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# ARTICLE WITH PEER COMMENTARIES AND RESPONSE

# Helping children apply their knowledge to their behavior on a dimension-switching task

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## Abstract

*To investigate why 3-year-olds have difficulty in switching sorting dimensions, children of 3 and 4 years were tested in one of four conditions on Zelazo's card sort task: standard, sleeve, label and face-up. In the standard condition, children were required to sort blue-truck and red-star cards under either a blue-star or red-truck model card, first by color or shape, and then by the other dimension. Here 3-year-olds sorted correctly until the dimension changed; they continue to sort by the initial dimension. The sleeve condition (placing the sorting cards in an envelope prior to sorting) had little effect. In the label condition, the child labeled the relevant sorting dimension on each trial. Most 3-year-olds succeeded; evidently their labeling helped them refocus their attention, overcoming 'attentional inertia' (the pull to continue attending to the previously relevant dimension). In the face-up condition, attentional inertia was strengthened because sorted cards were left face-up; 4-year-olds performed worse than in the standard condition. We posit that attentional inertia is the core problem for preschoolers on the card sort task.*

Doublethink means the power of holding two contradictory beliefs in one's mind simultaneously, and accepting both of them. (George Orwell, *1984*)

## Introduction

Children of 3 years can sort items by their color or shape with little difficulty. If they start by sorting color, and are then asked where items of either shape should go, 3-year-olds respond correctly. Similarly, if the sorting criterion changes from shape to color, 3-year-olds can answer queries about the rules for sorting by color correctly. However, if you actually hand children of 3 years an item to sort by the second criterion, they tend overwhelmingly to sort the item by the previously correct, first criterion whether that was shape or color (e.g. Zelazo, Frye & Rapus, 1996).

A typical testing session would be as follows: The tester asks a child of 3 years to sort cards depicting a blue truck or a red star into boxes that display a red truck or blue star. Thus, the cards can be sorted either according to their color or shape. The tester asks the child where the trucks go and where the stars go, and the child answers the questions correctly (by pointing to the appropriate box). During testing, the experimenter hands the child a card to sort (depicting, e.g. a red star) saying, 'Here is a star.' The child sorts it correctly. This correct performance is repeated over several trials. Then the experimenter announces that the game is switching to the 'color game' so that the cards should now be sorted by their color and not by their shape. In this case, the cards should now be sorted into the opposite boxes from those used during the previous sorting. The tester asks the child where the red ones go and where the blue ones go; the child points to the correct bins. Then the tester hands the child a card to sort (depicting, e.g. a blue truck) saying, 'Here is a blue one', and the child sorts it *incorrectly*. The child sorts it according to the previously correct dimension (shape), putting it in the pile with the red trucks rather than with the blue stars.

This performance – correct response to the 'knowledge' question but incorrect sorting – is repeated over as many trials as are administered for the second criterion.

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Indeed, recent evidence shows that although 3-year-olds perform significantly better when given feedback, a substantial number still persist in sorting the cards incorrectly after the rule switches, even when told that is incorrect (Yerys & Munakata, 2001). Moreover, if a 3-year-old child sees a puppet sort the cards correctly by the second criterion, the child erroneously corrects the puppet when the puppet switches appropriately, and asserts that the puppet is correct when the puppet perseverates in sorting by the previously correct dimension (Jacques, Zelazo, Kirkham & Semcesen, 1999).

## Why do 3-year-old children err on the card sort task when the sorting criterion switches?

It is not (a) that they do not understand what sorting by the category 'color' or 'shape' means, for they sort errorlessly by either until the sorting criterion is switched (e.g. Zelazo, Reznick & Piñon, 1995; Zelazo *et al.*, 1996). It is not (b) that their preferred category was used first, because performance is similar whether sorting starts with color or shape (Zelazo, Frye, Reznick, Schuster & Argitis, 1995; Zelazo *et al.*, 1996). It is not (c) that the children do not realize that the rules for sorting have changed after the switch to the second dimension. The experimenter makes a point of emphasizing that 'the game' has changed and then carefully goes over where cards with one value and then the other of the new dimension should be sorted, often asking the child to point to where a card with one of those values and then the other should be sorted. The reason 3-year-olds err when the sorting criterion switches is not (d) that they lack the memory span needed to hold four rules in mind (two for color, two for shape) for Zelazo and colleagues (Zelazo *et al.*, 1995; cf. Zelazo & Jacques, 1997) have shown that 3-year-olds can hold in mind four rules that pertain to the same dimension and can sort correctly using those rules. Indeed two recent studies have shown that 3-year-olds can hold in mind two sets of rules, each set with two rules apiece, just as in the card sort task (Brooks, Hanauer, Padowska & Rosman, 2003; Perner & Lang, 2002). Other evidence against a memory explanation for 3-year-olds' failure to switch sorting criteria is that 3-year-olds succeed when memory demands are increased (when no model cards are present; Perner & Lang, 2002; Towse, Redbond, Houston-Price & Cook, 2000), and fail even when memory demands are minimized, such as when the experimenter reminds the child at the outset of each and every trial how to sort the cards by the currently relevant dimension. Indeed, even when children are queried at the outset of the trial how to sort a card with each value of the currently relevant dimension, and indicate the correct locations flawlessly, 3-year-olds still persistently err by continuing to sort by the previously correct dimension (Zelazo *et al.*, 1996). It is possible that children answer the knowledge questions correctly not based on their memory of the instructed rules, but by simply looking at the models (only one of which has the color or shape referred to in the knowledge question) and deducing that the model with the queried feature must be the correct choice. If 3-year-olds are capable of that correct deduction, and the experimenter labels the stimulus presented immediately after the knowledge question as having a feature that matches only one of the model cards, why then can't 3-year-olds deduce the correct answer there as well?

### *Cognitive Complexity and Control (CCC) theory*

The theory proposed by Zelazo and Frye (1997) to account for errors on the card sort task and for the developmental trajectory of performance on the task is the Cognitive Complexity and Control (CCC) theory. The CCC theory posits that as children get older they come to be able to represent increasingly complex rule structure, the complexity of which is determined by the number of levels of embedded rules within a particular rule system. For example, in the card sort task, the rules that govern where the red and blue cards should go during the color game are embedded within the higher order rule of which game is being played: If this is the color game, then the red cards go in one box, and the blue cards go in the other box. If it is the shape game then a different set of sorting rules applies.

The theory also posits a two-level hierarchical system. The top level is a representational mechanism, which is under conscious control. This mechanism controls the lower-level response-based system that is unconscious, automatic, and works according to associationist principles (similar to the prepotent or dominant response tendency in Diamond's work, 1990, 1991a, 1991b). Over development the representational mechanism becomes capable of representing increasingly complex (i.e. embedded) rules. This theory posits that at $2^1/_2$ years, children can represent only one rule (e.g. red cards go in this box) and, thus, tend to place all cards in the first box even before the sorting criterion switches. By 3 years of age, children can represent both rules of one dimension (e.g. red cards go in this box, and blue cards go in that box) but cannot embed those rules within an even higher order rule. In other words, they are one step higher than the $2^1/_2$-year-olds in that they can represent either 'if red, put in this box, and if blue, put in this other box' or 'if a truck, put in this box, and if a star, put in this other box' but they cannot embed those into 'if sorting by color, follow the red-blue rules, and if sorting by shape, follow the truck-star rules'. Therefore, according to the CCC theory, 3-year-olds cannot switch to the second sorting criterion because switching requires a new level of embedding. By 4 to 5 years of age, however, children can represent that level of complexity and, therefore, successfully switch dimensions.

