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# Executive Function in Preschoolers: A Review Using an Integrative Framework

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During the last 2 decades, major advances have been made in understanding the development of executive functions (EFs) in early childhood. This article reviews the EF literature during the preschool period using an integrative framework. The framework adopted considers EF to be a unitary construct with partially dissociable components (A. Miyake et al., 2000). The authors focus on 3 EF components: working memory, response inhibition, and shifting. For the present purposes, the central executive is conceived of as a central attention system that is involved in all EF component operations. Research to date suggests that elementary forms of the core EF components are present early during the preschool period. Changes in EF during the latter half of the preschool period appear to be due to the development of attention and integration of component EFs. Finally, the review outlines a number of areas that warrant further investigation if researchers are to move forward in understanding early EF development.

*Keywords:* executive functions, preschoolers, working memory, inhibition, shifting

The first 5 years of life play a critical role in the development of executive functions (EFs). EFs are adaptive, goal-directed behaviors that enable individuals to override more automatic or established thoughts and responses (Lezak, 1995; Mesulam, 2002). As the definition implies, these functions are particularly critical when solving novel problems. EFs have been strongly associated with the prefrontal cortex, which is one of the slowest developing brain areas (Benes, 2001; Huttenlocher & Dabholkar, 1997; Lezak, 1995; Scheibel & Levin, 1997). Research indicates that the most important function of the prefrontal cortex is in regulating perception, thought, and behavior through the activation and inhibition of other brain areas (Knight & Stuss, 2002; Shallice, 2002). During infancy and the preschool period, core components of EF develop, forming a critical foundation that will set the stage for the development of higher cognitive processes well into adulthood.

Although the study of EF in adulthood has long been a field of active research, comparatively little was known about early EF development until the last two decades (Welsh & Pennington, 1988; Welsh, Pennington, & Groisser, 1991). Early work on infants and primates (Diamond, 1985, 1990a, 1990b; Diamond & Goldman-Rakic, 1985, 1989) suggested that in humans the prefrontal cortex is operative as early as the 1st year of life. This foundational work led other researchers to investigate the early development of EF (Welsh & Pennington, 1988; Welsh et al., 1991). During this period, one of the obstacles to the study of EF in very young children was the lack of age-appropriate EF tasks. Innovative adaptations of adult tasks and the creation of new tasks have resulted more recently in a proliferation of research on EF in the preschool years (Diamond, 1991; Espy, 1997; Frye, Zelazo, & Palfai, 1995; Gerstadt, Hong, & Diamond, 1994; Hughes, 1998a, 1998b; Kochanska, Murray, Jacques, Koenig, & Vandeceest, 1996).

A remaining challenge is the need for an EF framework to serve as a basis for conceptualizing results from the field and designing new child-appropriate tasks. Many of the tasks for adults are complex, involving multiple operations. One challenge is that when simplifying a task to make it more age-appropriate for young children, it is difficult to know whether the critical EF component has been retained. The adoption of an EF framework can therefore guide researchers not only at the interpretation stage but also when creating new tasks.

In this article we review the literature on EF development during the preschool period using the integrative EF framework proposed by Miyake et al. (2000). In this framework, EF is organized hierarchically and is conceptualized as consisting of both a unitary construct and dissociable components. We begin by elaborating on this integrative framework and by providing a rationale for its use in understanding EF development in young children. We then review the empirical findings on preschoolers using this framework as a guide. Although we look at aspects of EF development from infancy to year 5, our review focuses on the preschool years, defined for our purpose as ages 3 to 5.

Throughout this article we refer to frontal networks underlying the components of EF. Although a detailed discussion of these networks is beyond the scope of this article (for reviews, see Casey, Galvan, & Hare, 2005, and Nelson, de Haan, & Thomas,

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2006), reference is made to them in order to support and enrich our discussion of the cognitive processes underlying EF development. The increasingly sophisticated work into the brain networks underlying EF not only provides further evidence for the proposed EF framework but also clarifies the nature of the EF structure.

## Description of and Rationale for an Integrative Framework

Historically, there have been two broad approaches to the development of EF frameworks. The first considers EF as a unitary construct with constituent subprocesses (e.g., Baddeley, 1986, 1992; Norman & Shallice, 1986; Shallice, 1988). For instance, in both Baddeley's (1986) and Norman and Shallice's theories (1986; also see Shallice, 1988), a central attention system is thought to regulate various subprocesses (Baddeley, 1986; Norman & Shallice, 1986; Shallice, 1988). Developmentally, Posner and Rothbart have also argued that a central attention system underlies the important changes taking place in EF control from 2 to 6 years (Posner & Rothbart, 1998; Rothbart & Posner, 2001). In contrast to a central attention system, Dempster (1992) has suggested that a general inhibitory process is responsible for developmental changes in EFs.

There is a wealth of evidence supporting the unitary EF view. First, a consistent finding in the literature is that different measures of EF are intercorrelated for both children and adults, suggesting a common process (Carlson, Mandell, & Williams, 2004; Diamond, Prevor, Callender, & Druin, 1997; Friedman & Miyake, 2004; Hughes, 1998a, 1998b; Hughes & Ensor, 2005; Kochanska et al., 1996; Lehto, Juujärvi, Kooistra, & Pulkkinen, 2003; Miyake et al., 2000). Evidence indicates further that performance on a variety of EF tasks is highly correlated with a central attention process (Engle, Tuholski, Laughlin, & Conway, 1999; Kane, Bleckley, Conway, & Engle, 2001; Kane & Engle, 2000; Roberts, Hager, & Heron, 1994; Rosen & Engle, 1998). Finally, there seems to be a general developmental spurt in the performance of many EF tasks at certain ages, notably the 3- to 6-year-old period (Carlson, 2005; Diamond, 2001; Rothbart & Posner, 2001).

The second broad theoretical approach emphasizes dissociable EF processes, those most frequently cited in the developmental literature being working memory and inhibition (e.g., Carlson & Moses, 2001; Diamond, 1991; Pennington, 1997; Welsh et al., 1991). Diamond (2001, 2002), for example, argues that working memory and inhibition are dissociable components that have different developmental trajectories. In support of this view, variation exists in the developmental timing of various EF abilities (Archibald & Kerns, 1999; Carlson, 2005; Klenberg, Korman, & Lahti-Nuuttila, 2001; Luciana & Nelson, 1998, 2002; Murray & Kochanska, 2002; Rosso, Young, Femia, & Yurgelun-Todd, 2004; Welsh et al., 1991).

Many proponents of the componential view have used factor analysis to delineate component EFs (e.g., Hughes, 1998a; Pennington, 1997; Welsh et al., 1991). Findings from this work indicate that performance on different EF tasks clusters into distinct functional domains (Carlson & Moses, 2001; Collette et al., 2005; Espy, Kaufmann, & Glisky, 1999; Friedman & Miyake, 2004; Hughes, 1998a; Lehto et al., 2003; Miyake et al., 2000; Murray & Kochanska, 2002; Pennington, 1997; Welsh et al., 1991). Other researchers have divided EF components on the basis of prefrontal networks (Casey, Durston, & Fossella, 2001). Evidence from neuropsychological studies of patients with lesions of the prefrontal cortex indicates that different EF processes have differential associations with areas of the prefrontal cortex (V. Anderson, Levin, & Jacobs, 2002; Brookshire, Levin, Song, & Zhang, 2004; Chow & Cummings, 1999; Eslinger, Biddle, & Grattan, 1997; Rolls, Hornak, Wade, & McGrath, 1994; Stuss et al., 2002).

Over the last decade, with accumulating evidence to support both unitary and componential views of EF, the literature has shifted toward the integration of these perspectives (Baddeley, 2002; Collette et al., 2005; Friedman & Miyake, 2004; Knight & Stuss, 2002; Lehto et al., 2003; Miyake et al., 2000; Shallice, 2002). This is well represented by the integrative EF model proposed by Miyake et al. (2000). Miyake et al. have argued for a common EF mechanism, similar to either executive attention (Baddeley, 1986; Engle, Kane, & Tuholski., 1999; Norman & Shallice, 1986) or a central inhibitory system (Dempster, 1992), as well as partially dissociable EF components.

Although there is evidence for both unitary and componential views of EF, only recently have the two views been compared systematically. Miyake et al. (2000) used confirmatory factor analysis (CFA), a structural equation modeling technique, to assess the validity of their model. One of the strengths of CFA is that it is theory driven, and thus researchers can explicitly test their model against competing models. An additional strength is that CFA extracts common variance from measures. Miyake et al. argued that part of the difficulty in studying components of EF is that the measures are not pure. By using different measures of the same EF component and extracting the common variance, the resultant latent variable is assumed to be a purer measure of the EF construct. In reviewing the literature on EF, Miyake et al. found that the most common EF components were mental set shifting, information updating and monitoring (which has been interpreted by most authors as working memory), and inhibition of prepotent responses. For each of these components, they used three common EF measures (see Table 1 for task descriptions). The best model was one in which the three latent EF variables were partially independent but still correlated with one another. Further, this model was a better fit than a model in which the three EF variables were completely independent or one in which all measures formed a single central EF component. Finally, the latent variables were associated with more complex EF tasks such as the Wisconsin Card Sorting Test and the Tower of Hanoi.

