

Attentional Inertia:  
Accounting for young children's difficulty on the Dimensional Change Card Sort

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the Faculty of Graduate Studies and Research  
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Master of Arts

by

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### Abstract

The Dimensional Change Card Sort (DCCS) requires children to sort bivalent test cards first along one dimension, and then along a second. Children's difficulty on the DCCS has been explained by attentional inertia (the inability to overcome seeing test cards in terms of the initially relevant dimension; Kirkham, Cruess, & Diamond, 2003). Sixty 3- and 4-year-old children were tested on the Standard DCCS and a novel modification that highlighted the relevant dimension of the cards (Easy). By occluding the cards during labeling, children were able to attend to the relevant dimension before automatically considering the stimuli on the pre-switch dimension. Three-year-olds' performance on the Easy version was significantly greater than on the Standard, but only when the Easy came first. This finding indicates that young children's performance on the DCCS is more fragile than first anticipated and calls into question the efficacy of attentional inertia in accounting for their difficulties.

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## Introduction

Executive Function (EF) is a cognitive construct that generally refers to a set of cognitive processes that coordinate flexible, goal-directed behaviour and it is thought to be related to the development of the Prefrontal Cortex (Hughes, 2002; Zelazo, & Jacques, 2005). As is the case with many cognitive constructs, definitions of EF are theoretical and somewhat varied throughout the literature. Approaches to defining EF range from the very theoretical, conceptualizing EF as a higher level, homuncular ability coordinating the control and shifting of attention and action to guide a response (Shallice, 1982), to the very empirical, studying deficits of EF in individuals with frontal brain injuries or in lesion studies with animal models (e.g. Luria, 1973). Others attempt not to specify EF itself, but conceptualize it as part of a problem-solving framework, defining EF only in terms of what it accomplishes (Zelazo, Carter, Reznick, & Frye, 1997). While these approaches are very different theoretically, each has described EF as a heterogeneous set of cognitive processes involved with the planning and control of goal-directed responses. However, none of these approaches is able to specify or describe the individual processes comprising EF.

A more recent approach to studying the specific components of EF has focused largely on studying the development of executive function in children. Since EF is widely known to be related to the development of the prefrontal cortex (Luria, 1973), and since the prefrontal cortex undergoes major changes in the early years of childhood, the study of EF in children has allowed researchers to tease apart the specific components of EF as they develop, providing richer information than was previously available through studies of adult populations and patients with frontal lobe injuries (Hughes, 2002).

Of course, the dramatic increase in the study of executive function in children in recent years has been motivated by more than just the desire to examine components of the construct itself. EF has been implicated as a major factor related to a host of other aspects of cognitive development during the early years of life, including problem solving (e.g., Frye, Zelazo, & Palfai, 1995; Zelazo, Frye & Rapus, 1996), future thinking (e.g., Atance & O'Neill, 2005), theory of mind development (the ability to attribute mental states to oneself and others – Carlson & Moses, 2001; Carlson, Moses, & Breton, 2002), reading ability (e.g., Cain, Oakhill, & Bryant, 2000), and early numeracy skills (e.g., DeStefano & LeFevre, 2004; Geary, Bow-Thomas, & Yow, 1992) as well as to indices of self and social understanding and academic success (e.g., Hughes, 1998). Further, deficits in one of the specific components of EF, conflict inhibition, have been cited as one of the major indicators of childhood disorders, such as attention deficit/hyperactivity disorder, learning disabilities and autism (e.g., Russell & Jarrold, 1999; Zelazo, Jacques, Burack, & Frye, 2002).

This paper begins by outlining the most frequently cited measures of executive function in preschool-aged children, paying special attention to the tasks aimed at measuring the specific components of EF in young children and the typical developmental trajectories reported on those tasks. Next, the factor of conflict inhibition (the main topic of the present study) is examined in detail, including an analysis of the primary task used to measure conflict inhibition in preschool-aged children (the dimensional change card sort, DCCS), and the literature accounting for young children's performance on this task is critically reviewed, in light of two major theoretical accounts

of that performance. Finally, a novel modification to the DCCS is presented in the current study to help clarify what factors account for preschoolers' performance on the task.

### *Executive Function in Preschool-aged Children*

The main approach in the developmental literature for the study of executive function involves presenting children with batteries of neuropsychological tasks aimed at measuring the components of EF and using factor-analysis to determine the underlying structure of the construct and its processes (see Zelazo & Müller, 2002 for a review). Generally, these studies reveal as many as six distinct factors, including clusters such as: (1) cognitive/attentional flexibility or set-shifting; (2) freedom from distractibility; (3) self-monitoring and error detection; (4) planning; (5) inhibitory control (both conflict and delay); and (6) working memory. Unfortunately, these terms are applied quite variably across the literature, and the extent to which some of these factors overlap is often unclear (Zelazo, Muller, Frye, & Marcovitch, 2003). For instance, there is much overlap between tasks used to measure attentional flexibility and tasks used to measure inhibitory control – conflict (IC-conflict), and it is unclear whether this is the result of overlap between the factors themselves, or simply the result of inconsistencies in the naming of these factors. Similarly, because many of the tasks were devised for use with different age groups, the results of factor analyses depend, to some degree, on the age groups being studied. For comprehensive reviews of the EF tasks frequently cited, and information on the age groups they are appropriate for and the components they represent, see Zelazo and Müller (2002) and Carlson (2005).

The factors most frequently cited and studied as distinct components of EF within preschool aged children (three- to five-year-olds) are planning, cognitive or attentional

flexibility, working memory, and inhibitory control (conflict and delay). Each of the factors comprising EF undergoes major developmental changes over the preschool ages, with performance moving quite abruptly from consistently failing to consistently passing, across a multitude of studies, methodologies and laboratories (Frye et al., 1995; Zelazo et al., 1996; Jacques & Zelazo, 2005; Carlson, 2005).

The present study focuses on the development of inhibitory control (conflict) in preschool aged children, and hence, the discussion of the components of EF and the tasks used to measure these components will be limited to this age range. While the research and theory related to the development and measurement of conflict inhibition in three- to five-year-old children will be discussed in great detail, each of the components will first be discussed briefly to provide context for the present study.

### *Planning*

Planning involves the ability to plan and sequence future events in pursuit of a defined goal-state (Carlson, Moses & Claxton, 2004). Developmental measures of planning present children with a goal-state and require them to sequence events to reach that goal state. An example of a planning task is the Tower of London (adapted from the Tower of Hanoi) which serves as an adult measure of planning ability (Shallice, 1982). In the Tower of London, children are presented with two peg boards, each with three pegs (a large peg that can hold three beads, a medium peg that can hold two beads and a small peg that can hold only one bead) and three beads - two of one colour and one of another colour. One peg board represents the goal-state with a specific configuration of coloured beads on the pegs, and the other peg board is the initial state, with the beads in a different configuration. Children are required to move beads from one peg to the other, one bead at

a time, to reproduce the configuration of the goal-state. Since some of the pegs can hold only one or two beads, children are required to plan the movement of beads accordingly, in order to reach the goal-state. Children are scored on the number of moves they make before reaching the goal-state. Typically, children younger than three- to four-years have difficulty completing a two-move problem, while children four-years and older are able to perform well on both two- and three-move problems (Zelazo & Muller, 2002).

### *Cognitive Flexibility*

The second distinct factor comprising EF is Cognitive Flexibility. Cognitive Flexibility is a very broad cognitive process, literally referring to the ability ‘think flexibly’ or to consider an object or event in more than one way, simultaneously (Jacques & Zelazo, 2005). While there is overlap between measures of cognitive flexibility and some of the other factors of EF, namely inhibitory control (as will be discussed below), tasks that measure cognitive flexibility can be conceptualized as assessing a broader ability than that required of inhibitory control. That is to say, while all inhibitory control tasks require some degree of cognitive flexibility, measures of cognitive flexibility should not necessarily require inhibitory control.

An example of a task measuring cognitive flexibility is the Ambiguous Figures task of Rock, Gopnik, and Hall (1994). In this task, children were presented with ambiguous stimuli that can be interpreted in more than one way (e.g., a line drawing that looks like both a duck and a rabbit) and were queried on what they saw. While most adults reported reversing the ambiguous figure in their minds (shifting from seeing it first as a duck, then as a rabbit, then as a duck again, and so on), preschool aged children were very unlikely to reverse, even when the dual-nature of the stimuli were demonstrated for

them (Rock et al., 1994). The Ambiguous Figures task measures the degree to which children interpret the ambiguous stimuli in more than one way; typically, children younger than three-and-a-half are not able to do so, while children four-years and older are (Gopnik & Rosati, 2001).

A second and more recent example of a task measuring cognitive flexibility is the Flexible Item Selection Task or FIST (Jacques & Zelazo, 2001). In this task, children were presented with arrays of objects that differed along three dimensions (size – small, medium, large; colour – red, yellow, blue; and shape – boat, teapot, shoe). After considerable practice with these dimensions and with choosing pairs of items, children were asked first to select a pair of items that ‘go together’ in one way, and then to select a pair that ‘go together’ in a different way. In any given trial, children were presented with three items that could be paired in different ways, according to two of the three possible dimensions. The researchers held one dimension constant (what they called the ‘irrelevant’ dimension) while they varied the other two dimensions (the ‘relevant dimensions’). For example, children may be presented with a large red shoe, a medium red shoe and a medium red boat. From this array, children might first select the large red shoe and the medium red shoe, because they are both shoes, and might then select the medium red shoe and the medium red boat, because they are both medium. In this example, colour is held constant, and as such, any selection based on colour would be counted as incorrect (i.e., selecting the large red shoe and the medium red boat is considered an error).

Children are scored on both the number of correct first selections and the number of correct second selections over fifteen test trials. Performance on the first selections and

second selections are then compared, both within and across age groups. In general, three-year-olds perform above chance on the first selection, but do not perform significantly different from chance on the second selection, whereas five-year-olds perform at ceiling on the first selection and above chance on the second selection (Jacques & Zelazo, 2001). The FIST measures the degree to which children are able to flexibly consider any item in terms of more than one of its dimensions (for example, as a shoe, a red one, or as a medium one), providing an index of their attentional flexibility. A detailed discussion of some methodological concerns with this task and its administration are addressed below, with reference to the present study.

#### *Working Memory*

The third distinct factor that makes up EF is Working Memory (WM), which can be defined as the ability to hold information in mind while simultaneously manipulating that information (Baddley, 1992). An example of a developmental measure of working memory is the Counting and Labeling task (Gordon & Olson, 1998). In this task, children are presented with three small objects (for example, a tree, a gift, and a cow). In a demonstration trial, the experimenter proceeds first to label each of the objects ("Tree, gift, cow") and then to count each of the objects ("One, two, three"), and finally, to count and label the objects at the same time ("One is a tree, two is a gift, three is a cow"). Children are then presented with three novel objects and asked first to label the objects, then to count the objects, and finally to count and label the objects at the same time. Children are scored as correct if they are able to count and label the objects together, without error. The task typically proceeds for two trials and children's scores range from zero to two. Typically, children younger than three-and-a-half fail the task, failing to

correctly count and label the objects, in turn, often perseverating on the counting aspect of the task (e.g. “*One* is a tree, *one* is a skate, *one* is a bird,”), while older children perform well, both counting and labeling the items, without difficulty.

Another example of a WM measure is the Backward Digit Span task (Davis & Pratt, 1996). In this task, children are presented with strings of digits, spoken one second apart, and are asked to repeat those digits back to the experimenter in reverse-order. After one demonstration trial and two practice trials (each two digits in length), trials proceed in sets of two strings (of equal length), beginning with two-digit strings and increasing in length, one digit at a time. Children are scored in two ways: both on the highest string they are able to repeat in correct reverse-order, and on the highest set of strings that they are able to complete without error. Typically, children younger than four fail the task, repeating numbers in forward order, rather than backwards, while older children are successful.

### *Inhibitory Control*

The final component of EF frequently studied in preschool populations is Inhibitory Control. Inhibitory Control, in general, refers to the ability to inhibit a very strong (prepotent) response tendency in favour of a more contextually appropriate response, given the task circumstances (Frye et al., 1995). In other words, inhibitory control refers to the ability to moderate or control one’s initial reaction to a situation or stimulus. Inhibitory control breaks down into two sub-factors, delay inhibition and conflict inhibition, as described below. While both of these components involve the inhibition of a prepotent response, they do so in different ways and there is considerable

support that they represent distinct cognitive processes (e.g., Carlson et al., 2002; Carlson et al., 2004; Jacques & Zelazo, 2005)

*Delay inhibition.*

Delay inhibition requires the delay of a prepotent response until a time when it is more appropriate, as in tasks that require children to delay gratification. A common example of a delay inhibition task presents children with a tempting reward (e.g., one tasty marshmallow) and gives them the option of either consuming that reward immediately, or waiting a few minutes for a greater reward (e.g., ten tasty marshmallows). The experimenter then leaves the child alone with the smaller reward and records the amount of time (up to the predetermined maximum, usually 10 minutes) that the child waits before either consuming the smaller reward or receiving the larger reward. Typically, three-year-old children perform poorly on these tasks, while children older than four perform well (e.g., Kochanska, Coy & Murray, 2001).

*Conflict inhibition.*

While delay inhibition involves only inhibiting a (contextually) inappropriate response, conflict inhibition refers to the ability to replace a prepotent response tendency with a different, conflicting or incongruent response. Conflict inhibition is a component of EF that has received a great deal of attention, in that it has been implicated as a major factor accounting for young children's difficulties with many tasks thought to measure other cognitive developments in the preschool period, such as representational understanding (Bialystok & Martin, 2003; Sabbagh, Moses, & Shiverick, 2006) and theory of mind development (see Perner & Lang, 1999 for a review). While there is a wide range of developmental measures of conflict inhibition, each task requires children

to replace a prepotent response strategy with an incongruent response strategy, depending on the rules of the task.

A frequently used task in the measure of conflict inhibition in the preschool years is the Bear/Dragon task (Reed, Pien, & Rothbart, 1984; Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996). The Bear/Dragon task proceeds as a simplified version of the game "Simon Says," requiring children to respond to the requests of one puppet and ignore the requests of another puppet. This task treats performing a stated action as the prepotent response (as does the game Simon Says) and requires children to inhibit that response when the dragon says to do something, but not when the bear does. After ensuring that children can perform each of ten simple actions (e.g. 'touch your nose,' 'touch your cheeks,' et cetera), children are presented with two puppets, a 'nice bear' (who speaks in a high-pitched voice) and a 'naughty dragon' (who speaks in a gruff voice) and are instructed to perform the actions that the nice bear requests of them, but to *not* perform actions requested by the naughty dragon (i.e., *inhibit* their tendency to respond). After up to five practice trials, with both rules stated each time, ten test trials proceed in quasi-random order. Halfway through the testing trials a rule-reminder is given to all children. Children receive scores ranging from 0 to 3 for each of the dragon trials (0= full movement, 1= partial movement, 2 = different movement, 3= no movement) and scores are summed to a maximum score of fifteen. Typically, three-year-old children do poorly on the task, performing both the actions requested by the bear and the dragon, whereas older children are able to selectively inhibit responding to the dragon while performing the requests of the bear.

Another frequently used task in the measure of conflict inhibition is the Day/Night Stroop task developed by Gerdstadt, Hong, and Diamond (1994). In this task, children are presented with test cards depicting pictures of either a moon or a sun, and are asked to label the cards with the semantically incongruent label, rather than the semantically congruent label. When presented with a picture of a moon, for example, children are asked to respond by saying 'day' instead of 'night' (which is the stronger, prepotent response). Children are scored on the number of 'correct' incongruent responses they provide over sixteen test trials, and frequently reaction times for each trial are also measured and summed. Performance is also often examined as a function of trials, comparing performance in earlier trials to performance on later trials as a measure of stability.

To address potential working memory demands of the Day/Night task, Gerdstadt and colleagues also included a memory condition wherein children were asked to respond 'day' when presented with one abstract line-drawing and 'night' when presented with a different abstract line-drawing. This condition served to match the working memory demands of the task while negating the need for conflict inhibition as there was no prepotent response. Thus, a comparison of children's performance on the Day/Night condition to the memory condition was proposed to yield a more 'pure' measure of conflict inhibition (Gerdstadt et al., 1994).

Typically, performance on the Day/Night task increases dramatically between the ages of three-and-a-half and five-years of age; few three-and-a-half-year-olds are able to reliably produce the 'correct' response, while most five-year-olds perform near ceiling. Further, the few three-and-a-half-year-olds that do perform well on the task make

significantly more errors and take significantly longer to respond than five-year-olds, and their performance shows deterioration over the number of trials, whereas five-year-olds' performance remains stable (Gerstadt et al., 1994; Carlson & Moses, 2001). Further, three-and-a-half-year-olds' performance on the Gersradt and others' memory condition was comparable to that of five-year-olds and did not differ in terms of reaction times or stability, suggesting that differences in working memory alone cannot account for the superior performance of older children (Gerstadt et al., 1994).

The Dimensional Change Card Sort (DCCS) developed by Frye, Zelazo, and Palfai (1995) is the most widely-used measure of preschoolers' conflict inhibition across a variety of areas in cognitive development, including studies of theory of mind development (e.g., Carlson & Moses, 2001), autism and attention deficit disorder (Zelazo et al., 2002). More generally, the DCCS has come to serve as an index of young children's overall executive function, and is highly correlated with other measures of EF, including delay inhibition (Carlson & Moses, 2001) and planning (Carlson, Mandell, & Williams, 2004), as well as to more general measures of social understanding (Carlson & Moses, 2001). Young children's performance on the DCCS is the focus of the present study, and the literature accounting for this performance is considered in detail, as follows.