### *'Attentional inertia': a failure to exercise inhibitory control of attention*[1]

We hypothesize that when asked to sort by the second criterion, children of 3 years have difficulty inhibiting their focus on the first aspect of a stimulus that was relevant for their behavior (e.g. its 'blueness'), and hence do not switch the focus of their attention to the currently relevant aspect (e.g. its 'truckness'). It is not that they fail to realize that something can be both blue and a truck. Indeed, if queried they can easily state the color and shape of the stimulus. However, having adopted the mindset that blue things go with the blue model card, they have great difficulty switching to think of a blue truck in terms of its shape and sorting it with the red-truck model card, even though they are told that the correct dimension is now shape. We posit that 3-year-old children's difficulty lies in disengaging from a mindset (a way of thinking about the stimuli) that is no longer relevant. Thus, 3-year-olds might be said to have 'attentional inertia'. Having focused their attention on a particular dimension, their attention gets stuck there, and they have extreme difficulty redirecting it.

This idea is consistent with the CCC theory to the extent that the CCC theory, too, places an emphasis on inhibitory control. The CCC theory also claims that reflection on and formulation of higher-order rules allows inhibition and refocusing to occur. We hypothesize that the poor performance of 3-year-olds on the card sort task can be accounted for simply by a failure to fully inhibit attending to what had been relevant and redirect attention to what is newly relevant.

Markman's (1989) mutual exclusivity principle suggests that if children up to 4 years old already have a label for an object, they will reject a new label for the object. Remnants of this can be seen perhaps in the difficulty that adults have in representing more than one interpretation of an ambiguous figure at one time (Chambers & Reisberg, 1985). Even when informed of the alternatives in an ambiguous figure, children of 3 years remain stuck in their initial way of perceiving the figure; they cannot reverse (Gopnick & Rosati, 2001). By 5 years of age most children can reverse. Perhaps something analogous happens with the card sort task. 'Blue' and 'truck' are not different labels for the same object, but in the card sort task they are pitted against one another. A blue truck goes with red trucks when one is thinking about it in terms of its truckness, but it goes with blue stars when thinking of it in terms of its blueness. The correct response from one perspective is the incorrect response from the other.

If this is the key to the task's difficulty for young children then perhaps it is not that they cannot represent the relations between if-then statements, but that they are cognitively rigid. Thus, (1) 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). Children of 3 years are perfectly capable of switching from sorting rabbits and boats by red and blue to sorting yellow flowers and green cars by their shape (Zelazo *et al.*, 1995, Exp. 3). (2) Similarly, children should be able to succeed if the previously relevant values on the now-irrelevant dimension (and/or the previously irrelevant values on the now relevant dimension) are no longer present on the model cards (and they do). Indeed, they succeed when no model cards are present at all (Perner & Lang, 2002; Towse *et al.*, 2000). (3) They might also find it easier to switch if the second dimension were made more salient, although that has not yet been tested. Thus, the children should be able to succeed if the interfering aspects are removed or if the correct aspect is highlighted. (4) They should succeed in switching if that does not require changing their attentional focus. Indeed, if the stimuli vary along one dimension, 3-year-olds can switch from sorting trucks with trucks and stars with stars to sorting trucks with stars and stars with trucks (Brooks *et al.*, 2003; Perner & Lang, 2002).

Even adults have difficulty when required to change the focus of their attention and behave accordingly. For example, Rogers and Monsell (1995) tested adults in a task-switching study that required participants to switch between two tasks that used the same stimuli, a letter task and a digit task. For both tasks, participants were shown a compound stimulus of two characters (e.g. N2). In the letter task, partici parts were required to classify the letter as a consonant or a vowel; in the digit task they were to classify the digit as even or odd. In the 'cross-talk' condition the stimuli were often 'bivalent', i.e. relevant to both tasks, whereas on 'no cross-talk' trials the stimuli were univalent, i.e. relevant to only one of the tasks (e.g. N*). Predictably, when adults had to switch their mindset from one of these tasks to the other, if the stimulus was bivalent, and if different responses

[1] We had thought ourselves quite original in coining the phrase, 'attentional inertia', but have since discovered that Allport and colleagues (Allport, Styles & Hsieh, 1994; Allport & Wylie, 2000) introduced a very similar term, 'task set inertia', to refer to a similar idea.

were associated with the same stimulus in the two tasks, adults were much slower to respond.

This has been replicated in a great many task-switching studies, many of which are reported in Monsell and Driver (2000). Indeed, we have recently shown that when adults are tested on a computerized version of Zelazo's card sort, they show elevated reaction times when switching from Dimension 1 to Dimension 2. This switch cost parallels what children of 3 years show in their percentage of correct responses (Diamond & Kirkham, 2001). The CCC theory cannot account for adults' difficulty in switching tasks as adults certainly have the requisite abilities to represent hierarchical rules. Adults' difficulty here, however, is fully consistent with our hypothesis, because while adults are able to inhibit their prepotent tendency to focus on the previously relevant dimension and to act according to its associated rules, this inhibition exerts a cost and that cost is seen in their slower performance.

Even though children of 3 years can correctly switch sorting criteria if the values of the first sorting criterion are no longer available, it is not simply that such a change helps children switch successfully because it emphasizes that things have changed: For example, if the stimuli change only with regard to the new sorting dimension (e.g. the stimuli were red and blue rabbits and boats for sorting first by color, and then when the sorting criterion switches to shape the stimuli are red and blue cars and flowers), 3-year-olds still fail. They continue to sort by color instead of switching to sorting by shape (Zelazo *et al.*, 1995).

If our hypothesis is correct, why do children of 3 years point to the correct locations in response to the 'knowledge questions' in the card sort task? The answer is that knowledge questions do not mention the previously correct dimension; they simply ask about the present dimension ('Where do the red ones go?' or 'Where do the trucks go?'). When asked where the red ones go, given that there is only one red model card, the answer is easy. Similarly, when 3-year-olds are asked to sort a card with blue grapes by color or a card with a yellow truck by shape under either the red-truck or blue-star model cards, the task is easy. The problem comes when the stimulus is bivalent and incongruent (relevant to both tasks in conflicting ways). When children see (in the outside world or in their mind's eye) an actual stimulus (that is not just red or a truck, but both red and a truck) their attention is captured by the initially relevant (the previously correct) dimension. Indeed, when asked to verbally respond to a knowledge question that mentions both dimensions (not 'where do the blue ones go?', but 'where do the blue trucks go?'), 3-year-olds err in their verbal response when the sorting criterion switches, mirroring their error in physically sorting the cards (Munakata & Yerys, 2001).

To test our hypothesis and to better understand why children of 3 years have such difficulty switching dimensions, we administered the standard version of Zelazo's card sort task and three variations of it. To help children refocus their attention, we administered a 'label' condition. If children of 3 years are responding to the knowledge question without integrating that question and their response into the actual sorting game, then perhaps having them label the relevant dimension of the card to be sorted will force them to inhibit attending to the previously relevant dimension and help them refocus their attention on the currently relevant dimension. Further, an ability to label the cards lends support to the idea that memory is not the issue. The label condition differed from the standard procedure only in that instead of the experimenter labeling each sorting card before the child sorted it ('Here is a blue one' or 'Here is a truck'), the child was invited to do the labeling. For the first trial for each sorting criterion the experimenter asked, 'What color is this one?', or 'What shape is this one?' After that, the experimenter asked simply, 'What's this one?' Our prediction: Even 3-year-old children should be able to succeed here.

The other two conditions were designed to investigate the role of inhibitory control in performance of the task by increasing or decreasing the inhibitory demands. In the 'face-up' condition, the only change from the standard procedure was the orientation of the cards in the sorting boxes. Instead of placing the cards face-down in the sorting boxes, children were allowed to leave the sorted cards face-up in the sorting boxes. This increased the salience of the previously correct dimension; there was now a visual pull to continue placing the cards in the same boxes as before the switch. Our prediction: Even 4-year-old children should perform poorly here.

In the 'sleeve' condition, the experimenter placed the sorting card in an 'envelope' immediately after showing the card to the child, and before the child sorted it. We thought this would decrease the salience of the irrelevant dimension because the child could not see the card while sorting it. We hoped this might help the child focus on what the experimenter had said (e.g. 'This is a truck') instead of focusing on having just seen a blue truck. Note, however, that in this condition there was an increased demand on memory because children had to remember what they had just seen. Without the benefit of having the stimulus in front of them, the children had to remember which stimulus they had seen last and sort accordingly. Thus, we predicted that this condition would not boost performance to the same degree as the label condition.