Recently, Lehto et al. (2003) applied this model to children. In 8- to 13-year-olds, EF measures were found to cluster into three factors: working memory, set shifting, and inhibition. Again, a CFA indicated that the best fit was a model with three partially dissociable but moderately intercorrelated latent variables. In a more recent study that used CFA on data from a sample of age 7 to 21, Huizinga, Dolan, and van der Molen (2006) found partial support for Miyake's model. Like Lehto et al., they found evidence of dissociation between the measures underlying the three EF components. An advantage of this study was that Huizinga et al. conducted a multiple-group CFA in order to compare latent factors across development. However, whereas two latent variables could be extracted from the working memory and set-shifting measures, this was not the case for the three inhibition measures, which did not load onto a common factor. It is possible that the wide age

Table 1
*Description of Tasks Used in Miyake et al. (2000)*

| Task | Description | EF component |
|---|---|---|
| Keep track | Participants saw several lists and were asked to keep track of the last item of each list, which they had to write down at the end of the trial. | Working memory |
| Tone monitoring | Participants were presented with low, medium, and high pitched tones. They were asked to respond after hearing a particular pitch for the fourth time. They had to keep track of how many times each particular pitch was presented. | Working memory |
| Letter memory | Several letters were presented serially and participants were asked to recall the last four letters of each list. As letters were added to the list, participants had to rehearse out loud the last four letters by adding the most recent letter and dropping the fifth letter back. | Working memory |
| Antisaccade | A visual cue was presented to the left or right on a screen, followed by a target (arrow) on the contralateral side. Participants were asked to inhibit looking at the cue and respond to the arrow target by pressing a button indicating the direction of the arrow. | Inhibition |
| Stop signal | Two blocks of trials were used. In the first block, participants had to perform a categorization task. In the second block, participants were asked to inhibit doing the task when they heard a computer tone. | Inhibition |
| Stroop | Participants were asked to verbally name the color of a stimulus as quickly as possible. Incongruent trials included color words printed in a different color (e.g., *BLUE* printed in red color). | Inhibition |
| Plus–minus | Three lists of numbers were used. On the first, participants added 3 to each number; on the second, participants subtracted 3 from each number; on the third, they alternated between adding and subtracting. | Shifting |
| Number–letter | Number–letter pairs were presented in one of four quadrants. For upper quadrants, participants indicated whether the number was odd or even. For lower quadrants, participants indicated whether the letter was a vowel or consonant. | Shifting |
| Local–global | A global figure made up of small local figures was shown on the screen. If it was blue, participants said the number of lines in the global figure. If it was black, they said the number of lines in the local figure. | Shifting |

*Note.* EF = executive function.

range used in this study may have complicated the results, as variance in task performance would be due to development in addition to component EFs. Nonetheless, using the three inhibition measures in the model along with two latent factors (working memory and shifting), Huizinga et al. still found an adequate fit for a model with dissociable EF components that were modestly correlated. More important, they found that the same common underlying factors were evident over separate age groups, providing support for the stability of executive components over middle childhood, adolescence, and adulthood.

Miyake et al. (2000) offer a framework within which to integrate current developmental theories of EF, which, like those proposed for adults, have focused on either unitary or componential aspects of EF (see Table 2). Munakata's (2001) theory, for instance, emphasizes the unitary nature of changes in EF during early childhood. She posits that there are two main types of representations: latent and active. Active representations are more strongly associated with attention and working memory, whereas latent representations are more strongly associated with habits and long-term memory storage. The latent memory system develops early, and the active memory system develops slowly over childhood. These two types of representations interact, and when there is a conflict between the two, a stronger active representation is required to overcome the latent representation. Another developmental theory that considers EF as a unified construct is the cognitive complexity and control theory proposed by Zelazo and his colleagues (Zelazo & Frye, 1998; Zelazo & Müller, 2002). As in Munakata's theory, the cognitive complexity and control theory focuses on the representation of information and how this changes over development. Zelazo et al. propose that during the preschool period, rule representation becomes more hierarchical. Perseveration occurs because young children do not have an integrated representation of incompatible rules, resulting in discrepancies between what they know and what they do. Toward the end of the preschool period, however, children become able to reflect on rules, integrating conflicting elements of knowledge into a more complex rule system (Zelazo, Qu, & Müller, 2005).

In contrast to the previous two theories, Diamond (2006b) takes a componential view of EF development, noting that working memory, inhibition, and cognitive flexibility (shifting) show different developmental trajectories. Nonetheless, her research has indicated that an overarching ability to coordinate EF components follows its own developmental trajectory, with growth spurts occurring in the last half of the 1st year and from 3 to 6 years of age (Diamond, 2001; Diamond et al., 1997). Like the latent/active representation and cognitive complexity and control theories, Diamond emphasizes that difficulty overcoming conflict is the root cause of perseverative behavior in young children. She describes EF as the ability to overcome automatic, prepotent behavior despite the pull of previous experience (Diamond, 1985, 2001). Thus, in all three of these theories, the ability to deal with conflict during information processing is considered a critical EF development during the preschool period.

Posner and Rothbart's developmental theory of attention provides additional insight into the potential role that conflict resolution plays in the development of EF (Posner & Rothbart, 2007; Rothbart & Posner, 2001, 2006). They propose that the anterior attention system is important for EF and have, in fact, termed it the "executive attention network" (Rothbart & Posner, 2001). The executive attention network is hypothesized to resolve conflict by

Table 2
*Comparison of Three Developmental Executive Function Theories With the Miyake et al. (2000) Hierarchical Model*

| Theory | Cognitive complexity and control | Graded representation | Dissociable EFs | Hierarchical model of EF |
|---|---|---|---|---|
| Proponents | Zelazo & Frye (1998) | Munakata (2001) | Diamond (2006b) | Miyake et al. (2000) |
| Definition of EF | Goal-directed behavior | Flexible behavior/thought | The ability to use a representation to guide behavior despite pull of previous experience | General purpose control mechanism that modulates cognition |
| Organization of EF components | • During development, rules become gradually more hierarchically organized<br>• At 2 years, children can represent one arbitrary rule<br>• At 3 years, children can represent a pair of arbitrary rules<br>• A higher order rule representation at 4 years allows children to integrate incompatible (conflicting) rules | • Multiple systems of representations<br>• Representations are graded, not all or nothing<br>• Two main types: latent and active representations<br>• Latent representations develop earlier and reflect gradual learning<br>• Active representations develop later and provide top-down support<br>• Active representations are used to maintain and manipulate information<br>• Active representations are linked to memory and attention | • Three separate components<br>• Working memory, inhibition, and cognitive flexibility are dissociable processes<br>• They show separate developmental paths<br>• These components interact<br>• Attention is important in all three components | • Evidence for both unity and diversity of EF<br>• Inhibition, working memory, and shifting are separable but moderately correlated<br>• Best model is partially dissociable EF components that have a common underlying mechanism<br>• Common mechanism could be attention/activation or inhibition |
| Role of conflict in perseveration | Perseveration occurs when<br>• child cannot represent a hierarchical rule structure that integrates two conflicting rules | Perseveration occurs when<br>• conflict exists between active and latent representations *and*<br>• active representation is weak | Perseveration occurs when<br>• conflict exists between representation held in mind and prepotent thought/behavior *or*<br>• conflict exists between two mental sets | • Not directly addressed<br>• All tasks used in CFA have some degree of conflict |
| Developmental account of EF changes | Hierarchy of rule representation | Weak active representation | Coordination of EF components | Not addressed |

*Note.* EF = executive function; CFA = confirmatory factor analysis.

regulating other brain networks (Rothbart & Posner, 2006). Moreover, Posner, Rothbart, and their colleagues have found major improvements in the central executive attention network during the preschool period (Rothbart, Ellis, Rueda, & Posner, 2003; Rueda, Posner, Rothbart, & Davis-Stober, 2004). Taken together, these developmental theories complement the claims of Miyake et al. (2000) not only in proposing a common process underlying early development of EF but also in emphasizing the critical role of attention in the development of its structure.

Indeed, the findings in early EF development indicate that maturation of attentional capacity forms a foundation for the development of EF abilities during the preschool period and, in fact, may be the source of common variance underlying various EF skills. For example, differences in attention during infancy predict later ability to inhibit responses (Sethi, Mischel, Aber, Shoda, & Rodriguez, 2000). Similarly, performance on attention control tasks has been found to differentiate preschoolers with low and high working memory span (Espy & Bull, 2005). Finally, the manipulation of attention in set-shifting sets has a significant effect on the performance of children 12 months to 4 years old (Kirkham, Cruess, & Diamond, 2003; Thelen, Schöner, Scheier, & Smith, 2001; Zelazo, Müller, Frye, & Marcovitch, 2003).

Following Miyake et al. (2000) and in line with evidence from both children and adults, we have adopted an integrative model for our review of the literature on EF development during the preschool period. Table 3 provides a brief description of the EF tasks we review. We have focused on the three EF components specified by Miyake et al.: updating/working memory, response inhibition, and set shifting. Given that attention has been widely viewed as pivotal to the construct of a central executive (Baddeley, 2002; Conway & Engle, 1994; Kane & Engle, 2003), we begin by providing an overview of the development of attention. We then review the empirical work on each of the three EF components during the preschool period. Within each section, we focus on studies that have examined age-related differences and changes in EF components using either cross-sectional or longitudinal designs. Research on EF development during the preschool period is largely based on cross-sectional designs, although longitudinal exceptions will be highlighted throughout our review. Finally, we end by identifying common themes and directions for research aimed at better understanding of early EF development.

## The Development of Attention

The attention system is a complex network of interconnected subsystems (Posner & Fan, in press). During the preschool period, there are important developments in two of these subsystems that have major implications for the support of EFs. The development of these two subsystems and their interconnections enables preschoolers to progressively exert more voluntary control over their thoughts and behavior.

