling and much faster correct responses). However, it is important to remember that the increased errors were found for neutral control conditions, and these conditions are not typically found in studies with children. In fact, for conditions inspired by studies with children, the RT differences are consistent with what has been found in children—for example, the *IR* and *NP* conditions are more difficult than their respective control conditions, as assessed by RT, and children make errors on these manipulations for the FIST and DCCS tasks (Jacques & Zelazo, 2001; Zelazo et al., 2003). It is possible that the apparent discrepancy can be explained by the addition of neutral conditions that include a dimension in the probe that is not expected from the prime, by speed–accuracy trade-off, or by a combination of other factors that are not under experimental control.

Theoretical explanations for cognitive inflexibility on set-shifting tasks. Attentional inertia and negative priming find commonality with theories of task switching in the adult literature, notably with a model known as *task-set inertia*. This model suggests that shift costs arise from proactive interference of both persisting facilitation or positive priming of previously relevant (but now irrelevant) stimulus attributes, *and* persisting suppression or negative priming of the previously irrelevant (but now relevant) stimulus attributes (Allport et al., 1994; Allport & Wylie, 1999, 2000). Thus, successful selective attention in these tasks stems from a combination of successful target activation and successful distractor suppression. It can readily be seen that this model simultaneously encompasses aspects of both the attentional inertia and negative priming theories from the developmental literature.

The task-set inertia model is one exemplar of accounts that emphasize stimulus-based priming (Allport & Wylie, 2000; Koch & Allport, 2006; Schneider & Logan, 2005), or bottom-up, stimulus-driven contributions to task-switch costs (Meiran, Chorev, & Sapir, 2000; Waszak, Hommel, & Allport, 2003). Alternatively, top-down accounts emphasize competition between endogenous task sets (Meiran et al., 2000; Rogers & Monsell, 1995). Task set, in the cases considered here, refers to abstract representations that apply to all realizations of the goals of a task. For example, a task set in the present study would apply the broad rule "attend to color," covering all realizations of that rule, rather than the more "item-specific" representations relevant for stimulus values (e.g., "red" or "blue").

The issue of whether interference occurs at the level of task set or at the level of individual stimulus values has not been sufficiently characterized in the developmental literature. Both attentional inertia and negative priming focus on interference from stimulus values (Kirkham et al., 2003; Müller et al., 2006). There is, however, some evidence that task-set interference occurs as well; approximately 25% of children still fail the *Total Change* version of the DCCS, even though there are no interfering stimulus values during the postswitch phase of this task (Zelazo et al., 2003). Empirical findings from the adult literature support a contribution for both sources of interference (Allport et al., 1994; Allport & Wylie, 2000, Experiment 5; Besner, 2001; Klein, 1964; Koch, 2001; Meiran et al., 2000; Monsell, Taylor, & Murphy, 2001). Mayr and Keele (2000) and others (Schuch & Koch, 2003) provide evidence that shifting to a task set that has recently been abandoned is more difficult than shifting to a task set that has been abandoned less recently, even when interference effects from specific stimulus values are controlled. These latter findings suggest that to implement a new task set, the previous task set must be actively inhibited (a process termed *backward inhibition*; Mayr & Keele, 2000). Indeed, many authors acknowledge task-switch costs arise from both task priming and higher-level task-set reconfiguration (Allport & Wylie, 2000; Goschke, 2000; Monsell, Yeung, & Azuma, 2000), although the contribution of these sources to switch costs potentially differs by the task under study (Yeung & Monsell, 2003).

Our data speak to the source of interference from negative priming, at the level of stimulus values or at the level of task set. If there is negative priming of the distractor task set (e.g., suppression of "categorize by shape" when "categorize by color" is the relevant task set), when all stimulus values are removed during the probe, it should be easier to shift to a neutral stimulus (as in *NC*) than to a stimulus in which the prime distractor task set is the probe target task set (as in *TC*; i.e., $NC < TC$). In the present study, we did not find this to be the case; *TC* was not significantly different from *NC*. Thus, while the data do provide evidence for negative priming of specific stimulus values, on this particular task, negative priming of the previous task set does not occur, a finding that is consistent with Mayr and Keele (2000, Experiment 2). For task-switch paradigms, this might explain the phenomenon that children can often state correctly the rules for the task but fail to employ them (i.e., they can state correctly where blue bowls go in the shape game, even after the rule switch, but fail to sort the cards correctly; Zelazo, Frye, & Rapus, 1996). In the case of verbally stating the rules, the conflicting perceptual stimulus (test card paired with target card) is not a focus of attention. If this conflict contributes to interference in part via a process of negative priming, as we argue, proactive interference may not occur when this conflict is not visually present.