**Table 1** *Mean ages and age ranges, in months, of children in each condition*

| Age group | Condition | *N* | Mean age (SD) in months | Age range |
|---|---|---|---|---|
| 3-year-olds | Standard | 19 | 39.7 (3.4) | 34.8–44.4 |
| | Face-up | 16 | 39.1 (3.6) | 34.8–45.6 |
| | Sleeve | 14 | 39.6 (4.2) | 32.4–45.6 |
| | Label | 18 | 38.0 (2.5) | 34.8–43.2 |
| 4-year-olds | Standard | 12 | 49.9 (4.4) | 46.8–58.8 |
| | Face-up | 14 | 50.0 (2.9) | 46.8–54.0 |
| | Sleeve | 13 | 50.7 (3.1) | 46.8–55.2 |
| | Label | 13 | 53.0 (4.6) | 45.6–59.0 |

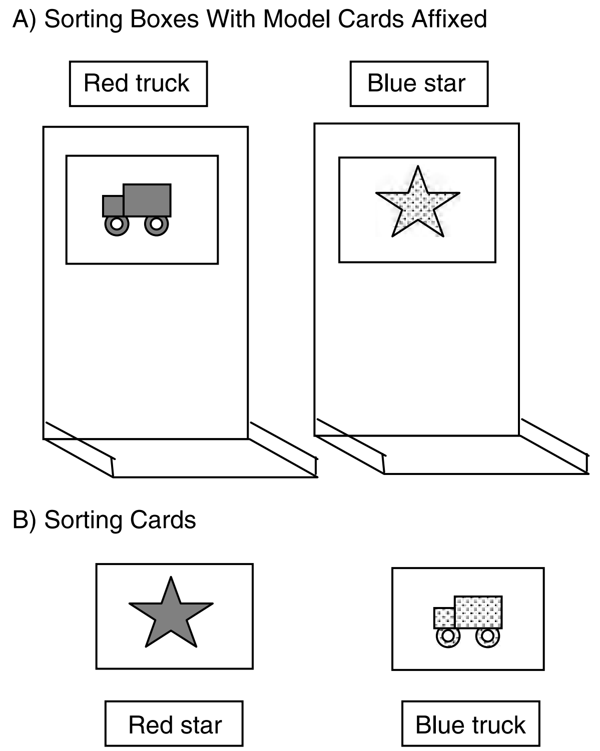


**Figure 1** *Depiction of the model cards, sorting bins and sorting cards used in the card sort task.*

## Methods

### Overview

We administered four conditions of the card sort task (Zelazo *et al.*, 1996) – the standard procedure and 'label', 'face-up' and 'sleeve' conditions – to children 3 and 4 years old. Each child was tested in only one condition.

### Participants

A total of 119 children participated in this experiment: 67 children of 3 years (37 females, 30 males; $M = 39.1$ months, SD = 3.5 months, range = 32.4 months to 45.6 months) and 52 children of 4 years (23 females, 29 males; $M = 50.9$ months, SD = 3.9 months, range = 45.6 months to 59.0 months); see Table 1 for breakdown by condition. Children were recruited from local Boston daycare centers and through a database of parents in the Boston, MA area who had expressed interest in participating in research. This was supplemented by recruitment of a few children in the Ithaca, NY area. Informed consent was obtained from the parents of all children who participated. All children were full-term and healthy. Most were from middle-class homes and of European Caucasian descent. Most parents were college graduates (mean years of education were 16 for both mothers and fathers). The mean age of the mothers was 32 years, and the mean age of the fathers was 35 years. In addition to the 119 children included in the data analyses, another four sessions were attempted but were not useable. Two of the children were 3 years old and in the standard condition. One of these children did not know his colors; the other child was omitted because she refused to play the game. The other two children were 4 years old and in the face-up condition. Both refused to play due to shyness.

### Materials

The same cards and sorting boxes were used for all conditions. The model cards consisted of two white laminated cards (9 cm × 11 cm), one depicted a red truck and the other depicted a blue star (see Figure 1). The sorting cards were the same size and shape as the model cards, but each depicted a blue truck or red star. Thus, no sorting card matched a model card on both color and shape. The back wall of the sorting boxes was 28 cm × 13 cm, and the base was 13 cm × 11 cm. A sorting card was mounted over the bin of each box (see Figure 1). The children were trained to sort by color with training cards that depicted blue or red grapes, and were trained to sort by shape with training cards that depicted yellow trucks or stars.

### Procedures

#### Procedures common to all conditions

Each child was tested individually in a testing session that took approximately 10 minutes. Testing occurred either at the child's daycare center (in a quiet area designated by the supervisor), at the Center for Developmental Cognitive Neuroscience at the Shriver Center Campus of UMass Medical School, or at the Cornell University Baby Lab. Once the child was comfortable with the experimenter, the child was shown the two sorting boxes with the model cards affixed to the back wall of the boxes, facing the child. The experimenter then introduced the child to the training part of the game, which consisted of sorting cards that matched on only one dimension (i.e. cards depicting blue and red grapes for the color game or cards depicting yellow trucks and stars for the shape game) by saying:

> We're going to play a card game now. In this game we can play the color (shape) game. In the color (shape) game all the blue ones (all the trucks) go in this box, and all the red ones (all the stars) go in this box. Okay? Can you point and show me where the blue ones (trucks) go? [Child pointed. Experimenter praised the child if correct or corrected the child if wrong. Instructions were repeated if the child was wrong.] And where do the red ones (stars) go? [Child pointed. Experimenter praised the child if correct or corrected the child if wrong. Instructions were repeated if child was wrong.] Here's a blue one (truck). Where does this one go? [Child sorted the card by placing it in the bin of one of the boxes. Experimenter corrected the child if wrong.] Here's a red one (star). Where does this one go? [Child sorted the card by placing it in the bin of one of the boxes. Experimenter corrected the child if wrong.]

The first dimension on which children were trained was counterbalanced across children within each age × gender × condition. Each child was given a minimum of four cards (one card for each of the two values of each of the two dimensions), and a maximum of eight cards (i.e. allowing for four errors). The two cards were presented for one dimension first, and then there was a switch to the other dimension. Children had to correctly sort four cards (two for each dimension) to pass the training phase. Children were given feedback. All children passed the training phase except for the one 3-year-old noted above, who did not know his colors. The last dimension sorted during the training phase was always the first dimension administered during the test trials (e.g. if the final training card sorted depicted red grapes, then the first test dimension would be color). The test trials started immediately after the child had finished the training trials. 'Great job! Let's keep playing the color (shape) game. Remember [child's name], in the color (shape) game, all the blue ones (trucks) go here [pointing to the bin of the appropriate box], and all the red ones (stars) go here [pointing to the other bin].'

There was a minimum of 12 test trials (i.e. six consecutive trials for the first dimension, and six consecutive trials for the second dimension). Since children needed to sort six trials in a row to reach criterion, if a child made one or more errors on the first dimension, more trials were administered until the child passed criterion on that dimension. Additional trials were needed on only five occasions: One 3-year-old in the face-up condition required eight trials. One 3-year-old in the standard condition required seven trials, and one 3-year-old in the sleeve condition required 10 trials. One 4-year-old in the standard condition needed seven trials to reach criterion on the first dimension. The same pseudo-random order of card presentation was used for all children (i.e. blue truck, blue truck, red star, red star, blue truck, red star, blue truck, red star, etc.). Before each trial, regardless of condition, either the child was told the rules of the current game or was asked to tell the experimenter the rules of the current game by pointing to the appropriate boxes in answer to 'knowledge' questions (e.g. 'Where do the red ones go in the color game? Where do the blue ones go?'). In general, on alternating trials, the experimenter stated the rules and had the child answer the knowledge questions. The order of which value (e.g. red or blue) was first mentioned, or asked about, was randomly varied.

