Abstract

The goal of this dissertation was to examine how specific scaffolding strategies could affect executive functioning (EF) performance in preschool aged children, specifically shifting performance as measured by the Dimension Change Card Sort task (DCCS; Zelazo, 2006). In the DCCS, children must sort test cards initially based on one dimension (e.g., shape) and then switch to sort by another dimension (i.e., colour). When asked to switch rules, 3-year-olds tend to perseverate whereas 5-year-olds can shift successfully. Theoretical accounts center on the notion that children have difficulty successfully representing rules that have embedded if-if-then conditional (Bunge & Zelazo, 2006). If this is true, interventions that are designed to make representing the embedded conditional rule less taxing should lead to better performance on post-switch trials of the DCCS. Given that preschool aged children struggle to describe objects in new ways on the basis of different dimensions (Kloo & Perner, 2005), children may perseverate because they have difficulty reconceptualising the stimuli to match with the post-switch sorting parameters. The studies in this dissertation sought to test the hypothesis that DCCS performance could be scaffolded by promoting children’s attention to the multidimensional nature of objects.

In Study 1 and 2, brief experimental games were used to scaffold 3-year-old children’s ability to think about the multidimensional nature of objects by both separating and aggregating dimensions. Results showed that promoting multidimensional understanding facilitated DCCS performance relative to controls. Moreover, it seems that this is the case regardless of the nature of the scaffolding dimensions.
In Study 3, we included an additional extra-dimensional sorting parameter, order, in an attempt to facilitate performance on a more advanced version of the DCCS in 5-year-olds. Again, children in the experimental condition performed significantly better relative to controls, suggesting that difficulty conceptualizing objects in different ways may be a critical component of shifting performance across the preschool age range.

The findings will be discussed with regard to their theoretical implications concerning the nature of EF development more broadly, and shifting more specifically, and their potential to inform research with children who may be at risk for difficulties with shifting.
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<td>EF</td>
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<td>DCCS</td>
<td>Dimensional Change Cart Sort</td>
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<td>IR</td>
<td>Iterative Reprocessing Theory</td>
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<td>PATHS</td>
<td>Promoting Alternate Thinking Strategies</td>
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<td>CSRP</td>
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Chapter 1

General Introduction

Many times in our day-to-day lives we are faced with situations that require decision-making and goal-directed behaviour under challenging circumstances. This can be navigating a busy street as a pedestrian, focusing on an important assignment for work, or refraining from eating the cookies we know are in the cupboard. Navigating these instances requires executive functioning (EF), a broad array of cognitive abilities that support the conscious control of thoughts, actions and behaviour (Miyake et al., 2000). EF is typically defined as three interrelated, yet separate, abilities: updating information in working memory, inhibitory control, and shifting between mental sets (Miyake et al., 2000). The maturation of EF plays an integral role in the development of a number of social, emotional and academic domains (see e.g., Zelazo, Carlson, & Kesek, 2008, for review). Indeed, EF is a better predictor of long-term academic success than IQ (Diamond, 2006; Duckworth & Seligman, 2005; Hughes & Ensor, 2011; McClelland, Acock, & Morrison, 2006).

Likewise, serious impairments in EF have been associated with a variety of negative outcomes including poor physical health, criminality, and interpersonal deficits (Moffitt et al., 2011). The importance of EF has led researchers to investigate the factors that are necessary for EF development in an effort to determine if it is possible to train and improve this important set of abilities. The goal of my doctoral research is to examine how targeted scaffolding strategies may facilitate specific aspects of EF performance in preschool aged children.
First, I will briefly discuss EF development, after which I will transition to the Dimensional Change Card Sort (DCCS; Zelazo, 2006), a task frequently used to assess shifting abilities in preschool aged children, and the focus of our research. I will then review two prominent theories of DCCS improvement and integrate these into a single approach that emphasizes their necessary dependencies. After establishing the theoretical basis for the current work, I will review the EF training literature, including classroom and lab-based interventions. Finally, I will discuss the approach we took in our research and lay out the goals of the current studies.

**Executive Functioning Development**

Research examining the developmental trajectory of EF has found evidence to suggest a protracted linear course of development with two periods of rapid age-related improvement (Best & Miller, 2009, 2010; Romine & Reynolds, 2005; Zelazo et al., 2013). The first, and most rapid, period of development is during the preschool age range, 3-5, which has been suggested to result from whole-scale changes to the structure of cognition, as different abilities emerge and develop. The second is during the shift from childhood to adolescence, as skills differentiate and continue to improve (Best & Miller, 2010; Romine & Reynolds, 2005; Welsh et al., 1991; Zelazo et al., 2013). EF development play a critical role in a number of domains, including social functioning, physical and mental health, job success, and school performance, to name a few. It appears that EF is trainable, and that children are able to benefit from early interventions (Diamond & Lee, 2011). Training targeting EF skills is of particular interest given how important these skills are for later functioning and success. A child’s early EF ability’s has been shown to predict later achievement, health outcomes, social status and overall quality of life (see e.g., Diamond, 2013 for review). Though a full investigation of atypical EF development is beyond the
scope of this dissertation, deficits in EF skills have been found to relate to a host of negative outcomes, including cognitive, social and mental health impairments, (see, Zelazo & Muller, 2010 for review). As such, it is of interest to better elucidate the developmental processes important for successful EF development and translate this research to applied settings.

**The Dimensional Change Card Sort (DCCS)**

The tasks used to assess the shifting aspect of EF in young children often require acting according to a novel rule that runs counter to some recently learned or habitual action. One of the most frequently used tasks is the Dimensional Change Card Sort (DCCS; Zelazo, 2006). In this task, children are instructed to sort test cards – red rabbits and blue boats – initially based on one dimension (e.g., colour – “we’re playing the colour game”) and then switch to sort by another dimension (i.e., shape “now we’re going to play the shape game”).

Successful performance on the DCCS relies most heavily on the ability to shift between the sorting rules, though navigating the task does require a modicum of inhibition, and updating abilities (Cragg & Chevalier, 2012; Perner & Lang, 2002; Waxer & Morton, 2011). In order to successfully perform the task one must shift their attention to the second sorting dimension, which naturally necessitates inhibiting acting according to the initial rule. While the task information must be maintained in working memory, the sorting rule – “All the rabbits go here and all the boats go here, here is a blue boat, where does this one go?” – is repeated before each trial.

Performance on the DCCS develops substantially over the preschool years (Carlson, 2005). For instance, when asked to switch, 3-year-olds tend to perseverate on sorting according to the initial rule whereas 5-year-olds shift successfully (Garon, Bryson, &
Smith, 2008; Zelazo, 2006). Indeed on this task, performance tends to be bimodally distributed, with children either passing or failing all post-switch trials (Zelazo, 2006). Perhaps most intriguing is that when asked where, for example, the blue boat goes during the colour or shape game, children are able to answer correctly. Thus, though children are able to remember accurately what they should be doing, they are unable to use this knowledge when responding to the stimulus cards.

**Theoretical background.** Age-related improvements can be seen in DCCS, and in EF performance more broadly, during the preschool years (Carlson, 2005). However little is known about the specific cognitive changes that are responsible for these developments. There are multiple theoretical accounts concerning the mechanism behind preschoolers’ DCCS improvement and EF development. For the purpose of this dissertation I will focus on two prominent theories.

**Iterative reprocessing (IR).** The iterative reprocessing (IR) approach proposed by Zelazo (2015) builds from previous theories that have stressed the importance of conscious reflection as it relates to rule use (Zelazo, 2004; Zelazo & Frye, 1998; Zelazo, Muller, Frye, & Marcovitch, 2003). IR theory hypothesizes that children’s ability to form and use conditional rules is essential for EF performance. According to this theory, as children age they are able to represent increasingly complex rule structures which are in turn used to control behaviour. It is believed that rule complexity is determined in a hierarchical fashion based on the number of embedded conditionals required in a single rule structure (Zelazo et al., 2003). For example, Figure 1 shows the rule structure necessary for the DCCS. There are two branches contingent on which game one is playing and thus, which dimensions of the test cards one must attend to. For instance, if a child is given a red rabbit during the colour game then they should attend to the colour red and act accordingly, however the
same card during the shape game would necessitate a different action. “If I’m playing the colour game, and if it is red then it goes here...If I’m playing the shape game, and if it is a rabbit then it goes there” In order to navigate the task successfully, children must create embedded conditional rules that follow an “if-if-then” structure.

IR theory posits that children form these rules in an ad-hoc fashion, and that the level of complexity – that is, embedded conditionals within a rule – a child can represent increases with age (Cunningham & Zelazo, 2007; Zelazo, et al., 2003; Zelazo, 2015). Developmental gains in rule use are spurred by a child’s ability to reflect on task pertinent information. IR theory suggests that reflection necessitates reprocessing information, which then promotes top-down control and successful rule representation. Thus, age-related developments are the result of a child’s ability to consciously reflect on increasingly complex hierarchical rule structures (Cunningham & Zelazo, 2007; Marcovitch & Zelazo, 2009; Zelazo, 2015).

In regards to the DCCS, IR theory suggests that children are able to successfully navigate the post-switch when they are able to recognize the choice between the colour game and the shape game. Children then must reflect on the stimuli and realize that there are two different ways to approach the test cards and form a conditional rule structure to guide their behaviour (Zelazo, 2015).

Evidence. Early research on rule use found that young children have difficulty following a single conditional rule. When asked to press a ball in response to a flashing light, 2-year-olds tend to ignore the conditional clause and act immediately once presented with the stimulus (Zelazo & Jacques, 1997). Young 3-year-olds are often able to wait for the initial demonstration of the condition – in this case a light, but then continue to carry out the action unsystematically. It is not until later in the preschool years, approximately 5
years of age, that children are able to consistently follow if-if-then conditional structures (Carlson, 2005; Garon et al., 2008; Zelazo, 2004; Zelazo, Carlson, & Kesek, 2008). It is also during this same age range that children are able to easily navigate the DCCS.

Versions of the DCCS that do not require conditional rules are much easier for young children to navigate. For example, using four separate rules to sort the test cards without including a conditional if-if-then structure, or only using simple stimulus response rules, allow children who fail the standard DCCS to successfully navigate the post-switch (Zelazo et al., 2003). Further evidence for IR theory comes from a recent training study. Espinet, Anderson, and Zelazo (2013) adapted an earlier training program (Kloo & Perner, 2003) to encourage 3-year-old children to reflect on the DCCS’ if-if-then rule structure. They found that the children who were encouraged to reflect showed a significant improvement in DCCS performance relative to simple yes/no feedback (Espinet, et al., 2013). Moreover, this translated to a smaller N2, an event related potential thought to be associated with error monitoring and conflict detection, suggesting that encouraging reflection made resolving the conflict inherent in the choice presented at the rule switch less taxing (Bunge & Zelazo, 2006; Espinet et al., 2013; Espinet, Anderson, & Zelazo, 2012; Rueda, Posner, Rothbart, & Davis-Stober, 2004). Thus, it seems that navigating conditional rules can be challenging for young children and scaffolding this aspect of the DCCS may serve to facilitate performance.

**Re-description.** According to the re-description theory, children have difficulty conceptualizing objects in new ways (Kloo & Perner, 2003; 2005; Perner & Lang, 2002). For instance, if something is initially identified by its colour, children subsequently struggle to re-describe it by its shape. This accounts for young children’s DCCS failures by suggesting that children continue to sort by the initial rule because they are unable to hold
in mind two competing conceptualizations of the stimulus. That is, they are unable to think simultaneously of the stimulus being described as a boat and as being blue. Accordingly, no matter which parameter they are asked to sort by initially, they have difficulty conceptualizing the object in a way that is consistent with the post-switch sorting parameters. For example, in the colour game the red rabbit must be thought of as “a red thing” while in the shape game the red rabbit must be thought of as “a rabbit.” This difficulty is compounded by the target cards, which are in direct conflict with the test cards, i.e. target cards on trays – blue rabbit and red boat, test cards to be sorted – red rabbit and blue boat. That is, during the post-switch the child must re-describe the target, as well as the test stimuli.

Evidence. There are multiple pieces of evidence to support the hypothesis that re-description is a critical component of DCCS performance. The first concerns instances when only a response reversal is necessary (i.e., “we’re playing the normal game where all the apples go with the apples and all the pears go with the pears, – now we’re going to switch and play the silly game where the apples go with the pears and the pears with the apples”), 3-year-olds are able to perform the described switch successfully (Brooks, Hanauer, Padowska, & Rosman, 2003; Kloo, Perner, Kerschhuber, Dabernig, & Aichhorn, 2008; Perner & Lang, 2002). In this type of simplification, no object re-description is required because children are still sorting pears and apples, albeit in a different way. Moreover, if the dimensions on the stimuli cards are separated (i.e., a red circle next to an outline of a banana, see, Kloo & Perner, 2005) then once more children do not have to think of the stimuli in a new way after the rule switch. The red thing remains a red thing and the banana shape remains the banana shape. Children who fail the standard DCCS are able to navigate task manipulations that do not involve re-describing the stimuli (Diamond,
Carlson, & Beck, 2005; Kloo et al., 2008; Kloo & Perner, 2005; Kloo, Perner, Aichhorn, & Schmidhuber, 2010; Perner & Lang, 2002). These findings provide further evidence that re-description is a possible rate-limiting factor on DCCS performance in preschool aged children.

Second, performance is affected by manipulations that target either the relevant or irrelevant sorting dimension. Children are more successful when the relevant (post-switch) dimension is highlighted and struggle when the same is true of the irrelevant (pre-switch) dimension (Kirkham, Cruess, & Diamond, 2003; Kloo & Perner, 2005; Mack, 2007; Towse, Redbond, & Houston-Price, 2000). It is possible that highlighting the relevant dimension helps the child to shift and focus their attention to the aspect of the stimuli necessary for successful performance. However, it is also possible that the critical manipulation is the reduction in conflict in the information being presented (Doebel & Zelazo, 2015). That is, it is not the presence of the relevant dimension that is important, but the absence of the irrelevant dimension. This is in line with studies showing that children are also more successful when only the relevant dimension is labelled i.e., “The blue ones go here and the red ones go here, this is a blue one, where does this one go?” As opposed to when both dimensions are labelled, i.e., “The blue ones go here and the red ones go here, this is a blue boat, where does this one go?” A recent meta-analysis found that children were 2.13 times more likely to pass the DCCS if the test cards were labeled by the relevant dimension only versus both dimensions (Doebel & Zelazo, 2015). The conflict described in this case is similar to re-description understanding. By only highlighting the relevant feature, children are better able to perform this task because they themselves do not have to reconceptualise the objects.
**Integrative view.** It is our contention that these two theories, IR and re-description, in fact work together by targeting different points in the timeline of processing necessary for successful DCCS performance. Insofar as successful navigation of the DCCS requires the construction of a conditional rule structure, experiences that can help scaffold the contents of those rule structures should positively affect performance. IR theory posits that children form rules ad hoc through conscious reflection. In the DCCS, rule formation is triggered when a child detects the conflicting sorting options available to them based on the test card dimensions. However, if children have difficulty mentally describing objects in different ways, then they might fail to recognize the “if-if-then” choice of the post-switch. That is, they will be unable to understand that they can approach the stimuli cards as either a colour or a shape, thereby making shifting to the post-switch sorting dimension impossible. Thus re-description appears to be a critical component of the rule formation process.