#### *The Dimensional Change Card Sort*

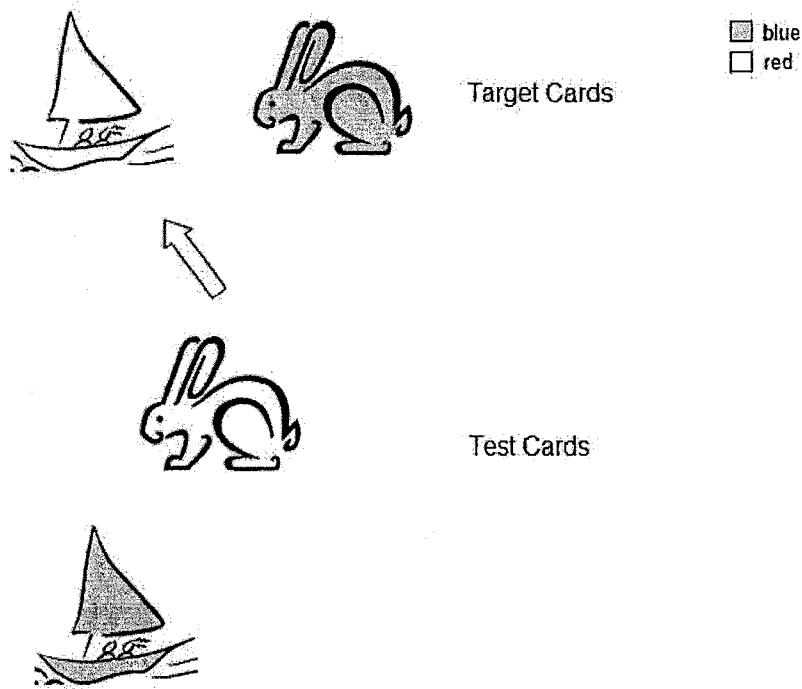
The DCCS task is designed to measure children's ability to flexibly switch between rule pairs in a card sorting task. Adapted from the Wisconsin Card Sorting Task (WCST), a widely used measure of executive function in adult populations, the DCCS is considered to provide a relatively pure and robust measure of conflict inhibition in

children. In the now-standard version of the DCCS (Zelazo, 2006), children are presented with two target cards (affixed to open sorting trays) that vary along two dimensions, typically colour and shape (e.g., a blue rabbit and a red boat). These target cards and sorting trays remain in front of the child for the duration of the task. After pointing to and labeling each of the cards on both dimensions (e.g. ‘Here is a blue rabbit, and here is a red boat.’) the rules for the first phase (the pre-switch phase) of the task are explained. In the pre-switch phase of the task, children are required to sort six bivalent test cards that match one of the target cards on only one dimension. The test cards are red rabbits and blue boats and children need to sort them by one dimension (colour or shape) into the sorting trays (face down). When sorting by colour, participants need to place the *red rabbit* test cards into the tray with the *red boat* and the *blue boat* test cards into the tray with the *blue rabbit*. When sorting by shape, participants need to sort the *red rabbit* test cards into the tray with the *blue rabbit* and the *blue boat* test cards into the tray with the *red boat*. The dimension chosen for the pre-switch phase is inconsequential, either colour or shape can be selected, as order effects have been extensively tested for and have not been found (Zelazo, 2006). See Figure 1 for example test and target cards, sorting by colour.

The rules for sorting in the pre-switch phase are presented to children as a game: “We are going to play a card game. This is the colour game. In the colour game, all the blue ones go over here [while pointing to the tray with the *blue rabbit*] and all the red ones go over there [while pointing to the tray with the *red boat*.]” The experimenter then demonstrates by sorting a *blue boat* into the tray with the *blue rabbit*, labeling the card on only the relevant dimension, and sorting it into the corresponding tray (e.g., ‘Here is a

*blue one, so it goes over here [while sorting the card into the tray with the blue rabbit].')*

Next, the rules of the pre-switch phase are repeated again, and then the child is presented with the other type of card (e.g., a *red rabbit*) labeled by the experimenter on the relevant dimension only. The experimenter asks the child where the card should be sorted, and provides feedback: if the child sorts the card correctly (as is almost always the case), the experimenter praises the child, and if the child sorts the card incorrectly the experimenter intervenes and corrects the mistake.



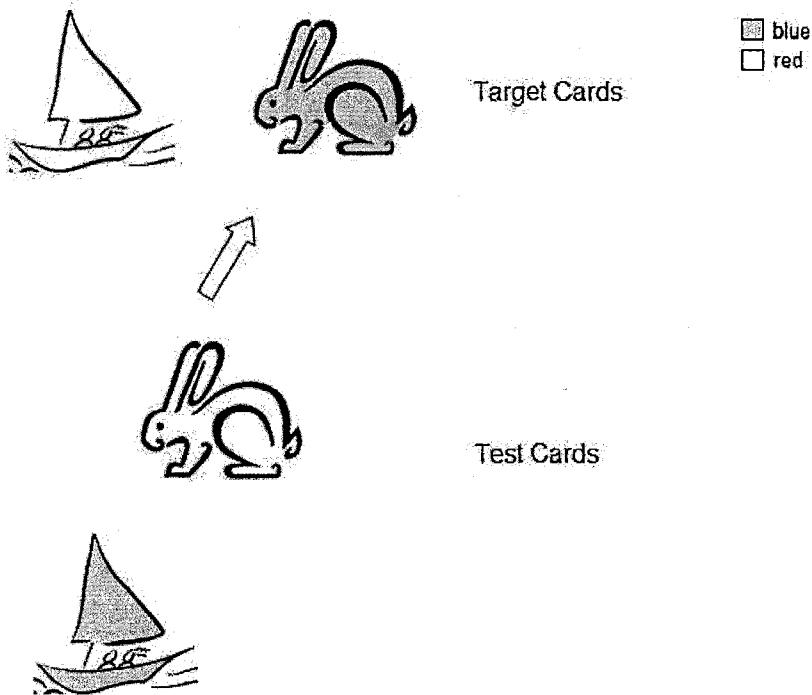
*Figure 1.*

Adapted from Zelazo (2006), this figure displays typical bivalent target cards and test cards for the DCCS, and demonstrates how a red rabbit is sorted in the colour game.

After the demonstration trial and feedback trial, the game proceeds immediately to the pre-switch phase, wherein children are presented with six bivalent test cards, in quasi-random order, such that no more than two cards of the same type are presented in a row. The rules for sorting are repeated before each pre-switch trial. More specifically, the experimenter says, “Remember, if it’s a blue one it goes here [pointing to the tray with the *blue rabbit*], and if it’s a red one it goes there [pointing to the tray with the *red boat*].” The experimenter then shows the child the next test card and says, “Here’s a red/blue one. Where does it go?” No feedback is given on any of the pre-switch trials.

Immediately following the last pre-switch trial, the experimenter announces the switch in the rules of the game from sorting on the first dimension to sorting on the second dimension. Specifically, she says, “Now we’re going to play a new game. We’re not going to play the colour game anymore. We’re going to play the shape game. In the shape game, all the rabbits go here [pointing to the tray with the *blue rabbit*], and all the boats go there [pointing to the tray with the *red boat*.]” Neither the target cards nor the pre-switch cards are removed from the sorting trays as the post-switch phase begins.

Before each post-switch trial the rules for sorting are repeated again (e.g., ‘If it’s a rabbit it goes here [pointing to the tray with the *blue rabbit*], and if it’s a boat it goes there [pointing to the tray with the *red boat*.]’) and each post-switch card is labeled on the relevant dimension only (e.g., ‘It’s a *boat*, where does it go?’) and the same constraints for card selection are applied. Again, no feedback is given on any of the post-switch trials. For a full version of the protocol for the standard version of the DCCS see Zelazo (2006). See Figure 2 for example test and target cards, sorting by shape.



*Figure 2.*

Adapted from Zelazo (2006), this figure displays typical bivalent target cards and test cards for the DCCS, and demonstrates how a red rabbit is sorted in the shape game.

The task is typically scored on a pass/fail basis, since there is typically very little variability in children's performance. Because scores on the DCCS are usually bi-modal, with children either passing all trials or failing all trials, the examination of mean scores violates the assumptions for parametric tests, and variance/mean scores are uninformative. Therefore, performance on both the pre-switch and post-switch phases of the task is summed (out of six in each phase) and children scoring either five or six out of six are considered as passing each phase of the task, respectively<sup>1</sup>. Subsequently, performance on the post-switch phase is compared to performance on the pre-switch

<sup>1</sup> It is important to note, however, that five out of six is not significantly different from chance performance, according to the binomial distribution,  $p < .05$ .

phase of the task; typically analysis of post-switch performance is only considered for children who pass the pre-switch phase of the task. In general, most normally developing three-year-old children pass the pre-switch phase of the task and fail the post-switch phase of the task, while four- and five-year-old children typically pass both the pre-switch and post-switch phases. Further, performance on the post-switch phase of the task is typically bimodal, with children either passing or failing all of the trials.

As can be seen, the DCCS requires cognitive flexibility because it requires considering both the test and target cards in two different ways: each card can be classified in terms of its colour as well as its shape. However, the DCCS requires more than cognitive flexibility in that it requires children to treat the bivalent test cards in conflicting ways, first in terms of one dimension in the pre-switch phase (e.g., ‘the *red boat* is a *red* one), and then in terms of the second dimension in the post-switch phase (e.g., ‘the *red boat* is a *boat*’). Thus, test cards sorted correctly as according to the post-switch phase are being sorted incorrectly in terms of the pre-switch rules, and for this reason, the DCCS requires conflict inhibition (IC-conflict). The pre-switch phase of the task builds a prepotent response tendency, and the post-switch phase of the task requires the inhibition of that response tendency in favour of a new and *inconsistent* response (Zelazo, 2006). Though multiple pre-switch trials are typically given to help develop a prepotent response, it has been shown that three-year-olds will perseverate on the pre-switch dimension even after only one pre-switch trial (Zelazo et al., 1996). The DCCS also requires working memory, as children are required to hold the rules for sorting in mind while performing the task, but considerable supports to working memory are provided in that the rules for sorting are repeated before each trial and the test cards are

labeled on the relevant dimension during every trial (e.g., in the colour game, a *red boat* is introduced as a ‘red one’).

The DCCS is one of the most widely used measures of conflict inhibition within preschool populations for several very practical reasons: it is easy to administer and score, it is of short duration (roughly 5 minutes), and it is very suitable for use with young children since its instructions are straightforward and are repeated for children before each trial. Furthermore, the interpretation of children’s errors on the DCCS is unambiguous—children’s difficulty is not the result of memory for the rules, hypothesis testing, or some other artifact of the task or its administration (Zelazo, 2006).

In terms of the utility of the DCCS on an experimental level, the DCCS lends itself very well to experimental manipulation, allowing systematic exploration of various factors thought to be related to the measurement of conflict inhibition in young children, making it an ideal task to use in studies aimed at specifying the components of EF and the relationship between these components (Zelazo et al., 2003; Kirkham, Cruess, & Diamond, 2003; Perner & Lang, 2002). Also, the task is extremely robust to minor methodological changes; despite being run rather inconsistently throughout the literature - across different studies, different researchers and laboratories – extremely similar results are obtained for preschoolers time and time again. For instance, the task has been run with five, six, or more pre-switch and post-switch trials, with various stimuli varying on colour and shape, shape and size, et cetera, test cards have been labeled on both dimensions or on the relevant dimension only, demonstration cards have been the same as the target cards or the same as the test cards, and so forth (Carlson & Moses, 2001; Carlson et al., 2002; Perner & Lang, 1999; Perner & Kloo, 2002; Frye et al., 1995; Zelazo

et al., 1996; Zelazo et al., 1997). None of these inconsistencies proved significant, in that children's performance was unchanged and results were typical, across studies.

The general finding that performance on the DCCS shifts dramatically over the preschool years has been replicated across a multitude of studies and a range of manipulations focused on determining the specific features of the task that may contribute to young children's poor performance (e.g., Frye et al., 1995; Zelazo et al., 1996; Zelazo et al., 1997; Jacques, Zelazo, Kirkham, & Semcesen, 1999; Perner & Kloo, 2003; Zelazo et al., 2003; Rennie, Bull, & Diamond, 2004; Diamond, Carlson, & Beck, 2005; Muller, Gela, Dick, Overton, & Zelazo, 2006). This is consistent with the idea that moving from failing to passing the task is the result of a real and abrupt conceptual change, occurring sometime between three and five years of age.

#### *Accounting for Young Children's' Difficulty on the DCCS*

In recent years, much research has attempted to account for the apparent difficulty faced by three-year-olds with the DCCS. In general, explanations for young children's poor performance on the task come in two varieties: (1) those that propose *performance* constraints in terms of children's understanding of the rules of the task, working memory capacities, et cetera, and (2) those that propose *conceptual* changes in children's ability to flexibly switch between sorting in the pre- and post-switch phases, proposing more general cognitive mechanisms involving rule-use and attentional flexibility. While the former performance accounts have been examined extensively and have received little empirical support, accounts proposing conceptual changes in young children's cognitive flexibility continue to be the topic of much debate, and unfortunately, few studies have addressed this debate directly. Before turning to the conceptual change accounts, it is

worth reviewing the major performance accounts, as several important findings have emerged from these studies.

*Knowledge of the rules.*

To examine the relationship between children's knowledge of the rules and their actual sorting performance on the task, Zelazo, Frye, and Rapus (1996) added two knowledge questions and one action question after the post-switch phase of the standard task. In the knowledge questions children were asked about each of the post-switch rules, without being shown test cards. For instance, if shape was the relevant dimension of the post-switch phase, children were sequentially asked where each of the two shapes should be sorted in the shape game (e.g., 'Where do (boats/rabbits) go in the shape game?') and children were asked to point to the correct sorting tray. Immediately following the two knowledge questions, the action question required children to sort one more card by the post-switch dimension (e.g., 'Play the shape game. Here is a (boat/rabbit). Where does this go in the shape game?').

The authors found that of the eighteen three-year-olds who failed the post-switch phase of the card sort, seventeen answered both knowledge questions correctly, sixteen of whom went on to fail the action question. Only three four-year-olds failed the post-switch phase of the card sort, and two of these children answered the knowledge questions correctly, but failed the action question. Zelazo and others replicated these findings in three other experiments, requiring children to respond to the knowledge questions either verbally (by saying which sorting tray the card belonged in) or manually (by pointing to the sorting tray), and found very similar results. In all cases, three-year-olds were able to

answer the knowledge questions accurately after failing the post-switch phase of the task (Zelazo et al., 1996).

The high performance of three-year-old children on the knowledge question, despite having just failed the post-switch phase of the card sort, demonstrates a powerful discrepancy between young children's knowledge of the sorting rules and their actual performance on the task. Since three-year-olds are able to demonstrate their understanding of the rules of the game both manually and verbally, their apparent difficulty with the post-switch phase of the task cannot be attributed to a failure to understand the rules of the game, since in the absence of test cards, they were able to correctly indicate where cards should be sorted. Even more striking is the finding that immediately following their correct answers to the knowledge questions, these same children failed the action question, again continuing to sort on the pre-switch dimension. Thus, failure on this task by three-year-olds cannot be due to their lack of knowledge of the rules of the game, but instead appears to be related to their inability to flexibly switch between sorting on one dimension to sorting on the other.

#### *Memory constraints.*

Another possible performance explanation to account for young children's difficulty on this task explored the possible role of working memory constraints. Zelazo, Müller, Frye, and Marcovitch (2003) tested the hypothesis that three-year-olds' poor performance on the DCCS was the result of an inability to simultaneously hold in mind the multiple sorting rules required to perform the task. Over a series of three experiments, the authors compared three- to four-year-olds' performance on four different memory conditions of the card sort to their performance on the Standard version of the task. In

each of these conditions, children were required to hold four sorting rules in mind (as in the Standard version – two pre-switch rules and two post-switch rules), however, the rules did not require children to sort any card in more than one way (unlike the Standard version). That is to say, the pre-switch and the post-switch sorting rules referred to different stimuli (not different dimensions of the same stimuli) and therefore did not require any one stimulus to be sorted in a different way after the switch. Zelazo and colleagues reasoned that if young children's difficulty was the result of memory limitations alone, their performance on versions of the card sort that matched or exceeded the number of rules required by the Standard task should be similarly poor. If, however, young children's poor performance on the DCCS is the result of an inability to sort the test cards in more than one way (as they suggested), young children's performance should be much lower on the Standard version than on any of the memory conditions (Zelazo et al., 2003).

Despite matching the memory demands of the Standard version (in terms of the number of rules required), three- to four-year-olds performed significantly better on each of the new conditions than on the Standard version of the task (on which their performance was typical) and they perseverated in sorting on the pre-switch dimension. Since children were required to hold just as many rules in mind as required by the Standard version, Zelazo et al. concluded that young children's difficulty with the DCCS cannot be accounted for by memory constraints alone. They argued that since these conditions (collectively) only differed from the Standard task in that the cards could not be considered in more than one way, depending on the sorting phase, children's difficulty on the Standard task must result from an inability to deal with conflict between the cards

based on the sorting rules presented (Zelazo et al., 2003). This series of studies offers much support to the notion that children's difficulty with the DCCS has to do with conflict between sorting rules and the bivalent nature of the cards, and not simply with holding in mind two sets of rules.

*Response inhibition.*

While three-year-olds' difficulty with the DCCS cannot be explained by a failure to understand or hold in mind the rules of the game, as demonstrated by the studies outlined above, several studies proposed that children's perseveration on the pre-switch rules may have been the result of a lack of response inhibition. That is to say, as demonstrated by the knowledge and action questions (Zelazo et al., 1996), while children were able to verbalize where a card should go in the post-switch game, when they were actually presented with the card they were unable to override the prepotent *motoric* response of sorting on the pre-switch rules.

To test this hypothesis Zelazo, Frye, and Rapus (1996) labeled the two sorting trays by using familiar figures (Ernie and Big Bird) in addition to the target cards, and the rules were presented to children in terms of whose tray the card should go in (e.g. 'If it's red it goes in Ernie's tray, and if it's blue it goes in Big Bird's tray,'). As in the Standard version of the task, both of the relevant sorting rules were presented to children before each test card, during both the pre-switch and post-switch phases. In the *manual* condition, children were asked to sort the cards themselves, as in the Standard version. In the *verbal* condition, however, children were asked to place their hands on cardboard handprints on the table in front of them, and to respond verbally to each card. As is typical of performance on the Standard task, nearly all three-year-olds perseverated on

the pre-switch rules in both the manual and verbal conditions, failing the post-switch phase of the task. Again, most children correctly answered the knowledge questions, posed in the same manner as discussed above (e.g. ‘Whose tray do red ones go in the colour game?’), but failed the action questions. No differences were found between the manual and verbal conditions (Zelazo et al., 1996), and thus, it again appears that young children’s difficulty with the DCCS is not one of motoric response inhibition, *per se*, but an inability to flexibly switch from sorting on the first dimension to sorting on the second dimension.

In another study aimed at investigating the role of response inhibition in the DCCS, Jacques, Zelazo, Kirkham, and Semcesen (1999) made use of an error detection paradigm and had children monitor the performance of a puppet on the DCCS. If three-year-old children’s failure on the Standard version of the task was due to performance limitations, the use of an error detection approach should alleviate these constraints and allow children to demonstrate their understanding of the task. Three-year-old children received both a child-sort condition of the task (the Standard version) and one of three puppet-sort conditions, in which they were required to report on each trial whether a puppet had sorted the test card correctly or incorrectly. In each of the three puppet conditions, the puppet sorted all of the pre-switch cards correctly. However, in the post-switch phase the puppet either sorted: perseveratively, sorting all of the post-switch cards on the pre-switch dimension; correctly, accurately sorting all of the post-switch cards on the post-switch dimension; or incorrectly, switching sorting dimensions when there was no rule-switch announced.