Children were given feedback on their responses to the knowledge question. If the child answered the knowledge question incorrectly, the experimenter reiterated the rules and asked the knowledge question again. Six 3-year-olds were incorrect once and one 4-year-old was incorrect twice; they were distributed across conditions. If the child was incorrect again, the error was noted and the next trial commenced; as noted, this happened only once. If the child was correct, the experimenter said, 'Excellent!' or 'Very good.' Then the child was given the next card and asked to sort it according to the appropriate dimension (e.g. 'Here's a blue one. Where does it go?' or 'Here's a truck. Where does it go?'). Note, even in the standard condition, our experimenters labeled only the relevant dimension of each stimulus ('Here's a blue one'), whereas in their early work Zelazo and colleagues (1996) labeled both dimensions of each stimulus ('Here is a blue truck'). No feedback was ever provided to the child's sorts during testing. After the child had sorted six cards correctly by the first dimension, the sorting dimension was switched:

> Let's not play the color (shape) game anymore, ok? We're not going to play that game anymore! Let's play the shape (color) game now. Remember, in the shape (color) game, all the trucks (blue ones) go here, and all the stars (red ones) go here. [Experimenter pointed at the appropriate bins.] So, stars (red ones) go in this box, and trucks (blue ones) go in this box. Can you show me where the trucks (blue ones) go in the shape (color) game? [Child pointed at the appropriate

box. Child was given feedback.] Now, can you show me where the stars (red ones) go? [Child pointed at the appropriate box. Child was given feedback.] Here's a truck (blue one). Where does it go? [Or] Here's a star (red one). Where does it go?

The child was considered to have passed the second dimension if he or she sorted five out of the six cards correctly. Children were allowed to self-correct.

In the standard condition and the label condition, the child was to place the sorting cards face-down in the sorting boxes. If the child placed a card face-up, the experimenter simply turned it over.

### Procedure specific to the label condition

In the label condition, the wording when each test card was presented was slightly different from that in the other conditions. In all other respects this condition was identical to the standard condition. Instead of the experimenter presenting the sorting card by saying, for example, 'Here's a red one, where does it go?', in the label condition, the experimenter said to the child, 'What's this one?' and waited for the child to answer 'a truck' or 'blue', for example, before asking, 'Where does it go?' Thus, instead of the experimenter labeling the relevant dimension of each sorting card, the child labeled the relevant dimension each time. For the first trial of each dimension (i.e. the first card to be sorted by color and the first card to be sorted by shape), the experimenter asked, 'What color (shape) is this one?' The experimenter prompted the child gently if the child was incorrect in labeling on the first trial (e.g. if the child replied 'a square' when asked the shape of the truck, or used both dimensions, 'a red star') by repeating the question and verbally emphasizing the dimension: 'Yes, that's true, but what color (shape) is it?' This only happened with three children. No prompting or feedback occurred on any of the remaining trials.

### Procedure specific to the face-up condition

In the face-up condition, each sorting card was placed face-up in the bins of the sorting boxes. In all other respects, this condition was identical to the standard condition. Children spontaneously placed the cards face-up in the bins, so no instruction was required. This placement of the sorting cards intensified the perceptual pull to continue to sort according to the previous dimension, since the blue (truck) sorting card would be under the blue (truck) model card and the red (star) sorting card would be under the red (star) model card. Thus, the previously correct dimension remained extremely salient.

### Procedure specific to the sleeve condition

In the sleeve condition, the card was shown to the child and then placed in a manila sleeve before the child sorted it. Otherwise, the procedure was the same as in the standard condition. If seeing the irrelevant dimension on the sorting card makes the task harder for children, then covering the card should help performance. On the other hand, this condition places an additional demand on memory since the card-to-be-sorted is no longer visible, which might increase the difficulty of the task. The child was asked to wait while the experimenter placed the card in the manila envelope, and the child was instructed not to remove the card from the envelope.

## Results

Passing the training sort was defined as sorting one card for each value of each dimension correctly (i.e. one yellow truck, one yellow star, one red grapes and one blue grapes card). Only one child failed to do this within the maximum of eight cards allowed. That child is excluded from the analyses. Four 3-year-olds took more than the minimum of four cards to pass the four training trials; they all needed one extra card. Two were in the standard condition, one was in the face-up condition and one was in the label condition.

Virtually all children (96%) in all conditions sorted all the cards correctly for the first dimension. Children were considered to have passed the second dimension if they sorted five out of the six cards correctly. After the switch to the second dimension, most of the children (83%) either sorted every card correctly or every card incorrectly.[2]

Given the lack of variance, nonparametric categorical analyses were used to analyze the data (i.e. chi-square). The results are reported as percentages of children in that condition/age-group who succeeded on a particular condition (i.e. successfully switched dimensions; see Table 1 for number of children in each condition). No significant effects of gender, tester or pre-switch

[2] Out of the 16 children whose performance was not all or none, 11 were 3 years old and five were 4 years old. Among the 3-year-olds, four were in the face-up condition (three sorted five out of six cards correctly, and one sorted one out of six), two were in the sleeve condition (one sorted five out of six cards correctly, and one sorted four out of six cards correctly), two were in the label condition (both sorted five out of six cards correctly), and three were in the standard condition (one sorted four out of six cards correctly and one sorted three out of six cards correctly). Of the five 4-year-olds, two were in the face-up condition (both sorted five out of six cards correctly), two were in the standard condition (both sorted five out of six cards correctly) and one was in the sleeve condition (he sorted one out of six cards correctly).