This view is further supported by studies looking at children’s ability to attend to dimensional differences. Research shows that there is a change in children's attentional processing of multidimensional objects across development (Smith & Kemler, 1977). Free classification tasks, wherein a child is given a set of stimuli and then must separate them into categories of like items, show that preschool aged children tend to classify multidimensional objects as undifferentiated wholes, as opposed to integrated or multi-featured objects. When grouping objects young children tend to classify them based on overall similarity as opposed to on the basis of dimensional differences (Smith & Kemler, 1977; Smith, 1989). The developmental change in selective dimensional attention has recently been put forth as a potential process relating to children’s shifting abilities (Hanania & Smith, 2010). It has been found that though preschool aged children are able to attend selectively to separate dimensions if prompted, without guidance they tend to apply
holistic rules in classification tasks (Perry & Samuelson, 2013; Smith, 1989; Smith & Kemler, 1977; Visser & Raijmakers, 2012). Over the course of development children become better able to focus on selective dimensions and by 6 or 7 years of age, begin to assess similarity on the basis of separate stimulus dimensions (Smith, 1989). This process relates directly to re-description and preschool aged children’s difficulty maintaining two competing representations of a single stimulus at the same time.

**Summary**

It appears that manipulations that simplify the rules make the DCCS less taxing for young children. There is evidence to support the conclusion that children may have some difficulty attending to the multiple dimensions of the DCCS stimuli, which may in turn prohibit the necessary rule formation. It has been shown that if preschool aged children are cued either by the use of verbal labels (Perry & Samuelson, 2013), or are first given experience on stimulus dimensions (Perone, Molitor, Buss, Spencer, & Samuelson, 2015), they are able to then navigate demands relating to distinct dimensions. It is our contention that helping children to focus on the multidimensional nature of objects would scaffold the creation of the conditional rules necessary for the DCCS. I will review the existing EF training and intervention literature below.

**EF Training**

Due to the widespread effects EF has on later functioning there has been a recent surge of interest in the development of EF specific interventions. Training research tends to fall into two distinct categories, broad, large-scale classroom interventions and lab-based interventions targeting specific skills. The goals of these two kinds of programs differ; classroom interventions are geared towards improving children’s EF and thus their ability to succeed in an academic setting, while lab-based programs assess whether certain
practices affect performance in an effort to determine what underlying mechanisms are important for development. I will briefly review each in turn and discuss how targeted lab-based programs may be able to inform the intervention literature and programming.

**Classroom interventions.** There are a handful of classroom programs designed to target preschool aged children’s EF abilities. These include: Promoting Alternate Thinking Strategies (PATHS), the Chicago School Readiness Project (CSRP), and Tools of the Mind (henceforth, Tools) (for a review see, (Diamond & Lee, 2011).

Each program is structured differently and to date, empirical studies evaluating their efficacy have produced mixed results (Diamond, 2012; Diamond & Lee, 2011; Jacob & Parkinson, 2015; Jones, Bub, & Raver, 2013; Raver, Jones, Li-Grining, & Metzger, 2008; Raver et al., 2011; Riggs, Greenberg, Kusché, & Pentz, 2006). In PATHS children practice taking deep breaths before acting and use self-talk to consciously control and inhibit their reactions (Greenberg & Kusché, 1998; Kam & Greenberg, 2004). The effects have not yet been examined in preschool aged children, though it was found that 7- to 9-year olds who participated in the program performed better on inhibition and shifting measures compared to age-matched controls (Riggs et al., 2006). CSRP is a preschool specific program meant to supplement Head Start classrooms. Teachers are trained in stress-reduction techniques with the goal of developing classrooms with clear and consistent routines that are emotionally open and supportive (Raver et al., 2008; 2011). It was found that 4-year-old children who participated in CSRP classrooms performed significantly better on measures of attention, inhibition and impulsivity than age-matched controls (Jones et al., 2013). Moreover, these children continued to outperform controls academically for the next 3 years, and these gains were largely mediated by improvements in EF and teacher-student relationships (Jones et al., 2013). The findings of the PATHS and CSRP programs are
promising, yet we do not yet know exactly why these improvements occur, as these programs do not target EF specifically but take a more general behavioural approach.

Alternatively, Tools is rooted in Vygotskian theories including social learning and the use of guided scaffolding practices (Diamond, Barnett, Thomas, & Munro, 2007). Children engage in pretend play, during which they must follow rules and inhibit acting out of character with the express purpose of practicing and exercising EF abilities. In addition, Tools uses visual scaffolding tools, for instance, children who have difficulty listening in classrooms might be given a drawing of an ear to help remind them in situations that require that skill. A recent review by Jacob & Parkinson (2015) found that though the Tools program has garnered significant public interest, there has been little evidence to support its success. Diamond et al. (2007) found that children who were in Tools classrooms performed significantly better on EF tasks when compared to controls. However, follow-up studies using more rigorous statistical techniques including baseline and post-intervention measures – not present in Diamond et al. (2007) – have found no effects of the Tools curriculum (Barnett et al., 2008; Farran, Wilson, Lipsey, & Turner, 2013). In fact, one study found a significant within group positive effect for the control group on 3 of 7 EF measures (Farran et al., 2013).

Classroom interventions tend to be long-term, multi-year, resource heavy programs, which means widespread implementation can be difficult. Moreover, it can be difficult to ascertain the specific effects of large-scale programs because they tend to involve many different components, including general classroom practices, and it is hard to gauge their effects. Thus, though there has been some success in large-scale classroom interventions, these types of domain-general programs tend to make it hard to pinpoint why EF is improving. Doing so would help improve existing interventions and could allow for the
development of more targeted programs. This in turn may help to cut down on the resources needed for implementation, thereby allowing more schools to incorporate EF programs. Given the smaller-scale and targeted nature of lab-based studies, they can provide us with supporting evidence concerning the underlying developmental mechanisms important for EF in preschool aged children.

**Lab-based training.** Studies using lab-based training in preschool aged children are summarized in Table 1. It is both interesting and encouraging that many of these studies are successful and thus as suggested by the classroom studies, it seems that it is possible to affect EF performance in young children. Only a handful of studies have included extensive follow-up assessments (see Table 1) so the long-term effects of these different manipulations remain unclear. However, it does appear that during the preschool age range, EF can be influenced by external environmental factors, and specific experiences can affect performance.

Lab-based training studies tend to focus on improving a distinct EF skill in an effort to determine whether a specific ability, such as rule-use, or self-reflection, are important components of EF performance and development. The training portion often involves a period of practice with the task in question – such as a working memory task – that may include corrective feedback and increasing difficulty levels (Bergman Nutley et al., 2011; Blakey & Carroll, 2015; Bohlmann & Fenson, 2005; Dowsett & Livesey, 2000; Espinet et al., 2013; Kloo & Perner, 2003; Rueda, Rothbart, McCandliss, Saccomanno, & Posner, 2005; Thorell, Lindqvist, Bergman Nutley, Bohlin, & Klingberg, 2009; van Bers, Visser, & Raijmakers, 2014). For instance, Cogmed is a routinized computer-training program that targets working memory. In preschool aged children, Cogmed training studies have included daily 15-minute game playing sessions over the course of 5 weeks. The games
continue to increase in difficulty based on individual levels of play (Bergman Nutley et al., 2011; Thorell et al., 2009). Research shows that preschool-aged children improve relative to controls on the trained working memory games, and that these improvements transfer to other untrained working memory tasks (Bergman Nutley et al., 2011; Jaeggi, Buschkuehl, Jonides, & Shah, 2012; Thorell et al., 2009). However, based on the current research it does not appear that the Cogmed program improves EF skills other than working memory (Bergman Nutley et al., 2011; Klingberg, 2010; Shipstead, Hicks, & Engle, 2012; Thorell et al., 2009). When inhibition training conditions are included in either Cogmed, or other similar computer training paradigms, transfer rarely extends beyond the actual task used in the training, or no effects of the training are found at all (Blakey & Carroll, 2015; Rueda et al., 2005; Shipstead et al., 2012; Thorell et al., 2009). It is possible that the working memory programs are developed to a greater extent than others, or that there is something about the processes involved in working memory that lend themselves better to the type of training Cogmed includes, which is primarily routinized practice.

The majority of studies that have investigated training effects beyond working memory have provided preschool aged children with corrective feedback during the DCCS. This is then followed by testing performance on a new DCCS – e.g. training DCCS with corrective feedback that uses blue rabbits and red boats, and a testing DCCS that uses yellow apples and green houses. Certain studies have also included what has been termed a “transfer DCCS” with different dimension in the training and testing measures, e.g. a training DCCS with corrective feedback that uses two red houses and one blue house and a testing DCCS that uses a big yellow horse and a small red bird. For instance, the training used by Kloo & Perner (2003), which was later adapted for Bohlman & Fenson (2005) and Espinet et al. (2013), used a training DCCS with shape and amount as the sorting
dimensions (i.e., we’re not going to play the shape game anymore, now we’re going to play the how many game!) and reads as such,

_Question:_ “What game are we playing now?”

_Feedback:_ “Right/No. We are playing the How-Many game now. This is the game with one and two, so you have to look at how many houses are on the card.”

_Question:_ “Look, how many are on this card?”

_Feedback:_ “Right/No There are two.”

[Then the children were asked to label the corresponding target card.]

_Question:_ Look, how many are on this card?

_Feedback:_ “Right/No. There are two. In the How-Many game, all the cards with two on it [experimenter points to test stimulus] go into the box with two on it [experimenter points to target stimulus].”


The type of training demonstrated above includes walking the child through the task with feedback multiple times. We would argue that by solely providing children with corrective feedback you are teaching the child how to navigate that particular _task_ as opposed to training EF, or shifting, per se. It is difficult to determine what type of training effect is occurring during these types of studies. Has the child truly learned the skills necessary for passing the task, or have they merely been reminded enough times that they have memorized the requisite game play. We argue that this distinction is an important one, because it is difficult to pinpoint why a child succeeds. It is possible that a child has learned
a new skill through the feedback, or they may have memorized the steps necessary to perform the task. Because one cannot say for certain what has changed, the process does not shed light on the developmental processes involved.

That is not to say that there is no merit to corrective feedback models, which have been used to various ends in past research. For instance, Dowsett and Livesey (2000) found that children who received corrective feedback during a card-sorting task (an early version of the DCCS) performed better on said task relative to children who practiced without feedback. Kloo and Perner (2003) used corrective feedback during the DCCS to show that not only did children improve significantly on the DCCS, but also improved significantly post-training on a false-belief task. Espinet et al. (2013) found that using corrective feedback not only improved performance on the DCCS, but also reduced the amplitude of the event-related potential component N2, which is thought to be associated with the conflict detection necessary for switching between rules.

Both types of methods described above, computerized targeted practice and experimenter corrective feedback, occur within the context of the task then used as the outcome test measure. It would beneficial to see whether gains in task performance can be achieved through experiences that occur outside of the immediate task context. For instance, it would be interesting to see if it would be possible to teach or scaffold the skills necessary for passing the DCCS, without first teaching children task rules. By creating training techniques that one can use separate from the task we would be able to get a better understanding of the underlying mechanisms important for shifting performance without the potentially confounding factor of task training or practice. Moreover, if similar methods facilitate performance in different shifting tasks it would speak to how the cognitive mechanisms important for this function develop beyond the DCCS. This would then allow
for the broader applicability of lab-based studies, as we could target the necessary mechanisms for development in shifting specifically and given more study, EF more broadly.

The studies in this dissertation were designed with the express purpose of using scaffolding separate from the task context to facilitate performance. Only one study to our knowledge has used a DCCS training design outside the task context. Based on dynamic neural field theory, Perone et al. (2015) played a colour or shape memory game with 3-year-old children before administering the DCCS to see if giving children prior experience with the post-switch dimension should enhance performance. According to their hypothesis, prior experience with the testing dimensions would activate specific neurons and create working memories associated with shape or colour, thereby priming attention to the post-switch dimension. They found that children who played the game then went on to perform significantly better on the DCCS relative to those who only participated in the testing phase. Interestingly, this was true only when children were given previous experience with colour and then sorted colour as the post-switch dimension. No effects were found when children were given previous experience with shape, and then tested with shape as the post-switch dimension. Previous research shows that children perform similarly on the DCCS regardless of the order of the pre- and post-switch dimensions (Zelazo, Frye, & Rapus, 1996). The authors suggested that the shapes used were not distinct enough from one another and thus more extensive experience with the dimension may have been necessary (Perone et al., 2015). In this particular study the control group did not interact with the training stimuli in any way and instead only performed the DCCS. Thus, it is unclear what types of experiences with the colour dimension facilitated performance and why experience with shape did not produce the same results. Given the theoretical literature
discussed previously, we suggest that in order to facilitate performance children must not only have experience with the colour and shape dimensions, but must attend to the fact that both may exist within a single stimuli at the same time.
Table 1.
*Summary of lab-based training studies in preschool aged children*