If three-year-olds' difficulty was one of motoric response inhibition, despite underlying competence in the understanding of the task, both children who passed and children who had failed the child-sort version of the DCCS would be expected to report that the puppet sorted incorrectly in the perseverative and incorrect-switch conditions, and to report that the puppet had sorted correctly in the correct-switch condition. This was not the case, however, as most children who failed the child-sorts condition also judged the puppet's perseverative responses as correct, and, similarly, judged the puppet's correct responses as incorrect. Further, children's performance on the puppet version was correlated with their own performance on the Standard version of the task – children who passed the child-sort task also tended to do well on puppet-sort tasks, and children who failed the child-sort task tended to fail the puppet source tasks, lending little support to the notion that three-year-olds' difficulty with the DCCS is one of response control, rather than understanding.

In sum, the studies outlined above demonstrate considerable evidence that three-year-olds' poor performance on the DCCS cannot be accounted for by a failure to understand the rules or instructions of the game, by an inability to hold in mind the rules of the task itself, or by an inability to inhibit a prepotent motoric response. Since young children's performance on the task is not significantly limited by any of the aforementioned characteristics of the task itself, it seems likely that it is due to a more general difficulty in dealing with the nature of the task. That is, young children's difficulty with the DCCS appears to be due to an inability to deal with the conflict that exists at many different levels in the task, and requires children to respond in two different ways over the two phases of the task. Several attempts have been made to

specify the precise role of conflict in the DCCS to explain young children's failure of the task, the most prominent of which are considered below.

### *The Role of Conflict in the DCCS*

Given that what seems to account for children's failure on the DCCS has to do with their inability to deal with the conflict in the task, it is important to examine this in more detail. It is important to note that conflict in the DCCS can exist at many different levels. There is conflict between the target cards and the test cards, in that each of the test cards matches the target cards on opposing dimensions. That is, when colour is the relevant dimension, matching cards are of different shapes, and when shape is the relevant dimension, matching cards are of different colours. There is also conflict within the cards themselves, as each card can be categorized as either a shape ('a *boat* one'), or as a colour ('a *blue* one'). Further, there is conflict between the sorting rules required of children in the pre-switch and the post-switch phases, as children are required to sort test cards in incongruent ways, depending on the relevant dimension. When shape is relevant, for example, a *blue boat* is sorted into the *red boat* tray, but when colour is relevant, the same card, a *blue boat*, would be sorted into the *blue rabbit* tray. Different accounts have examined young children's performance on the task as a function of the conflict at each of these levels. While these accounts all contend that young children's difficulty on the task is a result of an inability to deal with the conflict in the task, each account characterizes the conflict in a slightly different way and proposes different explanations for children's difficulties. The most prominent of such accounts will be considered in turn.

*Conflict between test and target cards.*

One account for three-year-olds' poor performance on the DCCS implicates the role of conflict, or a visual-clash, between the test and target cards, since the test cards match each of the target cards on only one dimension. According to this account, children's difficulty with the DCCS arises from an inability to consider any one card in two different ways (e.g., as a *rabbit* in the shape game, but as a *red one* in the colour game) since the target cards are always in conflict with the test cards. In the pre-switch phase of the Standard version of the task, for instance, the target cards act as a memory support to children, reminding them where they should sort test cards. In the post-switch phase of the task, however, the target cards create a visual-clash for children because cards are now expected to be sorted under cards that they no longer match on the first dimension.

For example, in the pre-switch phase of the task, children may be required to sort *red rabbits* into the sorting tray with the *red boat* on the target card. For the duration of the pre-switch phase, children may sort by attending to the relevant dimension of the target card (in this case, its colour). In the post-switch phase, however, while the target and test cards themselves do not change, the relationship between each of the test cards and the target cards shifts. Now, for example, a *red rabbit* would be sorted into the sorting tray with the *blue rabbit* target card. While the target cards may help children perform well on the pre-switch phase, they may encourage children's poor performance on the post-switch phase in the same way. By this account, difficulty on the task results from children's difficulty in overcoming the salient, visual-clash between test and target

cards, which makes it difficult for young children to consider the target cards in two different ways (e.g., as *rabbits* or as *red ones*) (Perner & Lang, 2002).

To test this hypothesis, Perner and Lang (2002) introduced two new manipulations of the DCCS along with the Standard task to three-year-old children. In the reversal-shift condition, children were presented with test cards (suns and cars) that varied on only one dimension (shape). In the pre-switch phase, children were asked to sort target cards (suns and cars) into corresponding trays, and in the post-switch phase children were asked to sort suns into the car tray and cars into the sun tray. Because there were still different rules for sorting between the pre- and post-switch phases, and because children were still required to inhibit an earlier response strategy to be successful in the post-switch phase, the reversal-shift condition was included to address the role of visual-clash between test and target cards. With no visual-clash between test and target cards, children were expected to perform well on the reversal-shift condition.

In a second manipulation, Perner and Lang sought to eliminate the role of target cards altogether by placing puppets beside the sorting trays. In the pre-switch phase target cards were red cars and yellow suns. Children were told that Donald Duck really likes suns and that Mickey Mouse really likes cars, and were asked to sort the test cards accordingly. In the post-switch phase, the rules were switched and children were told that 'now' Donald wants all the red ones, whereas Mickey wants all the yellow ones. This condition was included to eliminate the effect of visual-clash between test and target cards altogether, by eliminating the target cards themselves. Similarly, children's performance on the puppet condition was expected to be better than performance on the Standard task (2002).

These two conditions, reversal-shift and target puppets were crossed, resulting in four conditions: reversal-shift with target cards, reversal-shift with target puppets, standard with target cards, and standard with target puppets. Children were exposed to each of the four tasks, over two sessions, such that in either session they had one of each type of task (one reversal-shift or Standard, and one target card or puppet). The within-subjects design of this task was utilized to examine whether there were carry-over effects between the conditions – that is, to examine whether sorting without target cards or sorting in the reversal-shift condition would benefit performance on the standard version of the DCCS.

The results of the study were in clear support of the hypotheses, the only condition in which three-year-olds showed any difficulty was the Standard DCCS, and this difficulty was only found when the Standard version preceded the other conditions. While these findings did support the idea that children's performance on the Standard task was improved when the visual-clash between test and target cards was not present (as in the puppet conditions), several key features of the reversal-shift and puppet conditions need be considered.

While the puppet version of the DCCS matched the Standard version in all other aspects but the inclusion of target cards, it seems to eliminate the possibility of perseveration altogether because of the increased memory load required to persevere. That is to say, in order for a child to persevere on the post-switch phase of this task, as in the Standard version, he would need to remember that *before* - in the first phase - Donald wanted suns and Mickey wanted cars, and that *now* - in the current phase - Donald wants yellow ones and Mickey wants red ones. It seems likely that children could

perform well on this task as if they were performing two pre-switch phases, in serial; it would require a great deal of working memory *in order to* persevere on the pre-switch sorting rules in the absence of target cards. In reducing the visual-clash, this manipulation changed the nature of the task itself. It seems likely that children forego the need to regard any single test card as being *both* a car and a red one, as is the case with the standard task, but to regard that card simply as what Donald wants in one game and as what Mickey wants in another game.

Similarly, while the reversal-shift version of the task did require children to switch from sorting cards in one way to sorting cards in another way, it did not necessarily require children to negotiate between two sorting strategies or sets of rules. As suggested by Zelazo in correspondence with the authors (as reported in the paper), children may have passed the reversal-shift version by applying a strategy of *sorting backwards* or *doing the opposite* instead of using explicit rules. That is, in order to sort perfectly in either of the reversal-shift conditions, children only needed to reverse their sorting, and because the cards only differed on one dimension, this did not require the cards to be reconsidered or recategorized at all. Again, while this condition successfully eliminated the visual clash between test and target cards, it changed the nature of the sorting required altogether.

Finally, the finding that children's performance was only poor on the Standard task, and only when it was the first task, supported the idea that children made some gain from the puppet conditions and the reversal-shift conditions that they then applied to the Standard task. Due to a flaw in the design of the study, however, this finding cannot really be supported. As a result of the counterbalancing procedure, in all cases that the

Standard version was not presented to children as the first task, a reversal-shift version of the task preceded the puppet version of the task, since children were only presented with one of each type of task per session. Because it is possible, Zelazo (in comments to the authors) suggested that children were able to apply a ‘sort backwards’ strategy in the reversal-shift conditions. Thus, it seems likely that once children received a reversal-shift condition they may have applied this strategy to all subsequent conditions as well. If this was the case, there is no clear support that there was any benefit of the puppet condition at all, as children’s performance on all of the tasks may have resulted from their reversal-shift strategy. This explanation is an equally plausible account for the finding that the DCCS was only difficult for children when it came first in a set.

*Conflict within test cards.*

Another similar account for children’s poor performance on the DCCS implicates the role of conflict within the test cards themselves. Because of the bivalent nature of the test cards, children are required to consider the cards in two conflicting ways, depending on the relevant dimension of the task. For instance, in order to be successful on the task, a child should consider a *blue boat* as only a *boat* in the shape game, or as only a *blue one* in the colour game, to minimize the likelihood of sorting on the irrelevant dimension. Because the item on the test card is both a boat *and* a blue one, regardless of which dimension is relevant, sorting becomes difficult on the post-switch phase because it is difficult to consider the newly relevant dimension.

Several studies have addressed the role of conflict in the sorting cards in the DCCS by attempting to separate the dimensions of shape and colour, to varying degrees, within the sorting cards themselves. Perner and Kloo (2005) for instance, tested a

separated-dimensions version of the DCCS, wherein test cards depicted a colourless shape and a swatch of colour, side by side. Thus, while the test cards still depicted both dimensions, the conflict was alleviated in that no card depicted a single object that was both a blue one *and* a boat, for example. As hypothesized, these authors found that significantly more children passed the separated dimensions version than the standard version of the task.

In a very similar study, Diamond, Carlson and Beck (2005) tested a background/foreground version of the DCCS in which test cards depicted a colourless, outline of one of two shapes in the center of the card (in the foreground), with the background of the card shaded in one of two colours. Again, in this version of the task conflict in the test cards was lessened or alleviated in the sense that the cards no longer depicted a single object that had both colour and shape, although both of the dimensions were still present in the cards. Consistent with the findings of Perner and Kloo (2005), these authors also found that children performed significantly better on the background/foreground version of the DCCS than on the Standard task.

Although each of these modifications to the standard DCCS worked to bolster young children's performance, the modifications changed the nature of the task altogether. In either version, young children could succeed on the task by restricting their attention to a different area of the test cards. In Perner and Kloo's version, for instance, children can selectively attend to one side of the test cards in the shape game, and to the other side of the test cards in the colour game. Similarly, in Diamond et al.'s version, children can selectively attend to either the background or the foreground of the test cards, depending on the relevant dimension. Because the dimensions of the cards are

physically pulled apart, these versions may as well have used different cards altogether. With no conflict within the objects depicted on the test cards, children can pass the task by playing two different games, in serial – either the left game or the right game, for example.

It seems as though any attempts to remove the conflict from various levels of the DCCS have resulted in a task that is fundamentally different, albeit much easier, than the Standard version. While each of the modifications to the task outlined above has successfully produced high performance from three-year-olds, each of the modifications has changed the requirements of the Standard task so dramatically that comparisons between these tasks are uninformative. The most prevalent observation from the above studies is that in removing the conflict between the test and target cards, or from within the test cards themselves, the resulting tasks do not really seem to measure conflict inhibition, and rather measure something akin to simple colour and shape categorization.

In order for the DCCS to maintain face validity in its measurement of conflict inhibition, certain characteristics of the Standard task need to be maintained: first, there must be conflict between the test cards and the target cards; also, the bivalent nature of both the test cards and the target cards needs to be retained, such that the two dimensions are part of a unified object (e.g., an object that is both blue *and* a boat); and finally, there must be a switch in sorting rules, such that test cards need to be considered first on one of the unified dimensions, and then on the other. Only if the nature of the task is retained can it be investigated if children's performance can be accounted for by explanations of conflict at one of these levels, or by any other explanation.

*Conflict between the sorting rules.*

Another account for young children's difficulty on the DCCS comes from the (now revised) cognitive complexity and control theory (CCC-r) of Zelazo, Muller, Frye, and Marcovitch (2003). The CCC-r proposes that three-year-olds' difficulty with the DCCS is not the result of visual conflict between the cards, *per se*, but of an inability to integrate the conflicting sorting rules under a super ordinate or higher-order rule. In other words, this account claims that the development of conflict inhibition is really just a manifestation of the development of a greater capacity to utilize complex rule structures, and it is this rule structure that governs performance on the DCCS. In the Standard version of the DCCS, the rules for sorting in the pre-switch and the post-switch phase need to be embedded under a higher-order rule (termed the setting condition) if children are to successfully switch between them. This rule hierarchy is depicted in Figure 3 (as adapted from Zelazo et al., 2003).

The ability to deal with embedding is thought to be a more general cognitive development related to problem solving ability and is highly consistent with the observation that children's performance on the DCCS moves abruptly from failing to passing. For instance, when asked to sort by a single set of rules (e.g., "if it's red, put it here" and "if it's blue, put it there") three-year-olds are very successful, as there is no need for rule embedding under the setting condition (see Figure 3). According to the CCC-r account, however, in order to be successful on the DCCS, the two conflicting sets of rules (the rules for colour and the rules for shape) must be embedded under the setting condition, that specifies which set of rules is in use during any particular phase of the task (e.g. sorting by shape versus sorting by colour). Only once this embedding has occurred

does it become possible for children to cross major branches of the rule hierarchy and successfully switch between relevant rule pairs.

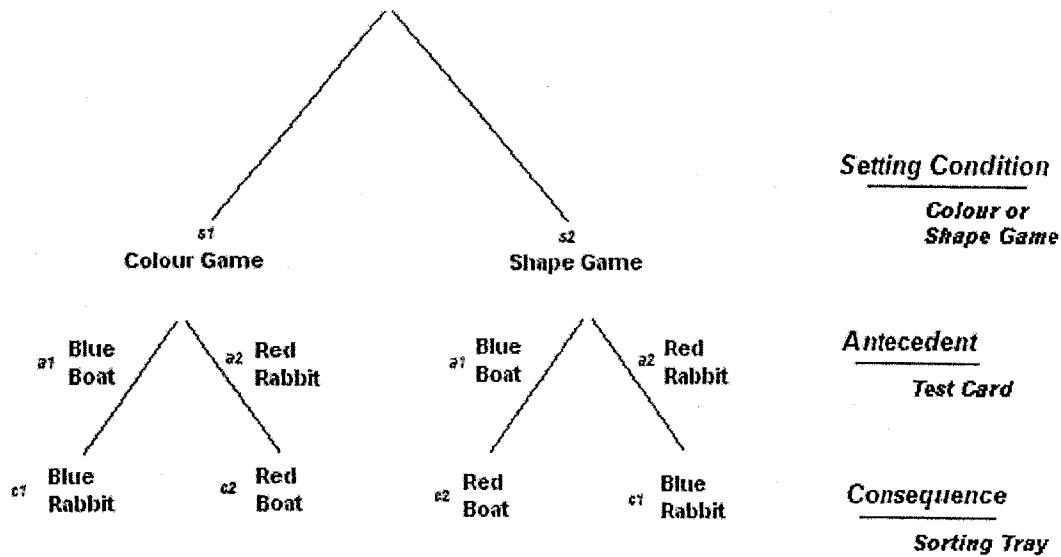


Figure 3.

This figure depicts the type of hierarchical rule structure proposed to enable performance on the DCCS. At the highest level in the figure, the setting condition contains two branches, one for each of the relevant dimensions, as specified by the game to be played. Below each of these branches are rules for the antecedent conditions, depending on the specific values of each test card presented. Finally, at the lowest level of the hierarchy are the possible consequences, representing the dimensions of the target cards on the sorting trays.

In general, the development of these increasingly complex levels of embedded rule structures is claimed to be age-related and quite rigid, following fairly specific timelines. According to their research, Zelazo and his colleagues describe this development, outlining that while two-year-olds have difficulty integrating a single rule

pair under a set of antecedents and three-year-olds have difficulty integrating two antecedents under a single setting condition, four-to five-year-olds can successfully represent and embed all of these levels of rules with ease (Zelazo et al., 2003). Unfortunately, the development of these more complex rule-structures is not further specified. Although the CCC-r account describes the developmental trajectory, the theory does not specify a mechanism to account for these developments, beyond implicating general developments in the prefrontal cortex.

The CCC-r theory describes three-year-olds' performance on the DCCS nicely, and is also able to account for their successful performance on the knowledge questions. Because the knowledge question states which setting condition is being used, and because children are not faced with the bivalent card during the knowledge question, the appropriate rule pair is selected for children – they do not need to cross major branches of the hierarchy. It is only when children are presented with the bivalent test card that they are faced with the choice between rule pairs, and because they have not integrated these rules under a setting condition, they perseverate on the rule they have already been using for the pre-switch phase.

In an account similar to the CCC-r, Kirkham, Cruess, and Diamond propose that three-year-olds' difficulty on the DCCS stems not from their inability to switch between sorting rules, *per se*, but from their inability to inhibit attending to a sort of prepotent mindset built-up in the pre-switch phase (2003). In what they have termed *attentional inertia*, these authors describe children's difficulty with the DCCS as an inhibitory one, wherein the *mindset* required by the pre-switch phase (e.g., seeing objects as shapes) becomes prepotent, and thus, when children are faced with a card in the post-switch

phase, they are unable to inhibit seeing the card in the original manner (e.g., as a shape) instead of seeing the card in the now-appropriate manner (e.g., as a colour). Unlike response inhibition accounts that propose a prepotent motoric response, the attentional inertia explanation is consistent with the results of the knowledge questions and the error detection paradigm: children are likely to answer knowledge questions accurately, as in these cases only the relevant dimension is highlighted and children are not faced with conflict in the cards, since test cards are not presented to them. Further, children are still expected to perseverate when responding verbally or when monitoring another's performance on the task, as in the error detection paradigm presented by Jacques and others (1999).

The attentional inertia account for young children's performance on the DCCS, especially with regard to their successful performance on the knowledge questions but failure on the action questions, is strikingly similar to the account put forth by CCC-r. And in essence, these accounts are not incongruent: both explanations acknowledge that young children's difficulty with the task stems from the conflict between the pre-switch and the post-switch sorting rules, only they do so with variable emphasis. Accounts from attentional inertia emphasize that young children have difficulty attending to the currently relevant dimension of the test cards in the post-switch phase, because they are mentally unable to disengage their attention from the pre-switch dimension. Attentional inertia does not deny that rule use governs performance on the DCCS, but it does not attempt to specify a mechanism for switching between rules. Similarly, the CCC-r does not deny the impact of attention to a particular dimension in performance on the DCCS, and acknowledges that highlighting one dimension or the other will influence performance on

the task by helping children to cross major branches of the rule structure, so long as the embedding has taken place (in contrast to the first CCC theory). Unfortunately, the degree to which either of these accounts accurately explains young children's difficulty with the DCCS is difficult to assess, since they do not, in and of themselves, make different predictions. Research directed at determining the role of attentional inertia in young children's performance on the task is discussed, as follows.