The ability to focus on a task and ignore irrelevant information in the environment is a necessary first step in any goal-directed behavior. Accumulating evidence indicates that focusing attention regulates activity in the primary sensory areas by enhancing target-relevant information and reducing target-irrelevant information (Iguchi, Hoshi, Tanosaki, Taira, & Hashimoto, 2005; Sarter, Gehring, & Kozak, 2006). Neuroimaging research suggests that there is a core parietal–frontal network, which modulates other brain areas in the service of task demands (see Lepsien & Nobre, 2006, for a review). This leads to a narrowing of the attention "spotlight" to a particular target (Posner & Raichle, 1995). Changes in selective attention during early childhood are due in part to the development of two attention subsystems (Posner & Fan, in press; Rothbart & Posner, 2001; Ruff & Rothbart, 1996). The first is the orienting system, which allows children to orient to stimuli in the external environment and to shift attention. This subsystem shows considerable age differences during the 1st year of life (Colombo, 2001). The anterior attention subsystem develops later during infancy, with major changes occurring between the ages of 2 and 6 years (Harman & Fox, 1997; Rothbart & Posner, 2001). This subsystem selects and enhances processing according to internal representations in part by inhibiting and facilitating the orienting subsystem (Ruff & Rothbart, 1996). These emerging systems contribute to the child's ability to selectively attend to and focus on EF tasks.

Some aspects of selective attention are already in place early during infancy. For instance, correspondence exists between physiological and behavioral indices of focused attention throughout infancy and the preschool period (Ruff & Rothbart, 1996). In both infants and preschoolers, focused attention is characterized by a reduction of heart rate, intense facial expression, and minimal body movement (D. Anderson, Choi, & Lorch, 1987; Oakes, Ross-Sheehy, & Kannass, 2004; Reynolds & Richards, 2007; Richards, 1989; Ruff & Capozzoli, 2003; Ruff, Capozzoli, & Weissberg, 1998). Another similarity evident from infancy throughout the preschool years is that once in a state of focused attention, children are resistant to distractors (Richards, 1985, 1989, 1997; Tellinghuisen & Oakes, 1997).

Naturalistic measures of attention across the infant–preschool period provide an index of the development of focused attention and resistance to distractors (Richards & Anderson, 2004; Richards & Turner, 2001). These paradigms usually involve a high-interest activity such as playing with a novel toy or watching a children's video, with distractors such as other toys or videos appearing in the periphery. For instance, in the distractor paradigm, children watch a video on a monitor while another brief video appears randomly on one of two monitors positioned to the left and right (Richards & Turner, 2001). Measures include heart rate deceleration (an indication of focused attention), length of looking episode, proportion of turns toward a distractor, and latency to look at a distractor. These studies have found that when children are in a state of focused attention, there are no age differences in distractibility between 6 months and 2 years (Oakes et al., 2004; Richards & Turner, 2001) or between 3 and 5 years (D. Anderson et al., 1987).

Many of the changes that occur in selective attention during the preschool years are due to the increased development and control of the anterior attention system over the orienting attention system (Ruff & Rothbart, 1996). One of these changes is the ability to stay in a state of focused attention for a longer period. Although infants behave the same way as older children once their attention is focused, they have difficulty sustaining this state for a long time. Evidence from cross-sectional studies indicates that the length and frequency of attention focus increases from late infancy throughout the preschool period (Lansink, Mintz, & Richards, 2000; Richards, 1989; Richards & Casey, 1991). In one study, Ruff and Capozzoli (2003) used a naturalistic free-play paradigm in which

Table 3
*Description of EF Tasks Given to Preschool Children*

Some believe these tasks only measure short-term memory.

| Task | Description | Age range |
|---|---|---|
| | Simple working memory tasks: Holding information in mind over delay | |
| Delayed response | An object is hidden at one of two (or more) locations, and after delay child must find object. DV: number of correct responses; delay tolerated | 5 months and up |
| Digit/word Span | Child is asked to repeat a list of digits or words. DV: longest sequence repeated correctly | 3 years and up |
| Corsi block span | E taps nine wooden blocks in a pattern, and child is asked to repeat sequence. DV: longest sequence repeated correctly | 3 years and up |
| | Complex working memory tasks: Holding in mind and updating/manipulating information | |
| Stationary pots | Objects are hidden under pots. Children must uncover each pot and avoid going back to one that has already been uncovered. DV: mean number of reaches to open all boxes; mean number of consecutive reaches to same position | 15 months and up |
| Spinning pots | Same as stationary pots except pots are spun after every choice. DV: mean number of reaches to open all boxes; mean number of consecutive reaches to same position | 15 months and up |
| Self-ordered pointing | Children are shown two pictures on a sheet and asked to select one. Then they are shown another sheet with the same two pictures in a different order and asked to select one they did not choose yet. The number of pictures increases until children make two consecutive errors. DV: highest number of pictures on which they succeed | 3 years and up |
| Invisible displacement | A toy is hidden under a small container. The container is moved under one of two larger containers, and the object is left inside. Child is then shown the empty small container. After a delay, the child searches for the object. DV: number correct | 15 months and up |
| Backward digit span | Child is asked to repeat lists of digits or words backward. DV: longest sequence repeated correctly | 3 years and up |
| Backward Corsi span | Same as Corsi except child taps the sequence backward. DV: longest sequence repeated correctly | 3 years and up |
| | Simple response inhibition: Withholding/delay of prepotent or automatic response | |
| Don't paradigm | Child is asked to inhibit a prepotent response. DV: percentage of time child inhibits behavior | 8 months and up |
| Delay of gratification: waiting | Child waits for a larger treat or rings bell for a smaller treat immediately. DV: duration child is able to delay | 2 years and up |
| Delay of gratification: choice | Child chooses between larger, delayed reward and smaller, immediate reward. DV: number of choices to delay | 3 years and up |
| Snack delay | Child must delay the urge to eat a treat until E rings a bell (trials of different durations). DV: number of trials child is able to delay; longest duration child is able to delay | 22 months and up |
| Gift delay (bow) | Child is asked to wait until E returns with a bow (3 min). DV: peeking (failure) | 22 months and up |
| Gift delay (wrap) | Child is asked not to look while E wraps a present noisily (60 s). DV: peeking (failure) | 22 months and up |
| Object retrieval | An object is placed in a transparent box. The opening is located where children cannot reach directly and must detour to get reward. DV: number of successful reaches | 6 months and up |
| Antisaccade | Child is rewarded for producing a saccade to the side contralateral to cue. DV: number of times child inhibits saccade to cue; number of times child produces saccade to contralateral side | 4 months and up |
| | Complex response inhibition: Holding a rule in mind, responding according to this rule, and inhibiting a prepotent response | |
| Bear and dragon | Child must do what bear asks and inhibit doing what dragon asks. DV: number of trials child does not move in response to dragon | 3 years and up |
| Tower | Child must take turns with E when building a tower. DV: proportion of blocks placed by E | 22 months and up |
| Simon says | Similar to bear and dragon. Child does action only when preceded by "Simon says." DV: same as bear and dragon | 4 years and up |
| Shape Stroop | Children are shown pictures of small fruit embedded in larger fruit. When asked to point to a fruit, they must point to small rather than large fruit. DV: number of correct responses | 22 months and up |
| Reverse categorization | Children sort big blocks into big bucket and little blocks into little bucket, then reverse in the "silly" game. DV: number of correct responses | 24 months an up |
| Baby Stroop | After matching small cups and spoons and large cups and spoons, child plays topsy-turvy game: Child matches small "baby" spoon to big cup and "mommy" spoon to small cup. DV: number of correct matches | 2 years and up |
| Grass–snow | Child must point to white when E says "grass" and to green when E says "snow." DV: number of correct points | 3 years and up |
| Day–night | Child must respond "night" to picture of sun and "day" to picture of moon. DV: number of correct responses | 3 years and up |
| Spatial conflict | Target appears on left or right of computer screen, and child presses key with picture of target. Conflict occurs when picture appears on side contralateral to corresponding key. DV: number of correct incompatible vs. compatible trials; reaction time difference on compatible vs. incompatible trials | 2 years and up |