<table>
<thead>
<tr>
<th>Study</th>
<th>N</th>
<th>Age</th>
<th>Groups</th>
<th>Outcome</th>
<th>Transfer</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thorell et al. (2009)</td>
<td>65</td>
<td>M = 56</td>
<td>WM group – Cogmed computer training Inhibition group – Go/no-go training Active control – Played computer games Passive control – Just testing</td>
<td>WM group did better at retest on all WM tasks compared to controls Inhibition group did better at retest on Go/no-go and flanker, not on stop signal compared to controls</td>
<td>WM group had transfer to other verbal and visuospatial WM tasks, not to inhibition or attention tasks</td>
</tr>
<tr>
<td>Bergman-Nutley et al. (2011)</td>
<td>10</td>
<td>M = 51.2</td>
<td>WM group – Cogmed computer training Reasoning group – Training based on the Leiter Battery, modified with increasing difficulty Combined group – Both trainings at lowest difficulty Placebo control</td>
<td>WM and the combined group did significantly better post training on two of the three WM tasks compared to controls Reasoning group and combined group did significantly better post training on reasoning tasks compared to controls</td>
<td>WM group had transfer to non trained WM tasks, but not to problem solving tasks</td>
</tr>
<tr>
<td>Rueda et al. (2005)</td>
<td>49</td>
<td>M = 52</td>
<td>Training group – Stroop practice, stimulus discrimination, anticipation exercises and conflict tasks on a computer Inactive control group – Watched commercially available videos</td>
<td>Training group had better response conflict and abstract reasoning scores than controls Both groups had faster reaction times post training and better performance on the attention network task</td>
<td>Not tested</td>
</tr>
<tr>
<td>Study</td>
<td>N</td>
<td>M</td>
<td>Group Description</td>
<td>Outcomes</td>
<td></td>
</tr>
<tr>
<td>-------------------------------</td>
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<td>-----------------------------------------------------------------------------------</td>
<td>--------------------------------------------------------------------------</td>
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</tr>
</tbody>
</table>
| **Dowsett et al. (2000)**     | 49 | 47.7    | **Training group** – Corrective feedback with increasing difficulty levels on new versions of the card sorting task  
**Practice group** – Practiced on the version of the task used in testing  
**Control group** – Just testing | **Training and practice groups both did significantly better at retest, controls did not.**  
**Training group did better than practice group**  
**Not tested** |
| **Blakey et al. (2015)**      | 54 | 52      | **Training group** – Practice with increasing difficulty on WM and inhibition tasks  
**Control group** – Practiced making perceptual judgements using the same stimuli as the training group | **Training group did significantly better than controls at retest on WM tasks, same as controls on inhibition tasks**  
**Training group had transfer to a non trained WM task**  
**No transfer for either group to non trained inhibition or shifting tasks** |
| **Kloo & Perner (2003)**      | 44 | 45.1    | **Feedback group** – Corrective feedback during the DCCS  
**Control group** – Number conservation training or relative clause training | **Feedback group did significantly better than controls on the post-training DCCS**  
**Feedback group had transfer to a DCCS with different sorting dimensions and a false belief task** |
| **Bohlman & Fenson (2005)**   | 24 | 39.46   | **Feedback group** – Corrective feedback during the DCCS  
**Control group** – No feedback | **Feedback group did significantly better than controls on the DCCS**  
**Feedback group had no transfer to a DCCS administered immediately after** |
<table>
<thead>
<tr>
<th>Study</th>
<th>Sample Size</th>
<th>M ± SD</th>
<th>Intervention</th>
<th>Results</th>
<th>Notes</th>
</tr>
</thead>
</table>
| Espinet et al. (2013)         |             | 57                      | Reflection training group – Corrective feedback during the DCCS with emphasis on reflection  
Control group – Number conservation training or relative clause training | Reflection group did significantly better than controls on the post-training DCCS                                                               | Reflection group had transfer to a new DCCS with different dimensions                                                                 |
|                               |             | 56                      | Reflection training group – Corrective feedback during the DCCS with emphasis on reflection  
Feedback group – Only corrective feedback during the DCCS  
Control group – Practice only                                                                                                           | Reflection group did significantly better than feedback and controls on the post-training DCCS, with longer reaction time                   | Not tested                                 |
| Van Bers et al. (2014)        |             | 56                      | Feedback group – Corrective feedback during the DCCS  
Control group – No feedback                                                                                                               | Feedback group did significantly better than controls on all versions of the DCCS                                                                 | Feedback group had transfer to a DCCS with different colours and shapes administered 5 min later and 1 week later |
| Perone et al. (2015)          |             | 54                      | Memory colour group – Played a colour memory game before the DCCS  
Memory shape group – Played a shape memory game before the DCCS  
Control group – Just testing                                                                                                            | Memory colour group did significantly better than controls on the DCCS  
Memory shape group performed the same as controls on the DCCS                                                                          | Not tested                                 |
**Training and intervention summary.** Research using both lab-based and large-scale classroom interventions show that it is possible to affect aspects of EF with interventions that are theoretically grounded and targeted in preschool aged children. Whether training targeting specific EF skills transfers to other abilities, or if the effects persist across time is still uncertain. We recognize that the two types of training described above tend to have different goals and thus follow different courses with different outcomes. Researchers have investigated the effects of long-term, large-scale classroom interventions, such as PATHS, CRSP, and Tools (Diamond, 2012; Diamond & Lee, 2011; Jacobs, Harvey, & Anderson, 2011; Jones et al., 2013; Raver et al., 2008; 2011; Röthlisberger, Neuenschwander, Cimeli, Michel, & Roebers, 2011). It is unclear how beneficial these programs are, moreover when they are successful, the specific reasons why are often unclear. By using more targeted means, lab-based training studies can help identify the specific developmental mechanisms important for different aspects of EF. To this end, lab-based training protocols tend to focus specifically on training children to improve their performance on a particular task often through the use of practice or corrective feedback. For instance, training often involves walking the child through the task multiple times with corrective feedback in order to foster a certain degree of improvement (Berkman, Kahn, & Merchant, 2013; Dowsett & Livesey, 2000; Espinet et al., 2013; Karbach & Kray, 2009; Kloo & Perner, 2003; Thorell et al., 2009). We believe that it would be beneficial both from a theoretical and applied perspective to facilitate performance without using corrective feedback. The purpose of this dissertation is to investigate possible mechanisms of EF improvement using the DCCS and to develop a theoretically driven, brief scaffolding technique to improve performance without task training.
Summary

EF is an important component of children’s functioning and the preschool period is a time of substantial development. It is possible to train different aspects of EF in young children, though the majority of lab-based training studies have used practice with corrective feedback within the task context. From a theoretical perspective, it is thought that children’s DCCS performance is contingent on the ability to create and represent conditional rule structures which in turn may be dictated by children’s ability to consider objects from multiple perspectives. In keeping with this hypothesis, children do better on versions of the DCCS that prime them to think about the different components of the stimuli simultaneously.

Goals of the Present Research

The goal of this dissertation was to develop a brief, scaffolding intervention outside the context of the task that could be used to facilitate children’s DCCS performance. That is, we wanted to create a technique that could be used with non-test stimuli and in a different manner than walking the child through the DCCS with feedback. Re-description appears to be an important component of the capacity to reflect on, and incorporate the rules necessary for successful performance. Thus, we created a novel game to test the hypothesis that the conditional rules required to pass the DCCS could be scaffolded by promoting children’s attention to the multidimensional nature of objects.

In study 1, 3-year-old children came into the lab and played a novel game with shapes and colours. One group of children played a version of the game where they were asked to separate composite objects into single color and shape dimensions, and aggregate the single dimensions into a composite object. The other group of children played a version of the game where they were asked to match different cards on the basis of a single dimension at a time – colour or
shape. The color-and-shape version was meant to prime children to think in a flexible manner about the multidimensionality of objects. Children were then assessed on their EF performance using an age-appropriate battery of tasks including the DCCS. We predicted that children who participated in the experimental condition would be more successful at the DCCS relative to those who participated in the control condition, as they would be better equipped to navigate the rule switch after having been primed to focus on objects in multiple ways.

The goal of study 2 was to replicate and extend the findings from study 1. Study 2 followed a similar paradigm, however we used a dimension unrelated to the dimensions used in the DCCS during the initial scaffolding game. Children played either the experimental or control version of the same scaffolding game, but with pattern and shape. Children were then assessed on one of two possible test measures, a pattern and shape DCCS, or a standard colour and shape DCCS. In total, study 2 had four different conditions, a control group tested on the standard DCCS, an experimental group tested on the standard DCCS, a control group tested on the pattern DCCS, and an experimental group tested on the pattern DCCS. This was done to see if firstly, the study 1 findings would generalize to another context, and secondly to see if the results from study 1 could be attributed to scaffolding multidimensional understanding, or, if had we primed children to attend to the dimensions they were then tested on – sorting colours and shapes. That is, the additional test manipulation allowed us to gauge the extent to which our scaffolding had general versus specific effects on DCCS performance.

Finally, in study 3, we wanted to investigate the developmental trajectory of how scaffolding can facilitate performance using the advanced version of the DCCS with 5-year-old children. The advanced DCCS includes an additional set of test cards with borders, and children are instructed that when they see a border they should play the colour game, and when they do
not see a border they should play the shape game (or vice versa). In order to successfully navigate the additional task demands children must integrate another level to their conditional rule structure. We used a colour and shape game similar to study 1, but with an added an extra-dimensional parameter, order, which was dictated by an extra-dimensional feature, a star on certain cards. By playing this game, children had to focus both on the dimensions of a single object, colour and shape, while also focusing on the order in which these cards were presented to them. This design is similar to the requirements of the advanced DCCS.

EF abilities form the basis of higher-order cognitive abilities and are critical for healthy development. We believe that by pinpointing factors important for different aspects of EF performance in preschool aged children we will be better positioned to develop targeted interventions and training programs aimed at improving these abilities in an accessible, theoretically driven manner.
Chapter 2

Study 1

In order to successfully navigate the DCCS one must create and maintain a hierarchical conditional rule structure. To do so, one must be able to integrate the necessary rules, which represent the two different ways one can approach the test stimuli. For example, when a child is playing the shape game and is given a red rabbit they are required to think about the object’s shape (e.g., that it is a rabbit) and then match that with the blue rabbit target card. However, during the post-switch trials, when a child is given a red rabbit they are required to think about the object’s colour (e.g., that it is red) and then match that with the red boat target card. Thus the ability to create the necessary rule structure may be contingent on one’s capacity to recognize and understand that it is possible to consider objects in multiple ways. The goal of study 1 was to determine if scaffolding this understanding without task training or corrective feedback, would facilitate children’s ability to successfully perform the DCCS.

To that end we developed a game that highlighted the concept of re-description (i.e., the multidimensional nature of objects). We used the dimensions important to the DCCS, colour and shape, separately, as well as combined, and had children break apart multidimensional objects (i.e. coloured shaped) into their constituent parts and also put two single dimensions (i.e., colour and shape represented separately) together to create a multidimensional coloured shape. The goal of this game was to prime children to the understanding that we can think about one thing in two different ways. For instance, something can be a colour and a shape and we can approach it as either. As this is the understanding important for rule use and DCCS performance, our
hypothesis was that children who played this game would then go on to do better on the DCCS relative to those who played the control version of the game, which did not include the re-description aspect.

We included two additional EF tasks, Day/Night and Bear/Dragon, both measures of inhibitory control, in order to see if any potential training effects would transfer to other tasks suitable for this age range. Given previous research concerning the lack of transfer to other tasks and components we were uncertain as to how our scaffolding game would affect other EF tasks.

**Methods**

**Participants**

Based on an a priori power analysis with a medium effect size, our final sample consisted of 40 children (22 girls and 18 boys, age range 38 – 47 months). Initially, a total of 52 preschool-aged children were recruited through the Child and Adolescent Development Group database at Queen’s University. The database consists of family members from Kingston, Ontario, a predominantly Caucasian, middleclass community and this is reflected in the final sample. Six children were excluded due to non-compliance, four failed the pre-switch condition of the DCCS, and two were unable to perform the initial scaffolding game – one in the experimental condition and one in the control condition. The experimental group consisted of 9 girls, 11 boys (age, $M = 41.1$, $SD = 3.4$, PPVT, $M = 64.95$, $SD = 17.18$). The control group consisted of 9 girls, 11 boys (age, $M = 41.0$, $SD = 3.0$, PPVT, $M = 71.1$, $SD = 16.65$). The children who were excluded did not differ from the final sample on the basis of gender, $\chi^2 (1, N = 52) = .308, p = .579$, or PPVT, $t(47) = 1.46, p = .158$, but were significantly younger than our final sample, $t(51)$
= 2.34, \( p = .023 \). Based on the design and purpose of the study, this is to be expected, and the age discrepancy will be addressed further in the discussion section.

**Design and Procedure**

Before the study began a random number generator was used to create condition placements for all potential participants and data collection progressed sequentially through said list for the duration of the study. In the experimental condition, children played a game that promoted re-description by having them navigate the multidimensional nature of stimuli. In the control condition, children played a game that used the same stimuli but only required them to focus on one dimension of the stimulus at a time.

Children were tested individually in a quiet room by the same experimenter while parents remained outside watching the session via a live feed. Before testing began children were familiarized with all aspects of the testing room, including the video camera. The testing session began with either the control or experimental colour and shape game. The experimenter then administered an EF battery including the DCCS, in a pre-determined random order followed by the PPVT, a measure of receptive language ability.

**Materials**

**Experimental condition.** The purpose of this condition was to highlight the multidimensional nature of stimuli and promote the understanding that one can think about objects in multiple ways. In this case, children were shown a display with separate sections, one with five blank shapes, one with five different colours and a final section with ten coloured shapes. Children played a game where they were asked to find the two pieces that together made up a specific coloured shape. For example, children might be shown a purple circle and asked to select the circle shape and the purple color swatch. They were also asked to do the opposite; that
is, they were asked to find the coloured shape that would result from combining a specific shape and colour (e.g., “If I give you this shape and this colour [removes red and pentagon from the display] and if we put these together, which one would we get from over here [indicate section of the display with coloured shapes]?”). Each shape and colour was displayed twice in the combined coloured shape display to prevent the child from merely matching on a single feature, see Figure 1. The full script can be found in Appendix A.

**Control condition.** The purpose of this condition was to provide a one-dimensional control that allowed for the same exposure to the stimuli used in the experimental condition. This condition used the same display with shapes and colours, however instead of being asked to interact with the stimuli in a way that promotes multidimensional understanding and cognitive flexibility, children were asked to match on single features. Children were asked to find the two other cards displayed that were the same colour (from crayon scribble cards) and the same shape (from blank shapes) as the card the experimenter indicated. For example, “Can you find me two cards that are the same colour as this one?” This way, children in both the experimental and control conditions interacted with the same cards for the same amount of time. The full script can be found in Appendix A.
Standard Dimensional Change Card Sort (DCCS, Zelazo, 2006). The child was shown two different trays, one with a picture of a blue rabbit and one with a picture of a red boat. The child was then told they are going to play “the colour game.” The experimenter told the child that in the colour game all the red ones go together in the tray with the red card, and all the blue ones go together in the tray with the blue card. The experimenter then demonstrated this sorting technique. This was followed by five test trials where the child was reminded of the rule with each trial, “if it’s blue it goes here, but if it’s red it goes there. Here is a red rabbit. Where does this one go?” If the child correctly sorted at least four out of the five trials, they then proceed to the rule switch. The experimenter then said that they would no longer be playing the colour game and would instead play “the shape game.” In the shape game all the rabbits go together and all the boats go together. There were five post-switch trials where the experimenter again repeated the post-switch rule. Children pass the DCCS if they correctly sorted at least four
of the five post-switch trials. The pre-switch condition was counterbalanced so an equal number of children in the experimental and control conditions started with the colour game versus the shape game.

**Day/Night (Gerstadt, Hong, & Diamond, 1994).** The experimenter and child began by talking about when the sun rises (daytime) and when the moon and stars come out (night time). The experimenter then showed the child a white card with a yellow sun on it and a black card with a white moon and stars. The child was instructed to say “day” when shown the card of the night sky and to say “night” when shown the card of the sun. Children were given two practice trials, after which 16 cards were presented in a fixed, pseudorandom order. At no point during the testing were children reminded of the rules. A score was derived from the number of correct responses.

**Bear/Dragon (Reed, Pien, & Rothbart, 1984).** The experimenter and child began by going through a series of “silly” movements. For example, “stick out your tongue,” “touch your ears” etc. The child was then introduced to two puppets, the “naughty” dragon and the “nice” bear. The child was told that in this game, (a modified Simon Says), they should listen to the bear (voiced soft and high-pitched), but not the dragon (voiced gruff and low-pitched). Children were given a practice trial with each puppet, followed by 10 test trials. The dragon and bear were used in an alternating order, and children received a score based on how successfully they inhibited their response to each of the dragon trials. A high score corresponds to high EF abilities, indicating children are able to successfully inhibit movements initiated by the dragon, while children receive a score of 0 on each trial if they follow the dragon’s instructions.