*The role of higher-order rule use and attention.*

Recently, Kirkham, Cruess, and Diamond (2003) attempted to investigate the role of children's ability to overcome attentional inertia. These authors investigated young children's performance on three novel versions of the DCCS that differed in terms of the level of attentional inertia imposed by the pre-switch sorting dimension. Three- and four-year-old children were presented with one of three manipulations of the DCCS, or the Standard task, and comparisons were made between these groups. Before completing the pre- and post-switch trials of either sorting task, however, all children received training and feedback in sorting univalent test cards by colour and by shape. After children demonstrated sufficient sorting skill, they proceeded to the card sort conditions.

First, in the sleeve condition, each of the test cards were presented visually to children and labeled on the relevant dimension only, as in the standard task, and were then hidden inside of small, plain envelopes (sleeves) prior to sorting. This condition was proposed to lessen the attentional inertia because children were not able to see both dimensions of the card when sorting. If children's difficulty in attending to the relevant dimension of the card was rooted in the salience of seeing that dimension, the sleeve

condition should lessen the attentional inertia of the task and make it easier to consider the card in terms of the currently relevant dimension.

In the second condition, the label condition, test cards were presented to children, as in the Standard task, and children were queried to label each card on the relevant dimension themselves. That is, if the relevant dimension was shape, when the first test card was presented the experimenter would ask “What shape is this one?” before handing the card to the child to be sorted. The authors reported that on all subsequent trials children spontaneously labeled cards on the relevant dimension without any further prompting. The label condition was proposed to lessen the attentional inertia created by the pre-switch dimension by redirecting children’s attention to the newly relevant dimension.

Third, in the face-up condition, all instructions and conditions were exactly as in the Standard task, except that children were asked to sort cards face-up into the trays. This condition was proposed to increase the attentional inertia created by the pre-switch dimension by increasing the perceptual pull to continue sorting on the pre-switch dimension, as cards sorted on that dimension were still visible in the sorting trays. Because children could still see the pre-switch cards in the sorting trays once the switch in sorting rules was announced, children were not only required to mentally overcome their previous sorting strategy, but to overcome the draw of the cards in the sorting trays (which matched the pre-switch rule).

Between-subjects comparisons lent some support to the impact of attentional inertia on children’s performance on the card sort. Most notably, it was found that significantly more three-year-olds passed the label condition of the task than the Standard

version, supporting the idea that having the child label the relevant dimension of the card increased the salience of that dimension, and thus bolstered performance. Further, significantly more three-year-olds successfully switched dimensions in sorting in the label condition than in the face up condition. This supports the idea that the reduction of attentional inertia in the label condition and the increase of attentional inertia in the face-up condition had some effect on three-year-olds' performance.

Although significant differences were not found between the Standard condition and face-up condition in three-year-olds (whose performance on the Standard condition was already far below chance), this difference was found to be significant in four-year-olds, supporting the idea that the face-up condition increased the attentional inertia of the pre-switch dimension in an age group that typically scores above chance on the task. Further, this finding lends further support to the idea that manipulating the level of attentional inertia can both help and hinder children's performance on the task, relative to their requisite abilities.

The sleeve condition had little effect on performance for either age group. Although the authors originally suggested that the sleeve condition should decrease the attentional inertia of the pre-switch dimension by reducing the visual-clash between test cards and target cards, in an attempt to explain these findings they also proposed that this condition may have placed a greater memory constraint on children, requiring them to remember the identity of each card as they sorted. For this reason, the authors speculated, the benefits from the reduction of visual clash and the drawbacks from the increased working memory load may have worked to cancel one another out, and led to non-significant findings. However, it seems more likely that since the test cards were

presented visually to children *before* they were occluded, that the manipulation had no effect on the difficulty of the task, in either direction; it is unclear how effective hiding the card in an envelope could have been at reducing the level of attentional inertia *after* the children had already seen and mentally labeled the card.

While the findings of this study provide some evidence of an effect of attentional inertia on performance on the DCCS, it is important to consider this evidence in light of several methodological features of the study. Perhaps most significantly, the manipulations presented above differ from the Standard task in several important ways, other than in the redirection of children's attention.

In the label condition, for instance, children are specifically queried and prompted to label the test card on the relevant dimension in the first trial, and were said to spontaneously label on the relevant dimension in subsequent trials. This is problematic for two reasons: First, the post-switch trials are not identical to the pre-switch trials, as in the Standard version of the task – in the pre-switch dimension the cards are labeled for children, but in the post-switch dimension children are prompted to label the cards themselves. Second, two factors were being manipulated simultaneously. Not only was the child's attention being drawn to the relevant dimension by the experimenter's queries, as indicated, but the child was also given a more active role in the task than in the Standard version. According to a meta-analysis of research on false-belief understanding, which is also related to prefrontal cortex development and develops along the same developmental timetable as conflict inhibition, a child's participation in making the critical change in a task has been found to significantly increase performance (Wellman, Cross & Watson, 2001). In light of this research, it is not possible to determine whether

gains in performance in the label condition were solely the result of the labeling of the card itself, rather than the child's participation in that labeling. In addition, some recent studies have failed to replicate this finding (Sophie Jacques, personal communication).

The comparison of children's performance on the label condition (thought to decrease attentional inertia), and the face-up condition, (thought to increase attentional inertia) is similarly problematic. Not only is the role of the child's participation implicated as a likely confounding factor in the label condition (but not the face-up condition), but the conditions themselves are not otherwise identical. In the label condition attentional inertia is manipulated by explicitly and verbally querying the child on the relevant dimension (e.g., by asking what shape or colour the test card item is), while the manipulation in the face-up condition is much less explicit and works on attentional inertia by creating a perceptual draw to continue sorting on the pre-switch dimension. These differences in the tasks make comparisons between them tentative at best. Finally, since all of the comparisons were made between-subjects and since the cells are quite small (ranging from 12 to 19 participants) it is questionable that these findings accurately reflect the subtle differences in children's abilities.

While the notion of attentional inertia itself may be able to describe young children's performance on the Standard DCCS and on these manipulations, there is a clear need for paradigms that match the Standard version of the task more closely, while manipulating only one possible contributing factor at a time. Similarly, if comparisons were made within-subjects, rather than between, it may have been possible to comment on the different theoretical accounts for young children's difficulty with the task. That is, the relative contributions of attentional inertia and higher-order rule use may be made

clearer if children's performance on the two versions of the DCCS can be directly compared.

Of the wide body of literature examining variations of the DCCS, few studies have examined differences in performance in a within-subjects design, and the ones that have are shrouded by other methodological difficulties. Beyond allowing a more sensitive comparison of children's performance on the two versions of the DCCS, in making comparisons within-subjects it will become possible to examine whether the impact of attentional refocusing will have carry-over effects to performance on the Standard version of the task. Finally, comparing children's performance on the Standard DCCS to their performance on the Easy version of the task in a *within-subjects* design would allow a more sensitive analysis of the factors influencing their performance.

While carry-over effects are typically a major concern in within-subjects designs, repeated presentations of versions of the DCCS have not typically yielded such effects. For instance, Kloo and Perner (2003) conducted two studies investigating training transfer between several versions of the DCCS and measures of false-belief understanding in three-year-old children. In the first of these studies, the authors administered either the Standard DCCS, the reversal-shift version of the DCCS or the puppet version of the DCCS (both as described earlier) followed by the standard version of the task. Despite the administration of one of the easier versions of the DCCS (which the majority of children passed – 86% in both cases), three-year-olds' performance on the (second) Standard version of the DCCS was not affected. Similarly, children who received two administrations of the Standard version showed no differences in performance on the Standard DCCS between the first and second administrations. Thus,

neither repeated exposure to the task, nor experience with an easier version of the task yielded any benefit to children's subsequent performance.

In the second of their studies, however, Kloo and Perner administered specific training sessions to three- to four-and-a-half-year-old children who failed the post-switch phase of the Standard DCCS, consisting of extensive feedback and explanation during the post-switch phases of the task, emphasizing the need to 'redescribe' stimuli in terms of the relevant dimension. The results of the training study revealed a significant improvement in children's performance on the Standard DCCS, relative to a control group that received unrelated training, wherein children's performance improved from 28.6% of post-switch sorts correct at pretest to 85.7% of post-switch trials correct after training. Taken together, the findings from Kloo and Perner suggest that while children receive no benefit from repeated administrations of the Standard DCCS, or variations thereof, there is considerable support that children may benefit from specific training in the task that emphasizes the need to attend to the relevant dimension of the stimuli (2003).

#### *The Present Study*

The primary aim of the present study was to investigate the impact of attentional inertia (attentional refocusing) on the performance of three- and four-year old children on the dimensional change card sort in a cleaner and more systematic way than had previously been done. By making comparisons between children's performance on the Standard and modified versions of the DCCS (decreasing the attentional inertia it to make 'Easy'), and by doing so within-subjects, it became possible to examine the degree to which attention makes a difference in performance. Further, since the Easy manipulation

to the card sort was made in such a way that all other aspects of the task were unchanged, it became possible to investigate the relative importance of rule-switching and attentional inertia in children's performance on the task.

The Standard version of the task proceeded exactly as outlined in Zelazo's protocol (Zelazo, 2006) with two modifications. First, cards were sorted into closed boxes with slots in the front instead of face-down into open trays. This modification served the simple purpose of preventing children from re-sorting the test cards, as is sometimes the case. Second, in the present study eight pre-switch and eight post-switch trials were administered to children, instead of the traditional six and six. The administration of eight trials instead of six allowed children's performance to be classified more reliably as passing versus at chance, even when they erred on one trial of each phase.

In previous studies, many researchers have classified five out of six trials as passing, even though five out of six is not statistically different from chance performance. As according to the binomial distribution, a score of seven or eight out of eight trials is statistically different from that expected by chance,  $p < .05$ , and can therefore be considered a pass. In addition to being a more statistically sound scoring method, the classification of children's performance as passing or failing becomes increasingly important in that their scores on the Standard and Easy version of the DCCS will be compared to one another. It will also be important to have a reliable manner of classifying children as passing the Standard and Easy versions of the task.

The Easy manipulation put forth to impact attentional inertia in the present study matches the Standard version of the DCCS in all other respects. As such, any changes in performance between the Standard and Easy condition can clearly be attributed to the

specific modification aimed at manipulating the degree of attentional inertia, and not to any other variations between the tasks. In the Easy DCCS, the only methodological change from the Standard task is the orientation of the test card when it is first presented to and labeled for the child. In the Easy DCCS, each test card is presented to the child, facing away from the child (to occlude the image on the card) and the card is labeled on the relevant dimension, just as in the Standard version. Every other detail of the task is identical between the two tasks.

This manipulation works to accomplish what was intended of Kirkham and others' sleeve condition. In holding the card in such a way that the child cannot see its identity, and labeling the card on the relevant dimension *before* the child has seen it, the child is given an explicit cue about the identity of the card, before he is faced with the conflict within that card. If children perseverate on the card sort because they fail to consider the test cards on the relevant dimension (even though that dimension is always labeled), it seems likely that the visual presentation of the test cards is much more salient than the experimenter's verbal label for the card and that children simply do not attend to the label. That is to say, because children see the test card before it is labeled for them, they have likely already identified the card mentally as being either 'a boat' or a 'blue one.' If this internal labeling is with reference to the irrelevant dimension, it has already occurred by the time the experimenter labels the card for the child. In order to overcome the effects of children's attentional inertia, any manipulation to the Standard task needs to occur *before* children see the identity of the card and form their own mental labels.

The current study therefore provided children with the relevant label for each test card (pre- and post-switch) in such a way that the label did not need to compete with the

child's own classification of the card, since the child had not yet seen the card. The Easy version of the task should allow young children who typically fail the Standard DCCS because of attentional inertia to perform well on the task. In other words, if children's failure is a result of their inability to inhibit considering the test cards on the pre-switch dimension (i.e., attentional inertia), the Easy condition should provide some scaffolding to encourage them to consider each card on the relevant dimension, before the appearance of the card can interfere.

### *Hypotheses*

It was hypothesized that three-year-olds' performance on the Easy condition would surpass their performance on the Standard DCCS. Four-year-olds' performance on the Easy condition was expected to be similar to their performance on the Standard version, as four-year-olds, as a group, typically perform quite well on the task.

If the Easy modification of the DCCS were found to impact children's performance, as hypothesized, it would lend considerable support to the role of attentional inertia in young children's performance on the DCCS. While embedded rule use, as proposed by the CCC-r, may be a necessary condition for children to succeed on the task, attentional inertia may be a more important variable to consider in accounting for young children's difficulty on the task. That is to say, if some three-year-olds' performance is aided by the Easy modification, then it is likely the case that these children have the embedded rule use required to switch sorting strategies, but that the attentional inertia of the Standard version is too great to overcome. If this is the case, while higher-order rule use is a necessary ability to perform well on the task at all, it is the children who are better able to overcome the attentional inertia of the Standard task

and flexibly consider a test card on both dimensions that are more likely to succeed on the task.

In light of this possibility, in addition to the Standard and Easy version of the DCCS, children were also administered a battery of other measures of EF, including measures of WM, conflict inhibition, and attentional flexibility. It was of specific interest to compare the children whose performance was affected by the Easy version of the DCCS to the children whose performance was not. If the reason that children's performance on the DCCS was affected by the Easy modification is because of the impact on the attentional inertia of the task, it is likely that these children would differ from those whose performance was not impacted in their ability to flexibly consider the items on more than one dimension. These differences in attentional flexibility should manifest on children's performance on the most current measure of attentional flexibility, the Flexible Item Selection Task (FIST), outlined earlier. The FIST parallels the demands of the DCCS in that it requires children to consider the test items in terms of different dimensions, but the FIST does not impose the need to use higher-order embedded rule structures, or to deal with conflict in the same way as the DCCS. There is no need to deal with conflict between the test and target cards, for instance, and there is no explicit means for attentional inertia to impact performance, as there is no prepotent response bias, and the 'relevant' dimensions change on every trial.

Thus, it was also hypothesized that children whose performance was impacted by the Easy modification to the DCCS would differ in terms of their performance on the FIST. That is, it was expected that the children whose performance was better on the Easy modification than on the Standard DCCS would demonstrate greater flexibility (as

shown by the FIST) than the children whose performance was not aided by the Easy modification.

The other measures of EF included in this study are well-used measures of conflict inhibition and working memory, including: Bear/Dragon (conflict inhibition), Day/Night Stroop (conflict inhibition), Backward Digit Span (WM), Counting & Labeling (WM) and Forward Digit Span (WM or Short Term Memory). These measures were included for two reasons. First, the other measures of EF were present to examine their relationship with the Easy DCCS, relative to the typical relationships found with the Standard version of the task. While this was not a primary hypothesis of the study, it was important to determine that the Easy DCCS and the adapted Standard version relate to other measures of conflict inhibition as expected. Second, the other measures of EF were also administered to allow for a comparison between the performances of children who were aided by the Easy DCCS to those who were not. Again, it was hypothesized that children whose performance was impacted by the modification to the DCCS are likely to differ in terms of their performance on these other measures of EF as well as the FIST.

Finally, children were also administered a measure of receptive vocabulary, the Peabody Picture Vocabulary Test – III, as an index of verbal ability. The PPVT-III is a Standardized measure of receptive vocabulary and is useful to control for the effects of verbal ability in young children's performance on such tasks, and previous research has supported that children's scores on the PPVT-III has distinguished between children with high and low inhibitory control (conflict) and WM (Wolfe & Bell, 2004).

### Method

#### *Participants*

A total of 60 children (40 three-year-olds and 20 four-year-olds) were recruited from local daycares (with written parental consent) to participate in the study, with best efforts made to ensure relatively equal numbers of males and females within each age group.

A larger group of three-year-olds was recruited to permit within-subject comparisons of order effects for the order of the Easy and Standard DCCS. That is, half of the three-year-olds performed the Easy version first (at the beginning of the first session) and the Standard version second (at the end of the first session), and half performed the Standard version first and the Easy version second. This allowed for an examination of any carry-over effects of the modification. If children were found to benefit from the Easy modification and performed well on this version of the DCCS, it was of interest to see whether that benefit carried to the Standard version of the task. Therefore, scores on the Standard version of the DCCS were compared between children who received the Easy version first and those who received the Standard version first. Because four-year-olds typically pass the Standard DCCS and it was therefore not hypothesized that these children would receive any benefit from the Easy modification, a smaller group of four-year-olds was sufficient for comparison purposes.

#### *Design*

Children were tested individually, over two sessions, approximately one week apart. Each session lasted approximately twenty-five minutes, and was conducted in a quiet area of the child's daycare. The measures consisted of two Standard versions of the

DCCS, the Easy version of the DCCS, the Day/Night Stroop, the Bear/Dragon task, the Counting and Labeling task, a Backward Digit Span task, a Forward Digit Span task, the FIST, and the PPVT – III.

Within each age group, half of the children received the Standard DCCS first, and half of the children received the Easy DCCS first, to allow for an analysis of order effects. The order of the tasks, for all children, was as follows: In the first session, children were administered the Monkey/Tiger task (this is the Bear/Dragon, with different characters), followed by either the Easy or the Standard DCCS (counterbalanced), the Counting and Labeling task, the Day/Night Stroop task, a Backwards or Forwards Digit Span task (counterbalanced), and finally, either the Standard or Easy DCCS (whichever version was not administered first). In the second session children received a second Standard version of the DCCS (with alternate target and test cards), the FIST, the remaining Digit Span task (Backwards or Forwards), and the PPVT-III.

The second administration of the Standard DCCS in the second session served to investigate whether any effects of the Easy version were lasting. That is, if effects of the Easy modification were found within the first session, and children who received the Easy version of the DCCS first performed better (or worse) on the Standard version than children who received the Standard version first, these children's performance on the second administration of the Standard DCCS were examined to see if the benefits (or decrements) lasted for a week (give or take a day).

*Materials and Procedure**Conflict Inhibition**i. Standard DCCS.*

The administration of the Standard DCCS proceeded as outlined above (p.12), as adapted from Zelazo's protocol (2006). Children were presented with two target cards and eighteen bivalent test cards. Testing proceeded with one demonstration trial and one practice trial, followed by sixteen test trials (eight pre-switch and eight post-switch). Stimuli for the first administration of the Standard DCCS were green and pink fish and green and pink airplanes (see Appendix A for the full protocol) and for the second administration of the Standard DCCS were red and blue boats and red and blue rabbits (see Appendix B for the full protocol).

Children received a score on the number of correct pre-switch trials (out of 8) and the number of correct post-switch trials (also out of 8). Children scoring 7 or 8 out of eight were considered as passing, since 7 is significantly different from chance performance according to the binomial distribution ( $p < .05$ ). Only children who passed the pre-switch phase were included in the analyses (this is standard in DCCS studies).

Children received two Standard versions of the task, and one Easy version. The order in which children received the Standard and Easy version was a within-subject variable: half of the children, within each age group, received the Standard version first, and half received the Easy version first.