Table 3 (*continued*)

| Task | Description | Age range |
|---|---|---|
| | Complex response inhibition: Holding a rule in mind, responding according to this rule, and inhibiting a prepotent response (*continued*) | |
| Less is more | Child is asked to choose between smaller and larger trays of candy. Child receives tray not pointed to. DV: number of smaller tray selections | 3 years and up |
| Hand game | After imitating E for six correct trials (fist or pointed finger), child must make a gesture opposite the one made by E. DV: number of correct trials | 3 years and up |
| Knock–tap | Anti-imitation game similar to hand game. Child must knock when E taps and tap when E knocks on table. DV: number of correct trials | 3 years and up |
| Detour-reaching box | If yellow light is on, child turns knob to get reward. If green light is on, child must detour and turn the switch down to get reward. DV: number of correct detour sequences | 3 years and up |
| | Response shifting: Forming an arbitrary S-R set in the first phase and shifting to a new S-R set in the second phase | |
| Spatial reversal | While concealed behind a screen, a reward is placed under one of two identical cups. Once reward has been successfully retrieved for a certain number of consecutive trials, side of hiding is reversed. DV: number of trials needed to learn reversal | 23 months and up |
| Object reversal task | Same as spatial reversal except cups differ in color or shape (side counterbalanced) and reversal is based on identity. DV: number of trials needed to learn reversal | 23 months and up |
| A-not-B | In sight of child, a reward is hidden at Location A, and child retrieves reward after a delay. Once child has successfully retrieved object for a number of consecutive trials, object is hidden at Location B. DV: number of correct trials on B; number of errors before success on B; longest delay before fail | 6 months and up |
| Multilocation search | Variation on A-not-B. An object is hidden at one of three locations. After three consecutive correct responses, object is visibly switched to another hiding place and a 10-s delay imposed. DV: number of correct responses after switch; number of perseverative responses | 24 months and up |
| | Attention shifting: Similar to response shifting except the first mental set involves attention to one aspect of the stimuli (e.g., dimension such as color with response) and the shifting phase involves shifting attention to a new aspect of the stimuli | |
| DCCS | Child is shown cards depicting colored shapes that can be sorted according to color or shape. Child must sort according to one dimension and then shift to sort according to the other dimension. DV: number of correct responses on the postswitch phase | 3 years and up |
| Teddy bear task | Similar to DCCS except child is not explicitly told rule but must deduce it from feedback. Postswitch phase differs in that all values change (but retain same dimensions). DV: number of correct responses within 20 trials | 3 years and up |

*Note.* EF = executive function; DV = dependent variable; E = experimenter; S-R = stimulus–response; DCCS = dimension change card sort.

children played with multiple toys and their attention was coded on three levels: casual, settled, and focused. These levels formed a continuum, with *casual attention* defined as looking at a toy but not engaged, *settled attention* defined as steady looking with some physical movement, and *focused attention* defined as intense looking at a toy with very little movement or talking. From 10 to 42 months, there was an increase in time spent in settled attention. From 26 to 42 months, casual attention decreased and focused attention increased in frequency. These findings were taken as evidence for a transitional period, at 26 months, when the anterior attention network is becoming more influential. At 42 months, children were found to increase their attention focus in response to distractors, suggesting enhanced ability to modulate attention in response to task demands. Further developmental changes have been reported between 42 and 50 months, with older children being more readily able to focus attention in structured tasks (Ruff, Capozzoli, & Weissberg, 1998).

There have been only a few longitudinal studies on the development of focused attention during infancy and the preschool period. Results support the findings of cross-sectional studies, suggesting that the duration of focused attention increases linearly from 7 months to 3.5 years (Kannass, Oakes, & Shaddy, 2006; Ruff & Lawson, 1990; Ruff, Lawson, Parinello, & Weissberg, 1990). Kannas et al.'s (2006) findings indicate that there are important developmental changes in the attention systems from 7 to 31 months. This study used two tasks: a free-play paradigm and the peripheral distractor paradigm (described above). Whereas attention measures were correlated across tasks for 31-month-olds, they were not for 7- or 9-month-olds. This suggests that attention systems become more unified over the preschool period, with this process beginning at approximately 9 months. Another interesting finding was that attention was stable from 7 to 9 months and from 9 to 31 months but not from 7 months to 31 months, suggesting important changes in how the attention system is structured from 9 to 31 months. The authors hypothesize that endogenous attention begins to exert greater control after 9 months of age, which is consistent with other findings of important changes in voluntary control of attention around this period (see Ruff & Rothbart, 1996, for a review).

Differences between focusing attention during naturalistic situations and more formal structured tasks are important. Changes in preschoolers' ability to focus during structured tasks probably reflect maturation of the anterior attention subsystem and its control over the orienting subsystem. Studies on preschool versions of the continuous performance task, for example, implicate large improvements in sustained attention focus between 3 and 5 years of age (Akshoomoff, 2002; Corkum, Byrne, & Ellsworth, 1995; Mahone, Pillion, & Hiemenz, 2001). These tasks involve sitting at a table and pressing a button when the target stimulus comes up on a screen. This type of task is monotonous and repetitious and requires a great deal of control over attention processes. Even by 5 years, children still make many omission errors (Akshoomoff, 2002), suggesting that the ability to focus and sustain attention under experimenter-demand tasks is just emerging at the end of the preschool period.

One requirement of EF tasks is the need to flexibly shift the focus of attention according to internal goals and task demands. This is particularly difficult for young infants, whose attention is strongly determined by environmental factors such as novelty. Although the ability to exercise voluntary control over shifts of attention is one of the first aspects of selective attention to develop, such control shows considerable development throughout the preschool period (Colombo, 2001; Johnson, Posner, & Rothbart, 1994). At its emergence between 4 to 6 months, it allows infants to shift attention between two objects, and later, during the latter part of the preschool period, to shift between internal representations held in mind and stimuli in the environment (Rothbart & Posner, 2001). The ability to shift between external events and internal representations partially underlies the toddler's ability to recognize the self in the mirror and engage in pretend play, both of which emerge between 18 and 24 months (Nielsen & Dissanayake, 2004).

Although attention focus and shifting show age differences over the preschool period, they seem to initially show separate developmental paths (see Posner, Sheese, Odludas, & Tong, 2006, for a review). In fact, attention focus and attention shifting can be antagonistic processes in some contexts. For instance, the stronger the focus of attention is, the more difficult it is to shift attention. Not surprisingly, during the preschool period, these attention processes are sometimes negatively correlated (Jones, Rothbart, & Posner, 2003). Jones et al. (2003) argued that at this age, these two attentional processes may not yet be integrated. In their study, 3- and 4-year-old children who were rated high in attentional focus and low in attentional shifting were found to do better on an inhibition task. What leads to the integration of these two processes later on in childhood? Jones et al. claimed that these two attentional processes become organized within a common attentional system with the maturation of the anterior attention system.

The ability to resolve conflicts during information processing is hypothesized to be one of the results of this maturing anterior attention system (Rothbart & Posner, 2001). This ability has been taken as the most important milestone in the development of EFs (Rothbart & Posner, 2001). Conflict tasks, in fact, have been regarded as a good measure of how attention directly influences EF (Rothbart & Posner, 2001). Moreover, in most models of cognitive control, the ability to resolve conflicts is crucial (Botvinick, Braver, Barch, Carter, & Cohen, 2001; Cohen, Aston-Jones, & Gilzenrat, 2004; Posner & Fan, in press). Although the mechanism underlying this is still not clear, most theorists have suggested that attention networks resolve conflicts by modifying the activation of other brain networks (Miller & Cohen, 2001). As such, the ability to resolve conflict may be seen as a special function of selective attention, which helps children increase focus on a particular stimulus in the service of task demands. The ability to resolve conflicts develops slowly in the first 2 years, showing marked increases in development after this period until about 6 years of age (Clohessy, Posner, & Rothbart, 2001; Gerardi-Caulton, 2000; Rothbart et al., 2003; Rueda, Fan, et al., 2004; for a review, see Rueda, Posner, & Rothbart, 2005). As we note in the sections on specific EF components, the age at which the ability to resolve conflict emerges depends on the type of conflict involved.

In summary, the rudimentary ability to select a stimulus and to focus attention is present early on in infancy. Furthermore, the selective attention of young infants shares many similarities with the more mature selective attention of toddlers and older preschoolers. Once in a state of focused attention, for example, infants and children are resistant to distractors. However, attention is initially dependent on the orienting network and is strongly determined by environmental factors such as novelty. With the development of the anterior attention system toward the end of the 1st year, attention becomes more voluntary and less determined by external factors. The ability to shift attention shows considerable development, with children initially being able to shift between two objects during the 1st year and then being able to shift between internal representations and percepts in the environment during the 2nd year. Other developments during the preschool period include the ability to sustain attention focus for longer periods and to focus attention during structured tasks. The development of conflict resolution shows the most extensive development during the preschool period and is an important aspect of EF development.

These changes in attention allow older preschoolers to form a stronger, longer lasting, and more selective attention set in service of an EF task. One outstanding issue is the developmental course of separate aspects of the attention system and their interaction with one another. Although we have some longitudinal data on the development of attentional focus, we do not have longitudinal data on behavioral tasks involving attentional shifting and conflict. Such data would help us understand how these processes emerge and become integrated over childhood.

Attention seems to play an integral role in the development of EF components, allowing children to increasingly control what information (internal and external) they process. As we shall show, EF components do not appear to develop in parallel but rather build upon already existing networks, with a core attention system serving as a foundation.

## EF Components

### *Working Memory*

Baddeley's (1986, 2000, 2002) model of working memory has probably been the most influential. It comprises a central executive and two storage buffers. The phonological loop is thought to store auditory information, whereas the visual–spatial sketchpad is thought to store visual–spatial information (Baddeley, 1986; Shah & Miyake, 1996). Baddeley's conceptualization of the central executive parallels that of others outlined earlier (Engle, Kane, & Tuholski, 1999; Norman & Shallice, 1986; Shallice, 1988). In Baddeley's model, the central executive is defined in terms of attention (focused, divided, and shifting) and includes active manipulation of information in mind. Both storage buffers are characterized by two functions: passive storage and rehearsal (Baddeley, 2000, 2002; Gathercole, 1998).