**Peabody Preschool Vocabulary Test (PPVT).** The Peabody Preschool Vocabulary Test, Fourth Edition (PPVT-IV, Dunn & Dunn, 2007) allows for the assessment of children’s
receptive vocabulary abilities. In each trial, children were presented with four pictures and then asked to point to the picture that corresponded to a given vocabulary word. Items became progressively more difficult as children continued through the measure.

**Results**

Scores on the PPVT and age did not differ significantly by condition, experimental, age, $M = 41.1$, $SD = 3.4$, PPVT, $M = 64.95$, $SD = 17.18$, control group age, $M = 41.0$, $SD = 3.0$, PPVT, $M = 71.1$, $SD = 16.65$, as no significant differences were found between groups in age, $t(38) = .097$, $p = .963$, or receptive vocabulary, $t(37) = 1.136$, $p = .263$.

Based on the bimodal pass/fail nature of the DCCS we used a chi-squared test to examine the primary hypothesis that children who were in the experimental condition would perform significantly better on the DCCS relative to children in the control condition. In keeping with Espinet et al. (2013), children were considered to pass the DCCS if they sorted four of the five post-switch cards correctly. Only 4 of the 20 (20%) children in the control condition passed the DCCS. In the experimental condition the results were quite different. Eleven of the 20 (55%) children passed the DCCS. A chi-square analysis showed that significantly more children passed the DCCS in the experimental condition than in the control condition $\chi^2 (1, N = 40) = 5.26$, $p = .022$. Rate of passing did not differ based on pre-switch dimension, colour as pre-switch $n = 8$, shape as pre-switch $n = 7$. 
Figure 2. Graph of DCCS performance by condition in study 1

There was no difference in performance between the experimental and control groups on either Bear/Dragon (experimental group, $M = 11.89$, $SD = 7.84$, control group $M = 9.95$, $SD = 8.36$), $t(37) = -0.749$, $p = .459$ or Day/Night (experimental group, $M = 8.40$, $SD = 3.68$, control group $M = 8.45$, $SD = 4.14$), $t(38) = .040$, $p = .968$. Age was correlated with Bear/Dragon performance, $r = .476$, $p = .002$ but not significantly with the other measures. Performance on Bear/Dragon reaches ceiling earlier than the other tasks, with 4-year-olds at an 80% pass rate (Carlson, 2005). Thus, given the age range of children in this study it stands to reason that age and Bear/Dragon performance would be correlated, while performance on Day/Night and DCCS are still in early developmental stages.

**Discussion**

Broadly speaking the aim of this study was to determine if a brief scaffolding game to help prime children to focus on re-description would facilitate children’s performance on the
DCCS. Results showed that children in the experimental group who played the scaffolding game performed significantly better on the DCCS relative to controls. Thus it is possible to help children improve performance without relying solely on corrective feedback and task training. Moreover, it seems that multidimensional understanding is an important component of children’s DCCS performance. This finding has implications both for training programs and for understanding the theoretical background and developmental trajectory of DCCS performance.

The scaffolding game did not affect children’s performance on Day/Night or Bear/Dragon. There are several possible explanations for this finding. Firstly, though EF is considered a unitary construct during the preschool years, both Day/Night and Bear/Dragon are classified as inhibitory control tasks, while the DCCS is a measure of shifting abilities (Garon et al., 2008). It is possible that the tasks are too dissimilar for the benefits of a brief scaffolding intervention to transfer. The factors affecting performance on the three tasks in question may differ greatly during this age range, and the multidimensional scaffolding may not aid in the rule use necessary for inhibition tasks. This possibility dovetails nicely with theories concerning neural development through interactive specialization. It has been hypothesized that EF becomes more specialized through activity-dependent neural activations which alter the processing associated with EF from one of broad functionality, to a more targeted, specialized process (Bardikoff & Sabbagh, in press; Johnson, 2011). This may explain why other training programs have shown very little transfer effects, as the neural processing necessary for each EF component, inhibition, updating and shifting, require different experiences to develop into mature specialized networks. Thus, it is possible that the scaffolding techniques used in this study were targeted too specifically at shifting and the DCCS.
It is important to consider whether the ability to perform the scaffolding game itself served to bias sampling. The experimental and control games were both relatively brief, children spent a total of approximately 25 to 30 minutes in the testing room to complete the full study. Only two children were excluded on the basis of their game play, one in the experimental group and one in the control group, which negates the concern that the scaffolding game itself served as a tool to select a specific sub sample. As a whole the excluded children were significantly younger than those in the final sample. Yet the children in this study were younger than those that typically succeed on the DCCS. The age range was selected based on previous research (Bohlmann & Fenson, 2005; Carlson, 2005; Espinet et al., 2013; Kloo & Perner, 2003; Perone et al., 2015) and because initially poor performance is necessary to show improvement on the tasks that can be attributable to their experience in the scaffolding game. It stands to reason that the children excluded were younger than the final sample as many of the excluded children were unable to successfully navigate the pre-switch trials, indicating that comprehending the initial rule was beyond their grasp.

There are questions that still remain. Perhaps the most important question concerns whether general practice with re-description and multidimensionality understanding facilitated DCCS performance, or was it experience with the sorting dimensions themselves. In Perone et al. (2015) children who played a simple matching game with colour then went on to perform better on the DCCS when colour was the post-switch dimension compared to children who only performed the DCCS. The same was not true when an analogous version of the experiment used shape. By giving children prior exposure to colour, and then having colour constitute the post-switch dimension, the authors were able to promote performance, though the same was not true for shape. Our study focused specifically on helping children to realize they could think about
multiple aspects of an object at one time, as we believe the specific type of experience a child has with said dimensions is a critical part of later performance. Based on the results from study 1 the question of what facilitated performance: prior exposure to the sorting dimensions, prior exposure to colour specifically, or re-description understanding, remains unclear. We designed study 2 in order to answer this question.
Chapter 3

Study 2

The goal of study 2 was two-fold. First, we wanted to replicate study 1 in a different context. We chose to do this by creating a similar scaffolding game that used pattern and shape as opposed to colour and shape. Second, we wanted to extend study 1 and see what types of experiences were responsible for the improved DCCS performance. That is, we wanted to determine whether simply having previous experience with the necessary dimensions was sufficient for improved performance as suggested by Perone et al. (2015), whether there was something specific to experience with the colour dimension, or if it was promoting attention to re-description and multidimensional understanding that facilitated performance. To that end, we included two different DCCS testing measures, a new pattern and shape DCCS, which allowed us to assess the replicability of study 1 (albeit in a slightly different context), and a standard colour and shape DCCS, which allowed us to assess whether experience with re-description and multidimensional understanding in a context different from that used during testing could facilitate performance in a similar manner. Thus, the additional test manipulation allowed us to gauge how specific our scaffolding game has to be in order to facilitate children’s DCCS performance.

Methods

Participants

A total of 95 preschool-aged children were recruited through the Child and Adolescent Development Group database at Queen’s University. Six were excluded due to non-compliance,
1 was excluded due to experimenter error, 3 failed the pre-switch condition of the DCCS, 5 were unable to perform the initial scaffolding game - 3 in the experimental condition, 2 in the control condition. The final sample consisted of 80 children (43 girls and 37 boys, age range 38 – 47 months). The children who were excluded were not significantly different from the final sample on the basis of gender, $\chi^2 (1, N = 95) = .004, p = .932$, PPVT, $t(90) =1.72, p = 0.09$, or age, $t(93) = 1.8, p = 0.065$. Children who participated in study 1 were not eligible for recruitment in study 2.

**Design and Procedure**

Random assignment was carried out before study data collection began in the same manner as study 1. Children played either the experimental or control version of the same scaffolding game used in study 1, but we asked them to find cards on the basis of shape and pattern, as opposed to shape and colour. Children were then assessed on one of two possible test measures, a pattern and shape DCCS, or a standard DCCS with colour and shape. Thus in total, study 2 had four different conditions, a control group who was tested on the standard DCCS, an experimental group who was tested on the standard DCCS, a control group who was tested on the pattern DCCS, and an experimental group who was tested on the pattern DCCS.

Children were tested individually in a quiet room after being familiarized with the setting by the same experimenter while parents remained outside watching the session via a live feed. The testing session began with either the experimental or control pattern and shape game. The experimenter then administered an EF battery including the DCCS, in a random order followed by the PPVT, a measure of receptive language ability.
Materials

**Pattern experimental condition.** Similar to study 1, the purpose of this condition was to highlight the multidimensional nature of stimuli and promote the understanding that one can think about objects in different ways. Children were shown a display with separate sections, one with five blank shapes, one with five different patterns and a final section with ten patterned shapes. Children played a game identical to the experimental scaffolding game in study 1 but with pattern and shape instead of colour and shape. The full script can be found in Appendix B.

**Pattern control condition.** Similar to study 1, the purpose of this condition was to provide a one-dimensional control, allowing the children assigned the same exposure to the stimuli used experimental condition. This condition used the same display with the same shapes and patterns, however instead of being asked to interact with the stimuli in a way that promotes multidimensional understanding and cognitive flexibility, children were asked to match on single features only. The full script can be found in Appendix B.

![Pattern stimuli](image)

Figure 3. Sample of the stimuli used in the pattern and shape game
**Dimensional Change Card Sort (DCCS, Zelazo, 2006).** There were two different versions of the DCCS used, a pattern and shape DCCS and a standard colour and shape DCCS. In the standard condition the child was shown two different trays, one with a picture of a blue rabbit and one with a picture of a red boat. The child was then told they are going to play “the colour game.” The experimenter told the child that in the colour game all the red ones go together in the tray with the red card, and all the blue ones go together in the tray with the blue card. The experimenter then demonstrated this sorting technique. This was followed by five test trials where the child is reminded of the rule with each trial, “if it’s blue it goes here, but if it’s red it goes there. Here is a red rabbit. Where does this one go?” If the child correctly sorted at least four out of the five trials, they then proceed to the rule switch. The experimenter then said that they would no longer be playing the colour game and would instead play “the shape game.” In the shape game all the rabbits go together and all the boats go together. In the pattern condition children were asked to sort cards on the basis of shape and pattern as opposed to shape and colour, i.e. “if it’s a striped one it goes here, but if it’s a polka dot one it goes here. Here is a polka dot rabbit. Where does this one go?” Both conditions included five post-switch trials where the experimenter again repeated the post-switch rule. Children pass the pattern and standard DCCS if they correctly sorted at least four of the five post-switch trials. The pre-switch condition was counterbalanced across conditions.

**Day/Night (Gerstadt, Hong, & Diamond, 1994).** See study 1 methods section.

**Bear/Dragon (Reed, Pien, & Rothbart, 1984).** See study 1 methods section.

**Peabody Preschool Vocabulary Test (PPVT; Dunn & Dunn, 2007).** See study 1 methods section.
Results

The groups did not differ on the basis of age or PPVT, ($F > 1.82, p > .05$), see table 2 for descriptive statistics by group.

Table 2. 
Participant information by condition

<table>
<thead>
<tr>
<th>Condition</th>
<th>Gender</th>
<th>Age</th>
<th>PPVT</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard DCCS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exp. Group</td>
<td>$F = 11, M = 9$</td>
<td>$M = 41.40, SD = 2.78$</td>
<td>$M = 58.30, SD = 13.29$</td>
</tr>
<tr>
<td>Control group</td>
<td>$F = 11, M = 9$</td>
<td>$M = 40.50, SD = 2.28$</td>
<td>$M = 58.65, SD = 17.27$</td>
</tr>
<tr>
<td><strong>Pattern DCCS</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Exp. Group</td>
<td>$F = 10, M = 10$</td>
<td>$M = 41.20, SD = 2.79$</td>
<td>$M = 66.26, SD = 14.41$</td>
</tr>
<tr>
<td>Control group</td>
<td>$F = 11, M = 9$</td>
<td>$M = 41.00, SD = 2.71$</td>
<td>$M = 60.25, SD = 13.5$</td>
</tr>
</tbody>
</table>

DCCS Performance

Due to the bimodal pass/fail nature of the DCCS a logistic regression was conducted to determine if condition (i.e. type of scaffolding game) and DCCS type predicted DCCS performance. The predictor model fit the data well, $-2 \text{LL}X^2 (76) = 93.848, p > .05$, and was a significant improvement over the constant only model, $-2 \text{LL}X^2 (78) = 104.775, p = .023$, $X^2 (3) = 10.927, p = .012$.

There was no difference in performance based on type of DCCS, pattern/shape or standard colour/shape, $B = .666, SE = 1.645$, Wald’s $X^2 (1) = .146, p = .703$, $e^B = 1.946$.

However, the odds of passing the DCCS increased 4.64 times when children were in the experimental group as opposed to the control group, $B = 1.534, SE = .771$, Wald’s $X^2 (1)$ =
3.960, $p = .047$. There was no interaction between condition and DCCS type $B = -.030$, $SE = 1.034$, Wald’s $X^2 (1) = .001$, $p = .977$, $e^B = .971$. Thus, children were not more likely to pass either DCCS at a different rate based on their condition. In keeping with study 1, rate of passing did not differ on the basis of the pre-switch dimension, pattern and shape DCCS, $X^2 (1, N = 40) = 2.283$, $p = .131$, colour and shape DCCS, $X^2 (1, N = 40) = .173$, $p = .677$.

**Table 3.**
*Observed and predicted frequencies for DCCS performance by logistic regression with the cut off of 0.50*

<table>
<thead>
<tr>
<th>Observed</th>
<th>Predicted</th>
<th>Fail</th>
<th>Pass</th>
<th>% Correct</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fail</td>
<td></td>
<td>43</td>
<td>8</td>
<td>84.3</td>
</tr>
<tr>
<td>Pass</td>
<td></td>
<td>17</td>
<td>12</td>
<td>41.4</td>
</tr>
<tr>
<td>Overall Correct</td>
<td></td>
<td></td>
<td></td>
<td>68.8</td>
</tr>
</tbody>
</table>

**Table 4.**
*Logistic regression analysis of 80 children’s DCCS performance*

<table>
<thead>
<tr>
<th>Predictor</th>
<th>$\beta$</th>
<th>$Se\beta$</th>
<th>Wald’s $X^2$</th>
<th>$Df$</th>
<th>$P$</th>
<th>Exp($\beta$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Condition (1 = Con., 2 = Exp.)</td>
<td>1.534</td>
<td>.771</td>
<td>3.960</td>
<td>1</td>
<td>.047</td>
<td>4.636</td>
</tr>
<tr>
<td>DCCS Type</td>
<td>.666</td>
<td>1.645</td>
<td>.146</td>
<td>1</td>
<td>.703</td>
<td>1.946</td>
</tr>
<tr>
<td>Condition*DCCS Type</td>
<td>-.030</td>
<td>1.034</td>
<td>.001</td>
<td>1</td>
<td>.977</td>
<td>.971</td>
</tr>
<tr>
<td>Constant</td>
<td>-3.269</td>
<td>1.331</td>
<td>6.034</td>
<td>1</td>
<td>.014</td>
<td>.038</td>
</tr>
</tbody>
</table>
To examine the effects further and to more closely replicate study 1, a chi-square analysis was done and showed that significantly more children passed the DCCS in the experimental condition than in the control condition when tested on the pattern DCCS, \(\chi^2 (1, N = 40) = 5.03, p = .025\), and the group tested on the standard DCCS, \(\chi^2 (1, N = 40) = 4.27, p = .038\).