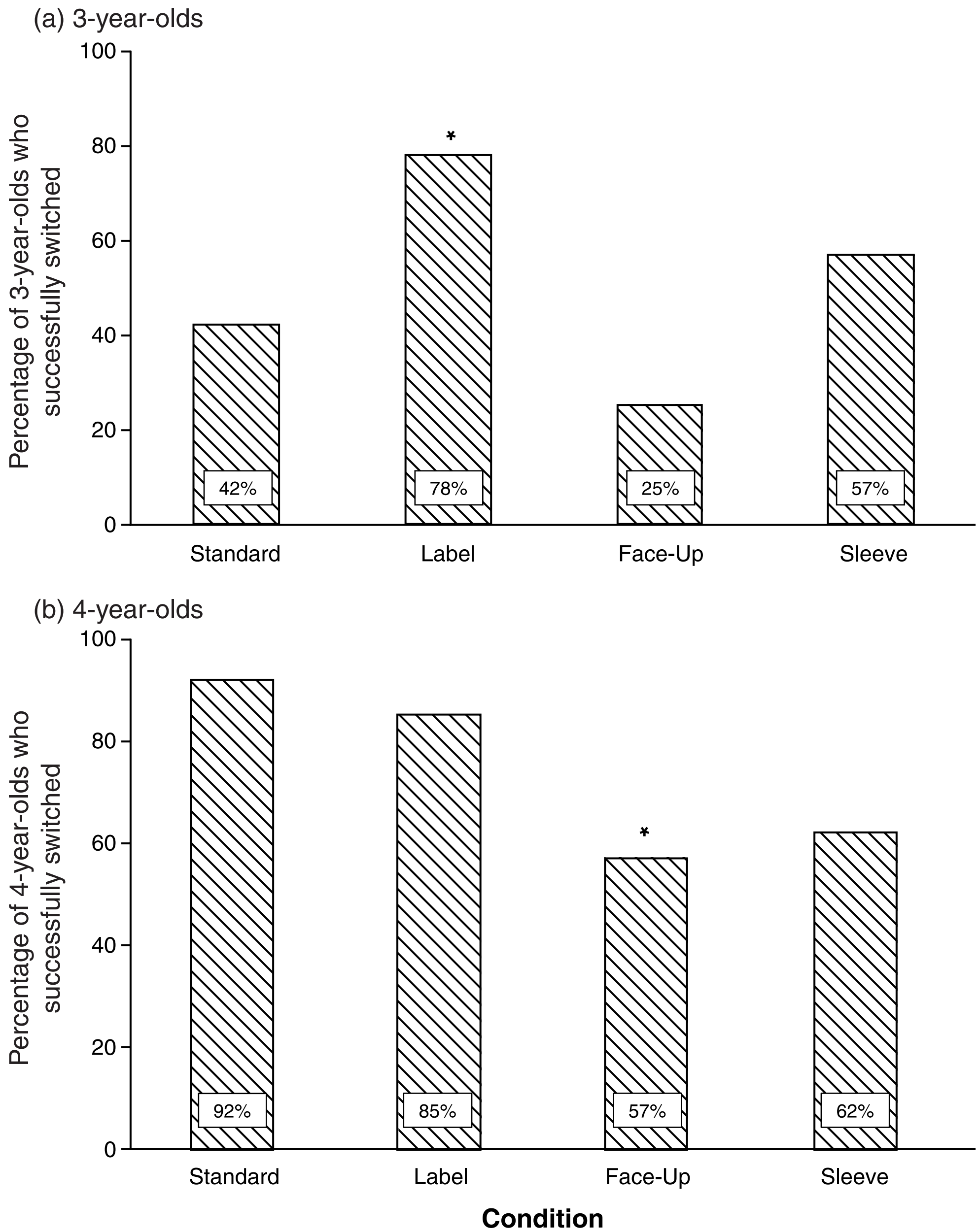


**Figure 2** *Percentage of children who successfully switched dimensions by condition and age group. Asterisks indicate a significant difference between performance in the starred conditions vs. performance in the standard condition.*

dimension were found; therefore, all results are reported collapsed across those variables.

Consistent with reports in previous studies (e.g. Zelazo *et al.*, 1995, 1996), most 3-year-olds performed poorly on the standard condition of the card sorting task (only 42% successfully switched dimensions), whereas most 4-year-olds performed well (92% successfully switched dimensions). The difference in performance on the standard condition at 3 years versus 4 years was significant ($\chi^2$ [df = 1, $N = 31$] = 7.6146, $p = .006$). In addition, there was a trend towards significance between 4-year-olds' performance on the face-up condition and 3-year-olds' performance, with 4-year-olds performing slightly better (57% vs. 25%; $\chi^2$ [df = 1, $N = 30$] = 3.2143, $p = .078$).

Children of 3 years performed better in the label condition than in any other condition, with 78% successfully switching dimensions in the label condition (see Figure 2). Significantly more 3-year-olds successfully switched dimensions in the label condition than in the standard condition ($\chi^2$ [df = 1, $N = 37$] = 4.8796, $p = .027$). Similarly, significantly more 3-year-olds successfully switched dimensions in the label condition than in the face-up condition ($\chi^2$ [df = 1, $N = 34$] = 9.4707, $p = .002$).

We had predicted that the performance of 3-year-olds on the sleeve condition would be intermediate between their performance on the label condition and the face-up and standard conditions (worse than on the label condition and better than on the face-up and standard conditions). Their performance on the sleeve condition seemed to be intermediate between their performance in the label condition and the face-up and standard conditions, but it was not significantly different from any. Percentage of correct responses by 3-year-olds in the label condition was 78%, in the sleeve condition 57%, and in the face-up and standard conditions 25% and 42%, respectively.

As predicted, children of 4 years of age performed worse in the face-up condition than in the standard condition (57% vs. 92% correct; $\chi^2$ [df = 1, $N = 26$] = 3.9144, $p = .048$). There was a trend toward a significant difference between performance on the standard condition and performance on the sleeve condition with 4-year-olds performing better on the standard than the sleeve condition (92% vs. 62% correct, $\chi^2$ [df = 1, $N = 25$] = 3.1053, $p = .078$). There were no other significant differences between performances in the 4-year-old age group.

## Discussion

### *Relation of this task to a larger literature*

The card sort task devised by Zelazo *et al.* (1995, 1996) can be thought of as a simplified version of the *Wisconsin Card Sorting Task* (WCST; Grant & Berg, 1948), a more difficult version of the *A-not-B task* for infants (Piaget, 1954 [1936]), the simplest possible test of *task-switching* (Rogers & Monsell, 1995) or as a *conditional discrimination task* (Gollin, 1964, 1965).

The WCST is a classic test for studying the functions of dorsolateral prefrontal cortex in adults (Milner, 1963, 1964; Drewe, 1974; Nelson, 1976; Stuss, Levine, Alexander, Hong, Palumbo, Hamer, Murphy & Izukawa, 2000).[3] As in Zelazo's card sorting task, participants are to sort each WCST card under a model card, sorting first by one dimension, then another. Instead of only two dimensions (color and shape), only two values per dimension (red, blue; truck, star), and only one switch of dimension, in the WCST there are three dimensions (color, shape and number). There are four values per dimension, and multiple switches of sorting criterion. Zelazo's task and the WCST require switching both attentional focus and stimulus–response mappings when the sorting dimension switches. However, instead of being told what the correct criterion is, when the criterion is changing and what it is changing to, and receiving no feedback after any sorting response, participants taking the WCST are never told which sorting criterion is currently correct and are not forewarned when the criterion changes. They do, however, receive feedback after each sorting response, and are to use that to deduce the currently correct criterion and to flexibly change their manner of sorting when the experimenter changes sorting criteria without warning. Thus, unlike Zelazo's task, the WCST requires creativity in generating hypotheses about what the relevant dimension might be, and using feedback to test one's hypotheses and to guide one's behavior. Children cannot usually perform well on the WCST until they are about 9–11 years old (Chelune & Baer, 1986; Rosselli & Ardila, 1993).

The performance of children on Zelazo's task exhibits important similarities to the performance of patients with prefrontal cortex damage on the WCST. Like frontal patients, even children of 3 years perform superbly on the first sorting dimension but persist in sorting by the previously correct criterion after the criterion for sorting changes. Frontal patients can sometimes correctly verbalize the new sorting criterion even as they persist in sorting by the previously correct criterion (Milner, 1963, 1964; Luria & Homskaya, 1964), just as 3-year-old children can respond correctly to the knowledge question but persist in sorting by the previously correct criterion. Frontal patients show evidence that at some level they know when they are responding incorrectly because they show considerable agitation when making perseverative errors (e.g. Golding, Hodgson & Kennard, 2001). Informal observations made during the present study suggest that some 3-year-olds show the same kind of agitation when perseverating on the card sort task.

[3] It was originally reported that WCST performance was especially sensitive to damage to dorsolateral prefrontal cortex (Milner, 1964, 1971). Over the years that idea has sometimes been challenged (e.g. Anderson, Damasio, Jones & Tranel, 1991), but it is now fairly firmly established that being able to switch criteria and resist perseverating on the previously correct dimension on the WCST test selectively recruits lateral prefrontal cortex, perhaps especially dorsolateral prefrontal cortex. Performance is particularly vulnerable to damage to dorsolateral prefrontal cortex compared with damage elsewhere in the brain, including other prefrontal regions (Stuss *et al.*, 2000). Konishi *et al.* (Konishi, Kawazu, Uchida, Kikyo, Asakura & Miyashita, 1999; Konishi, Nakajima, Uchida, Kameyama, Nakahara, Sekihara & Miyashita, 1998) found increased activation in a posterior portion of the inferior frontal sulcus (dorsal Brodmann Areas 45/44, normally considered ventrolateral prefrontal cortex, but referred to by the authors as dorsolateral) that was time-locked to when the sorting dimension changed. This was so even when participants were explicitly informed of the new sorting dimension (Konishi *et al.*, 1999; much as children are explicitly informed of the new sorting dimension on Zelazo's card sort task).

In the *A-not-B task*, a classic test for studying cognitive development in infants, a participant watches the experimenter hide a reward in one of two wells. A very brief delay ensues and then the participant can try to find that reward. With delays of 2–5 seconds, infants of $7^1/_2$–9 months and prefrontally-lesioned rhesus monkeys are correct at the first place the reward is hidden, but after watching the reward being hidden at the other location, infants of $7^1/_2$–9 months and prefrontally-lesioned monkeys fail to switch where they search and perseveratively search at the original hiding place (e.g. Gratch & Landers, 1971; Diamond, 1985; Harris, 1986). Infants of $7^1/_2$–9 months can occasionally indicate with their eyes that they know the reward is in the new hiding place even as they persist in reaching back to the previously correct location (Diamond, 1990, 1991a, 1991b; Hofstadter & Reznick, 1996), just as 3-year-old children and frontal patients can indicate that they know the new sorting criterion even as they persist in sorting by the previously correct criterion. Studies with human infants and with rhesus monkeys link the A-not-B task to dorsolateral prefrontal cortex (Bell & Fox, 1992, 1997; Diamond & Goldman-Rakic, 1989; Diamond, 1991a, 1991b).