Factor analysis of data from children and adolescents indicates that simpler tasks requiring that information be held over a delay and more complex tasks requiring the updating and manipulation of information cluster into separate factors (Alloway, Gathercole, Willis, & Adams, 2004; Gathercole, Pickering, & Ambridge, 2004). Neuroimaging studies have also supported this distinction, suggesting a different pattern of activation for tasks requiring storage and tasks requiring operations on the contents of storage (Smith & Jonides, 1999). For each storage buffer, the passive storage function has been associated with more posterior brain areas, where a stimulus is initially perceived, whereas the rehearsal function has been associated with distinct frontal networks such as Broca's area (Baddeley, 2002; Gathercole, 1999; Gazzaley, Rissman, & D'Esposito, 2004; Smith & Jonides, 1999). Moreover, tasks that require updating or manipulation of information held in mind have been found to activate additional brain regions associated with attention control, particularly the anterior cingulate and dorsolateral prefrontal cortex (Smith & Jonides, 1999).

In the literature, these complex tasks requiring information updating and/or manipulation have become synonymous with working memory and have been used often as a measure of the central executive (Gathercole, 1998; Pelphrey & Reznick, 2002). Baddeley has suggested that these complex tasks require the coordination of a central executive (attention system) with systems involved in simple holding in mind (Baddeley, 1986). However, before information can be actively manipulated in mind, infants must be able to hold the information in mind over a delay. We review the literature on the development of this simpler ability before moving on to the more complex.

The most common task used to assess holding in mind during infancy is the delayed response task. In this task, a toy is hidden at one of two possible locations, with the location randomly determined from trial to trial. There is evidence from cross-sectional studies that some capacity to hold a representation in mind over a delay develops before 6 months (Johnson, 2005; Pelphrey et al., 2004; Reznick, Morrow, Goldman, & Snyder, 2004; see also Pelphrey & Reznick, 2002, for a review). What appears to develop after this age is the length of time that representations can be held in mind and the number of items that can be retained (Pelphrey & Reznick, 2002). Longitudinal data from a study by Diamond and Doar (1989) on the delayed response task indicate an increase in the number of seconds infants are able to hold a simple representation in mind in the last half of the 1st year. Whereas 6-month-olds are able to retain a representation for a few seconds, this capacity increases to over 10 seconds by 12 months of age. Slaughter and Boh (2001) found that the type of representation affects how long infants can hold in mind. Using a modified delayed response task in which the caregiver rather than the object was hidden, they found that infants 7 to 14 months old could tolerate delays 3 to 5 times longer when caregivers were hidden. One explanation for these results is that working memory load is reduced when the caregiver rather than an object is hidden because the representation of the caregiver is already well established in infants. Finally, a cross-sectional study by Pelphrey et al. (2004) found that by 12 months, infants were able to find objects in a delayed response task when there were four possible locations, indicating an improvement in memory capacity (number of items held in mind).

After 2 years of age, the ability to hold information in mind over a delay is assessed with span tasks, such as the phonological and spatial span tasks used to assess the phonological loop and visual–spatial sketchpad. Several cross-sectional studies have found that the number of items retained differs from 3 to 5 years of age, whether using digit or word span tasks (Bull, Espy, & Senn, 2004; Davis & Pratt, 1995; Espy & Bull, 2005; Gathercole, 1998, 1999; Keenan, 1998) or object or spatial span tasks (Ewing-Cobbs, Prasad, Landry, & Kramer, 2004; Keenan, 1998; Kemps, Rammelaere, & Desmet, 2000; Luciana, 2003). However, for both digit–word and object–spatial spans, capacity continues to improve after the preschool period (e.g., 4 blocks at 5 years to 14 blocks at 11 years; Gathercole, 1998).

Updating information that is held in mind develops later than simple retention. An example of an updating task is self-ordered pointing (SOP; Petrides, 1995), which has been adapted for preschoolers as the box–cup scramble (Diamond et al., 1997; Hughes, 1998a, 1998b; McEvoy, Rogers, & Pennington, 1993). In SOP tasks, rewards are hidden under cups; a screen is lowered after each choice, and children must keep track of which cups they have uncovered in order to search efficiently. The child's ability to update spatial memory is assessed when the cups are stationary. When the cups are scrambled after each trial, the child's ability to update object memory is assessed. Developmental improvements from 15 to 30 months in both abilities have been documented in a longitudinal study (Diamond et al., 1997). Cross-sectional studies suggest further development between 3 and 5 years of age, as children become more accurate on SOP tasks (Diamond, 1991; Ewing-Cobbs et al., 2004; Luciana, 2003; Luciana & Nelson, 1998, 2002) and are increasingly able to keep track of and update a larger number of items in mind (i.e., 4.5–6.7 items; Hongwanishkul, Happaney, Lee, & Zelazo, 2005). In a longitudinal study, Diamond et al. (1997) found age improvements in a six-box stationary task from 3.5 to 7 years. Similarly, in another longitudinal study from 3 to 4 years, Hughes (1998b) found age improvement in the ability to update working memory using the noisy book task, in which children repeated different noise sequences by pressing buttons that made various animal sounds.

There are few tasks for children younger than 3 years that involve manipulation of a representation in mind, a notable example of which is the invisible displacement task (Corrigan, 1981). In single displacement trials, an object is hidden under a small container at the child's midline. The container is then moved to one of two larger containers to the child's left or right, and the toy left under the larger container. The child is then shown the empty small container and asked to find the toy. Double displacements involve moving the small container under both larger containers. In order to keep track of the toy, the child needs to manipulate the representation of the object being hidden under the small container. It is not until 24 months that children are able to pass this task (Call, 2001; Collier-Baker & Suddendorf, 2006; Corrigan, 1981; Triana & Pasnak, 1986; Ross, Boatright, Auld, & Nass, 1996).

Backward span tasks are also used to assess the ability to manipulate representations in mind. In these tasks, children have to recall a sequence in reverse order. Verbal versions of this task include backward word and digit span (Carlson, Moses, & Breton, 2002; Davis & Pratt, 1995; Perner, Lang, & Kloo, 2002), whereas the backward Corsi span is a spatial version (Pickering, Gathercole, & Peaker, 1998). The number of items that children can remember backward improves between the ages of 3 and 5 years (from 1.58 to 2.88 items; Carlson, 2005; Carlson et al., 2002) and beyond (Davis & Pratt, 1995; Gathercole, 1998; Perner et al., 2002). It is interesting to note that the manipulation of verbal and visual information shows different developmental paths, providing support for the idea of separate "slave" systems (Gathercole, 1998).

In summary, the ability to hold a representation over a delay develops before 6 months of age (Pelphrey & Reznick, 2002). Over the preschool period, children gradually can hold more items in mind (Gathercole, 1998), and the evidence suggests improvement in both the phonological loop and visual–spatial sketchpad (Bull et al., 2004; Davis & Pratt, 1995; Espy & Bull, 2005; Ewing-Cobbs et al., 2004; Gathercole, 1998, 1999; Keenan, 1998; Kemps et al., 2000; Luciana, 2003). Capacity continues to increase beyond the preschool years (Luciana, 2003; Rasmussen & Bisanz, 2005). More complex working memory abilities such as updating or manipulating representations develop later in infancy (in the 2nd year), and there is continued development throughout the preschool period (Alloway et al., 2004; Gathercole, 1998). These abilities are thought to more strongly reflect the functioning of a central attention system, and their improvement implicates changes in the coordination of the developing attention system and systems involved in storage.

Relatively little research has been done on more complex working memory tasks in children under 3 years of age. Furthermore, whereas tasks requiring holding in mind rather than more complex aspects of working memory have been shown to cluster into separate factors in older children (Gathercole et al., 2004), we do not yet know whether this is the case in younger preschoolers. At present, we are limited both by the tasks that are available for this age group and by the difficulty of giving multiple tasks to young children.

Finally, the lack of longitudinal data on working memory precludes firm conclusions about the developmental pattern of working memory. In particular, one needs longitudinal data on simple and complex working memory tasks in order to draw conclusions about whether complex working memory tasks build upon simpler working memory abilities and skills. A related issue requiring further exploration is the relation between attention development and working memory, as has been demonstrated in adults (Awh & Jonides, 2001; Engle, Kane, & Tuholski, 1999). Recently, Espy and Bull (2005) have reported that the ability to control attention differentiates high- and low-span children. There is also evidence that during a delayed response task, infants are able to tolerate longer delays when not distracted and allowed to continue to fixate the object location (Diamond & Doar, 1989). This suggests a particularly important role of attention in working memory starting very early in life. Further research in this area would provide insight into what aspects of attention affect working memory development.

### *Response Inhibition*

Response inhibition involves withholding or restraint of a motor response. This is probably one of the most extensively researched EF components in preschoolers. In the last decade, several child-appropriate response inhibition tasks have been created. Kochanska and her colleagues in particular have amassed a wealth of longitudinal data on the development of response inhibition from 8 months to school entry (Kochanska et al., 1996; Kochanska, Murray, & Coy, 1997; Kochanska, Murray, & Harlan, 2000; Kochanska, Tjebkes, & Forman, 1998). Recently, Carlson (2005) has provided cross-sectional data on 602 preschool children from a battery of tasks that require response inhibition. She not only looked at age-related differences but also compared performance across tasks, providing insight into their relative difficulty. In examining developmental trends in response inhibition, we therefore rely heavily on work done by both of these researchers.