**Bear/Dragon and Day/Night Performance**

A factorial ANOVA was conducted to compare the effects of group (experimental versus control) and test type (pattern versus standard DCCS) on Bear/Dragon performance. The main effect of group yielded an F ratio of \(F(1,74) = .365, p = .548\), indicating no difference between group (control group, \(M = 9.18, SD = 9.35\), experimental group \(M = 10.36, SD = 8.87\)). The main effect of test type yielded an F ratio of \(F(1,74) = 2.247, p = .138\), indicating no difference between DCCS test type (pattern group, \(M = 8.28, SD = 8.89\), standard group \(M = 10.34, SD = 9.11\)). Nor was there a significant interaction effect between the two, \(F(1,74) = 1.141, p = .239\).

A factorial ANOVA was conducted to compare the effects of group (experimental versus control) and test type (pattern versus standard DCCS) on Day/Night performance. The main effect of group was not significant \(F(1,73) = .158, p = .692\), indicating no difference between groups (control group, \(M = 8.95, SD = 4.73\), experimental group \(M = 8.50, SD = 4.54\)). The main effect of test type was not significant \(F(1,73) = .427, p = .516\), indicating no difference between DCCS test type (pattern group, \(M = 8.37, SD = 5.18\), standard group \(M = 9.08, SD = 4.10\)). Nor was there a significant interaction effect between the two, \(F(1,73) = 2.984, p = .170\). These findings are consistent with the Bear/Dragon and Day/Night study 1 results.
Discussion

The goal of this study was to assess further the effects of scaffolding re-description and multidimensional understanding on EF performance. Consistent with the study 1 results, we found that children who played the experimental scaffolding game then went on to perform significantly better on the DCCS relative to children in the control condition. Moreover, this was true regardless of the type of dimensions incorporated in the pre- and post-switch of the DCCS. If there had been an effect of DCCS type then it is possible that the results, and those from study 1, were due to helping children focus and attend to the dimensions they then had to navigate during sorting trials. While an interesting finding, it would have led to a narrow interpretation and application of the re-description theory as in order to navigate the task more successfully children require prior experience with the sorting dimensions, not with multidimensional understanding in general.

In Perone et al. (2015) they found that children who were pre-exposed to colour then went on to perform better on the DCCS when colour was the post-switch dimension, though a similar manipulation with shape did not yield significant results. The authors suggested that more extensive experience with shape would have led to similar improvements in performance, yet it is also possible that there was something unique about giving children experience with colour and then sorting by colour that differentially affected performance. In our new scaffolding game children aggregated and separated objects on the basis of shape and pattern, as opposed to shape and colour. When children were then tested on a pattern and shape DCCS, the results were similar to study 1, suggesting that there was no specific effect of colour exposure. Rather priming children to the multidimensional nature of objects, regardless of the dimensions in question, can facilitate DCCS performance. In conclusion, it seems that children were not merely
primed to sort the dimensions they had experience with, nor was there anything specific to colour exposure, but rather children were primed to a more general understanding of re-description. I will discuss the implications of these findings further in the general discussion.

Again, in accordance with study 1, there was no effect of condition on either Bear/Dragon or Day/Night, nor does it seem that the scaffolding game itself served as a selective sampling tool. Children in both study 1 and study 2 were tested by the same experimenter, with the same level of enthusiasm so as to motivate performance, in the same testing room. Given the results of the two studies we feel that there is clear evidence that re-description understanding is important for 3-year-olds DCCS performance. However, it remains unclear whether this is a specific mechanism that is necessary during this particular developmental window, or if multidimensionality understanding facilitates shifting performance in a broader sense across development in the preschool age range. It may be that re-description is necessary for one to navigate simple if-if-then conditional rules, however once an additional embedded rule or “if” is added to the rule structure, focusing on multidimensionality may not result in the same boost in performance. Given that EF continues to develop through the preschool age range, we wanted to determine if the results from studies 1 and 2 were providing specific insight into the underlying mechanisms important for 3-year-olds shifting performance, or if similar processes are also integral to older children’s shifting abilities. To that end, we designed study 3 to investigate re-description and rule use in 5-year-old children using a more advanced DCCS.
Chapter 4

Study 3

The goal of study 3 was to examine the developmental trajectory of the processes necessary for DCCS performance within the preschool age range. To that end, we developed a more advanced version of the colours and shapes scaffolding game that could be used in conjunction with an advanced border DCCS in 5- to 6-year-old children. In the border DCCS, after performing the initial pre- and post-switch successfully, children are introduced to cards that are identical to the previous test cards (i.e., red rabbits and blue boats) however with the addition of a black border. The border then dictates which game they are meant to play, “If there is a border we play the shape game, and if there no border we play the colour game. Here is one with a border, where does this one go?” See Appendix D for the full script. Thus, including a border dimension necessitates the consideration of an additional extra-dimensional parameter within the test stimuli, necessitating another embedded rule one must navigate for successful performance.

The border DCCS does not reach ceiling until early childhood, with 5- to 6-year-old children passing at a rate of approximately 20 – 30% (Carlson, 2005; Hongwanishkul, Happaney, Lee, & Zelazo, 2005). Thus, in order to see if the scaffolding measures used with 3-year-olds in study 1 and 2, would be successful in a similar capacity for the use of an additional rule and dimension, we followed a procedure similar to study 1 and 2 but with older children. We used a colour and shape game similar to study 1 with an added extra-dimensional parameter. By playing this game children were required to focus both on the dimensions of a single object, colour and
shape, as well as an additional feature, order, and integrate a further rule. This task structure is similar to the requirements of the advanced DCCS and the study design enabled us assess whether similar developmental processes, such as the ability re-describe objects in support of conditional rule use, is important for DCCS performance in older preschool aged children.

**Methods**

**Participants**

A total of 64 preschool-aged children were recruited through the Child and Adolescent Development Group database at Queen’s University. Two were excluded due to non-compliance, 4 failed the post-switch condition of the DCCS and thus were ineligible for the border trials, 1 did not pass the rule check for the border trials of the DCCS and 1 was unable to perform the initial scaffolding game. Children who were excluded did not differ from the final sample on the basis of age, t(62) = .332, p = .741, PPVT, t(60) = 1.394, p = .168, or gender, $\chi^2$ (1, N = 64) = .009, p = .925. The final sample consisted of 56 children (27 girls and 29 boys, age range 62 – 71 months, $M = 66.60$, $SD = 3.1$). No children who had previously participated in study 1 or study 2 were eligible for recruitment.

**Design and Procedure**

Children were randomly assigned to one of two conditions, an experimental condition, or a control condition. Children were tested individually in a quiet room by the same experimenter while parents remained outside watching the session via a live feed. The testing session began with advanced scaffolding rule game. The experimenter then administered the advanced DCCS followed by the PPVT.
Materials

Experimental condition. The purpose of this condition was to highlight hierarchical conditional rule use. Children were shown a display with separate sections, one with five blank shapes, one with five different colours and a final section with ten coloured shapes half of which had a small “x” in the top right hand corner. Children played a game where they were asked to find the two pieces that together made up a specific coloured shape, for example, finding the square shape and colour blue to make up the depicted blue square. To encourage multidimensional thinking and conditional rule use children were also instructed to pay attention to whether or not there was an “x” on the card. They were told that if there was an “x” they should find the colour card first and then the shape card and if there was not an “x” they should do the opposite and find the shape card first and then the colour card. For example, “which two do we need to make up this one [remove blue square with an x from the display], and which one do we need to find first?” Children were also asked to do the opposite, and find the coloured shape that would result from combining a specific shape and colour, while also attending to what order the cards were presented to them. For instance, “if I give you the colour card first then I want you to find me the one we need with an x on it, but I give you the shape card first then I want you to find me the one we need without an x on it.” The dimension associated with the “x” card was counterbalanced across children. Each coloured shape was displayed twice once with an “x” and once without to prevent the child from merely matching on the basis of colour and shape and not taking into account the additional order rule. The experimenter provided feedback and support where necessary. The full script can be found in Appendix C.

Control condition. The condition used the same display as the experimental condition. Instead of being asked to interact with the stimuli in a way that promotes conditional rule use,
children were asked to attend to 3 dimensions without the additional embedded rule. To do this we included two additional cards, a blank card with a small x – “the x card” and a blank card – “the no x card”. Children were asked to find the three cards that made up the card presented to them. For example, “Can you find me the three cards we need to make up this one? [i.e. removes purple circle with an “x” – need to find the circle shape, colour purple and the “x” card].” Children were also asked to do the opposite and find the coloured shape that would result from combining a specific shape, colour and either “x” or “no x” cards. The full script can be found in Appendix C.

![Figure 4. Game playing board for scaffolding game](image)

**Advanced Dimensional Change Card Sort (DCCS, Zelazo, 2006).** The child initially played the standard DCCS colour and shape game, with blue boats and red rabbits. If they passed the post-switch condition they continued to the advanced trials. The experimenter told the child that they would continue playing and showed them new cards that included a border. The child
was told that if there was a border, they should play the shape game, and if there was no border they should play the colour game. They then sorted an additional 12 cards, 6 with a border and 6 without. Children passed if they sorted 9 out of the 12 trials correctly. All conditions were counterbalanced – pre-switch, post-switch and border parameter.

Figure 5. Cards for the advanced DCCS

**Peabody Preschool Vocabulary Test (PPVT).** The Peabody Preschool Vocabulary Test, Fourth Edition (PPVT-IV, Dunn & Dunn, 2007) allows for the assessment of children’s receptive vocabulary abilities. In each trial, children were presented with four pictures and then asked to point to the picture that corresponded to a given vocabulary word. Items became progressively more difficult as children continued through the measure.

**Results**

The groups did not differ on age (experimental group $M = 66.75$, $SD = 3.09$, control group $M = 66.46$, $SD = 3.14$, $t(54) = .343$, $p = .733$), PPVT (experimental group $M = 110.25$, $SD = 18.16$, control group $M = 106.71$, $SD = 15.82$, $t(54) = .777$, $p = .441$), or gender (experimental group 14 girls, 14 boys, control group 13 girls, 15 boys, $X^2 (1, N = 56) = .07$, $p = .789$). Age and
DCCS performance was not significantly correlated, $r = .24, p = .075$, nor was the PPVT and DCCS, $r = .26, p = .081$.

Based on the bimodal pass/fail nature of the DCCS we used a chi-squared test to examine the primary hypothesis that children who were in the experimental condition would perform significantly better on the DCCS relative to children in the control condition. In keeping with Zelazo (2006) children were considered to have passed the border DCCS if they successfully sorted 9 out of the 12 border trials. Six of the 28 (21%) children in the control condition and 13 of the 28 (46%) children in the experimental group passed the border DCCS. A chi-square analysis showed that significantly more children passed the DCCS in the experimental condition than in the control condition $\chi^2 (1, N = 56) = 3.90, p = .048$.

![Figure 6. Graph of Border DCCS performance by condition in study 3](image)

Further analysis showed that within the experimental condition there was a significant difference in the counterbalancing conditions within the scaffolding game. When the “x” in the corner was associated with colour, 10 out of 14 children (71%) passed the border DCCS, while
when the “x” in the corner was associated with shape, 3 out of the 14 (21%) children passed the border DCCS, ($\chi^2 (1, N = 28) = 7.04, p = .008$). Thus, unexpectedly, it seems that the scaffolding effect was driven primarily by the “x means colour first” association.

**Discussion**

The goal of study 3 was to assess the developmental trajectory of the skills required for successfully navigating the DCCS. To do this we used the advanced DCCS, which includes an additional set of sorting cards that have a black border. The children are then told that the border dictates which game they will be playing, for instance, “If there is border play the colour game, if there is no border play the shape game.” In order to facilitate this type of rule use we added an additional aspect of the scaffolding game stimuli children had to consider. Children in the experimental condition were told that they had to find either the colour or the shape first based on whether or not there was a small x in the corner of the card presented to them. Alternatively, when aggregating the dimensions, they had to find the coloured shape with or without an x contingent on which order the cards were presented to them. Thus, as with the advanced DCCS there was an extra-dimensional parameter that dictated their game play.

By using the more advanced border version of the task, and by including the consideration of card order in our initial game, we were able to assess whether scaffolding similar mechanisms, namely multidimensionality understanding, would facilitate 5-year-old children’s performance. Children in the experimental group who played the scaffolding game that included an additional extra-dimensional parameter, order, necessitating the use of a further embedded rule, performed significantly better on the border DCCS relative to controls who considered the multidimensionality of the same stimuli without including order. Thus, it seems
that as with 3-year-old children, not only is it possible to facilitate performance using specific experiences outside of the task, but also multidimensionality understanding appears to be an important component of the ability to navigate the advanced DCCS, as including added dimensions to the stimuli beyond basic two-dimensional colour/shape priming, helped children with more advanced, rapid rule switching.

Broadly speaking then, the developmental trajectory of DCCS performance relies on certain similar processes across preschool aged children. To date, most studies examining potential developmental differences in shifting tasks have compared adults to children, as opposed to looking specifically within the childhood age range (Bunge, Hazeltine, Scalon, Rosen, & Gabrieli, 2002; Casey et al., 2004; Moriguchi & Hiraki, 2013; Morton, Bosna, & Ansari, 2009). This study is the first to compare the skills necessary for DCCS performance within the preschool age range, and whether or not scaffolding similar mechanisms can be equally helpful for children’s performance. We must be cautious when extending the scope of these findings beyond the DCCS, whether to other more advanced measures of shifting, or to other types of EF tasks. In study 3 we chose not to include other EF tasks as we were focused on whether or not scaffolding the same abilities as those examined in study 1 and 2 could affect older preschool aged children’s performance. Moreover, given the null findings with regard to inhibitory control tasks in the previous studies we had no reason to think this type of game play would bolster performance in tasks similar to Bear/Dragon or Day/Night.

What was unexpected was that the effects of our scaffolding game seemed to be driven primarily by the “x means colour first” association, while the “x means shape first” association was significantly less likely to facilitate border DCCS performance. Perone et al., 2015 found that children who played a matching colour game then went on to perform better on the DCCS
when colour was the post-switch dimension relative to control children, however the same was not true of children who played a shape matching game when shape was the post-switch dimension. Thus, there is some precedence to the asymmetry of the effectiveness of colour/shape exposure. However, in our study children had the same amount of experience with each dimension as there was an equal number of “x means find the shape/colour first” and “no x means find the other first.” This leads to the conclusion that it is not experience with the actual colour or shape dimension that affected performance, as seen in Perone et al. (2015), but rather the association between the if-if-then conditional, “if x then colour first, if not x then shape first” produced different results than “if x then shape first, if not x then colour first.” With the exception of the colour/shape order association all other elements of the testing session were identical and there was no indication that one game was more taxing than the other. Given the unexpected nature of this finding, this warrants further study and will be discussed in detail in the general discussion.
Chapter 5

General Discussion

The studies in this dissertation demonstrate that it is possible to affect DCCS performance with certain types of experiences. More specifically, priming children to think about the multidimensional nature of objects appears to promote shifting performance. In study 1, children played either an experimental scaffolding game focused on separating and aggregating the shape and color of objects, or a closely matched control game that required thinking about only one dimension of the object at a time. Both groups were then tested on the standard color/shape DCCS. Results showed that participating in the multidimensional scaffolding game promoted DCCS performance relative to control. The results from study 1 are consistent with our initial hypothesis that re-description can make creating and using conditional rule structures less taxing. That is, experience with the idea that one can think about objects on the basis of different dimensions, facilitated children’s performance on a task that required shifting between rules.