If we consider the card sort task to be an easier version of the WCST and a harder version of the A-not-B task, both of which depend on dorsolateral prefrontal cortex, then it is reasonable that developmental improvements on Zelazo's card sort task may also be made possible, in part, by maturational changes in dorsolateral prefrontal cortex. Dorsolateral prefrontal cortex is not fully mature until early adulthood (Giedd, Blumenthal, Jeffires, Castellanos, Liu, Zijdenbos, Paus, Evans & Rapoport, 1999; Huttenlocher, 1979, 1990; Jernigan, Archibald, Berhow, Sowell, Foster & Hesselink, 1991; Pfefferbaum, Mathalon, Sullivan, Raweles, Zipursky & Lim, 1993; Sowell, Delis, Stiles & Jernigan, 2001), and it may undergo important maturational changes during the age period when children are improving on Zelazo's card sort task (3–5 years; Diamond, 2002). For instance, a dramatic change in neuronal density in dorsolateral prefrontal cortex occurs between 2 and 7 years (Huttenlocher, 1990) and the dendritic trees of dorsolateral prefrontal layer III pyramidal cells expand greatly between 2 and 5 years of age (Mrzlijak, Uylings, Van Eden & Judas, 1990).

Zelazo's card sort task can also be thought of as a *task-switching task*, involving only one switch between tasks, and only single-task blocks. Task-switching paradigms have been a rich source of psychological insight in adults, but have been almost entirely ignored in developmental psychology. Our study on the developmental progression of children on Meiran's task-switching paradigm is one of the first explicit studies of task switching we know of in children (Cohen, Bixenman, Meiran & Diamond, 2001; see also Cepeda, Kramer & Gonzalez de Sather, 2001).

Adults show a similar pattern in their reaction time on task-switching tasks to what children of 3 years show in their percentage of correct responses on the card sort task. For both adults and 3-year-olds, performance suffers when the relevant dimension switches (see, e.g. Monsell & Driver, 2000), though switching is easy for both if the stimulus is only relevant to one dimension (e.g. a 'blue grapes' card in our card sort task) or if the stimulus is 'congruent' (e.g. a 'red truck' card in our paradigm, where the correct response for red or truck would be the same; Allport & Wylie, 2000; Goschke, 2000; Jersild, 1927; Mayr, 2001; Meiran, 1996, 2000; Rogers & Monsell, 1995; Spector & Biederman, 1976; Wylie & Allport, 2000). In addition, adults (Meiran, 1996, 2000; Mayr, 2001) and preschoolers (Zelazo *et al.*, 1995; Towse *et al.*, 2000) perform well if there are four univalent response options rather than two bivalent ones. The task-switching paradigms used with adults are more difficult than Zelazo's card sort task, involving many more switches between the relevant dimensions or tasks, and involving mixed-task blocks. Children of 4 years are unable to perform well on those more difficult paradigms, and even children of 11 years old are able to succeed on only 80% of the switch trials (Cohen *et al.*, 2001).

There is broad consensus that patients with damage to left prefrontal cortex, in contrast to patients with damage to other brain regions, are impaired at switching between tasks (e.g. switching between dimensions; Diedrichsen, Mayr, Dhaliwal, Keele & Ivry, 2000; Keele & Rafal, 2000; Owen, Roberts, Hodges, Summers, Polkey & Robbins, 1993; Rogers, Sahakian, Hodges, Polkey, Kennard & Robbins, 1998; Shallice & Burgess, 1991). They are impaired under the same conditions in which children of 3 years fail (when the stimuli are relevant to both tasks). They fail in the same way as do 3-year-olds (by perseverating on the previously relevant dimension), and as with children of 3 years, their deficit in switching to the newly relevant dimension persists over several consecutive trials.

Activity in lateral prefrontal cortex (both dorsolateral [Brodmann Areas 9 & 46] and ventrolateral [Areas 44 & 45]) is consistently found to be increased when adults must switch between tasks versus when they continue to do the same task (e.g. Badre, Jonides, Hernandez, Noll, Smith & Chenevert, 2000; Braver, Sikka, Satpute & Ollinger, 2001; Dove, Pollmann, Schubert, Wiggins & von Cramon, 2000; Dreher, Kohn & Berman, 2001; Landau, Schumacher, Hazeltine, Ivry & D'Esposito, 2001; Meyer, Evans, Lauber, Gmeindl, Rubinstein, Junck & Koeppe, 1998; Sohn, Ursu, Anderson, Stenger

& Carter, 2000; Postle & D'Esposito, 1998; Wylie, Frith & Allport, 2000). Results also suggest that dorsolateral prefrontal cortex is particularly needed to overcome attentional inertia during task switching: Wylie *et al.* (2000) found increased blood flow in dorsolateral prefrontal cortex when the task switched, as compared with when the task remained the same. This increased activation was only evident when participants were actually presented with a stimulus (i.e. when they needed to overcome stimulus-triggered attentional inertia). Meyer *et al.* (1998) found that dorsolateral prefrontal cortex activity did not increase for within-dimension switches, although those too required changing S–R mappings (paralleling the success of 3-year-olds on that condition [Brooks *et al.*, 2003; Perner & Lang, 2002]). Dorsolateral prefrontal cortex activity increased only when participants needed to re-focus their attention (i.e. overcome attentional inertia) and switch to a different dimension. Similarly, Pollmann (2003) found that when only S–R mappings had to be switched (attentional focus remaining unchanged), dorsolateral prefrontal activity did not increase.

Zelazo's card sort task can also be thought of as a *conditional discrimination* task (e.g. if color game, blue truck goes with blue star; if shape game, blue truck goes with red truck). Indeed, Zelazo and Frye (1997) have underscored this perspective in their CCC theory, which emphasizes the hierarchical rule structure implicit in the card sort task. In classic conditional discrimination paradigms participants first learn to always respond to one member of a pair of stimuli (analogous to the pre-switch block in the card sort task, or Task I in task switching). After participants reach a high level of accuracy on that single task, the stimuli are presented against a different background, and the reward contingencies are reversed. After passing criterion on the second sub-task, trials with each background alternate or are randomly intermixed (analogous to the mixed-task block in task-switching paradigms). The rules are arbitrary, as are the cues. Participants must remember the rule associated with each color cue, and are usually given no reminder of the rules. However, the color cue (the background), which tells them which sub-task they are performing, remains visible throughout (participants do not have to remember which discriminative cue is currently relevant). Participants receive feedback on every trial (unlike standard procedures in Zelazo's card sort task or task-switching paradigms). Conditional discriminations appear to require the frontal cortex regions, that in the monkey border the arcuate sulcus (Areas 6 & 8; premotor cortex and the frontal eye fields; Goldman & Rosvold, 1970; Halsband & Passingham, 1985; Lawler & Cowey, 1987; Passingham, 1988; Petrides, 1982, 1985, 1986, 1988). When children are tested with minimal instruction and so must deduce the rules, they cannot succeed until they are $4^1/_2$–$5^1/_2$ years old (Doan & Cooper, 1971; Gollin, 1964, 1965; Gollin & Liss, 1962; Heidbreder, 1928; Jeffrey, 1961). If told the rule, children of $3^1/_2$–4 years do much better, but perfect performance is not seen until about age 5 (Campione & Brown, 1974; Gollin, 1966; Osler & Kofsky, 1965; Shepard, 1957). Children younger than $3^1/_2$ years cannot do this at all, even with explicit instruction. Note again the transition between 3 and 5 years.