Ironically, one of the challenges in understanding the development of response inhibition is the multitude of response inhibition tasks. Many of the tasks involve working memory in addition to response inhibition. Such tasks examine a child's ability to use a rule to exert control over behavior. Some authors have argued for the importance of the distinction between tasks requiring both inhibition and working memory and tasks that require inhibition alone (Carlson & Moses, 2001; Diamond, 2001, 2002). Empirical evidence supports this distinction. Factor analyses of data from inhibition tasks have consistently indicated that simple and combination inhibition tasks cluster into different factors (Carlson & Moses, 2001; Murray & Kochanska, 2002) and are differently associated with theory of mind (Carlson & Moses, 2001; Carlson et al., 2002; for a review, see Moses, Carlson, & Sabbagh, 2005). As we discuss later, neuroimaging research also supports this distinction (Marsh et al., 2006). For the sake of clarity, we refer to inhibition tasks involving minimal working memory demands as *simple* response inhibition tasks and to those that involve moderate working memory demands as *complex* response inhibition tasks. Given that complex response inhibition tasks build upon abilities required for simple tasks, the latter are reviewed first.

*Simple response inhibition tasks.* The ability to suppress a dominant response develops in the 1st year. The earliest form of response inhibition to emerge is seen when toddlers stop an enjoyable activity in response to a caregiver request. In the "don't" paradigm, the caregiver or experimenter tells the child to suppress a rewarding behavior (e.g., touching an attractive toy; Kochanska & Aksan, 1995). Whereas 8-month-olds are able to inhibit behavior 40% of the time (Kochanska et al., 1998), 22- and 33-month-olds are able to inhibit behavior the majority of the time (78% and 90%, respectively) in this type of situation (Kochanska, 2002).

One of the most popular paradigms for the preschool period is the delay of gratification paradigm, used extensively by Mischel and his colleagues (e.g., Mischel, Ebbesen, & Zeiss, 1973; Mischel & Moore, 1973). There are two main types of delay of gratification paradigms: the waiting and choice tasks (Mischel, 1974). In the typical waiting paradigm, children are shown two treats and told that if they wait the full period, they will get the two treats. However, they can ring a bell at any time and get one treat. Until recently, few studies have examined age differences, and in those that did, no age effects were found (see Mischel, Shoda, & Rodriguez, 1989, for a review; see Toner, Holstein, & Hetherington, 1977, for an exception). However, the preschoolers used in these earlier studies tended to be 3 years and older. More recently, Carlson (2005) has found age differences in her cross-sectional sample from 24 months to 4 years in the length of time children are able to delay. Whereas 50% of 24-month-olds were able to suppress eating a treat for 20 s, 85% of 3-year-olds suppressed the urge for 1 min (Carlson, 2005). This ability appears to improve throughout the preschool period, with 72% of 4-year-olds being able to suppress eating a treat for 5 min (Carlson, 2005). In a series of longitudinal studies, Kochanska and her colleagues have also found similar age developments from 22 to 56 months on waiting tasks (Kochanska et al., 2000, 1996). Other variations of this type of task, which also have shown age improvements, include gift-delay/bow and gift-delay/wrap, where children have to suppress the desire to open or peak at a present (Kochanska et al., 1996).

There has been a resurgence of work on the choice version of the delay of gratification paradigm in the last decade (Moore & Lemmon, 2001). In this paradigm, preschoolers choose between a small reward now and a larger reward for later. The number of times the preschooler chooses to delay is used as the dependent measure. Cross-sectional studies have found age differences in the number of choices to delay for a larger reward from 3 to 5 years (Lemmon & Moore, 2001; Lemmon & Moore, 2007; Moore, Barresi, & Thompson, 1998; Thompson, Barresi, & Moore, 1997). Not only do 4-year-olds choose the delayed, larger option more often, but their choices also reflect a consideration of size differences between the immediate and delayed options (Lemmon & Moore, 2007).

Some inhibition tasks involve overcoming responses that are automatic rather than reinforcing. In the object retrieval task (Diamond, 1990a), children are asked to retrieve an object from a clear container through an opening on the side. The child must inhibit the tendency to reach directly in a straight line for the object (dominant response) and instead retrieve it through the side opening. This sets up a conflict between a dominant and a subdominant response. Diamond (1990a) conducted a longitudinal study using this task and found considerable improvement from 6.5 to 12 months. In fact, it is not until 12 months that children pass this task without adult assistance. This task is the earliest type of response conflict that children are able to resolve. Another early example of a task involving response conflict is the antisaccade task. In the standard antisaccade task, participants are asked to inhibit a reflexive saccade to a lateral stimulus and instead execute a subdominant response to the opposite side. Some aspects of this ability to deal with conflict are evident during the 1st year. For instance, Johnson (1995) created a unique antisaccade task for infants. Findings indicated that 4-month-olds can inhibit a reflexive saccade but are still unable to execute a saccade to the contralateral side, even when the cue has disappeared. It is not until 12 to 18 months that children are able to overcome this conflict and produce an antisaccade (Scerif, Cornish, Wilding, Driver, & Karmiloff-Smith, 2004), coordinating inhibition of an automatic response with activation of an incompatible response.

*Complex response inhibition tasks.* Complex tasks involve holding an arbitrary rule in mind, responding according to this rule, and inhibiting a dominant response. In this respect, many of these tasks require some verbal control of behavior. In the bear and dragon game, for instance, children are asked to perform the action suggested by one puppet and to inhibit the actions suggested by another puppet (Reed, Pien, & Rothbart, 1984). Children have to suppress a natural inclination to do what they are told, which is particularly difficult when they are already following one direction. Virtually every study that has looked at this and similar tasks has found age differences from 3 to 5 years (Carlson, 2005; Carlson & Moses, 2001; Carlson et al., 2002; Carlson, Moses, & Claxton, 2004; Cole & Mitchell, 2000; Diamond, 1991; Dowsett & Livesey, 2000; Jones et al., 2003; Keenan, 1998; Reed et al., 1984; Strommen, 1973). These cross-sectional findings of age differences are also supported by longitudinal findings of age changes (Kochanska et al., 1996, 1997). However, Carlson's (2005) data indicate that this ability develops quickly at 3 years of age: Whereas only 51% of young 3s pass this task, the number jumps to 76% for older 3s (Carlson, 2005), suggesting a sudden increase in the ability to coordinate inhibition and activation during this age period. More difficult versions of initiating–suppressing tasks include tower and Simon says (Murray & Kochanska, 2002), which are challenging even for 4- and 5-year-olds (Carlson, 2005). These tasks are made difficult by increasing the prepotency of the dominant response. For example, Simon says involves inhibiting an action that the experimenter both tells the child to do and demonstrates. Tower, a turn-taking task, involves both doing something fun and inhibiting one's response while waiting for the experimenter to have a turn. Children also show a large improvement on this task at 3 years, with 24% of young 3s, 42% of older 3s, and 67% of young 4s passing the task.

The literature on Stroop-like tasks also suggests that as children get older, they can solve tasks involving larger degrees of conflict. In the standard Stroop task, participants are required to name the color in which words are written rather than read the words (color labels) themselves. In the conflict condition, ink color and word are discrepant, and participants must inhibit the dominant response to read the word. One of the simplest Stroop-like tasks is the shapes task (Kochanska et al., 1996), in which preschoolers are presented with small pictures of fruit embedded in a larger fruit picture (e.g., an apple inside a banana). The child must point to the small fruit as the experimenter names it and inhibit a dominant response to point to the larger fruit. Again, Kochanska's longitudinal research supports development in this ability from 24 months onward (Kochanska et al., 1996, 1997). A more difficult Stroop task, involving inhibition of a stronger prepotent response, is the reverse categorization task (Carlson, Mandell, & Williams, 2004). This task involves sorting by putting small blocks in a small bucket and large blocks in a large bucket and then sorting in the opposite manner. Carlson (2005) reported that only 20% of 2-year-olds pass this task, whereas about 85% of 3-year-olds are successful. Moreover, improvements from 2 to 3 years of age have been documented longitudinally on this task (Carlson, Mandell, & Williams, 2004). Hughes's (2007) longitudinal data also show significant age improvements from 2 to 4 years on the baby Stroop task. This task, developed by Hughes and Ensor (2005), involves having children match spoons and bowls according to size (large and small) and then sort large spoons with small bowls and small spoons with large bowls in the "silly" game.

Whereas the majority of 3-year-olds pass the reverse categorization task, they have much more difficulty with another Stroop-task, the grass–snow task, with only 45% of 3-year-olds passing (Carlson, 2005). It is not until about 4.5 years that 80% of children pass this task (Carlson, 2005). In this task, children must point to white when they hear "grass" and point to green when they hear "snow." The increased difficulty is probably due in part to the higher level conflict (i.e., semantic demand) posed by the grass–snow task. Several cross-sectional studies have shown improved performance between 3 and 5 years on the grass–snow and similar Stroop-like tasks, such as the day–night task (Carlson, 2005; Davidson, Cruess, Diamond, O'Craven, & Savoy, 1999; Diamond, 2001; Diamond, 2002; Diamond & Taylor, 1996; Gerstadt et al., 1994; Keenan, 1998; Simpson, Riggs, & Simon, 2004; but see Carlson & Moses, 2001, and Deák & Narasimham, 2003, for exceptions). Diamond et al. (1997) found significant developmental improvements on the day–night task between 3.5 and 7 years in their longitudinal study.