The focus of study 2 was to determine how similar to the subsequent sorting dimensions the scaffolding game had to be for performance to improve. Perone et al. (2015) found that giving children previous experience with colour by playing a simple matching game facilitated their subsequent performance on the DCCS when colour was the post-switch sorting parameter. A similar matching game that used shape did not have the same effect. The original sorting game in study 1 used both colour and shape, as the focus was not experience with the dimensions, but on the understanding that one can think about objects on the basis of multiple dimensions at the same time. In study 2, we removed colour from our game and replaced it with pattern. We then
tested children on one of two versions of the DCCS, the standard DCCS with colour and shape, or a novel DCCS with pattern and shape. By using two DCCS testing measures we were able to assess whether our scaffolding game was effective because children were given experience with the dimensions they then sorted, whether the effect was specific to colour experience, or, whether it was by promoting multidimensionality understanding more generally. We chose to use pattern as a start point in investigating the breadth of this type of training because it relates to an object’s description in the same manner as colour, and thus we felt it allowed for analogous comparisons. Similar to the results from study 1, children in the experimental groups performed significantly better than controls on the DCCS. Moreover, there was no effect of DCCS type on performance, leading to the conclusion that it was priming children’s attention to the multidimensional nature of objects that facilitated performance and not merely experience with the sorting dimensions in general, or colour in particular.

The findings from the current work add to a large existing body of research examining preschool aged children’s performance on the DCCS. There have been numerous other studies that have included manipulations to the standard presentation of the task in an effort to better understand the mechanism responsible for the noted improvement in performance evident during the age range in question. The recent meta-analysis of DCCS manipulations mentioned earlier in this dissertation highlighted the key findings (Doebel & Zelazo, 2015). We would argue that many of the manipulations previously administered support the hypothesis of re-description. The previously discussed rule simplifications remove the need for re-description, as do versions of the task that replace the target cards with images that are not in bivalent contrast to the cards children must sort (Brooks et al., 2003; Diamond et al., 2005; Kirkham et al., 2003; Kloo & Perner, 2003; 2005; Kloo et al., 2010; Mack, 2007; Zelazo et al., 2003). For instance, by using
cartoon images that “change their mind” in regards to what they would like, colours or shapes, children must only re-describe the test cards, simplifying the task demands (Kloo & Perner, 2003; Perner & Lang, 2002). Moreover, research investigating the effects of working memory representations by using congruent and incongruent flankers during testing found that cueing children to the game they are playing – i.e., by providing a colour flanker during the colour game, affected significantly performance when compared to neutral flankers (Jordan & Morton 2008; 2012). While this improvement may be due an increase in the salience of the necessary representation in working memory, we would suggest that rather the colour flanker facilitated children’s ability to re-describe the stimuli as colours thereby facilitating the switch from shape game to colour game.

It is necessary to consider alternative explanations to the findings described here. One possibility is that the children in the experimental groups performed significantly better on the DCCS relative to controls because the multidimensional scaffolding game was cognitively engaging to a greater extent than the control game. Previous research has found that children tend to perform better on EF tasks after first participating in cognitively demanding tasks that engage their EF abilities (Lavie, 2010). To ensure that was not the case, the control game was designed to be as engaging and as cognitively demanding as the experimental game. Children in all groups interacted with the same number of cards, were required to match cards on the basis of the same attributes, and both experimental and control games took approximately the same amount of time to complete. Additionally, all games were administered in the same manner by the same experimenter so as to equally motivate all participants across all conditions. Further evidence for the fact that the games were comparable in terms of difficulty come from the drop rates. In study 1, two children were unable to perform the initial game, one in the control
condition and one in the experimental condition. In study 2, five children were excluded on the basis of their game play, two in the control condition and three in the experimental condition. With these caveats in mind, we feel confident that the scaffolding games were not differentially engaging to children.

It could also be argued that giving children experience with a single dimension at a time in the control condition made them more rigid in their thinking and therefore less able to shift dimensions in the DCCS. That is, as opposed to promoting performance in the experimental groups, we suppressed performance in the control groups. However, children in the control conditions of both studies passed the DCCS at a rate of approximately 20%, which is developmentally appropriate given the age range in question (Carlson, 2005). Thus, we have no reason to think that children in the control conditions were at a disadvantage when completing the DCCS.

Lastly, while the scaffolding game was developed based on the hypothesis that multidimensional understanding is an important component of conditional rule use and can therefore facilitate DCCS performance, we cannot say for certain that that is in fact what occurred. We hypothesized, based on the literature, that a concrete understanding of multidimensionality is necessary for a child to be able to recognize the conflicting sorting options present at the rule switch. For instance, according to the re-description theory, in order to be able to switch from sorting the red rabbit as a rabbit and sort it instead as red, one must be able to easily conceptualize the stimuli cards as both dimensions simultaneously (Kloo & Perner, 2002). IR theory posits that recognizing this conflict in the sorting options triggers the iterative reprocessing of information, which allows one to create an if-if-rule structure and navigate the post-switch trials (Zelazo, 2015). We argue that these arguments are not mutually exclusive and
that without re-description understanding, one could not recognize the conflict, and thus could not create the conditional rule necessary for performance. Yet, while the scaffolding games in the present research focused on promoting re-description understanding, there was no overt emphasis on conditional rule use, nor did we test rule use separately from the DCCS. Subsequently, while we can speak to the importance of the hypotheses put forward by the re-description theory, we can only theorize as to whether conditional rule use was affected by our scaffolding, and therefore a critical component of successful DCCS performance. It is possible that the experimental game scaffolded a wholly different mechanism or skill. For instance, instead of the ability to navigate conditional rules, the game may have facilitated children’s abilities to form discrete categorizes which may have in turn assisted in classifying the sorting cards as colour or shape. Based on the current findings, we can conclude that helping children to focus on the fact that one can consider multiple attributes of a stimuli at a single time facilitated shifting performance on the DCCS. Future work should seek to clarify the relationship between re-description understanding, conditional rule representation and DCCS performance specifically, and shifting in EF more broadly.

The Developmental Trajectory of DCCS Performance

In study 3, we used a more complex scaffolding game that included an additional extra-dimensional sorting parameter, the order the child had to find the cards. This was indicated by the presence or absence of a small “x” at the top right hand corner of the cards. The order criteria mimicked the additional embedded rule in the advanced border DCCS, which stipulates that children should play either the shape or colour game based on the presence or absence of a border on the test cards. In keeping with the results from study 1 and study 2, children in the experimental condition then went on to perform significantly better on the advanced border
DCCS relative to children in the control condition. Thus, across the preschool age range, the ability to simultaneously consider multiple attributes of a single stimuli, in this case, the colour, shape and presence of an extra-dimensional “x,” is an important, and perhaps limiting component, to children’s DCCS performance.

The colour or shape first association in study 3 was counterbalanced and half the children in the experimental condition were told the “x” indicated find the colour first/if given colour first find the correct card with an “x” and the other half vice versa. To our surprise, there was a significant difference between the counterbalanced conditions. The results showed that the scaffolding effects were driven entirely by the “x means find colour first” relationship. The children who were told that “x” indicated shape first performed identically to controls; 21% of the children in the control condition passed the border DCCS, and 21% of the children in the “x means shape first” group passed the border DCCS. There was no difference in performance on the two versions of the scaffolding game, so one was not more effective because of differences during play. Nor was there any difference to the amount of experience children in each group had with each dimension or whether colour or shape constituted the border dimension.

As mentioned in the study 3 discussion section, the asymmetry of the current findings might be interpreted with reference to the results from Perone et al. (2015), who found that children performed significantly better on the DCCS relative to controls when they were given previous experience with colour as the post switch sorting parameter, but not when the same was true of shape. The study in question was designed to assess the application of dynamic neural field theory to DCCS performance. According to dynamic neural field theory, our brain consists of neural fields, which are populated by neurons that share excitatory capacities to specific dimensions (Buss & Spencer, 2014). For instance, a red stimulus would elicit an excitatory
reaction from neurons specifically tuned to the colour red, as well as other hues similar to red in a graduated manner. Having children attend to colour forms latent working memory representations and engages “colour neurons” meaning it will be easier for children to later focus on colours as the necessary neural areas are already active (Buss, 2013; Buss & Spencer, 2014). Perone et al. (2015) suggested that in their study they did not give children enough experience with shape, and thus the necessary neuronal excitation and engagement did not occur. It is has been suggested that the working memory representations formed by exciting colour neurons results in a more stable latent representation than when exciting shape neurons as there is a larger distinction between shapes than colours in the neuronal field (Franconeri & Alvarez, 2012). This means that there is a larger spread in the action potentials created by experience with colour than with shape. If this were the case then it would explain why one might need more experience with shape than with colour to achieve the same effect. In our study we gave children the same amount of experience with both colour and shape and found no difference in performance based on which dimension constituted the border sorting parameter. It is however possible that there was a primacy effect by having children consider colour first or shape first that then affected the latent working memory representations for each individual dimension. It may be that as with Perone et al. (2015) children may have needed more experience with shape to have the same affect on later DCCS sorting performance. Though without further study it is difficult to pinpoint how much more experience would be necessary and why the “x means colour first” and “no x means shape first” may have differentially affected neuronal excitation compared to “x means shape first” and “no x means colour first.”

It is possible that there may be a more straightforward explanation to our findings. It may be that the choice of indicator affected the outcome of the game. We chose an “x” for multiple
reasons; first, the border indicator on the advanced DCCS cards is also technically a shape and second, there are versions of the advanced DCCS that in fact use an “x” or a small star instead of a border. It has been found that both the border option, “x” or star options function identically in terms of an advanced DCCS task (Cragg & Chevalier, 2012; FitzGibbon, Cragg, & Carroll, 2014). Thus we felt confident using an “x” as an analogous indicator that one must consider a card with an “x” differently than a card without an “x,” just as in the advanced DCCS one must consider cards with a border differently than cards without a border. However the fact that the “x” was itself a shape may have affected the association made in the “x means shape first” group, as children may have then focused differently on the separate dimensions. Or, perhaps using an “x” shape as the indicator with the “x means colour first” group served to highlight even further multiple dimensions because children had to consider both a shape (the “x”) and colour at the same time. This association may have promoted re-description understanding to a greater extent for the “x means colour first” children compared to the “x means shape first” children. Thus, though unintentional, we may have given the “x means colour first” group more experience with multidimensional understanding and made the subsequent advanced DCCS rule use easier than in the case where children were faced with the same rule requirements but only shape indicators when considering order. These hypotheses are entirely speculative so further study is needed to determine the cause of the asymmetrical findings.

**Bear/Dragon and Day/Night**

The experimental scaffolding game had no effect on Bear/Dragon or Day/Night performance in either study 1 or study 2. There are two explanations as why this may have occurred. The accounts are in conflict with one another, however given the scope of the current research we are unable to rule either out.
First, the construct of EF is generally conceptualized as including both unitary and non-unitary components. That is, there is both separability and a degree of interrelation among the aforementioned component abilities, inhibition, shifting and updating (Agostino, Johnson, & Pascual-Leone, 2010; Huizinga, Dolan, & van der Molen, 2006; Lee, Bull, & Ho, 2013; Miller, Giesbrecht, Müller, McInerney, & Kerns, 2012; Miyake et al., 2000; Miyake & Friedman, 2012; Shing, Lindenberger, Diamond, Li, & Davidson, 2010; Wiebe, Espy, & Charak, 2008; Wiebe et al., 2011). In early childhood, EF specializes both behaviourally and neurologically with each component relying on the development of a different set of processes (Best & Miller, 2010; Bardikoff & Sabbagh, in press). There is evidence for the separability of the components in developmental research, as inhibition, shifting and updating have distinct developmental trajectories (Bunge & Wright, 2007; Conklin, Luciana, & Hooper, 2007; Luna et al., 2001; Romine & Reynolds, 2005; Tamnes et al., 2010). The greatest advancement in inhibitory abilities has been found to be between the ages of 5 and 8 (Romine & Reynolds, 2005), while updating develops in a more linear fashion until adolescence (Best & Miller, 2010; Conklin et al., 2007). The three components also rely on distinct neural pathways; inhibition on the ventral prefrontal cortex and the dorsal lateral prefrontal cortex, shifting on the parietal regions and updating a network including inferior and superior frontal cortices and the intraparietal sulcus (Collette et al., 2005).

Given these differences in both developmental trajectory and in areas of processing, it may be more accurate to conceptualize EF as an umbrella term as opposed to a unified set of skills. The interrelation between the components may stem from their use and applicability as opposed to a basic unity as it is rare to use one without the other. For instance, when shifting one must naturally inhibit the previous information to some extent, however that does not necessarily
mean that the two processes are inherently connected. Thus, it may be more accurate to classify
EF as a group of abilities that often work in conjunction to perform a task. If this
conceptualization is correct, then it stands to reason that the skills needed for the different
components of EF are quite dissimilar. As such, the underlying mechanisms for each EF
component may require different types of scaffolding at different points in time. This may in turn
hinder broad training transfer, as training that successfully promotes the skills necessary for
inhibition may be unhelpful in facilitating shifting, or updating performance. In the case of the
research presented here, promoting attention to the multidimensional nature of objects was able
to facilitate shifting between sorting rules, and it is possible that we may have seen transfer to
other shifting tasks if we had included additional measures beyond the DCCS in the EF battery.
However, targeting that understanding appears to have been unhelpful for inhibitory control. It is
possible that inhibition may not require a similar understanding, or, at least, it may be necessary
but not sufficient for performance, and rather a different mechanism may be limiting preschool
aged children’s inhibitory control. Thus, one possible explanation for the lack of transfer to
Bear/Dragon and Day/Night is that during the preschool age range, inhibition performance and
shifting performance rely, at least partially, on the development of different abilities, and thus
may benefit from different types of scaffolding measures.