### *Relation of our attentional inertia theory to other theories*

We predicted that significantly more 3-year-old children would be able to successfully switch sorting criteria in the label condition than in the standard condition; that was confirmed. We predicted that fewer children would be able to succeed in the face-up condition than in the standard condition overall and that this would be especially true for the 4-year-olds (because of floor effects at 3 years); that was confirmed. We predicted that 3-year-olds' performance on the sleeve condition would be intermediate between that on the label condition and standard and face-up conditions. The percentage of 3-year-old children succeeding on the sleeve condition certainly seems intermediate (almost exactly midway in between: label: 78%, sleeve: 57%, face-up: 25%), though with our small number of subjects per group, performance on the sleeve condition differed significantly from neither condition.

### Attentional inertia

The present experiment provides support for the hypothesis that at least part of 3-year-olds' difficulty on Zelazo's card sort task is in redirecting attention to a newly relevant sorting dimension when the values of the previous dimension are still present. Children of 3 years appear to have difficulty inhibiting a mindset (a way of thinking about the stimuli) that is no longer relevant. The variation of the task that most helped their performance was the label condition, in which their attention was redirected by their own labeling of the relevant dimension. This result is in sharp contrast with typical performance in the standard condition.

Consistent with this, Towse *et al.* (2000) found that when they instructed 3-year-old children who failed to switch sorting criteria in the standard condition to label the relevant dimension of the next sorting card, many who had failed to switch were then able to do so. Support for our hypothesis that the label condition worked because it succeeded in redirecting children's attention to the relevant dimension comes from our finding that after the first trial on the second dimension, children of 3 years spontaneously labeled the card by the second dimension in response to the open-ended question, 'What's this?'

Once children of 3 years classify a stimulus by a particular attribute, they have difficulty inhibiting that conceptual set and switching to think of the stimulus in terms of another of its attributes. Perhaps the label condition provides a scaffold that helps children switch, and perhaps this scaffolding succeeds because it gives children a way to use verbal mediation to help themselves inhibit the mental set that is no longer correct and thus refocus their attention (Luria, 1959; Vygotsky, 1978).

It is evidently critical that the children themselves label the relevant dimension – at least at 3 years of age. However, our 4-year-old children did perform better than that reported in the first study by Zelazo *et al.* (1995), in which, rather than labeling each stimulus according to the relevant dimension, the experimenter labeled each stimulus according to both dimensions (e.g. 'This is a blue truck'). Deak and Bauer (1996) found that children of 4 years benefited on a categorization task from experimenter labeling: when the experimenter labeled the stimuli, 4-year-old children found it easier to sort the items correctly. It is possible that the excellent performance of 4-year-olds in our standard condition may have been due to the salutary effect of the experimenter labeling the relevant dimension. It did not help 3-year-olds, but it is possible, given Deak and Bauer's (1996) findings, that it may have helped 4-year-olds.

By manipulating attentional inertia we were able to transform children's performance. Children of 3 and 4 years performed poorly in the face-up condition, which highlighted the previously relevant dimension by leaving the cards visible in the previously correct boxes. Children of 3 years performed best in the label condition, which highlighted the newly relevant sorting dimension by having the child label the sorting card by the currently relevant dimension. Thus, by directing their focus of attention (or more precisely, by scaffolding children's ability to inhibit their focus on the previously correct dimension) we were able to produce success in children 3 years old (the label condition). By increasing the inhibitory demand (by increasing the salience of the previously correct dimension), we produced failure in children of 4 years (the face-up condition).

Several studies, investigating a variety of paradigms, have demonstrated that children of 3–4 years can be helped to succeed by decreasing the perceptual salience of the incorrect answer (thereby reducing the inhibitory demand). For example, in most 'theory of mind' tasks (Wimmer & Perner, 1983), a child is asked to differentiate between his or her own knowledge about the location of a hidden object and another person's outdated (mistaken) knowledge about the location of the same object. Manipulations that reduce the perceptual salience of the true state of affairs enable children of 3 years to redirect their attention in the theory of mind paradigm and perform well (e.g. telling the children where the object is really hidden but never actually showing them [Zaitchik, 1991]). Reducing perceptual salience (thereby reducing inhibitory load) has also been found to aid toddlers' performance in the appearance–reality paradigm (Heberle, Clune & Kelly, 1999) and on Piaget's liquid conservation task (Bruner, 1964). Diamond (2002) has hypothesized that all of these tasks pose related problems for a young child, and intercorrelations have been reported among them (e.g. Carlson & Moses, 2001). All of these tasks require, in part, inhibiting focusing on, or reacting to, what is salient in the situation.

Zelazo and colleagues cite the finding that 3-year-olds fail to switch even after only one pre-switch trial (Zelazo *et al.*, 1995; Zelazo & Jacques, 1997) as evidence against an inhibitory (or inertial) explanation of children's failures on the task. This is not a problem for an inhibitory explanation, however, because a bias or even a conditioned tendency can be instilled by just one trial (e.g. Thompson, 1990). Indeed, infants fail to switch to the new hiding place on the A-not-B task after only one pre-switch trial (e.g. Butterworth & Jarrett, 1982; Butterworth, Jarrett & Hicks, 1982; Diamond, 1983). Although prepotent tendencies can be established by just one trial, many trials will instill a stronger response tendency than will just a few. In keeping with that, 4-year-olds are more likely to err when the sorting criterion switches on Zelazo's card sort task the more trials they have received with the initial sorting criterion (Zelazo *et al.*, 1995), just as infants are more likely to err when the side of hiding switches on the A-not-B task the more trials they have received at the initial hiding location (Landers; 1971; Marcovitch & Zelazo, 1999; Smith, Thelen, Titzer & McLin, 1999).

## Memory

Another argument against an inhibitory explanation is that memory alone is sufficient, as it entails both enhanced activation of (or strengthened links to) the correct representation and diminished activation of (or weakened links to) the incorrect dimension (Munakata, 1998, 2000). This would seem to be compatible with our viewpoint. Rather than eliminating the inhibitory component, this viewpoint places both inhibition and enhancement within the memory system. However, some have questioned whether a concept of inhibition is even needed in addition to memory. One such argument has been that if the representation of the correct sorting dimension is sufficiently strengthened, then inhibition of the competitor (the previously correct dimension) is not necessary (Kimberg & Farah, 1993). Diamond (1998) has countered that the notion that the correct representation could be strengthened to that extent is biologically implausible. Consistent with Diamond's view, the computational model of Cohen, Dunbar and McClelland (1990) has upper bounds on how much a code can be activated, and Houghton, Tipper, Weaver and Shore (1996) have shown that activating the appropriate code alone is not sufficient for differentiating between rival codes; the rival code must also be inhibited. Indeed, within the literature on task switching in adults, there is broad consensus that switching tasks requires not only enabling/activating/retrieving the rules appropriate for the new task, but also inhibiting/deactivating/disengaging from the mindset relevant to the other task (Allport, Styles & Hsieh, 1994; Allport & Wylie, 2000; De Jong, 1996; Goschke, 2000; Mayr & Keele, 2000; Mayr & Kliegel, 1993; Rogers & Monsell, 1995).

These are not simply opposite sides of the same coin. Our viewpoint is that before the stimulus appears, children have clearly in mind what the new sorting criterion is and the appropriate rules for that dimension. This is shown by their correctly answering questions about the rules and the relevant dimension. Thus, before the stimulus appears they are all set to perform correctly. They have activated the appropriate rules; their mental 'reconfiguration' process is complete. Then a stimulus appears that is relevant to both sorting dimensions in incompatible ways. That *creates* a problem, triggering the previous mindset that must then be inhibited anew. Moreover, the familiar target cards, each with a valid value on the previously relevant dimension, serve as attractors, pulling the child to think and act according to the previously relevant rules (Perner & Lang, 2002; Towse *et al.*, 2000). Children's well-laid memorial preparation is now in danger; they must inhibit the pull to focus on the previously relevant dimension and to act according to the previously relevant rules (Allport *et al.*, 1994; Allport & Wylie, 1999, 2000; Mayr & Keele, 2000). The core problem for 3-year-olds lies in inhibiting that pull.[4]

One of the important features of Zelazo's card sort task is that it goes a long way toward eliminating insufficient memory as an explanation for poor card sorting performance. Young children do not fail to switch sorting criteria because they cannot remember the currently relevant sorting criterion: the participant is reminded of the current sorting criterion on every trial; yet 3-year-old children err anyway. In addition, on the card sort task children respond correctly to questions about the current sorting rules, pointing to the appropriate sorting bin, though when given a card to sort, they put it in the incorrect bin.