*ii. Easy DCCS.*

The Easy version of the DCCS proceeded exactly as the Standard version with one modification: each test card was first presented to the child facing away from the

child to occlude the image on the card while being labeled on the *relevant* dimension. Every other detail of the task was identical to the Standard DCCS. The stimuli for the Easy version were purple and yellow birds and purple and yellow trains (see Appendix C for the full protocol). Scoring for the Easy DCCS was identical to scoring for the Standard version.

*iii. Monkey/Tiger.*

The Monkey/Tiger task was identical to the Bear/Dragon task, with different puppets. Children were required to perform the actions requested by the nice monkey, but to inhibit the actions requested of the naughty tiger. The administration of the task is outlined in detail above (p. 10), and a full protocol can be found in Appendix D.

Ten test trials were administered, in which the nice monkey and the naughty tiger requested simple actions of the child in a fixed order (neither the monkey nor the tiger made requests more than twice in a row). Halfway through the testing trials a rule-reminder was given to all children. Children received scores ranging from 0 to 3 for each of the tiger trials (0= full movement, 1= partial movement, 2 = different movement, 3= no movement) and scores were summed to a maximum score of fifteen.

*iv. Day/Night Stroop.*

In this task, as described above (p. 11), children were presented with test cards depicting pictures of either a moon or a sun, and were asked to label the cards with the semantically incongruent label, rather than the semantically congruent label. When presented with a picture of a moon, for example, children were asked to respond by saying ‘day’ instead of ‘night.’

First, children were presented with the moon card and were told the rule for responding: "This looks like night, right? When you see this picture, I don't want you to say *night*, no, I want you to say *day*." Then, children are presented with the sun card and are told the other rule for responding: "This looks like day, right? When you see this picture, I don't want you to say *day*, no, I want you to say *night*." Children were then presented with two training trials in which they were presented with the sun card and the moon card and asked "What do you say for this one?" Children were provided with feedback on each of these trials, and the two trials were repeated up to three times, with feedback, until children were successful on each trial. After the training trials, twenty-one test trials were administered in fixed order, such that no more than two of the same type of card is presented in a row. Children were scored on the number of 'correct' incongruent responses they provided over the twenty-one test trials. See Appendix E for a full protocol.

### *Cognitive Flexibility*

#### *Flexible Item Selection Task.*

The administration of the FIST was adapted from Jacques and Zelazo (2001), as described above (p. 6), with one major deviation. Recall that in the test trials of the FIST, children are presented with arrays of objects that differ along three possible dimensions (size, colour, and shape) and are asked to choose two items that go together in terms of one dimension, and then two items that go together in terms of another dimension. In the administration of the FIST put forth by Jacques and Zelazo (2001), within each array of items, two items shared a common value on one dimension, two items shared common value on another dimension, and *all three items* shared a common value on the third, so

called ‘irrelevant,’ dimension. It is the shared values on the irrelevant dimension that is the cause of methodological concern in the present study. If all items are large, or all items are blue, for instance, it is unclear how this dimension is to be perceived as *irrelevant* at all.

For example, in Jacques and Zelazo’s administration of the FIST, items in one array could include a large blue shoe, a large blue teapot, and a medium blue teapot. In this example, selection one may include the large blue shoe and the large blue teapot, because these items are similar in terms of size, and selection two may include the large blue teapot and the medium blue teapot, because these items are similar in terms of shape. In spite of Jacques and Zelazo’s claim that color is the ‘irrelevant’ dimension in this example, its relevance is quite apparent. Since each of the three items in the array is matched in terms color, scoring the task becomes very difficult: if all three items are matched on the irrelevant dimension, then the selection of any pair is an accurate one. In this example, even the selection of the large blue shoe and the medium blue teapot is an accurate selection, since both of these items are blue, though that is not how Jacques and Zelazo score such selections.

To address this concern, in the administration of the FIST in the present study, the three items always *differ* along the irrelevant dimension. Thus, in each trial, two of the items have a common value on one dimension, two of the items have in common a value on another dimension, and no items have in common a value on the third, irrelevant dimension. This is an important deviation from the version of the FIST presented by Jacques and Zelazo (2001). In their version of the task it was virtually impossible for children to fail to make two correct selections, as any choice of two items would go

together in terms of the constant dimension, and any other choice of two items would necessarily go together along one of the remaining dimensions (though such choices would be scored as incorrect). In contrast, by varying all three items on the irrelevant dimension as is done here, only two possible pairs from the three items actually share values on one dimension, and the third possible pair of items does not, so children can actually make an incorrect selection if they choose this pair of items.

As per Jacques and Zelazo, the administration of the test trials of the FIST are preceded by two preliminary activities: an item identification task to ensure that children are familiar with all values of the three dimensions, and a ‘favourites’ task to familiarize children with the procedure of choosing two objects from an array of three objects.

#### *Item Identification Task*

In the item identification task, children were presented with three 8 ½ x 11 inch cards, one at a time, each depicting an array of three items that represent the three dimensions presented in the test trials. The items were presented in three vertical panels on the card, and the size and arrangement of these cards was identical to the cards used throughout the FIST. One of these cards presented the three shapes used in the test trials of the FIST: a shoe, a flower, and a teapot. These items are colourless, line-drawings, and are equal in size to one another. The second of these cards presented the three colours used in the test trials: a blue rectangle, a yellow rectangle, and a red rectangle. The last card presented the three different sizes used in the test trials: a small book, a medium book, and a large book. A book was chosen to display the three values for size as to not bias children’s familiarity with any of the test items.

Children were told that they were going to play a pick-some-pictures game, and were then questioned about the identity of each of the three items on each of the three cards, in turn. Children were asked to point to each of the items that the experimenter asked them to (e.g. "Can you show me the shoe?"). When children correctly identified the item in question, they were provided with positive feedback, and if they failed to identify the item in question, or they identified an incorrect item, the experimenter corrected them, and asked them about that item again at the end of the three items (for the full protocol, see Appendix F). Cards were presented to children in counterbalanced order, across children, and items were queried about in quasi-random order.

#### *Favourites Task*

The purpose of the favourites game is to provide children with some experience choosing two out of three pictures. In the favourites task, children were told that they were going to play a different pick-some-pictures game and that they were going to pick some of their favourite pictures with the experimenter. Children were then presented with four cards, one at a time, identical in size and layout to the cards in the item identification trials. Each of the cards depicted three, novel objects for children to choose from.

Children were told that the experimenter would pick her favourite pictures first, and then children were given three trials to choose their own favourite pictures. The order of the four favourites trials was fixed, but the order and identity of the two-items chosen by the experimenter was counterbalanced, between children. [Note: the two items chosen by the experimenter in the favourites task were never in the same position as the two items chosen by the experimenter on the first of the FIST test trials.]

The experimenter demonstrated the favourites task in the first trial, and then children were asked to perform the next three trials. Children were given positive feedback for successfully pointing to two of the three items, and were prompted and corrected if they failed to do so. For example, if children chose only one or none of the three items, they were prompted to choose their two favourite items, and if children chose all three items they were asked to choose only two. Prompting and correcting was repeated until children successfully chose exactly two of the three items. (See Appendix G for the full protocol).

#### *FIST Test Trials*

The test cards for the trials of the FIST were identical in size and layout to the cards in the item identification and favourites tasks. There were eighteen trials in the task, including a demonstration trial, two practice trials with feedback, and fifteen test trials with no feedback. Each of the test cards depicted three items that varied along three dimensions (size – small, medium, large; colour – red, yellow, blue; and shape – boat, teapot, shoe), such that two of the items shared a common value on one dimension, two of the items shared a common value on another dimension, and no items shared a common value on the remaining, irrelevant dimension (unlike the original FIST task, in which all items shared a common value on the irrelevant dimension). Each of the three dimensions (colour, shape and size) was irrelevant in six of the eighteen trials.

In the demonstration trial, children were presented with the first test card and were told that the experimenter was going to choose two items that go together in one way. For example, children may have been presented with a card depicting large red shoe, a medium blue shoe and a medium yellow flower. From this array, the experimenter

might first have selected the large red shoe and the medium blue shoe, because these two items go together in terms of shape (they are both shoes). The entire selection process was narrated by the experimenter, without labeling any of the dimensions of the items (e.g. "I'm going to choose two items that go together in one way. So I'm going to point to this item here [pointing to the large red shoe] and to this item here [pointing to the medium blue shoe] because these two items go together in one way"). Then, the experimenter announced that she would select two items that go together in another way, and she would select, in this example, the medium blue shoe and the medium yellow boat, because they go together in terms of size. The second selection was narrated again (e.g. "Now do you know what I'm going to do? Now I'm going to choose two items that go together, but in another way. So I'm going to point to this item here [pointing to the medium blue shoe] and to this item here [pointing to the medium yellow boat] because these two items go together, but in another way"). After the second selection, the experimenter summarized both selections for the child (e.g. "So these two items go together in one way [pointing to the two items from selection one], and these two items go together, but in another way [pointing to the two items from selection two]"). (See Appendix H, for the complete protocol).

After the demonstration trial, children were presented with two test trials during which they were provided with extensive feedback after each selection. If children failed to select items that go together in either selection, the correct pairs of items were demonstrated for them, with appropriate narration. After each trial the two selections were summarized for children, as in the demonstration trial. Finally, after the two practice trials with feedback, children proceeded to the fifteen test trials, which were administered

without feedback or summary. Children were simply asked "Can you show me two items that go together in one way?" and then "Can you show me two items that go together, but in another way?" Children were scored on both the number of correct first selections and the number of correct second selections over fifteen test trials. The order of the eighteen test cards was counterbalanced between children such that each child received one of three fixed orders. Within each order, the values of the dimensions presented were balanced across trials, as well as the order of the irrelevant dimension. This counterbalancing information is presented in Appendix I.

#### *Working Memory*

##### *i. Counting and Labeling.*

The counting and labeling task was administered as outlined above (p. 7). In this task, children were presented with three sets of three small objects and were asked to count and label each object, in turn. Children were scored as correct if they were able to count and label the objects together, without error. See Appendix J for a full protocol.

##### *ii. Backward Digit Span.*

In this task, children were presented with strings of digits, spoken one second apart, and were asked to repeat those digits back to the experimenter in reverse-order. After one demonstration trial (two digits in length) wherein the task was modeled for children by a puppet, children were given two practice trials (each two digits in length) and were provided feedback and corrected, if necessary. After the practice trials, test trials proceeded in sets of two strings (of equal length), beginning with two-digit strings and increasing in length, one digit at a time. Testing proceeded until children erred on both trials within a set. Children were scored in two ways: both on the highest string they

were able to repeat in correct reverse-order, and on the highest set of strings that they were able to complete without error. For a full protocol, see Appendix K.

*iii. Forward Digit Span.*

This task proceeded exactly as the Backward Digit Span task, only digits were repeated back to the experimenter in forward-order, and there was no demonstration trial with a puppet. Thus, children were told the rules of the game, and were given two practice trials (two digits in length) with feedback. Test trials proceeded in the same manner as the Backward Digit Span task, and scoring methods were identical. For a full protocol, see Appendix L.

*Receptive Vocabulary*

*Peabody Picture Vocabulary Test – III (PPVT – III).*

The PPVT-III is a standardized measure of receptive vocabulary. As per the standard instructions of the task, children were presented with arrays of four pictures of objects and were asked to point to the picture that best represented the word that the experimenter read. After two practice trials, with feedback, testing trials proceeded. Testing began at the appropriate age set for the child, based on the test norms. Each set contained twelve items. In order to establish a basal rule, children were required to correctly identify all of the items in a set, with zero or one error. The vocabulary required became increasingly more difficult with each array. Once the basal rule was established, testing proceeded through each set until a ceiling was reached, wherein children made eight or more errors within a given set. Children's raw scores were used in the analysis.

## Results

### *Participants*

A total of 60 children (40 three-year-olds and 20 four-year-olds) were recruited from local daycares (with written parental consent) to participate in the study, with best efforts made to ensure relatively equal numbers of males and females within each age group.

### *Pre-switch Performance*

Only children who passed the pre-switch phase of both versions of the DCCS (Standard and Easy) were included in the analyses. Passing the pre-switch phase was defined as sorting at least seven of the eight test cards correctly, as according to the binomial distribution ( $p < .05$ ). Three children failed the pre-switch dimension of the Standard DCCS (two three-year-olds and one four-year-old), and two children failed the pre-switch dimension of the Easy DCCS (both four-year-olds). The final sample consisted of 56 children (38 three-year-olds and 18 four-year-olds. Table 1 displays mean ages and ranges of the final sample, grouped by age (in years), and gender.

### *Performance on the Standard and Easy DCCS*

Children's performance on both the Standard and the Easy DCCS were considered in two ways: parametrically, in terms of mean scores on the post-switch phases of the tasks, and non-parametrically, in terms of the number of children who passed (or failed to pass) the post-switch phase of the tasks. Children who correctly sorted seven or eight of the eight post-switch test cards correctly were considered *passers*; those scoring less than seven were considered *non-passers*, as according to the

binomial distribution ( $p < .05$ ). The parametric analyses of mean scores are presented first, followed by the non-parametric analyses of passers versus non-passers.

Table 1

*Gender, Mean Age (in months) and Range (in months) of the Final Sample of Children,  
N=56, Grouped by Age (in years)*

Age in years	N	Mean age (months)	Standard deviation	Range (months)
<b>3-year-olds</b>				
Male	17	41.41	3.48	36-47
Female	21	40.43	3.82	33-46
Total	38	40.87	3.66	33-47
<b>4-year-olds</b>				
Male	11	53.27	3.07	48-58
Female	7	52.71	4.50	48-59
Total	18	53.06	3.57	48-59

#### *Parametric Analysis*

Preliminary analyses consisting of a 2 x 2 mixed-designs analysis of variance (ANOVA), with DCCS Version (Easy versus Standard) as the within-subjects factor and gender as the between-subjects factor revealed no significant effects of gender on either version of the task. Therefore, all subsequent analyses collapsed across gender.

Children's mean post-switch scores (out of 8) on the Standard and Easy DCCS, by age group and DCCS Order are presented in Table 2. Recall that in each age group, roughly half of the children received the Easy DCCS first and half received the Standard DCCS first (separated by several other tasks).

Table 2

*Mean Scores and Standard Errors of Children's Performance on the Standard and Easy Versions of the DCCS, as a Function of Age Group and DCCS Order*

		3-year-olds	4-year-olds	
		Standard DCCS Mean (SE)	Easy DCCS Mean (SE)	Standard DCCS Mean (SE)
				Easy DCCS Mean (SE)
Standard first		1.65 (.730)	2.00 (.750)	5.71 (1.48)
Easy first		2.06 (.734)	3.72 (.851)	6.27 (.954)
Total		1.84 (.512)	2.82 (.574)	6.06 (.794)
				5.94 (.786)

A 2 x 2 x 2 mixed-designs ANOVA was conducted to compare children's performance on the Easy and Standard versions of the DCCS. DCCS Version (Easy or Standard) was a within-subjects factor, while DCCS Order (Standard or Easy first) and Age (three-year-olds versus four-year-olds) were between-subjects factors. The ANOVA revealed a significant main effect of age, wherein four-year-old children significantly outperformed three-year-old children, overall  $F(1, 52) = 16.90, p=.0001, \eta^2= .245$ . There was no main effect of DCCS Version, or DCCS Order, and there were no significant interactions.

Inspection of the raw data revealed that performance on the post-switch phase of the Easy and the Standard DCCS was extremely bimodal. That is, 86.8% of three-year-olds and 88.9% of four-year-olds either succeeded on at least seven of eight trials or erred on at least seven of eight trials of the post-switch phase of the Easy DCCS, and similarly, 89.5% of three-year-olds and 94.4% of four-year-olds either succeeded on at least seven

of eight trials or erred on at least seven of eight trials of the Standard DCCS.

Consequently, the parametric analyses may be misleading, as mean scores are somewhat uninformative. As such, non-parametric comparisons were also conducted.

#### *Non-Parametric Analysis*

McNemar's Test of Change was conducted to compare the number of passers and non-passers on the post-switch phases of both versions of the DCCS, as a function of age group and of DCCS Order, to mirror the comparisons made by the ANOVA, above.

McNemar's Test of Change (using the binomial distribution) revealed a difference between the number of children who passed the Easy and the Standard DCCS, that was approaching significance ( $p=.063$ ) within the Easy First order in three-year-old children. These numbers are presented in Table 3. Within this group of children, of the sixteen that failed-to-pass the Standard DCCS, five children passed the Easy DCCS.

#### *Alternative Comparison of Performance on the Standard and Easy DCCS*

Recall that, in general, children's performance on the DCCS improves as a function of age; three-year-olds tend to fail the post-switch phase of the task, while four-year-olds tend to pass. Typically, comparisons are made between groups of children who differ in terms of their age (in years). It can be argued, however, that age in years is an arbitrary classification on which to compare young children's abilities on a task, when it is known that these abilities improve as a function of development. Further, as can be seen in Table 3, while the majority of four-year-old children in the sample did tend to pass the Standard DCCS, 28% of children still failed the task.

Table 3

*Number of Children who Passed or Failed-to-pass Each Version of the DCCS, as a Function of Age Group (three-year-olds versus four-year-olds) and of DCCS Order (Standard or Easy first)*

3-year-olds			4-year-olds		
Order	Standard	Easy	Order	Standard	Easy
			Fail to Pass	Pass	
Standard	Fail to pass	13	3	Standard	Fail to pass
first	Pass	2	2	first	Pass
Easy	Fail to pass	11	5*	Easy	Fail to pass
first	Pass	0	2	first	Pass
			Fail to Pass	Pass	
			2	0	
			0	5	
			2	1	
			1	7	

\* p = .063

In the present study, in addition to comparing children on the basis of age in years, children were also grouped by the median age of the sample, comparing the younger children (those less than and equal to 43 months) to the older children (those greater than or equal to 44 months). This grouping allows a more continuous consideration of age and also serves to equalize the size of the age groups for the purpose of making comparisons between younger and older children's performance on the Standard and Easy DCCS. Table 4 displays mean ages and ranges of the final sample, grouped into "younger" and "older" age groups, between 43 and 44 months. Children are grouped in this way for all subsequent analyses with age as a factor.

Table 4

*Mean Age (in months) and Range (in months) of the Final Sample of Children, N=53,  
Grouped by Median Split*

Median split	N	Mean age (months)	Standard deviation	Range (months)
Younger (< = 43 months)	27	39.04	2.55	33-43
Older (= > 44 months)	29	50.14	4.76	44-59

#### *Parametric Analysis*

A 2 x 2 x 2 mixed ANOVA was conducted to compare children's performance on the Easy and Standard versions of the DCCS. DCCS Version (Easy or Standard) was a within-subjects factor, while DCCS Order (Standard or Easy first) and Age group (younger versus older children) were between-subjects factors. Mean Scores and Standard Errors are presented in Table 5.