Alternatively, it may be the case that the three EF components do in fact possess a
common, unifying element, however we may not have targeted the correct process. The
scaffolding games in our research focused on promoting re-description, operating under the
hypothesis that focusing on the different attributes of objects may make representing the sorting
rule less taxing. That is, the motivation behind highlighting multidimensionality was to enable
children to more easily form and shift between conditional rules. It is possible that re-description
understanding is not an important factor for navigating all types rules structures, or all types of EF tasks. In terms of the measures used here, Bear/Dragon and Day/Night are both inhibition tasks and may not rely on if-if-then conditional rules. Both could be instead by characterized as relying on stimulus response rules, wherein each separate stimulus is associated with a separate response. For example, “If I see the sun card I say night. If I see the moon card I say day” and “If the bear talks I listen. If the dragon talks I do not.” Alternatively, it could be possible that participation in the task itself necessitates a conditional rule. Normally one would see a sun card and say day, however since one is playing this game that same stimulus necessitates an alternate response. If this the case, then the rule would read as follows, “If I’m playing the silly game and if I see the moon card I say day” and “If I’m playing the silly game and if the bear talks I listen.” Regardless of how one characterizes the requisite rule, neither relies on an understanding of multidimensionality as we approached it. As a result, promoting the understanding that one can approach a single stimulus in two different ways would not necessarily have bolstered performance. It may be that if we had considered re-description as a broader concept, encompassing behaviour as well as object attributes, we may have been able to promote performance more broadly. For instance, during the inhibition tasks one must not conceptualize objects in two different ways, but rather one must conceptualize behaviour in two different ways. You can listen (i.e., do what the bear says) or you can act in an alternate manner and not listen (i.e., ignore the dragon’s commands). It may be that finding a way to scaffold multidimensional understanding more broadly would have facilitated performance on the inhibition tasks.

Based on the current research we are unable to say concretely why transfer to inhibition tasks did not occur. What is clear is that the experimental scaffolding games were developed to target shifting and DCCS performance specifically and achieved success in that regard. Given
the general difficulty in regards to transfer effects present in the training literature, it would be interesting to determine if creating a broader, more extensive training could have more widespread effects on different aspects of EF. Or, if given the distinct nature of inhibition, shifting and updating, it would be more beneficial to approach each as wholly separate processes and develop programs that target each individually.

**Interventions**

The results show that it is possible to facilitate DCCS performance without task training or corrective feedback, but instead by highlighting the multidimensionality of objects and thereby potentially scaffolding the application of conditional rule structures that necessitate these understandings. It is possible that this particular method of breaking down and aggregating different choices may be used as a training template for other situations wherein children must use shifting, or must navigate conditional if-if-then rule structures. For instance, there are many times in a typical day during which a child must regulate their behaviour based on different conditionals, or, situations where children must shift their attention and approach based on different aspects of objects. For example, in gym a child must focus on the weight or direction of objects, while in art class, colour becomes the dominant dimension. It may be possible to help children navigate these rule structures and attention shifting by highlighting the multiple options or choices they have. While these examples are more complex and involved than a simple card sort, they speak to the potential wide-ranging possibilities of the scaffolding techniques used in these studies.

**Limitations and future research**

The studies discussed in this dissertation were intended as a starting point for more extensive training research, and thus the goal was to determine if these types of scaffolding
techniques could have an effect on performance. Due to the preliminary nature of the research there were several limitations. Firstly, we did not use pre- and post-training measures. While we are confident that random sampling ensured equality between our control and experimental groups, without baseline scores it is difficult to assess the extent of the scaffolding games. Having a baseline shifting measure would also allow us to assess the longevity of this type of scaffolding. As of now, there is no way to determine if the scaffolding game promoted shifting in that particular moment, or in a more long-term capacity. Given the simple nature of the game play, it is most likely that the results were due to a brief boost in children’s ability to navigate specific rules. It would be interesting to see whether this type of scaffolding could be developed into a more comprehensive training program that could include long-term benefits.

Additionally, the studies in this dissertation used dimensions that were either identical, or tangentially related to the sorting dimensions children had to shift between. It may be that in order for children to benefit the dimensions must remain analogous to those they then must shift between, as in the case of pattern and colour. Alternatively, it may be that a game separating and aggregating amount and size, or orientation and location, would be equally successful in facilitating shifting between colour and shape. Future research will be necessary to determine how dissimilar from the sorting dimensions the training and DCCS parameters can be while still maintaining the positive effects of the training. The results would also speak more broadly to how the important re-description understanding is for preschool aged children to be able to shift within conditional rule structures.

Conclusion

The results from the studies discussed in this dissertation show that promoting attention to the multidimensional nature of objects scaffolds DCCS performance in preschool aged
children. Not only does it seem that re-description is an integral component of DCCS performance, but also that it is possible to facilitate said performance using brief, simple experiences outside the task context. These findings shed light on the developmental processes important for shifting performance during the preschool age range and the different ways in which we can foster this important set of abilities.
References


Appendix A

Study 1 Scaffolding Game

Experimental Condition

Exp: Okay! I have another game we can play this one has different shapes and colours.
[One display with two columns, one has outlines of different shapes – circle, square, pentagon, parallelogram, trapezoid. Other side has swatches of colours – purple, pink, navy, red, light blue. Another display with combinations, each colour and shape is displayed twice.]

Here we have lots of different shapes and colours! What’s your favourite colour? That’s great, I love [insert colour choice].

Now if I give you this one here [removes red pentagon] can you get me the colour and the shape we need to make this one?

[Child responds – experimenter gives feedback if needed]

Exp: That’s right, when we put this colour with this shape, we get this one! Can you get me the colour and the shape we need to make this one? [removes light blue square]

[Child responds – experimenter gives feedback if needed]

Exp: That’s right, when we put this colour with this shape, we get this one! Can you get me the colour and the shape we need to make this one? [points to separate pink parallelogram]

[Child responds – experimenter gives feedback if needed]
Exp: That’s right, when we put this colour with this shape, we get this one! Can you get me the colour and the shape we need to make this one? [points to separate purple circle]

[Child responds – experimenter gives feedback if needed]

Exp: That’s right, when we put this colour with this shape, we get this one! Can you get me the colour and the shape we need to make this one? [points to separate navy trapezoid]

[Child responds – experimenter gives feedback if needed]

Exp: That’s right, when we put this colour with this shape, we get this one!

Now let’s do something a little different. I’m going to give you one shape and one colour [removes red and circle from the display] if we put these into my colour-shape making machine, what will we get from over here? [indicate display with complete shape/colour combinations]

[Child responds – experimenter gives feedback if needed]

Exp: That’s right! If we put this colour and this shape together we get this one! What about if we put these two cards together [light blue and trapezoid], what will we get?

[Child responds – experimenter gives feedback if needed]

Exp: That’s right! If we put this colour and this shape together we get this one! What about if we put these two cards together [pink and square], what will we get?

[Child responds – experimenter gives feedback if needed]

Exp: That’s right! If we put this colour and this shape together we get this one! What about if we put these two cards together [purple and parallelogram], what will we get?
Exp: That’s right! If we put this colour and this shape together we get this one! What about if we put these two cards together [navy and pentagon], what will we get?

[Child responds – experimenter gives feedback if needed]
Control Condition

Exp: **Okay! I have another game we can play this one has different shapes and colours.**
[One display with two columns, one has outlines of different shapes – circle, rectangle, pentagon, parallelogram, trapezoid. Other side has swatches of colours – purple, pink, navy, red, light blue. Another display with combinations, each colour and shape is displayed twice.]

**Here we have lots of different shapes and colours! What’s your favourite colour? That’s great, I love** [insert colour choice].

Now if I give you this one here, can you find me two other things that are this colour? - Red
[Child responds]

Exp: **That’s right, these are all the same colour! How about two other things that are this colour? – Light Blue**
[Child responds]

Exp: **That’s right, these are all the same colour! How about two other things that are this colour?– Pink**
[Child responds]

Exp: **That’s right, these are all the same colour! How about two other things that are this colour?– Purple**
[Child responds]

Exp: **That’s right, these are all the same colour! How about two other things that are this colour?– Navy Blue**
[Child responds]

Exp: **That’s right, these are all the same colour!**
Now can you fine me two other things that are the same shape as this one? - Circle
[Child responds]

Exp: That’s right, these two are the same shape! Now can you fine me two other things that are the same shape as this one? - Trapezoid
[Child responds]

Exp: That’s right, these two are the same shape! Now can you fine me two other things that are the same shape as this one? - Square
[Child responds]

Exp: That’s right, these two are the same shape! Now can you fine me two other things that are the same shape as this one? – Parallelogram
[Child responds]

Exp: That’s right, these two are the same shape! Let’s do one more! Can you fine me two other things that are the same shape as this one? - Pentagon
[Child responds]
Appendix B

Study 2 Scaffolding Game

Experimental Condition

Exp: **Okay! I have another game we can play this one has different shapes and designs.**
[One display with two columns, one has outlines of different shapes – circle, square, pentagon, parallelogram, trapezoid. Other side has swatches of colours – purple, pink, navy, red, light blue. Another display with combinations, each colour and shape is displayed twice.]

**Here we have lots of different shapes and lots of different designs!**

Now if I give you this one here [removes striped pentagon] **can you get me the design from over here and the shape from over here we need to make this one?**

[Child responds – experimenter gives feedback if needed]

Exp: **That’s right, when we put this design with this shape, we get this one! Can you get me the design and the shape we need to make this one?** [removes polka dot square]

[Child responds – experimenter gives feedback if needed]

Exp: **That’s right, when we put this design with this shape, we get this one! Can you get me the design and the shape we need to make this one?** [removes cubed parallelogram]

[Child responds – experimenter gives feedback if needed]

Exp: **That’s right, when we put this design with this shape, we get this one! Can you get me the design and the shape we need to make this one?** [removes squiggle circle]
Exp: That’s right, when we put this design with this shape, we get this one! Can you get me the design and the shape we need to make this one? [removes triangle trapezoid]

[Child responds – experimenter gives feedback if needed]

Exp: That’s right, when we put this design with this shape, we get this one!

Now let’s do something a little different. I’m going to give you one shape and one design [removes red and circle from the display] if we put these into my design-shape making machine, what will we get from over here? [indicate display with complete shape/design combinations]

[Child responds – experimenter gives feedback if needed]

Exp: That’s right! If we put this design and this shape together we get this one! What about if we put these two cards together [polka dot and trapezoid], which will we get from over here?

[Child responds – experimenter gives feedback if needed]

Exp: That’s right! If we put this design and this shape together we get this one! What about if we put these two cards together [cubes and square], which will we get from over here?

[Child responds – experimenter gives feedback if needed]

Exp: That’s right! If we put this design and this shape together we get this one! What about if we put these two cards together [squiggle and parallelogram], which will we get from over here?
[Child responds – experimenter gives feedback if needed]

Exp: That’s right! If we put this design and this shape together we get this one! What about if we put these two cards together [triangle and pentagon], which will we get from over here?

[Child responds – experimenter gives feedback if needed]
Control Condition

Exp: **Okay! I have another game we can play this one has different shapes and colours.**
[One display with two columns, one has outlines of different shapes – circle, rectangle, pentagon, parallelogram, trapezoid. Other side has swatches of colours – purple, pink, navy, red, light blue. Another display with combinations, each colour and shape is displayed twice.]

**Here we have lots of different shapes and lots of different designs!**

Now if I give you this one here, can you find me two other things that are the same design as this one? – Lines
[Child responds]

Exp: **That’s right, these are all the same design! Now if I give you this one here, can you find me two other things that are the same design as this one? – Polka dots**
[Child responds]

Exp: **That’s right, these are all the same design! Now if I give you this one here, can you find me two other things that are the same design as this one? – Cubes**
[Child responds]

Exp: **That’s right, these are all the same design! Now if I give you this one here, can you find me two other things that are the same design as this one? – Squiggles**
[Child responds]

Exp: **That’s right, these are all the same design! Now if I give you this one here, can you find me two other things that are the same design as this one? – Triangles**
[Child responds]

Exp: **That’s right, these are all the same design!**
Now can you fine me two other things that are the same shape as this one? - Circle
[Child responds]

Exp: That’s right, these two are the same shape! Now can you fine me two other things that are the same shape as this one? - Trapezoid
[Child responds]

Exp: That’s right, these two are the same shape! Now can you fine me two other things that are the same shape as this one? - Square
[Child responds]

Exp: That’s right, these two are the same shape! Now can you fine me two other things that are the same shape as this one? – Parallelogram
[Child responds]

Exp: That’s right, these two are the same shape! Let’s do one more! Can you fine me two other things that are the same shape as this one? - Pentagon
[Child responds]
Appendix C

Study 3 Scaffolding Game

Experimental Condition

Exp: Okay! I have another game we can play this one has different shapes and colours.
[One display with two columns, one has outlines of different shapes – circle, square, pentagon, parallelogram, trapezoid. Other side has swatches of colours – purple, pink, navy, red, light blue. Another display with combinations, each colour and shape is displayed twice.]

Here we have lots of different shapes and colours! What’s your favourite colour? That’s great, I love [insert colour choice]. Want me to show you how we play this game? In this game when I give you a card from over here, you have to find the shape and the colour that if we put them together we’d make this one. But you have to pay attention to the top of the card. If there is an X on it, I want you to find the colour first from this side [indicate colour column] and then the shape [indicate shape column]. But if there is no X on the top I want you to find the shape first from this side [indicate shape column] and then the colour [indicate colour column]. Okay? Let’s get started!

Rule Check
Okay, so if you get one with an X, which do you find first colour or shape? [feedback as needed]

And if you get one without an X, which do you find first colour or shape? [feedback as needed]

Great! Let’s play!
Now I have this one here [removes red pentagon with an X] which two cards to we need to make up this one, and which one do we find first?

[Child responds – experimenter gives feedback if needed]

Exp: That’s right, if we put those two together we’d get this one! And you got the colour first and then the shape, because there was an X on it! [removes blue square with nothing] Which two cards to we need to make up this one, and which one do we find first?

[Child responds – experimenter gives feedback if needed]

Exp: Awesome, if we put those two together we’d get this one! And you got the shape first and then the colour, because there was no X on it! Which two cards to we need to make up this one, and which one do we find first? [removes pink parallelogram with an X]

[Child responds – experimenter gives feedback if needed]

Exp: That’s right, if we put those two together we’d get this one! And you got the colour first and then the shape, because there was an X on it! Which two cards to we need to make up this one, and which one do we find first? [removes purple circle with nothing]

[Child responds – experimenter gives feedback if needed]

Exp: Awesome! if we put those two together we’d get this one! And you got the shape first and then the colour, because there was no X on it! Which two cards to we need to make up this one, and which one do we find first? [removes light blue trapezoid with an X]

[Child responds – experimenter gives feedback if needed]

Exp: That’s right, if we put those two together we’d get this one! And you got the colour first and then the shape, because there was an X on it!
Now let’s do something a little different. I’m going to pull off one shape and one colour, and I want you to tell me what we’d get if we put these into my colour-shape making machine. But you have to pay attention to which one I give you first, if I pull off the colour first then I want you to find me one from over here with an X on it. If I pull off the shape first then I want you find me from over here without an X on it, Okay? Let’s get started!

**Remember to pay attention to which one I take first!** [remove red first then pentagon from the display]

Exp: **Awesome! If we put this colour and this shape together we get this one!** And because I gave you colour first you found me one with an X on it! **What about if we put these two together, which one would we get?** [remove square first then light blue]

[Child responds – experimenter gives feedback if needed]

Exp: **That’s right! If we put this colour and this shape together we get this one!** And because I gave you shape first you found me one without an X on it! **What about if we put these two together, which one would we get?** [remove pink first then parallelogram].