The card sort task requires holding four rules in mind (two per dimension). Conceivably, that might be too much for 3-year-olds to hold in working memory. However, as discussed in the introduction, Brooks *et al.* (2003), Perner and Lang (2002) and Zelazo *et al.* (1995) have shown that 3-year-olds have no trouble holding four rules in mind and sorting cards appropriately, as long as they do not need to change their attentional focus.

Further evidence that forgetting is not an adequate explanation for the poor card sorting performance of 3-year-old children comes from recent studies by Perner and Lang (2002) and Towse *et al.* (2000). Most researchers have assumed that displaying the target cards over the sorting bins is a memory aid, something that makes the task easier (so that the child does not have to remember where the red ones go or where the stars go). Perner and Lang (2002) and Towse *et al.* (2000) found, however, that when target cards were not mounted above the sorting trays, 3-year-olds succeeded on the card sort task. Towse *et al.* varied more than just the presence or absence of target cards, so their results might be due to other methodological differences between their version of the card sort task and the standard version, but the same cannot be said of the Perner and Lang (2002) study. They varied only the presence or absence of target cards and found excellent performance in children of 3 years. Evidently, remembering where the cards should go is not the problem for children of 3 years.

Go/No-go tasks require that a subject actively respond to one stimulus and refrain from responding to another. Success appears here at roughly the same age at which success appears on the card sort task, and again poor memory cannot account for the failure of younger children to master the task. Children indicate that they understand and remember the task instructions, for they repeat them back correctly. Yet, they do not behave in accordance with the instructions they have just stated. Studies of Go/No-go consistently find that children cannot succeed at the task until about age $4^1/_2$ years because of inhibitory failures (errors of commission to the No-go stimulus; e.g. Birch, 1967; Beiswenger, 1968; Dowsett & Livesey, 2000; Garber & Ross, 1968; Jeffrey, 1961; Livesey & Morgan, 1991; Luria, 1961; Miller, Shelton & Flavell, 1970; Tikhomirov, 1978; van der Meere & Stemerdink, 1999).

[4] An alternative perspective is offered by Monsell (Rogers & Monsell, 1995; Monsell, Yeung & Azuma, 2000), who argues that participants (in his case, adults) cannot completely reconfigure their mindsets for the currently relevant dimension until an actual stimulus appears (the 'stimulus-cued completion hypothesis').

Conditional discrimination tasks involve two relevant dimensions, and participants must relate two separate things (background color and foreground shape) to one another, but *only* two rules apply: e.g. if black background, choose circle; if white, choose triangle. Here, fewer rules must be remembered than on the card sort task, yet success appears at the same age. Similarly, the day-night and tapping tasks involve only two rules, but they require inhibition of strong stimulus–response mappings, and children of 3 years fail them miserably (Diamond & Taylor, 1996; Gerstadt, Hong & Diamond, 1994). Most of the improvement on these tasks occurs between $3^1/_2$ and 5 years of age (*ibid.*).

The only way that perhaps a memory interpretation could account for results on the card sort task would be to essentially turn it into an attentional interpretation. We are persuaded by children's repeatedly correct answers to the knowledge questions and by the repeated reminders by the experimenter of which game they are now playing and its rules, that children remember which dimension is relevant and remember the two rules for sorting according to that dimension. If at any point the child were asked about the current game and/or where 'a red one' or 'a truck' should be sorted in that game, even with a stimulus card in hand, we predict that a child of 3 years would answer correctly. However, it is possible that although the child knows and remembers this information, when the child sees a stimulus relevant to both sorting games in incompatible ways, the child is not attending to the rules he or she has in memory.

### Representational ability

Zelazo and Frye (1997) have theorized that the key requirement for success on the card sort task is an ability to represent if-then rules (e.g. if it is a truck, then it goes in this box, but if it is a star, then it goes in that box) and that the reason children have a problem switching between incompatible sets of if-then statements (e.g. if this is the shape game, then blue trucks go in the red-truck bin, *but* if this is the color game then blue trucks go in the blue-star bin) is because they cannot represent such complex sets of rules. The findings from the label condition, however, suggest that the problem for children is *not* in representing incompatible sets of rules, but in being able to shift their attention so that they focus on the relevant dimension when looking at a stimulus relevant, in incompatible ways, to both dimensions, both sets of rules. That requires inhibiting the pull (a) to attend to the previously correct dimension and (b) to act in accordance with the rules appropriate for the previously correct dimension. The label condition did not provide children with a more sophisticated conceptual structure; it helped them look at the stimuli in a different way (it redirected the focus of their attention to the newly relevant dimension).

Consistent with this, and contrary to the CCC theory of Zelazo and Frye (1997), even children of 6 or 7 years have difficulty flexibly switching between the shape and color rules randomly over trials on the card sort task (unpublished data, Diamond lab). Recently and independently, Brooks *et al.* (2003) and Perner and Lang (2002) tested children on discrimination reversal tasks where the relevant dimension never changed. Both tasks contained the same number of rules (four) and the same hierarchical embedding as Zelazo's card sort task (two games, two rules each), but unlike the card sort task, the tasks of Brooks *et al.* and Perner and Lang contained no switch of dimensions. In Brooks *et al.*'s 'same' game, children were to sort airplanes with the airplane model card and dogs with the dog model card. In the 'silly' game, children were to sort dogs with the *airplane* model card and planes with the dog model card. Similarly, in Perner and Lang's pre-switch 'normal' shape game, children were to put cars with the car target card and suns with the sun target card. In the post-switch 'reversed' shape game, children were to put cars with the *sun* target card and suns with the car target card. If the problem for children on the card sort task is its hierarchical rule structure (as the CCC theory of Zelazo & Frye purports), 3-year-old children should fail here, for the tasks of Brooks *et al.* (2003) and Perner and Lang (2002) involve the same logical structure as the card sort task. Children of 3 years succeeded! Indeed, 99% of the 3-year-olds in Brooks *et al.* succeeded.[5] Thus, when children did not have to switch their attentional focus, i.e. did not have to shift from focusing on one dimension to another, children of 3 years were able to succeed. It appears that the problem is not in lacking a sufficiently complex representation of rules, but in being able to flexibly shift attentional focus. This ability shows a long, protracted developmental progression (Cohen *et al.*, 2001) and even adults are slower to respond when they have to shift attentional focus than on non-switch trials, even on Zelazo's card sort task (Diamond & Kirkham, 2001).

[5] The silly game is like the day-night test, which 3-year-olds fail (Gerstadt *et al.*, 1994). The critical difference could be (a) that children were reminded of the rules on every trial in the silly game (as is done with the card sort, but not with day-night), (b) that fewer trials were administered here (even 3–4-year-olds are able to perform fairly well on the first several day-night trials), or (c) dogs and planes are neither semantically related nor opposites, as are 'day' and 'night' (children as young as have been tested find the day-night task trivially easy if the rules are to say 'dog' to the sun or moon stimulus and 'cat' or 'pig' to the other [Diamond, Kirkham & Amso, 2002]).

'Knowing the rules is sometimes insufficient to permit their use' (Zelazo *et al.*, 1996, p. 37). In addition, we contend, the ability to inhibit (a) attending to what had previously been relevant and (b) acting according to what had previously been correct, is required. 'A conception of development is offered emphasizing that the child must not only acquire knowledge, but must also inhibit reactions that get in the way of expressing knowledge that is already present' (Diamond & Gilbert, 1989, p. 223).

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