Top-down control processes, inhibition, and developing cognitive flexibility. The results of the present study suggest that bottom-up processes are a primary contribution to difficulty on set-shifting tasks. However, although bottom-up processes may lead to proactive interference or to negative priming, they do not necessarily resolve this interference (Arrington & Logan, 2005). Thus, a central developmental question remains unanswered: How do children come to succeed on set-shifting tasks? Competing explanations often center on whether an active inhibitory process is necessary to resolve interference. Some authors have rejected this idea. For example, the negative priming theory favored by Müller, Zelazo, and colleagues calls on a top-down cognitive process, application of a higher-order rule, to overcome both proactive interference and negative priming (Müller et al., 2006; Zelazo et al., 2003; see Andrews, Halford, Bunch, Bowden, & Jones, 2003; Halford, Wilson, & Phillips, 1998, for similar arguments). Several connectionist models explain the suppression of prepotent responses without reference to a specific active inhibitory mechanism (Cohen, Dunbar, & McClelland, 1990; Kimberg & Farah, 1993; Morton & Munakata, 2002; Munakata, Morton, & Yeyrs, 2003). Alternatively, in some models, the development of inhibition is a central mechanism explaining the development of cognitive flexibility (Carlson & Moses, 2001; Carlson, Moses, & Claxton, 2004; Dempster, 1993). For example, attentional inertia is overcome by successful inhibition of the interfering stimulus, a process that is immature early in development (Diamond et al., 2005; Diamond & Kirkham, 2005; Kirkham et al., 2003).

Inhibitory processes might also be necessary to explain negative priming and its development, although this continues to be a matter of debate. On one hand, when people attend to the target, they might need to actively inhibit representations of the distractor (Houghton & Tipper, 1994, 1996; Neill, 1977; Tipper, 1985; Tipper & Cranston, 1985). On the other hand, negative priming might be explained by memory retrieval mechanisms, without reference to a specific inhibition mechanism (Neill & Valdes, 1992; Neill, Valdes, Terry, & Gorfein, 1992; Park & Kanwisher, 1994). Although data are often interpreted as favoring either inhibition or memory accounts to the exclusion of each other (e.g., MacLeod, Chiappe, & Fox, 2002), an explanation presented by Tipper (2001) suggests there is no necessary conflict between these accounts—rather, a complete account would need to consider both inhibition at the encoding stage and memory processes at retrieval. Developmental investigations might inform on these competing theories, but surprisingly few studies of negative priming have been conducted with children (Amso & Johnson, 2005, 2008; Chevalier & Blaye, 2008; Müller et al., 2006; Pritchard & Neumann, 2004; Simone & McCormick, 1999; Tipper et al., 1989, for exceptions). In fact, the developmental progression of negative priming remains largely uncharacterized during preschool and early childhood, which is the age range in which tasks like the DCCS and the FIST are typically applied. Isolating how specific attentional mechanisms contribute to successful set shifting during this age range may require either new methodologies (e.g., such as those developed in the present paper and others; Chevalier & Blaye, 2008; Maes, Damen, & Eling, 2004; Maes, Vich, & Eling, 2006) and/or more intricate cognitive models to explain how processes contributing to successful cognitive flexibility are employed in some situations, but not others.

In summary, the findings reported here have implications for theories of the development of cognitive flexibility. First, they represent empirical evidence that both suppressing attention to the previously relevant stimulus and engaging attention to the previously irrelevant stimulus contribute to cognitive inflexibility on set-shifting tasks. Second, the findings speak to the need to pay greater attention to the perceptual and conceptual sources of interference in set-shifting tasks (i.e., whether interference occurs at the level of task stimulus or task set, or both). Finally, the study demonstrates the value of alternative approaches to investigating executive function development with the specific aim of determining the underlying cognitive and perceptual processes that contribute to impaired and successful task performance. This information is important not only for informing theories of cognitive flexibility in typical development, but it is essential if tasks like the FIST are applied to clinical populations (Jacques & Zelazo, 2001).

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