[Child responds – experimenter gives feedback if needed]

Exp: **Awesome! If we put this colour and this shape together we get this one!** And because I gave you colour first you found me one with an X on it! **What about if we put these two together, which one would we get?** [remove circle first then purple],

[Child responds – experimenter gives feedback if needed]
Exp: That’s right! If we put this colour and this shape together we get this one! And because I gave you shape first you found me one without an X on it! What about if we put these two together, which one would we get? [remove navy first then trapezoid]

[Child responds – experimenter gives feedback if needed]
Control Condition

Exp: **Okay! I have another game we can play this one has different shapes and colours.**
[One display with two columns, one has outlines of different shapes – circle, square, pentagon, parallelogram, trapezoid. Other side has swatches of colours – purple, pink, navy, red, light blue. Another display with combinations, each colour and shape is displayed twice.]

**Here we have lots of different shapes and colours! What’s your favourite colour? That’s great, I love** [insert colour choice]. **Want me to show you how we play this game? In this game when I give you a card you have to find the shape form over here and the colour form over and either the “x” card if there is an “x” or the “no x” card if there is no X on it. So if we put them together we’d get this one!**

**Now I have this one here** [remove red pentagon WITH an x] **can you find me the 3 cards we need to make up this one?**

[Child responds – experimenter gives feedback if needed]

Exp: **That’s right, when we put this colour, this shape and this card together, we get this one! Can you find me the 3 cards we need to make up this one?** [remove separate light blue square WITHOUT an x]

[Child responds – experimenter gives feedback if needed]

Exp: **Awesome! when we put this colour, this shape and this card together, we get this one! Can you find me the 3 cards we need to make up this one?** [remove separate pink parallelogram WITH an x]

[Child responds – experimenter gives feedback if needed]
Exp: That’s right, when we put this colour, this shape and this card together, we get this one! Can you find me the 3 cards we need to make up this one? [remove separate purple circle WITHOUT an x]

[Child responds – experimenter gives feedback if needed]

Exp: Awesome! when we put this colour, this shape and this card together, we get this one! Can you find me the 3 cards we need to make up this one? [remove separate navy trapezoid WITH an x]

[Child responds – experimenter gives feedback if needed]

Exp: That’s right, we put this colour, this shape and this card together, we get this one! Now let’s do something a little different. I’m going to give you one shape, one colour [red, pentagon and blank card] and one of these cards here, either the “x” card or the “no x” card. If we put these into my colour-shape making machine, what will we get from over here?

[Child responds – experimenter gives feedback if needed]

Exp: Awesome! If we put this colour, this shape and the no x card together we get this one! What about if we put these into my colour-shape making machine [navy, square, and x card], what will we get?

[Child responds – experimenter gives feedback if needed]

Exp: Great! If we put this colour, this shape together and the x card we get this one! What about if we put these into my colour-shape making machine [pink, parallelogram and blank card], what will we get?

[Child responds – experimenter gives feedback if needed]
Exp: Thanks! If we put this colour, this shape and the x card together we get this one! What about if we put these into my colour-shape making machine [purple, circle and x card], what will we get?

[Child responds – experimenter gives feedback if needed]

Exp: Great! If we put this colour, this shape and the no x card together we get this one! Let’s do one more! What about if we put these into my colour-shape making machine [light blue, trapezoid and blank card], what will we get?

[Child responds – experimenter gives feedback if needed]
Appendix D

Executive Functioning Battery

Day/Night

Day/Night Script

Exp: We’re gonna play a game with these cards. Do you know when the sun comes out? In the day or in the night?
Do you know when the moon and starts come out?

[Praise right answers, correct wrong]

Exp: Well we’re going to play a silly game. [Show moon card] In this game when you see this card, I want you to say “day” Can you say the word “day?” [Praise if said, prompt if not]
[Remove card and show white sun card] When you see this card, I want you to say “night.” Can you say the word “night?” [Praise if said, prompt if not]

Practice Trials

[Show white sun card and wait for response]
[If hesitates] What do you say when you see this card?

[Praise if said, show moon card]
[If hesitates] What do you say when you see this card?

[Test Trials]

[Praise if correct and continue to testing trials – if incorrect, repeat both rules starting with the one the child got wrong, and repeat practice]
Whenever child hesitates, ask “What do you say when you see this card?” but do not use the words “day” or “night,” do not give feedback on test trials

White sun card
Black moon card
Black moon card
White sun card
Black moon card
White sun card
White sun card
Black moon card
Black moon card
White sun card
Black moon card
White sun card
White sun card
Black moon card
White sun card
Black moon card
White sun card
Black moon card
Bear/Dragon Task

Warm-up

(Make sure child can follow all of the directions by having child do the following; Exp models the movements during warm-up)

OK, I'm going to ask you to do some silly things before we start our next game.
Stick out your tongue. (Exp remember to model each of these with the child)
Touch your ears.
Touch your teeth.
Touch your eyes.
Clap your hands.
Touch your feet.
Touch your head.
Touch your tummy.
Touch your nose.
Wave your hand.

OK. Good job!

Instructions
(Exp takes out the bear and dragon puppets)

Now I have a game to play with these puppets. This puppet (show the bear by holding it in front of you, towards the child) is a nice bear. When he talks to us, we’ll do what he tells us to do. This puppet (show the dragon in the same way) isn’t very nice. This puppet is a dragon. When he talks to us, we won’t listen to him. If he tells us to do something, we won’t do it.

Practice Trials
OK. Let's practice one time.
This is the good bear. He says, "Touch your nose." (in a mellow, nice voice)
(If child does not touch nose)
Remember, we listen to the nice bear. We do what he tells us to do because that's how we play the game.
(Exp repeats the command and may model the action until child succeeds)
(Once S touches nose)
Very good! Now let's practice with the naughty dragon. In this game, we won't do what the dragon tells us to do because he's not so nice.
DRAGON: Touch your tummy. (in a low, gruff voice)
(If child touches stomach)
Remember how we play this game. We're not going to listen to the mean dragon. We won't do what he tells us to do because he’s not so nice.
If child touches stomach again –
Do we do what the dragon tells us to do? Noooo! Ok, so let’s try again. “Touch your tummy!”
If child touches stomach again
Do we do what the dragon tells us to do? Noooo! Ok, so let’s try again. “Touch your tummy!”
If child touches stomach again, ask child to place both hands on the table in front of them and gently hold child’s hands down. Say,
Okay. Let’s try again.
(Repeat until child gets it right, note that holding child's hands down if necessary on the 6th try counts as a successful trial)
(When child succeeds)
Yeah! That was fun.

Rule Check

So, when the Bear tells you to do something, do you do it? (correct if necessary)
And when the Dragon tells you to do something, do you do it? (correct if necessary)

OK, let's play some more.

**Test Trials**
(Exp does not model or give feedback on test trials)
(using each of the character’s respective voices, and presenting each character in front of the child when it’s that character’s turn to speak an action:)

1. BEAR: Stick out your tongue.
2. DRAGON: Touch your ears.
3. BEAR: Touch your teeth.
4. DRAGON: Touch your eyes.
5. BEAR: Clap your hands.
(Reminder given regardless of performance)

Remember how we play this game. We do what the bear tells us to do because he’s nice, but we won't do what the dragon tells us to do because he’s not so nice.

6. DRAGON: Touch your feet.
7. BEAR: Touch your head.
8. DRAGON: Touch your tummy.
9. BEAR: Touch your nose.
10. DRAGON: Wave your hand.
Dimensional Change Card Sort Task (DCCS)

Instructions

(Exp places trays on table. Tray on right has a blue rabbit card pasted on back wall of the tray. Tray on left has a red boat card pasted on back wall of the tray.)

Now we’re going to play another game. This is the SHAPE game. In the shape game, all the rabbits go in this box (pointing to right box) and all the boats go in that box (pointing to left box). We don't put rabbits in this box. Nooo way (shaking head). Rabbits go here (point to correct box) and only boats go over here (point to correct box). So if it is a rabbit, then it goes here. If it is a boat, then it goes here. This is the SHAPE game.

OK. I'll go first so you see how we play. Rabbits go here (point at rabbit box), and boats go here (point at boat box). Here is a red rabbit, so it goes here. (Exp places a red rabbit card in box on right)

And here is a blue boat, so it goes here. (Exp places a blue boat card in box on left)

Pre-switch Trials

Note: On ALL pre-switch trials, if child is ever wrong (which basically never happens), say: No, that's not right. Remember the rules. (proceed to next trial)

OK. Now it's your turn.

1. If it’s a rabbit, it goes here (point to rabbit box), and if it’s a boat it goes here (point to boat box).

Here’s a red rabbit. Where does this one go?
(wait for child to place card in a box)
2. If it’s a rabbit, it goes here (point to rabbit box), and if it’s a boat it goes here (point to boat box).

Here’s a blue boat. Where does this one go?
(wait for child to place card in a box)

3. If it’s a rabbit, it goes here (point to rabbit box), and if it’s a boat it goes here (point to boat box).

Here’s a red rabbit. Where does this one go?
(wait for child to place card in a box)

4. If it’s a rabbit, it goes here (point to rabbit box), and if it’s a boat it goes here (point to boat box).

Here’s a red rabbit. Where does this one go?
(wait for child to place card in a box)

5. If it’s a rabbit, it goes here (point to rabbit box), and if it’s a boat it goes here (point to boat box).

Here’s a blue boat. Where does this one go?
(wait for child to place card in a box)

(Child must correctly sort 4 cards according to shape before proceeding to post-switch trials)

Post-switch Trials

Now we’re going to switch. We’re not going to play the shape game anymore. We’re going to play the COLOUR game. In the colour game, all the red ones go in this box (pointing to right box) and all the blue ones go in that box (pointing to left box). We don't put red ones in this box. Nooo way (shaking head). Red ones go here (point to correct box) and only blue ones go over here (point to correct box). So if it is a red one, then it goes here. If it is a blue one, then it goes here. This is the COLOUR game. Are you ready to play?
(Exp does not give feedback on post-switch trials)

1. If it’s red, it goes here (point to red box), and if it’s blue, it goes here. (point to blue box) Here’s a red rabbit. Where does this one go? (wait for child to place card in a box)

2. If it’s red, it goes here (point to red box), and if it’s blue, it goes here. (point to blue box) Here’s a blue boat. Where does this one go? (wait for child to place card in a box)

3. If it’s red, it goes here (point to red box), and if it’s blue, it goes here. (point to blue box) Here’s a red rabbit. Where does this one go? (wait for child to place card in a box)

4. If it’s red, it goes here (point to red box), and if it’s blue, it goes here. (point to blue box) Here’s a red rabbit. Where does this one go? (wait for child to place card in a box)

5. If it’s red, it goes here (point to red box), and if it’s blue, it goes here. (point to blue box) Here’s a blue boat. Where does this one go? (wait for child to place card in a box)
Border Trials

Because you were so good at that game we’re going to keep going! In this game, there are some cards that have a black border around it just like this one (show a blue boat card with a border. Draw your finger around the border of the card). If you see cards with a black border, you have to play the colour game. In the colour game, blue ones go here and red ones go here (point to respective boxes). This one’s blue, so I’m going to put it right here (placing it down in the appropriate box).

But if the cards have no black border, like this one (show them a blue boat card without a border. (Draw your finger around the outside of a card to show that there is no border.), you have to play the shape game. In the shape game, if it’s a boat, we put it here, but if it’s a rabbit, we put it here (point to the respective boxes). This one’s a truck, so I’m going to put it right here (place it down in the appropriate box).

Rule Check
(Exp is not showing a card during these checks) So what game do you play if there is a border? (colour game).
If Correct: Very good, that’s right.
If Incorrect: Uh oh. Remember, if there’s a border, play the colour game. If there is no border, play the shape game. (Repeat question and reminder 1 more time, only then mark as incorrect & move on.)

What game do you play if there is no border? (shape game).
If Correct: Very good, that’s right.
If Incorrect: Uh oh. Remember, if there’s a border, play the colour game. If there is no border, play the shape game. (Repeat question and reminder 1 more time, only then mark as incorrect & move on.)

Let’s try this game!
Before each trial say: “If there’s a border, play the color game. If there is no border, play the shape game.”

1. (Red Boat - border) Here’s one with a border, where does this one go?
2. (Red Boat) Here’s one without a border, where does this one go?
3. (Blue Rabbit - border) Here’s one with a border, where does this one go?
4. (Blue Rabbit) Here’s one without a border, where does this one go?
5. (Red Boat - border) Here’s one with a border, where does this one go?
6. (Red Boat) Here’s one without a border, where does this one go?
7. (Blue Rabbit - border) Here’s one with a border, where does this one go?
8. (Blue Rabbit) Here’s one without a border, where does this one go?
9. (Red Boat - border) Here’s one with a border, where does this one go?
10. (Red Boat) Here’s one without a border, where does this one go?
11. (Blue Rabbit - border) Here’s one with a border, where does this one go?
12. (Blue Rabbit) Here’s one without a border, where does this one go?
Appendix E

GREB Approval Form

February 10, 2015

Ms. Nicole Bardikoff
Ph.D. Candidate
Department of Psychology Humphrey Hall
Queen's University Kingston, ON, K7L 3N6

GREB Ref #: GPSYC-690-15; Romeo # 6014571
Title: "GPSYC-690-15 The Development of Executive Functioning in Young Children"

Dear Ms. Bardikoff:

The General Research Ethics Board (GREB), by means of a delegated board review, has cleared your proposal entitled "GPSYC-690-15 The Development of Executive Functioning in Young Children" for ethical compliance with the Tri-Council Guidelines (TCPS) and Queen's ethics policies. In accordance with the Tri-Council Guidelines (article D.1.6) and Senate Terms of Reference (article G), your project has been cleared for one year. At the end of each year, the GREB will ask if your project has been completed and if not, what changes have occurred or will occur in the next year.

You are reminded of your obligation to advise the GREB, with a copy to your unit REB, of any adverse event(s) that occur during this one year period (access this form at https://eservices.queensu.ca/romeo_researcher/ and click Events - GREB Adverse Event Report). An adverse event includes, but is not limited to, a complaint, a change or unexpected event that alters the level of risk for the researcher or participants or situation that requires a substantial change in approach to a participant(s). You are also advised that all adverse events must be reported to the GREB within 48 hours.

You are also reminded that all changes that might affect human participants must be cleared by the GREB. For example you must report changes to the level of risk, applicant characteristics, and implementation of new procedures. To make an amendment, access the application at https://eservices.queensu.ca/romeo_researcher/ and click Events - GREB Amendment to Approved Study Form. These changes will automatically be sent to the Ethics Coordinator, Gail Irving, at the Office of Research Services or irvingg@queensu.ca for further review and clearance by the GREB or GREB Chair.

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On behalf of the General Research Ethics Board, I wish you continued success in your research.

Yours sincerely,

Joan Stevenson, Ph.D. Chair General Research Ethics Board

c: Dr. Mark Sabbagh, Faculty Supervisor
Dr. Stanka Fitneva, Chair, Unit REB
Ms. Marie Tooley, Dept. Admin.