The ANOVA revealed a significant main effect of age,  $F(1,52)=21.81, p=.0001$ ,  $\eta^2=.295$ , wherein older children significantly outperformed younger children, overall. Further, the ANOVA also revealed a significant DCCS Version by Age interaction,  $F(1,52)=8.75, p=.005$ ,  $\eta^2=.144$ , and a significant DCCS Version by Age by DCCS Order interaction,  $F(1,52)=8.75, p=.005$ ,  $\eta^2=.144$ .

Following the significant three-way interaction, two two-way repeated measures ANOVAs were conducted to test the effects of DCCS Version and DCCS Order within the two levels of Age (Younger and Older). Within the older group of children, the ANOVA did not reveal any significant main effects of DCCS Version or Order, nor did it reveal any significant interactions. Older children's performance on the task did not differ

as a function of the Easy modification, or as a function of the order of presentation of the tasks.

Table 5

*Mean Scores and Standard Errors of Children's Performance on the Standard and Easy Versions of the DCCS, as a Function of Age Group (younger versus older) and DCCS Order*

		Younger (< = 43 months)	Older (> = 44 months)	
		Standard DCCS Mean (SE)	Easy DCCS Mean (SE)	Standard DCCS Mean (SE)
Standard first		1.21 (.772)	.64 (.509)	4.31 (1.51)
Easy first		1.08 (.625)	3.54 (1.04)	5.75 (.839)
Total		1.15 (.491)	2.04 (.621)	5.10 (.694)
				5.48 (.643)

Within the younger group of children, however, the ANOVA revealed a significant DCCS Version by DCCS Order interaction,  $F(1, 25)=5.86, p=.023, \eta^2=.190$ . Younger children's performance across the two versions of the DCCS differed as a function of the Order of presentation of the two tasks. Two paired-samples t-tests were conducted to compare the performance of younger children on the Easy and the Standard DCCS within the two orders of administration (Easy first and Standard first). The paired-samples t-tests revealed no significant differences between younger children's performance on the Standard and Easy DCCS when the Standard version was presented first, but did, however, reveal a significant difference in performance when the Easy DCCS preceded the Standard version of the task,  $t(12)=2.82, p=.016$ . Younger children's

performance on the Easy DCCS was significantly higher than their performance on the Standard DCCS, with mean scores of 3.54 and 1.08, respectively, when the Easy version of the task was presented first.

Again, since children's performance on the Standard and the Easy DCCS was extremely bimodal, parametric analyses are not ideal as mean scores can be somewhat uninformative. As such, non-parametric comparisons were also conducted.

#### *Non-Parametric Analysis*

McNemar's Test of Change was conducted to compare the number of passers and non-passers on the post-switch phases of both versions of the DCCS, as a function of age group (by median split) and as a function of DCCS Order, to mirror the comparisons made by the previous ANOVA. McNemar's Test of Change (using the binomial distribution) revealed a change between performance on the Easy and the Standard DCCS that was approaching significance ( $p=.063$ ) within the Easy First Order in the younger group of children, paralleling the findings of the two-way ANOVA. Within the younger group of children who received the Easy DCCS first, of the thirteen children that failed-to-pass the Standard DCCS, five children passed the Easy DCCS. These numbers are presented in Table 6.

The findings arising from the non-parametric analysis of children's performance on the Standard and Easy DCCS, grouped by median split, parallel the findings of the non-parametric analysis by age group; within the youngest group of children who receive the Easy DCCS first, more children passed the Easy DCCS than would be expected if the manipulation had no effect, at a level approaching significance,  $p=.06$ . In grouping children by median split, as in this latter analysis, this finding is paralleled in the

parametric analysis as well, wherein younger children who received the Easy DCCS first scored significantly higher on the Easy DCCS than on the Standard version of the task.

Table 6

*Number of Children who Passed or Failed to Pass Each Version of the DCCS, as a Function of Age Group (younger versus older children) and of DCCS Order (Standard or Easy first)*

Younger ( $\leq 43$ months)				Older ( $\geq 44$ months)			
Order	Standard	Easy		Order	Standard	Easy	
		Fail to Pass	Pass			Fail to Pass	Pass
Standard first	Fail to pass	11	1	Standard first	Fail to pass	4	2
	Pass	2	0		Pass	0	7
Easy first	Fail to pass	8	5*	Easy first	Fail to pass	5	1
	Pass	0	0		Pass	1	9

*Individual Differences in Attentional Flexibility and Executive Function*

Means and standard deviations of older and younger children's scores on all tasks appear in Table 7. To address the hypothesis that children who received benefit from the Easy modification to the DCCS (but who failed the Standard DCCS) would differ from children who did poorly on both the Standard and the Easy versions in terms of performance on the FIST and other EF tasks, children were assigned one of four values on a blocking variable, Easy Help: children who failed both the Standard and the Easy DCCS were assigned a value of 0; children who passed the Easy DCCS but failed the

Standard were assigned a value of 1; children who passed both the Easy and the Standard DCCS were assigned a value of 2; and children who failed the Easy but passed the Standard were assigned a value of 3. The number of children assigned each of these values appears in Table 8. As per the hypotheses, the comparison of interest is between the children assigned a value of 0 (who received no benefit from the Easy modification) and those assigned a value of 1 (who were able to pass the Easy version, but still failed the Standard DCCS). The subsequent analyses focus on these children (N= 37).

Table 7

*Means and Standard Deviations of Performance of Older versus Younger Children on all Included Measures*

Task	Younger (<44 months)	Older (>44 months)
Standard DCCS	1.15 (2.56)	5.10 (3.74)
Easy DCCS	2.04 (3.23)	5.48 (3.46)
Monkey/Tiger	4.69 (5.46)	12.36 (4.72)
Day/Night Stroop	7.15 (7.60)	11.76 (7.71)
Backward Digit Span	.111 (.42)	.29 (.55)
Forward Digit Span	1.96 (.84)	2.50 (.70)
Counting & Labeling	.33 (.68)	.83 (.89)
FIST	3.78 (2.79)	6.31 (3.16)
PPVT-III	42.71 (12.20)	55.93 (23.27)

Table 8

*Number of Children at Each Value of Easy Help*

Category	Value	N	Mean age (SE) in months
Failed Standard & failed Easy	0	28	41.96 (1.02)
Failed Standard & passed Easy	1	9	43.00 (2.26)
Passed Standard & passed Easy	2	16	51.19 (1.26)
Passed Standard & failed Easy	3	3	42.33 (3.19)

In order to compare children who received benefit from the Easy modification to those who did not in terms of their performance on the FIST and other EF tasks, the relationships between each of the EF measures (Monkey/Tiger, Day/Night Stroop, Counting and Labeling, Backward Digit Span, Forward Digit Span, FIST) as well as the receptive vocabulary measure (PPVT-III) and age (in months) were first examined. These correlations are displayed in Table 9.

As can be seen from the bivariate correlations, significant relationships were found between Monkey/Tiger and Age in months ( $r = .53, p = .001$ ), between Counting and Labeling and Age ( $r = .37, p = .026$ ) and PPVT-III ( $r = .517, p = .002$ ), and a relationship that was approaching significance between FIST and PPVT-III ( $r = .299, p = .085$ ). As such, a series of analyses of covariance (ANCOVAs) were conducted to test the differences in these EF measures (Monkey/Tiger, controlling for age in months; Counting and Labeling, controlling for PPVT- III; and FIST, controlling for PPVT - III) between children who were helped by the Easy modification and those who were not. Further, a series of t-tests were conducted to test the differences between children who

were helped by the Easy modification and those who were not on the remaining EF measures (Day/Night Stroop, Backward Digit Span and Forward Digit Span). It is important to note, however, that these tests were conducted despite largely unequal samples, comparing the nine children who received benefit from the Easy modification to the twenty-eight children who did not. As such, the results of these comparisons should be interpreted tentatively.

Table 9

*Bivariate Correlations between Measures of EF, PPVT-III, and Age (in months)*

Measure		1	2	3	4	5	6	7	8
1 Monkey/ Tiger	<i>Pearson R</i>		.15	.18	.06	.16	.53	.21	.53*
	N	---	36	36	36	34	36	33	36
2 Day/Night Stroop	<i>Pearson R</i>			.09	-.06	.20	-.03	.13	.09
	N	---		37	37	35	37	34	37
3 Count & Label	<i>Pearson R</i>				.30	.09	.21	.52*	.37*
	N		---		37	35	37	34	37
4 Backward Span	<i>Pearson R</i>					-.07	-.12	.01	-.21
	N				---	35	37	34	37
5 Forward Span	<i>Pearson R</i>						.19	.25	.10
	N				---		35	33	35
6 FIST	<i>Pearson R</i>							.30**	.14
	N				---			34	37
7 PPVT-III	<i>Pearson R</i>								.15
	N				---				34
8 Age (in months)	<i>Pearson R</i>								---
	N								

*Note: Bivariate correlations. N's are listed as some children refused to complete all measures.*

\*  $p < .05$

\*\*  $p = .085$

Of these comparisons, significant differences were found only between scores on Monkey/Tiger and Forward Digit Span. Children who were helped by the Easy modification significantly outperformed children who were not on Monkey/Tiger,  $F(1, 33) = 13.28, p = .001, \eta^2 = .287$ , with mean scores of 11.33 and 4.52, respectively. Similarly, children who were helped by the Easy modification outperformed those who were not on Forward Digit Span,  $t(12.8) = -2.20, p = .046$  (equal variances not assumed), with mean scores of 2.50 and 1.91, respectively. The two groups of children did not differ in terms of the other measures of EF or in terms of performance on the FIST.

While the comparison of FIST scores between children who were helped by the Easy DCCS and those who were not helped did not reveal significant differences, the performance of children who passed both the Standard and the Easy DCCS (Easy Help = 2) was compared to children who failed both the Standard and the Easy DCCS (Easy Help = 0) to ensure some degree of validity and sensitivity of the task. That is, if the FIST is a sensitive and valid measure of attentional flexibility it should detect differences between children who did well on both versions of the DCCS and children who did poorly on both versions. A univariate between-subjects ANCOVA with Easy Help as the between-subjects factor and PPVT-III as the covariate (since PPVT-III scores were significantly related to FIST scores,  $r = .42, p = .001$ ) revealed a significant difference in performance between children who passed both versions of the DCCS and children who failed both versions of the task,  $F(1, 37) = 5.73, p = .022, \eta^2 = .134$ . Children who passed both the Standard and the Easy DCCS scored significantly higher on the FIST than children who failed both versions, with mean scores of 7.21 and 3.96, respectively.

*Relationship to Other Measures of Executive Function*

Finally, to confirm that the Standard and Easy DCCS were related to other measures of EF, as is typical, partial correlations between all children's scores on the Standard and Easy versions of the DCCS and the remaining measures of EF (Monkey/Tiger, Day/Night Stroop, Counting and Labeling, Backward Digit Span, Forward Digit Span, FIST) were examined, after controlling for age (in months) and receptive vocabulary (PPVT-III), since all EF measures were correlated to these factors, with correlations ranging from  $r = .15$  to  $r = .67$ , which is a typical finding (Wolfe & Bell, 2004). The partial correlations between children's performance on the Standard and Easy DCCS and the other measures of EF, after controlling for age (in months) are displayed in Table 10 and Table 11 shows these partial correlations controlling for age in months as well as receptive vocabulary (PPVT-III).

As can be seen in Table 11, the Standard DCCS was significantly correlated with scores on the Easy DCCS ( $pr = .41, p = .005$ ), and Monkey/Tiger ( $pr = .41, p = .0015$ , after controlling for children's age and scores on the PPVT-III. Similarly, the Easy DCCS was also significantly correlated with Monkey/Tiger ( $pr = .34, p = .024$ ) after controlling for age and receptive vocabulary. These interrelationships support that performance on the Standard and Easy DCCS were related to one another, as well as to performance on Monkey/Tiger, another measure of conflict inhibition. Oddly, Monkey/Tiger was significantly, negatively correlated with performance on Backward Digit Span, however, upon closer inspection, children's scores on Backward Digit Span were extremely low ( $M = 0.2, SD = 0.5$ ) as most children scored zero on the task.

Table 10

*Partial Correlations between Children's Performance on the Standard and Easy DCCS and the Other Measures of EF Controlling for Age*

Measure		1	2	3	4	5	6	7	8	9
1 Standard DCCS	<i>Partial r</i>	---	.52*	.40*	.11	.25	.22	.19	.26	.41*
2 Easy DCCS	<i>Partial r</i>		---	.33*	.03	.35*	.14	.13	.33*	.45*
3 Monkey/Tiger	<i>Partial r</i>			---	-.02	.09	-.11		.11	.06
4 Day/Night Stroop	<i>Partial r</i>				---	.12	.24	.17	.19	.17
5 FIST	<i>Partial r</i>					---	.27	.10	.23	.42*
6 Count & Label	<i>Partial r</i>						---	.20	.04	.59*
7 Backward Span	<i>Partial r</i>							---	.16	.51*
8 Forward Span	<i>Partial r</i>								.21	---
9 PPVT-III	<i>Partial r</i>									---

*Note: partial correlations controlling for age (in months).*

\* $p < .05$       \*\* $p = .01$

Table 11

*Partial Correlations between Children's Performance on the Standard and Easy DCCS  
and the Other Measures of EF Controlling for Age and Receptive Vocabulary*

Measure		1	2	3	4	5	6	7	8
	<i>Partial r</i>								
1 Standard DCCS		---	.41**	.41**	.04	.09	-.04	-.02	.19
2 Easy DCCS	<i>Partial r</i>	---		.34*	-.06	.20	-.17	-.13	.27
3 Monkey/Tiger	<i>Partial r</i>		---		-.03	.07	-.18	-.39**	.10
4 Day/Night Stroop	<i>Partial r</i>			---		.06	.18	.10	.16
5 FIST	<i>Partial r</i>				---		.03	-.15	.16
6 Count & Label	<i>Partial r</i>					---		-.15	-.11
7 Backward Span	<i>Partial r</i>						---		.06
8 Forward Span	<i>Partial r</i>							---	

*Note: partial correlations controlling for age (in months) and receptive vocabulary (PPVT-III).*

\*  $p < .05$       \*\*  $p = .01$

### Discussion

The primary aim of the present study was to examine the importance of attentional inertia in accounting for three- and four-year-olds' performance on the DCCS, by examining children's performance on the Standard DCCS as compared to the Easy version of the task. The Easy DCCS was designed to allow children who would typically perseverate on the Standard DCCS to perform well on the task by providing them with an

opportunity to consider each test card on its relevant dimension. It was hypothesized that while older children would perform well on both the Easy and Standard DCCS (as is typical of four-year-olds on the Standard version) and that younger children's performance on the Easy DCCS would exceed their typically poor performance on the Standard task. Further, it was hypothesized that children who did receive benefit from the Easy DCCS (performing better on this version than on the Standard task) would differ from children who did not benefit in terms of their performance on a measure of attentional flexibility (FIST) and several other measures of EF. The findings of the present study lend partial support to the efficacy of the Easy modification in addressing these hypotheses.

#### *Age Differences in Performance on the Easy and Standard DCCS*

First, it was found that older children outperformed younger children (whether grouped by age in years or by the median age of the sample) on both versions of the DCCS, as predicted from previous studies (Frye et al., 1995; Zelazo et al., 1996; Zelazo et al., 1997), regardless of task difficulty or order. Since older children typically perform well on the Standard version of the task, as outlined in the introduction of this paper, they received no significant benefit from the Easy modification of the task. This finding was supported through both parametric comparisons of mean scores on the tasks, as well as non-parametric comparisons on the number of passers and non-passers on each version of the task.

While the overall effect of age was not of primary interest to the present study, since four-year-old children typically outperform three-year-old children, it served the important purpose of confirming that the Standard and Easy versions of the DCCS

exhibited the typical pattern of results in older children, despite two minor differences in task administration. First, both versions of the DCCS differed from the typical administration of the Standard task in the number of pre- and post-switch trials administered (eight, as opposed to the typical six) to allow children's performance to be reliably classified as passing versus failing. Second, since the Easy DCCS is a novel version of the task, it was important to confirm that it was not unlike the Standard task in terms of older children's performance. In light of both of these concerns, then, the finding that older children outperformed younger children on both versions of the DCCS, with no differences in performance between the versions, supports both the comparability of the Easy to the Standard DCCS, and of the present findings to the typical findings in the literature.

#### *Younger Children's Performance on the Easy and Standard DCCS*

Next, it was hypothesized that the Easy DCCS would help younger children overcome the attentional inertia posed by the Standard version of the task and that this benefit would be evidenced by superior performance on the Easy as compared to the Standard DCCS. This hypothesis found only partial support. Although an overall effect of DCCS Version was not found in any of the omnibus analyses (when grouped by age in years or by the median age of the sample), both parametric and non-parametric analyses revealed evidence of a significant effect of task order, masking any differences in performance between the Easy and Standard versions.

Results of the parametric analyses (only when grouped by median age of the sample) revealed a significant three-way interaction among age, DCCS Version, and DCCS Order, wherein younger (but not older) children performed significantly better on

the Easy DCCS, but only when the Easy DCCS preceded the Standard task. When the Standard DCCS preceded the Easy, younger children's performance was similar on both tasks. This finding found support in the non-parametric analyses, whether grouped by age in years or by median age, when the Easy DCCS was first it was found that more children passed the Easy DCCS than would be expected if the manipulation had no effect, and these differences were near significance at the alpha level of  $p=.06$ .

Again, while some children who failed the Standard DCCS were able to perform well on the Easy version since the attentional demands of the task were reduced, this benefit was only possible for children who received the Easy version first. Within the younger group of children (by median split) who received the Standard first, of the twelve children who failed the Standard, only one went on to pass the Easy DCCS. Within the thirteen children who received the Easy first, however, five children passed the Easy but did not pass the Standard task. None of the children in the younger group passed both versions of the task. This pattern of results suggests that young children's performance on the DCCS is even more fragile than was first anticipated.

The implications of these findings are three-fold. First, as anticipated, not all children received a benefit from the Easy version of the DCCS. Even within the group of children who received the Easy version first, many still failed both versions of the task. This finding was not unanticipated; in line with both attentional inertia and CCC-R accounts, reviewed earlier, not all three-year-old children are likely to be proficient with embedded rule-structures (Zelazo et al., 2003) and therefore not all three-year-olds were expected to perform well on the Easy version of the task. Recall that the aim of the present study was to reduce the attentional demands of the task in order to gain insight on

the relative importance of each of these factors for young children's performance; it was expected that some children would benefit from the Easy modification and that others would not. If proficiency with embedded rule structures was not yet in place for some children, the Easy modification could not have helped.