Other examples of complex tasks include Simon-like tasks (Gerardi-Caulton, 2000), flanker tasks (Rueda, Posner, et al., 2004), less is more (Carlson, Davis, & Leach, 2005), hand game, and knock and tap (Diamond, 1991; Hughes, 1998a; Klenberg et al., 2001). Although these tasks require resolution of different types of conflict (e.g., Simon-like task: location and identity vs. hand game: seeing and doing), they all make similar demands. That is, all require holding a rule in mind, the detection of conflict between dominant and subdominant responses, and a corresponding increase in top-down control (Cohen et al., 2004). Research indicates that various complex tasks show similar developmental profiles during the preschool period, with significant increases in accuracy from 3 to 5 years of age (Blair, Peters, & Granger, 2004; Carlson, 2005; Davidson et al., 1999; Diamond, 1991; Diamond et al., 1997; Diamond & Taylor, 1996; Espy, 1997; Espy, Kaufmann, Glisky, & McDiarmid, 2001; Gerstadt et al., 1994; Hanauer & Brooks, 2003; Kochanska et al., 1997; Rothbart et al., 2003; Rueda, Posner, et al., 2004).

*Hot and cool EFs.* The difference between simple and complex tasks illustrates the distinction between "hot" and "cool" aspects of EFs. Cool EF is elicited in tasks that are cognitive and emotionally neutral, such as working memory tasks, whereas hot EF is elicited in tasks that are motivational in nature, such as reward delay tasks (Metcalfe & Mischel, 1999; Zelazo et al., 2005) Suppressing or redirecting a prepotent response relies heavily on the orbitofrontal network (Rolls, 1999), which has been hypothesized to underlie hot EFs (Zelazo & Müller, 2002). Research implicates the orbitofrontal cortex in reward delay tasks (Roesch & Olson, 2005; Roesch, Taylor, & Schoenbaum, 2006; Winstanley, Theobald, Dalley, Cardinal, & Robbins, 2005), simple inhibition tasks such as object retrieval (Wallis, Dias, Robbins, & Roberts, 2001), and even emotion suppression (Ohira et al., 2006). In contrast, complex response inhibition tasks like the Stroop that require a combination of working memory and suppression of a prepotent response involve networks hypothesized to underlie both hot and cool EFs, including the orbitofrontal cortex, anterior cingulate, and lateral prefrontal cortex (Marsh et al., 2006).

As reviewed earlier, children under 4 years tend to fail many complex tasks. Part of the difficulty may be in using an abstract rule to control behavior, especially when it is a strong prepotent response. Zelazo and his colleagues have suggested that the ability to use language and abstract representations to regulate behavior develops during the preschool period (Zelazo & Frye, 1998; Zelazo, Reznick, & Spinazzola, 1998). This is in keeping with Luria's (1959) theory that difficulty using language to regulate behavior underlies the problems with response inhibition in young children. Metcalfe and Mischel (1999) claimed that an increase in the use of the "cool" system to regulate the "hot" system occurs as children get older.

There is evidence that providing preschoolers with a "cool" strategy helps improve performance on both delay and complex tasks. For instance, Mischel and Baker (1975) found that having children focus on the consummatory aspects of a food reward decreased their ability to delay the reward, whereas focusing on abstract aspects of the reward increased waiting time. On a similar delay of gratification task, asking preschoolers (3- to 6-year-olds) to verbalize the phrase "It is good to wait" allowed them to wait longer than conditions with either no verbalizations or verbalizations focused on the reward (Toner, 1981). In another affective task, Müller, Zelazo, Hood, Leone, and Rohrer (2004) had children choose a small card whose color matched the color of large cards in order to win a candy placed on the large cards. When the color of the candy and card did not match, 3-year-olds tended to choose small cards that matched the candy's color. Müller et al. found that 3-year-olds' performance improved if children labeled the color of the larger card before they chose the smaller card.

Changing aspects of tasks so that they become "cooler" also helps preschoolers. The less is more task (Carlson et al., 2005) involves showing children two trays of candy, one containing a larger number. Children are told that a naughty puppet will receive the tray of candy that they point to and they will get the other tray. They therefore need to point to the tray with fewer candies to get the larger treat. Despite being reminded of the rule, 3-year-olds fail this task. However, Carlson et al. found that replacing the trays with picture symbols (elephant and mouse) representing large and small amounts of candies improved performance considerably. This line of research suggests that making "hot" reinforcers more abstract allows children to inhibit responses to these reinforcers more easily (Metcalfe & Mischel, 1999).

*Summary.* There are a wealth of cross-sectional and longitudinal data on the early development of response inhibition. As with the other EF abilities discussed earlier, a simple form of response inhibition is present during the 1st year. Even 8-month-olds are able to show some inhibition of a naturally occurring prepotent response following a caregiver's prohibitions. The literature suggests that from infancy to the age of 5 years, children gradually become able to inhibit for longer periods and to inhibit both automatic responses and responses associated with a reinforcer. Performance on more complex response inhibition tasks develops later and shows considerable improvement during the preschool period. However, the ability to use a mental representation to regulate behavior is just emerging during this period, and thus even older preschoolers find these tasks challenging. In fact, many 5- and 6-year-old children fail some of the more challenging complex tasks such as Simon says (Carlson, 2005). Providing preschoolers with cool strategies (e.g., labeling) during these tasks has been found to significantly improve performance. This suggests that connections between frontal networks used to represent abstract thought and other regions such as the orbitofrontal cortex and limbic areas are just emerging during the preschool period (Thatcher, 1994).

Whereas response inhibition has been well researched, what remains to be done is a systematic examination of the factors that influence performance on tasks measuring this component of EF. At present, we can compare performance across tasks and hypothesize about which variables make some tasks more difficult. However, because tasks differ in many ways, identifying the variables responsible for developmental changes is often difficult, if not impossible. Systematic manipulation of the strength of the prepotent response in delay tasks, for example, would provide objective evidence of the intuitively appealing idea that there is an age-related change in the ability to overcome stronger responses.

Given that complex tasks involve both working memory and inhibition, they provide a unique opportunity to explore the interaction of the two component processes. Manipulation of these EF components within one task would provide insight into whether they develop separately or together. Some research suggests that for preschool children, inhibition has a more critical impact on performance in complex tasks than does working memory (Diamond, Kirham, & Amso, 2002; Simpson & Riggs, 2005). However, the focus of this work has been on the inhibition component, and it is difficult to equate inhibition and working memory requirements in such tasks. More recent work, which has attempted to equate inhibition and working memory requirements, has found that the performance of young children is influenced more by an increase in response inhibition requirements than by an increase in working memory load (Davidson, Amso, Anderson, & Diamond, 2006).

Finally, another interesting area to explore would be the association of attention and response inhibition. Mischel et al. (1989) suggested that cool strategies help children to delay responses by redirecting their attention. Evidence of an association between effortful control (a measure of attention control) and the development of response inhibition (Kochanska & Knaack, 2003; Kochanska et al., 2000) raises the provocative question of whether manipulating attention would affect performance on complex tasks. There is some evidence that the ability to control attention is important for successful performance on these tasks. Children who are better at redirecting their attention away from rewarding aspects of stimuli have more efficient performance on a complex response inhibition task during adolescence (Eigsti et al., 2006). Moreover, Diamond et al. (2002) found that inserting a distraction (in the form of a song) between the presentation of a stimulus (e.g., picture of night sky) and the response (e.g., say "day") improved performance in preschoolers. It would also be interesting to see whether increasing attentional focus on the prepotent response would be deleterious to performance.

## *Set Shifting*

Set-shifting tasks involve shifting from one "mental set" to another. Regardless of the particular form that they take, all set-shifting tasks involve two phases. The first phase requires participants to form a mental set in which an association is made between a particular stimulus and a response. In forming this set, participants must focus on relevant stimuli and ignore distractors and then hold the mental set (rule) in working memory. Tasks differ on this initial working memory load. The second phase of these tasks involves shifting to a new mental set that in some way conflicts with the first. Tasks may therefore also differ in the amount of conflict that participants have to overcome.

Probably the most important distinction that has been made in the literature concerns the nature or type of shift required (Dias, Robbins, & Roberts, 1996, 1997; Konishi et al., 1998; Nagahama, Fukuyama, & Shibasak, 2002). Shift type is determined by whether the conflict occurs at the perceptual or response stage. Tasks in which there is a change in the rule for selecting between aspects of the stimuli have been labeled *attention shifting*, whereas those that involve a rule change that affects selection of the relevant motor response have been variously labeled *response*, *intention*, or *task shifting* (Rushworth, Passingham, & Nobre, 2005). Research with humans and animals indicates that attention and response shifting are dissociable processes, with response shifting involving more medial frontal areas, and attention shifting, more lateral frontal areas (Brown & Bowman, 2002; Dias et al., 1996, 1997; Fox, Barense, & Baxter, 2003; Rogers, Andrews, Grashby, Brooks, & Robbins, 2000; Rushworth et al., 2005; Sylvester et al., 2003; see Wager, Jonides, & Reading, 2004, for more discussion of these distinctions). In both cases, recent research has suggested that shifting tasks involve frontal–parietal networks (Collette & van der Linden, 2002; Collette et al., 2005; Rushworth et al., 2005; Wager et al., 2004). Moreover, though the attention–response distinction is important, many set-shifting tasks used in the developmental and adult literatures involve both attention and response shifting. For instance, the three set-shifting measures used by Miyake et al. (2000) all rely, to varying degrees, on attention and response shifting. Finally, all attention-shifting tasks involve response shifting in that some stimulus–response (S-R) remapping is required in addition to the perceptual remapping required during the shift phase. Keeping these caveats in mind, we first review the literature on response-shifting tasks, as these are simpler and require fewer processes, and then turn to the literature on attention-shifting tasks.