Second, while several children who received the Easy DCCS first did perform better on *that* version of the task, whatever benefit they received (i.e., reduced attentional demands) did not carry-over to their performance on the subsequent Standard DCCS. This is consistent with findings outlined in the introduction of this paper with respect to practice effects. In one of the only studies that has specifically examined practice and training effects on the DCCS, Kloo and Perner found that short of intensive training on the DCCS, practice with easier versions of the task does not impact future performance of three- to four-year-olds on the Standard DCCS. In their study, despite the administration of one of two easier versions of the DCCS, on which 86% of post-switch trials were sorted correctly, children's performance on subsequent administrations of the Standard task did not differ from the performance of children who received no practice with easier versions (2003).

Third and most strikingly, it seems that the benefit found by some children on the Easy DCCS was neither strong nor robust enough to overcome the attentional demands of the task when it was preceded by the Standard version. Children were only able to perform well on the Easy version if they had not already performed poorly on the Standard version of the task. Since the primary aim of the present study was to examine the effects of the Easy modification to the Standard task, the strong and significant order effect was clearly an unexpected one.

One possible interpretation of this finding is that during the first presentation of the DCCS (whether Standard or Easy) children learn about *how* to play the card sort game, and that they then use or apply this knowledge when playing ‘similar’ games in the future. In short, if children learn to play the Standard DCCS first and they don’t attend to the verbal label since it is much less salient than the visible stimulus (as is the typical finding), then perhaps they are less likely to attend to the verbal label in future presentations of the game.

When children are faced with the Easy DCCS first, they learn that they will first sort cards on the dimension that the experimenter names for them, and that they will then have to switch rules and sort cards on the new dimension that the experimenter names for them. In the Easy version of the task, because the card is occluded from children at the time of labeling on the relevant dimension, children also learn to wait for the experimenter’s label before deciding where to sort the card; they *do* attend to the verbal label because there is nothing else for them to attend to, and they perform well on the Easy task. This is exactly what the manipulation was designed to do. When proceeding to the Standard task, however, these children are not still able to attend to the verbal label as it is overcome by the more salient visual presentation of the test card. Again, this is consistent with Kloo and Perner’s findings that children did not benefit from practice with easier versions of the task (2003).

In contrast, when children are faced with the Standard version of the DCCS first, they learn that they will first sort cards according to the pre-switch dimension and that they should then switch rules and sort cards on the new dimension that the experimenter names for them. [Recall from Zelazo, Frye & Rapus (1996) that even three-year-olds who

fail the Standard version of the DCCS are able to correctly answer knowledge questions about where cards should be sorted in the post-switch phase]. In the Standard version of the task, however, the card is visible to children at the time of labeling on the relevant dimension and children are not likely to attend to the verbal label given by the experimenter – they can *see* the card so they don't *need* to listen to the label. Children who receive the Standard version first learn to 'play the game' by sorting the cards as according to the dimension they *themselves* mentally label them on (the pre-switch dimension), despite the experimenter's (less salient) verbal labels. In proceeding to the Easy DCCS, then, these children are less likely to benefit from the experimenter's labeling since they have already played the game before without attending to them.

Whether this explanation for the pattern of findings is plausible or not, the results of the present study suggest that the attentional inertia alone cannot account for young children's difficulty on the task. Even when the attentional inertia of the DCCS is substantially lowered, as in the Easy version of the task, young children only benefit from the reduced demands when this easier version serves as their first exposure to the task.

It seems that the conditions for young children's successful performance on the DCCS are considerably more stringent than first proposed: not only do children need to master the embedded rule structures as proposed by the CCC-R theory (Zelazo et al., 2003), and not only do they need to overcome the attentional demands of the task (Kirkham et al., 2003), but it seems that (at least in some circumstances) children's experience with the task needs to occur in such a way that allows them to benefit from modifications designed to aid their performance. This is in stark contrast to the position of Kirkham, Cruess and Diamond who implicate attentional inertia as the "core problem"

in young children's performance on the DCCS (2003). If it were the case that attentional inertia was the primary difficulty, it is not likely that such a prevalent order effect would have manifested, precluding children from any benefits of the scaffolding provided.

It is also important to consider the implications of these results for other studies. In finding that the effect of the Easy modification was confounded by the order of presentation of the two versions of the tasks, the significance of other manipulations that have impacted young children's performance on the DCCS are called into question. Kirkham and others, for instance, have reported that significantly more children passed their label condition than the Standard DCCS and that significantly fewer four-year-olds passed their face-up condition as compared to the Standard version (2003). Similarly, Kloo and Perner present data that three- and four-year-old children performed significantly better on two easier versions of the DCCS than on the Standard task, but did not test a condition wherein children were first exposed to the Standard DCCS (2003).

While both of these studies have produced modifications that may have impacted the level of attentional inertia of the task, thus accounting for the significant differences in the proportions of children who passed these versions relative to the Standard DCCS, in light of the present study it is possible that these modifications may only have significantly impacted children's performance because they were their first exposure to the task. That is to say, if these versions of the DCCS were presented to children after exposure to the Standard DCCS, significant differences in performance may not have been found.

As can be seen, the findings of the present study emphasize the importance of within-subjects designs for studies examining children's performance on these tasks.

Clearly, if comparisons are not made in such a way that order effects such as this can be taken into account, the relative importance of such findings can be obscured. The finding that young children's performance on the DCCS is improved under only a very strict and specific set of circumstances is far less crucial than the finding that children's performance is improved in a robust, if not transferable way.

*Individual Differences in Attentional Flexibility and Executive Function*

The secondary goal of the present study was to examine the differences between children who received benefit from the Easy DCCS and those who did not in terms of their performance on the FIST and the other measures of EF. Unfortunately, since so few of the children did benefit from the Easy DCCS while failing the Standard (only nine children), as compared to the twenty-eight children who received no benefit (failing-to-pass both tasks), these comparisons should only be considered tentative due to the largely unequal groups and the very small group of children who were helped by the Easy modification.

The children who were helped by the Easy DCCS were not found to differ from those who were not helped in terms of performance on the FIST, contrary to the hypothesis, but again, these comparisons were made across largely unequal groups. As with any such comparison, it is possible that if a larger group of children had been tested, with similar proportions of children who were helped and not helped by the modification, differences may have emerged.

While differences were not found between children who passed only the Easy versus children who failed-to-pass both tasks were not found, performance on the FIST was also compared between children who passed both tasks and children who failed-to-

pass both tasks, even after controlling for age and receptive vocabulary. This finding supports the FIST as a valid and sensitive measure of attentional flexibility in three- and four-year-old children, and also suggests that the FIST may have been useful to distinguish between children who were helped by the Easy DCCS and those who were not, given a larger sample for comparison. This may prove to be a relatively important discovery as the FIST is a new measure of attentional flexibility and the previous use of the FIST has been confounded by many methodological and design flaws, as outlined above. The modifications to the task in the present study appear to have strengthened its utility (and validity) as a measure of attentional flexibility, and its use in subsequent studies will therefore be strengthened.

Although the two groups of children were not found to differ on the FIST, they did differ in terms of their performance on Monkey/Tiger and Forward Digit Span. In both cases, children who received a benefit of the Easy DCCS significantly outperformed those who did not. Again, although these comparisons should be interpreted with caution, they can at least be taken to suggest that the children who were helped by the Easy DCCS have greater EF resources available to them than the children who were not helped, offering at least some support that the Easy modification was tapping into what it was proposed to. This suggestion makes good theoretical sense, since the Easy and Standard DCCS themselves are both measures of conflict inhibition. It should be of no surprise that the children who were able to perform well on the Easy DCCS despite their difficulty on the Standard version also performed better on other measures of conflict inhibition and working memory.

*Limitations*

While the present study has led to several encouraging findings, it was not without limitations. First and foremost, the sample of children tested was not sufficient to provide rich comparisons between the children who were helped by the Easy modification and those who were not. While it was anticipated that a sample of forty three-year-olds would allow for sufficient comparisons to be made across the two versions and two orders of the design, since so few of the children actually received any benefit from the Easy DCCS, comparisons between these groups of children remain tentative, at best.

Further, as outlined in the analyses, upon examination of children's scores on the Standard DCCS, it was of interest to consider children's age in a more continuous way than is typical for these studies. Although it was expected that four-year-olds performance would be at (or at least near) ceiling on both tasks and that most three-year-olds would perform very poorly on the Standard DCCS, it was actually the case that several of the older three-year-olds were at ceiling on the Standard DCCS and several four-year-olds did not pass the Standard version. In grouping children by the median age of the sample to provide a more continuous view of age, the range and variance of children's age became somewhat unequal. If a larger sample of older children had been collected, upon grouping the children by median split, these problems would not have arisen.

Another potential limitation of the study was the apparent weakness of the Easy modification. If the Easy modification had a stronger effect on children's performance, its effects may not have been washed out by the order of the tasks. It is important to note,

however, that the Easy modification was designed to specific criteria: to match the sleeve condition of Kirkham, Cruess & Diamond (2003) without deviating from the Standard DCCS. Given these criteria, and given the lack of previous within-subjects comparisons on these types of manipulations, there were no discernible cues to the impending order effect. In this sense, this finding was also a strength of the study, in that it commented on the efficacy of previous studies, raising an important question about the relative importance of attentional inertia in accounting for young children's difficulty on the DCCS.

The final significant limitation of the present study was the inability of the FIST to discriminate between children who benefited from the Easy modification and those who did not. While this is likely at least partially due to the largely unequal samples that were compared, a more sensitive measure of attentional flexibility would probably have been more informative [none exists that we know of, however]. Further, three- and four-year-old children's performance on the FIST was lower than was anticipated. It is possible that the new, cleaner version of the task was more difficult than was ideal for the comparisons being made in this analysis.

#### *Future Research*

Taken together, the findings of the present study highlight the need for future research in this line of questioning. As has become clear in light of the order effects revealed in the present study, care needs to be taken to ensure that any modifications to the DCCS put forward to improve (or interfere with) young children's performance on the task do so across orders of presentation in a within-subjects design. If, as in the present study, these modifications are found to only aid (or hinder) children's

performance under very specific circumstances, then it is likely that the factor they are affecting does not account for much of the variance in young children's performance on the DCCS, in general.

Perhaps more importantly, there is a clear need for studies aimed at determining what other factors may be involved in accounting for young children's performance on the DCCS. Beyond an inability to reason about embedded rule structures as posited by the CCC-R account, at the outset of this study attentional inertia was implicated as the major factor accounting for young children's difficulty with the task. In light of these results, however, it seems that the combination of rule-use and attentional inertia can only partially account for the difficulty that some children have with the task. The other factors that contribute to young children's poor performance on the measure need be specified, however, if the DCCS is going to continue to serve as one of the most frequently cited indices of preschooler's conflict inhibition.

Moving beyond the DCCS, much more extensive research needs to be conducted on the revised version of the FIST. A much larger dataset from a wider range of preschool-aged children needs to be collected and general findings need to be compared to the original version of the task. Also, performance on the FIST should be compared in terms of performance on other, more established measures of attentional flexibility, and children's performance should also be considered in terms of factors including vocabulary and executive function (as in the present study) to determine what 'typical' performance on the FIST looks like. Further, since young children's performance on the FIST was poorer than anticipated, it is also of interest to try and adapt the FIST for

younger populations or to create an alternative measure of attentional flexibility for these age groups.

### *Conclusion*

Overall, the present study has offered several important contributions to the present body of research aimed at explaining young children's poor performance on the DCCS. First, the present study introduced a novel modification to the DCCS that worked to reduce the attentional demands of the task, without changing the task in any other way. Findings from the older children supported the comparability of the Easy DCCS to the Standard DCCS, offering a cleaner way to examine the role of attentional inertia in children's poor performance on the DCCS.

Although an overall effect of the Easy modification was hypothesized, but not found, the present findings did reveal that younger children received a benefit from the Easy modification when it preceded the Standard DCCS. This finding not only supported that the Easy modification worked to lower the attentional demands of the Standard task, at least to some extent, but it led to the discovery of a strong and significant order effect. This order effect, in turn, suggested both that young children's developing conflict inhibition is more delicate an ability than was first thought, and that the importance of carefully designed, within-subjects comparisons has perhaps been underestimated in this line of questioning. Finally, the present study introduced a novel version of the FIST that appears to be a more valid and useful measure of attentional flexibility than the original task. In sum, while the present study was not able to account for the major cause of young children's poor performance on the DCCS, these findings do suggest that attentional inertia alone is not likely to account for the broadest of these difficulties. The present

findings also contribute to the discussion of this issue by outlining the importance of methodologically sound studies of children's performance on these tasks, and in revamping one of the newest measures of attentional flexibility in the field.

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## Appendix A

**STANDARD DCCS – FISH AND PLANES**

**Target cards:**

"Here is a green fish and here is a pink plane. This one is green, and this one is a pink."

"We are going to play a game. This is the colour game. The colour game is different from the shape game. All the green ones go in this box, and all the pink ones go in that box. We don't put any green ones in that box. No way. We put all the green ones over here and only pink ones go over there. This is the colour game."

- Sort: "Here is a green one. This one goes here because it's green."
- Child Sorts: "Here is a pink one. Where does this one go?"

*Feedback:* "Very good" or "No, this one's pink, so it goes over here."

"Okay, now I'm going to show you some green ones and pink ones."

- Show preswitch cards, one at a time:

"If it's a green one, then it goes here. If it's a pink one, then it goes there."

Show the child the card. "It's a \_\_\_\_\_ (green/pink one)."

Give the child the card. "Where does this go?" ACCURACY (/ or X)

<input type="checkbox"/>							
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*No Feedback:*

"Let's do another one" or "Let's do it again"

"Okay, now we're going to switch, so I'm going to put my switch cards in now. We are not going to play the colour game anymore. We are going to play the shape game. All the fish go in this box, and all the planes go in that box. We don't put any fish in that box. No way. We put all the fish over here and only planes go over there. This is the shape game."

- Show 8 postswitch cards (pink fish and green planes) and for each:

"If it's a fish, then it goes here. If it's a plane, it goes there."

Show the child the card. "It's a \_\_\_\_\_ (fish/plane)."

ACCURACY (/ OR X)

Give the child the card. "Where does this go?" 

<input type="checkbox"/>						
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"Okay, let's do another one." (*No Feedback*)

## Appendix B

**STANDARD DCCS – BOATS AND RABBITS**

**Target cards:**

“Here is a blue boat and here is a red rabbit. This one is blue, and this one is red.”

“We are going to play a game. This is the colour game. The colour game is different from the shape game. All the blue ones go in this box, and all the red ones go in that box. We don’t put any blue ones in that box. No way. We put all the blue ones over here and only red ones go over there. This is the colour game.”

- Sort: “Here is a blue one. This one goes here because it’s blue.”
- Child Sorts: “Here is a red one. Where does this one go?”

*Feedback:* “Very good” or “No, this one’s red, so it goes over here.”

“Okay, now I’m going to show you some blue ones and red ones.”

- Show preswitch cards, one at a time:

“If it’s a blue one, then it goes here. If it’s a red one, then it goes there.”

Show the child the card. “It’s a \_\_\_\_\_ (blue/red one).”

ACCURACY (/ or X)

Give the child the card. “Where does this go?”

*No Feedback:*

“Let’s do another one” or “Let’s do it again”

“Okay, now we’re going to switch, so I’m going to put my switch cards in now. We are not going to play the colour game anymore. We are going to play the shape game. All the boats go in this box, and all the rabbits go in that box. We don’t put any boats in that box. No way. We put all the boats over here and only rabbits go over there. This is the shape game.”

- Show 8 postswitch cards (blue rabbits and red boats) and for each:

“If it’s a boat, then it goes here. If it’s a rabbit, it goes there.”

Show the child the card. “It’s a \_\_\_\_\_ (boat/rabbit).”

ACCURACY (/ OR X)

Give the child the card. “Where does this go?”

“Okay, let’s do another one.” (*No Feedback*)

## Appendix C

**EASY DCCS – BIRDS AND TRAINS**

Target cards:

“Here is a purple train and here is a yellow bird. This one is purple, and this one is yellow.”

“We are going to play a game. This is the colour game. The colour game is different from the shape game. All the purple ones go in this box, and all the yellow ones go in that box. We don’t put any purple ones in that box. No way. We put all the purple ones over here and only yellow ones go over there. This is the colour game.”

- Sort: “Here is a purple one. This one goes here because it’s purple.”
- Child Sorts: “Here is a yellow one. Where does this one go?”

*Feedback:* “Very good” or “No, this one’s yellow, so it goes over here.”

“Okay, now I’m going to show you some purple ones and yellow ones.”

For each trial:

“If it’s a purple one, then it goes here. If it’s a yellow one, then it goes there.”

Hold card facing away from child.

“It’s a \_\_\_\_\_ (yellow one/purple one).”

ACCURACY (✓ or X)

Give child the card face up. “Where does this go?”

<input type="checkbox"/>							
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No Feedback:

“Let’s do another one” or “Let’s do it again”

“Okay, now we’re going to switch, so I’m going to put my switch cards in now. We are not going to play the colour game anymore. We are going to play the shape game. All the trains go in this box, and all the birds go in that box. We don’t put any trains in that box. No way. We put all the trains over here and only birds go over there. This is the shape game.”

- Show 8 postswitch cards (yellow trains and purple birds) and for each:

“If it’s a train, then it goes here. If it’s a bird, it goes there.”

Hold card facing away from child.

“It’s a \_\_\_\_\_ (bird/train).”

ACCURACY (✓ OR X)

Give child the card face up. “Where does this go?”

“Okay, let’s do another one.” (No Feedback)

<input type="checkbox"/>						
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## Appendix D

**MONKEY/TIGER**

Can you do these things with me? (*check off the movements that the child can do*)

Stick out your tongue	Clap your hands	Touch your nose
Touch your ears	Touch your feet	Wave your hand
Touch your cheeks	Touch your head	
Touch your mouth	Touch your tummy	

**RULES:** "See these guys?" (Show monkey and tiger)

"This is a nice Monkey. So when he talks to us, we will do what he tells us to do."

"And this is a naughty Tiger. So when he talks to us, we won't listen to him. If he tells us to do something, we won't do it."

**TRAINING**

MOVING MONKEY'S MOUTH (HIGH-PITCHED VOICE): Touch your (nose).

Full action	Partial Action	No Action	Different Action
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MOVING TIGER'S MOUTH (LOW, GRUFF VOICE): Touch your (tummy).

Full action	Partial Action	No Action	Different Action
-------------	----------------	-----------	------------------

IF MOVEMENT ON TIGER TRIAL, REPEAT BOTH RULES AND FULL TRAINING TO A MAXIMUM OF 5 TRAINING SESSIONS.  
ALWAYS PROCEED TO TESTING!

**TESTING**

Degree of Movement:

	Full Action	Partial Action	No Action	Different Action
1 Monkey: Stick out your tongue				
2 Monkey: Touch your ears				
3 Tiger: Touch your mouth				
4 Monkey: Touch your cheeks				
5 Tiger: Clap your hands				

**REPEAT BOTH RULES**

Degree of Movement:

	Full Action	Partial Action	No Action	Different Action
6 Tiger: Touch your feet				
7 Tiger: Touch your head				
8 Monkey: Touch your tummy				
9 Monkey: Touch your nose				
10 Tiger: Wave your hand				

## Appendix E

**DAY/NIGHT STROOP**

Now we're going to play a different game!

- SHOW MOON. This looks like night, right? When you see this card, I don't want you to say 'night'. No, I want you to say 'day'.
- REMOVE MOON; SHOW SUN. This looks like day, right? When you see this card, I don't want you to say 'day'. No, I want you to say 'night'.

Training:

- SHOW SUN. (IF HESITATION, What do you say for this one?)  
[D] [N] (Good.)
- SHOW MOON. (IF HESITATION, What do you say for this one?)  
[D] (Good.) [N]

IF WRONG OR NO RESPONSE ON EITHER TRIAL, REPEAT BOTH RULES AND TRAINING. MAX. OF 3 TRAINING SESSIONS. ALWAYS CONTINUE WITH TEST TRIALS.

Testing (No feedback)

1	D	N	_____
2	D	N	_____
3	D	N	_____
4	D	N	_____
5	D	N	_____
6	D	N	_____
7	D	N	_____

8	D	N	_____
9	D	N	_____
10	D	N	_____
11	D	N	_____
12	D	N	_____
13	D	N	_____
14	D	N	_____

15	D	N	_____
16	D	N	_____
17	D	N	_____
18	D	N	_____
19	D	N	_____
20	D	N	_____
21	D	N	_____

## Appendix F

**FLEXIBLE ITEM SELECTION TASK – ITEM IDENTIFICATION (1)**

“You and I are going to play some pick-some-pictures games together. I’m going to ask you to pick some pictures and you’re going to point to the ones you want to pick.”

Size

“Can you show me the large one?” \_\_\_\_\_ 2<sup>nd</sup> try: \_\_\_\_\_

“Good job! That’s the large one!” **OR**

“Good try, but I think that this one is the large one. What do you think?”

“Can you show me the medium one?” \_\_\_\_\_ 2<sup>nd</sup> try: \_\_\_\_\_

“Good job! That’s the medium one!” **OR**

“Good try, but I think that this one is the medium one. What do you think?”

“Can you show me the small one?” \_\_\_\_\_ 2<sup>nd</sup> try: \_\_\_\_\_

“Good job! That’s the small one!” **OR**

“Good try, but I think that this one is the small one. What do you think?”

*(Return to items that child missed at the end)*

Shape

“Can you show me the teapot?” \_\_\_\_\_ 2<sup>nd</sup> try: \_\_\_\_\_

“Good job! That’s the teapot!” **OR**

“Good try, but I think that this one is the teapot. What do you think?”

“Can you show me the shoe?” \_\_\_\_\_ 2<sup>nd</sup> try: \_\_\_\_\_

“Good job! That’s the shoe!” **OR**

“Good try, but I think that this one is the shoe. What do you think?”

“Can you show me the flower?” \_\_\_\_\_ 2<sup>nd</sup> try: \_\_\_\_\_

“Good job! That’s the flower!” **OR**

“Good try, but I think that this one is the flower. What do you think?”

*(Return to items that child missed at the end)*

Colour

“Can you show me red one?” \_\_\_\_\_ 2<sup>nd</sup> try: \_\_\_\_\_

“Good job! That’s the red one!” **OR**

“Good try, but I think that this one is red. What do you think?”

“Can you show me blue one?” \_\_\_\_\_ 2<sup>nd</sup> try: \_\_\_\_\_

“Good job! That’s the blue one!” **OR**

“Good try, but I think that this one is blue. What do you think?”

“Can you show me yellow one?” \_\_\_\_\_ 2<sup>nd</sup> try: \_\_\_\_\_

“Good job! That’s the yellow one!” **OR**

“Good try, but I think that this one is yellow. What do you think?”

*(Return to items that child missed at the end)*

## Appendix G

**FLEXIBLE ITEM SELECTION TASK – FAVOURITES**

Favourite items to be selected, circle order: 12 13 21 23 31 32

"Now you and I are going to pick some of our favourite pictures together. I'm going to pick my favourite pictures first, and then it will be your turn. Okay?" [turn to favourites game]

"See, here's a picture, here's another picture, and here's another picture. I'm going to pick my two favourite pictures, so I'm going to point to this picture here, because that's one of my favourite pictures, and I'm going to point to this picture here, because that's my other favourite picture. So those two pictures are my favourite pictures. I'm not going to point to the other picture, because that's not one of my favourite pictures. I'm only going to point to these two pictures here, because these two pictures are my favourite pictures."

*For each item selected, enter corresponding number (1 = Left, 2 = Center, 3 = Right)*

"Now it's your turn. Can you point to your two favourite pictures?"

Child Selects: \_\_\_\_\_ 2<sup>nd</sup> try: \_\_\_\_\_

- If child selects two pictures, feedback:

"So these two pictures are your two favourite pictures? Good job! You didn't point to the other picture because it's not one of your favourite pictures, is it? No! So you only pointed to your two favourite pictures, good for you!"

- If child selects only one picture, prompt:

"Remember to point to TWO of your favourite pictures. You pointed to this one (point to picture child indicated) because that is one of your favourite pictures, now point to your other favourite picture."

- If child selects all three pictures, correct:

"Remember to only point to your TWO favourite pictures. Can you try again? Only point to TWO of your favourite pictures."

"Now it's your turn again. Can you point to your two favourite pictures here?"

Child Selects: \_\_\_\_\_ 2<sup>nd</sup> try: \_\_\_\_\_

- If child selects two pictures, feedback:

"So these two pictures are your two favourite pictures? Good job! You didn't point to the other picture because it's not one of your favourite pictures, is it? No! So you only pointed to your two favourite pictures, good for you!"

- If child selects only one picture, prompt:

"Remember to point to TWO of your favourite pictures. You pointed to this one (point to picture child indicated) because that is one of your favourite pictures, now point to your other favourite picture."

- If child selects all three pictures, correct:  
“Remember to only point to your TWO favourite pictures. Can you try again? Only point to TWO of your favourite pictures.”
  
- “Let’s try one more. Can you point to your two favourite pictures here?”  
Child Selects: \_\_\_\_\_ 2<sup>nd</sup> try: \_\_\_\_\_

  - If child selects two pictures, feedback:  
“So these two pictures are your two favourite pictures? Good job! You didn’t point to the other picture because it’s not one of your favourite pictures, is it? No! So you only pointed to your two favourite pictures, good for you!”
  - If child selects only one picture, prompt:  
“Remember to point to TWO of your favourite pictures. You pointed to this one (point to picture child indicated) because that is one of your favourite pictures, now point to your other favourite picture.”
  - If child selects all three pictures, correct:  
“Remember to only point to your TWO favourite pictures. Can you try again? Only point to TWO of your favourite pictures.”

## Appendix H

**FLEXIBLE ITEM SELECTION TASK – TEST TRIALS**

Order: 1    2    3

"Now you and I are going to play a different pick some pictures game. We're going to pick some more pictures together, but we are going to pick them in a different way. I'm going to pick some pictures first, just to show you how we pick pictures in this new game, and then it will be your turn. Okay?"

Demonstration Trial:Selection 1:

"I'm going to pick two pictures that go together in one way. So I'm going to point to this picture here and to this picture here, because these two pictures go together in one way. The other picture doesn't go with these two pictures here. No! So these two pictures go together in one way."      *Experimenter Selects:* \_\_\_\_\_ *Child Labels:* \_\_\_\_\_

Selection 2:

"Now, do you know what I'm going to do? I'm going to pick two pictures that go together, but in another way. So I'm going to point to this picture here and to this picture here, because these two pictures go together in another way. The other picture doesn't go with these two pictures. No way! These two pictures go together, but in another way."

*Experimenter Selects:* \_\_\_\_\_ *Child Labels:* \_\_\_\_\_

Summary:

"So these two pictures (selection 1) go together in one way (point to each picture), and these two pictures (selection 2) go together, but in another way (point to each picture)."

Practice Trial 1:

"Now it's your turn to pick some pictures! Can you point to two pictures that go together in one way?"

Selection 1: \_\_\_\_\_ Child Labels: \_\_\_\_\_

Child Selects Matching Pair:

"You know what? You're right! That's right, these two pictures here go together in one way. The other picture doesn't go with these two pictures here. No! Good Job! So these two pictures go together in one way."

Child Selects incorrect pair, no items, one item, or all three items:

"Good try, but you know what? I think that these two pictures here go together in one way. What do you think? That's right! These two pictures here go together in one way. The other picture doesn't go with these two pictures here. No! Good job! So these two pictures here go together in one way."

"Now can you point to two pictures that go together, but in another way?"

Selection 2: \_\_\_\_\_ Child Labels: \_\_\_\_\_

Child Selects Matching Pair:

"You know what? You're right! That's right, these two pictures here go together, but in another way. The other picture doesn't go with these two pictures here. No! Good Job! So these two pictures go together, but in another way."

Child Selects incorrect pair, no items, one item, or all three items:

"Good try, but you know what? I think that these two pictures here go together in another way. What do you think? That's right! These two pictures here go together, but in another way. The other picture doesn't go with these two pictures here. No! Good job! So these two pictures here go together, but in another way."

Summarize: "So see, these two pictures here go together in one way, and these two pictures here go together, but in another way. Good job!"

"You did a great job on this one, so let's pick some more pictures."

Practice Trial 2:

"Now it's your turn to pick some pictures again! Can you point to two pictures that go together in one way?"

Selection 1: \_\_\_\_\_ Child Labels: \_\_\_\_\_

Child Selects Matching Pair:

"You know what? You're right! That's right, these two pictures here go together in one way. The other picture doesn't go with these two pictures here. No! Good Job! So these two pictures go together in one way."

Child Selects incorrect pair, no items, one item, or all three items:

"Good try, but you know what? I think that these two pictures here go together in one way. What do you think? That's right! These two pictures here go together in one way. The other picture doesn't go with these two pictures here. No! Good job! So these two pictures here go together in one way."

"Now can you point to two pictures that go together, but in another way?"

Selection 2: \_\_\_\_\_ Child Labels: \_\_\_\_\_

Child Selects Matching Pair:

"You know what? You're right! That's right, these two pictures here go together, but in another way. The other picture doesn't go with these two pictures here. No! Good Job! So these two pictures go together, but in another way."

Child Selects incorrect pair, no items, one item, or all three items:

"Good try, but you know what? I think that these two pictures here go together in another way. What do you think? That's right! These two pictures here go together, but in another way. The other picture doesn't go with these two pictures here. No! Good job! So these two pictures here go together, but in another way."

Summarize: "So see, these two pictures here go together in one way, and these two pictures here go together, but in another way. Good job!"

"You did a great job on this one, so let's pick some more pictures."

Test Trials

"I think you know how to play my game now. Right? Yes! So I think we can go a little bit faster now."

Instructions for each trial: No Feedback, general praise only!

"Show me two pictures that go together in one way," then

"Now, show me two pictures that go together, but in another way."

1.1	_____	label:	_____	9.1	_____	label:	_____
1.2	_____	label:	_____	9.2	_____	label:	_____
2.1	_____	label:	_____	10.1	_____	label:	_____
2.2	_____	label:	_____	10.2	_____	label:	_____
3.1	_____	label:	_____	11.1	_____	label:	_____
3.2	_____	label:	_____	11.2	_____	label:	_____
4.1	_____	label:	_____	12.1	_____	label:	_____
4.2	_____	label:	_____	12.2	_____	label:	_____
5.1	_____	label:	_____	13.1	_____	label:	_____
5.2	_____	label:	_____	13.2	_____	label:	_____
6.1	_____	label:	_____	14.1	_____	label:	_____
6.2	_____	label:	_____	14.2	_____	label:	_____
7.1	_____	label:	_____	15.1	_____	label:	_____
7.2	_____	label:	_____	15.2	_____	label:	_____
8.1	_____	label:	_____				
8.2	_____	label:	_____				

## Appendix I

Table 1A

*Trials with Itemized Item Sets and Relevant Dimensions Appearing in FIST Test Trials*

Trial Set	Relevant dimensions	Left panel	Center panel	Right panel
A	Colour/Size	small red shoe	large yellow teapot	large red flower
B	Colour/Size	large red teapot	large yellow shoe	small yellow flower
C	Colour/Size	small blue teapot	medium blue flower	medium red shoe
D	Colour/Size	medium red teapot	large red shoe	medium yellow flower
E	Colour/Size	small red flower	medium yellow shoe	small yellow teapot
F	Colour/Size	small blue shoe	small red teapot	large blue flower
G	Shape/Colour	large yellow teapot	medium red shoe	small red teapot
H	Shape/Colour	large yellow flower	small blue flower	medium yellow shoe
I	Shape/Colour	medium yellow teapot	small yellow shoe	large blue shoe
J	Shape/Colour	medium red teapot	large blue teapot	small blue shoe
K	Shape/Colour	medium blue shoe	small blue teapot	large red shoe
L	Shape/Colour	large red teapot	small yellow flower	medium red flower
M	Size/Shape	medium red teapot	large blue flower	medium yellow flower
N	Size/Shape	small yellow teapot	small red flower	large blue teapot
O	Size/Shape	large blue shoe	medium red shoe	large yellow flower
P	Size/Shape	medium blue flower	large yellow teapot	large red flower
Q	Size/Shape	large red teapot	medium blue teapot	medium yellow shoe
R	Size/Shape	small blue flower	small red shoe	large yellow shoe

Table 2A

*Orders of Administration for the FIST with Trial Set (from Table 1A) and Relevant Dimensions*

Trial	Order 1		Order 2		Order 3	
	Order	Relevant dimensions	Order	Relevant dimensions	Order	Relevant dimensions
1 (demo)	C	Colour/Size	F	Colour/Size	L	Shape/Colour
2 (practice)	M	Size/Shape	I	Shape/Colour	N	Size/Shape
3 (practice)	H	Shape/Colour	P	Size/Shape	B	Colour/Size
4	B	Colour/Size	C	Colour/Size	H	Shape/Colour
5	P	Size/Shape	L	Shape/Colour	M	Size/Shape
6	K	Shape/Colour	Q	Size/Shape	C	Colour/Size
7	E	Colour/Size	J	Shape/Colour	P	Size/Shape
8	I	Shape/Colour	E	Colour/Size	G	Shape/Colour
9	Q	Size/Shape	O	Size/Shape	Q	Size/Shape
10	D	Colour/Size	H	Shape/Colour	A	Colour/Size
11	L	Shape/Colour	M	Size/Shape	J	Shape/Colour
12	N	Size/Shape	A	Colour/Size	O	Size/Shape
13	F	Colour/Size	N	Size/Shape	I	Shape/Colour
14	G	Shape/Colour	G	Shape/Colour	D	Colour/Size
15	A	Colour/Size	B	Colour/Size	R	Size/Shape
16	R	Size/Shape	K	Shape/Colour	F	Colour/Size
17	J	Shape/Colour	R	Size/Shape	K	Shape/Colour
18	O	Size/Shape	D	Colour/Size	E	Colour/Size

## Appendix J

**COUNTING AND LABELING**

"Now I'm going to show you some itty-bitty little things."

*Set out Tree, Gift and Cow.* (Point at each toy as mentioned.)

"I'm going to name these toys: Tree, Gift, Cow."

"Now I'm going to count them: One, Two, Three."

"Now I'm going to count and name them at the same time."

"One is a tree, Two is a gift, Three is a cow."

---

*Set out Cake, Frog and Teddy.*

"It's your turn now. Can you name these toys?" (correct if needed)

"Can you count them?" (correct if needed)

"Now count and name them at the same time." (do not correct)

     (✓ or X)

*Set out Sheep, Apple and Hand*

"It's your turn again. Can you name these toys?" (correct if needed)

"Now count them." (correct if needed)

"Now count and name these toys at the same time." (do not correct)

     (✓ or X)

## Appendix K

**BACKWARD DIGIT SPAN**

Instructions: Say one digit per second. Stop when child makes an error on both strings of the same length (e.g., when both items 5 and 6 are incorrect). Provide no feedback after 2 training trials.

"This is my friend, Willy. Whenever I say numbers, Willy says them backwards. Listen: 5 – 8. (*Willy says:*) 8 – 5. Now I want you to do the same as Willy and say my numbers backwards. Do you understand? Let's try one. Ready? Listen carefully. Remember to say the numbers backwards, 2 – 4." (score below)

"Let's try another one. Remember to say the numbers backwards, 7 – 1."

Digits ForwardChild's Response

- i.     2 – 4 ("That's right!" or correct the mistake) \_\_\_\_\_ – \_\_\_\_\_ ; \_\_\_\_\_ – \_\_\_\_\_  
ii.    7 – 1 ("That's right!" or correct the mistake) \_\_\_\_\_ – \_\_\_\_\_ ; \_\_\_\_\_ – \_\_\_\_\_
- 

1.     6 – 3

2.     4 – 9

3.     2 – 9 – 5

\_\_\_\_\_ – \_\_\_\_\_ – \_\_\_\_\_

4.     8 – 1 – 6

\_\_\_\_\_ – \_\_\_\_\_ – \_\_\_\_\_

5.     8 – 5 – 2 – 6

6.     3 – 9 – 5 – 7

7.     8 – 1 – 3 – 7 – 9

\_\_\_\_\_ – \_\_\_\_\_ – \_\_\_\_\_ – \_\_\_\_\_ – \_\_\_\_\_

8.     4 – 2 – 5 – 8 – 1

\_\_\_\_\_ – \_\_\_\_\_ – \_\_\_\_\_ – \_\_\_\_\_ – \_\_\_\_\_

9.     9 – 3 – 5 – 1 – 8 – 4

10.    6 – 5 – 8 – 4 – 2 – 7

## Appendix L

**FORWARD DIGIT SPAN**

Instructions: Say one digit per second. Stop when child makes an error on both strings of the same length (e.g., when both items 5 and 6 are incorrect). Provide no feedback after 2 training trials.

"I'm going to say some numbers, and I want you to say them back to me the same way I say them to you. Do you understand? Let's try one. Ready? Listen carefully. 2 - 4." (*score below*)

"Let's try another one now 7 - 1." (*score below*)

**Digits Forward****Child's Response**

i. 2 - 4 ("That's right!" or correct the mistake) \_\_\_\_\_ - \_\_\_\_\_ ; \_\_\_\_\_ - \_\_\_\_\_

ii. 7 - 1 ("That's right!" or correct the mistake) \_\_\_\_\_ - \_\_\_\_\_ ; \_\_\_\_\_ - \_\_\_\_\_

1. 6 - 3

2. 4 - 9

3. 2 - 9 - 5

4. 8 - 1 - 6

5. 8 - 5 - 7 - 6

6. 4 - 9 - 3 - 7

7. 8 - 1 - 3 - 7 - 9

8. 4 - 2 - 5 - 8 - 1

9. 9 - 3 - 5 - 1 - 8 - 4

10. 6 - 5 - 8 - 4 - 2 - 7