*Response shifting.* Before we begin, a distinction needs to be made between the *complex response inhibition* tasks discussed earlier in the context of response inhibition and the *response-shifting* tasks discussed here. Many of the complex response inhibition tasks that we reviewed earlier also involve a shift and conflict between two different response sets. For instance, in the hand game (Hughes, 1998a; Luria, 1959), children are asked to imitate the experimenter's hand posture (fist or pointed finger) in the first phase and then to switch to the alternative posture in the next phase. However, response-set-shifting tasks differ from these complex response inhibition tasks in that the initial "response set" is not an already established (prepotent) response. Instead, in response-shifting tasks, the first response set is often quite arbitrary and formed during the first phase of the game. Hence, in this article, we have made a distinction between complex response inhibition and response shifting based on this first stage involving an S-R association learned during the task (response shifting) versus an already established prepotent response (complex response inhibition).

The response reversal task is the simplest example of response shifting. This task places very minimal demands on working memory and involves a very simple S-R remapping. With such limited working memory requirements, this paradigm actually lies on a continuum between simple response inhibition and response-shifting tasks. However, because it involves learning of an arbitrary S-R association in the first phase followed by a shift in the response, it falls more clearly in the response-shifting category (e.g., Dias et al., 1996; Espy et al., 1999). There are several variations of this task. In Overman, Bachevalier, Schuhmann, and Ryan's (1996) object reversal task, the child is presented with two adjacent stimuli over several trials. The child is consistently rewarded for responding to one of the two stimuli so that activation builds for this stimulus. Once the child learns this contingency to criterion, the reward is reversed and applied to the other stimulus (Overman, Bachevalier, Schuhmann, & McDonough-Ryan, 1997; Overman et al., 1996). Children must inhibit their response to the previous stimulus and now respond to a new stimulus. Other examples of this type of task in the preschool literature are response selection, spatial reversal, and color reversal (Brooks, Hanauer, Padowska, & Rosman, 2003; Carlson, 2005; Carlson, Mandell, & Williams, 2004; Casey et al., 2001; Espy et al., 1999, 2001; Kloo & Perner, 2003; Perner & Lang, 2002; Senn, Espy, & Kaufmann, 2004; Silverman, 1966).

Scores on reversal tasks consist of errors to criterion and number of correct trials following reversal. With enough trials in the postshift phase, even 1-year-olds are able to perform such tasks (Overman et al., 1996). Furthermore, although development occurs throughout childhood (Luciana & Nelson, 1998), cross-sectional research indicates that the largest age differences on the reversal task occur between 1 and 3 years (Espy et al., 1999; Overman et al., 1996, 1997). In fact, by 24 months children are already correct on the majority of trials (60%–65%) for color reversal and spatial reversal (Espy et al., 1999), with very little further improvement by 5 years (65%–70% of trials correct; Espy et al., 2001).

The A-not-B task (Diamond, 1985; Piaget, 1954) is another simple response-shifting task and is similar in many respects to the reversal tasks. However, because children are shown where the object is hidden and a delay is imposed between hiding and searching, there is a higher demand on working memory. Another important difference is the ability to learn the S-R association on the basis of feedback. In the reversal task, children have to deduce the rule on the basis of feedback (e.g., always choose on the left) and then change their S-R mapping in the shift phase on the basis of error feedback. Hence, although both tasks involve shifting, they rely on different skills. Espy et al. (1999) found that despite apparent similarities in the two tasks, the A-not-B task did not load on the same factor as the reversal tasks.

In the standard A-not-B task, a toy is hidden in one of two identical wells to the left or right of the infant's midline, and after a delay, the infant is asked to retrieve the toy. This task involves forming a very simple response set in working memory (choose the A side) and then shifting to a new response set (choose the B side). Infants are typically given two or more trials on the A side before the side of hiding is switched to B. When there is a long enough delay between hiding and reaching at B, infants make the A-not-B error, in which they continue to reach for A. Cross-sectional and longitudinal data indicate that performance on the standard A-not-B task improves over the 1st year of life and throughout the preschool years (Thelen et al., 2001). Developmental changes are indexed by the length of delay tolerated, percentage of correct reaches, accuracy of memory for A, and effect of distinctiveness of A and B on task performance. Longitudinal data from Diamond and her colleagues indicate that from 7 months to 12 months, infants show a gradual increase in the delay they can tolerate before making the A-not-B error (Diamond, 1985, 1990b).

Several theorists suggest that the strength of the initial representation affects perseveration (Munakata, 2001; Thelen et al., 2001). Indeed, reviews of the literature on A-not-B have revealed that increasing the strength of the A set (by increasing the number of repetitions) leads to more perseveration on A during the postshift phase (Marcovitch & Zelazo, 1999; Thelen et al., 2001). The operating assumption here is that children will not perseverate on the first set until they form a strong response set. A recent longitudinal study has found that perseveration on the postshift phase increases from 5 to 8 months on a simplified version of the A-not-B task, suggesting that perseveration is actually a developmental stage in the acquisition of flexibility (Clearfield, Diedrich, Smith, & Thelen, 2006). Of interest, recent cross-sectional research also indicates that children continue to make A-not-B errors on the standard form of the task after 12 months of age, but at a very low rate (Espy et al., 1999). Whereas 24-month-olds will reach correctly on 72% of trials with a 10-s delay (Espy et al., 1999), 5-year-olds will reach correctly on 92% of trials (Espy et al., 2001).

Another developmental change in the A-not-B task is the ability to deal with greater similarity between the two hiding locations. Diedrich et al. (2001) found that 9-month-olds made significantly fewer perseverative errors when the B location was made distinct by using a striped lid on the well. Several other studies have found that the distinctiveness of locations A and B has an important impact on accuracy (Diedrich, Highlands, Spahr, Thelen, & Smith, 2001; Horobin & Acredolo, 1986; Schutte, Spencer, & Schöner, 2003; Wellman, Cross, & Bartsch, 1987). In contrast to their performance on the standard A-not-B task (Espy et al., 1999), 2- and 3-year-olds consistently make the A-not-B error when toys are hidden in a sandbox, a novel variant of the A-not-B task in which locations are unmarked (Schutte et al., 2003; Spencer, Smith, & Thelen, 2001; Thelen et al., 2001). Another factor that affects distinctiveness is the distance between A and B locations: The closer the two locations are, the more likely children will make A-not-B errors (Horobin & Acredolo, 1986). Using a cross-sectional design, Schutte et al. (2003) found that whereas 2-year-olds made A-not-B errors when locations were 9 in. apart, 6-year-olds made errors only when they were 2 in. apart.

With improvement in working memory, children can establish more difficult response sets in the preshift phase. One variation of the A-not-B task that increases working memory requirements is the multistep multilocation search task (Zelazo et al., 1998). In this task, the number of hiding locations increases from two to five. Additionally, children have to perform a more complex set of actions to get the toy. In the four-step variation, children have to remove a barrier, pull the tray, choose one of five symbols, and pull a string. In the two-step variation, children perform the last two steps alone. Research to date has indicated that although some 2-year-olds continue to perseverate on this task (Carlson, Mandell, & Williams, 2004; Zelazo et al., 1998), the majority of 2-year-olds show no perseveration (Carlson, 2005; Stahl & Pry, 2005). Furthermore, having more steps during search (four vs. two) does not seem to affect performance (Zelazo et al., 1998). Of interest, the most recent meta-analysis that has been performed on A-not-B task data indicates that an increase in the number of hiding locations does not decrease the number of correct responses on switch trials, and in fact leads to less perseveration because children can now search in locations other than A (Marcovitch & Zelazo, 1999).

This suggests that just increasing overall working memory demands of the set does not affect perseveration. However, there is some evidence that difficulty in motor planning is an important aspect of perseveration on the A-not-B tasks (see Thelen et al., 2001, for a review). For example, Berger (2004) found that 13-month-olds perseverated more on an A-not-B variant that involved descending a staircase compared with a version in which they walked on flat ground. The implication here is that having infants perform a more difficult motor response, notably one that is just emerging, results in increased response perseveration. Berger argued that using a motor response that was just developing increased the amount of attentional resources devoted to motor response, leaving fewer attentional resources for other aspects of the task, such as holding representations in mind.

The emerging ability to inhibit responses enables preschoolers to form an initial response set in which some degree of inhibition is necessary. A good example occurs in the detour-reaching box (Hughes & Russell, 1993). This task is a version of the object retrieval task (Diamond, 1990a), discussed in the *Simple response inhibition tasks* section above, but in this instance intended for older children. As with the infant object retrieval task, children can see the reward (a marble) through a transparent window and must suppress a response to reach directly for the marble. A light on the box serves as a discriminative stimulus. When the light is yellow, children are told that they must turn a knob to get the marble. In this stage, children respond until they reach criterion. The light is then changed to green, and children are told that they must now use a more complicated detour route in order to get the marble. This task is an example of a more difficult response set that goes beyond mapping a simple S-R association in the preshift phase, by requiring, in addition, inhibition of a prepotent response. It is also more difficult in that the new response set involves a two-step process and thus greater demands on working memory. Using a longitudinal design, Hughes (1998b) found improved success on this task from 3 to 4 years of age.

In summary, the literature on A-not-B task variants indicates that various aspects of shifting response set develop during the preschool period. Set-shifting tasks by their very nature build upon the other EF components (i.e., working memory and inhibition). Before children can shift, they must have formed a response set from which to shift. Increasing the strength of this initial response set increases perseveration (Thelen et al., 2001). In this sense, perseveration to the first response set is actually a stage in the development of response shifting (Clearfield et al., 2006). Recent research suggests that this perseveration to the first set has a U-shaped function, with perseveration increasing from 5 to 8 months and decreasing after 12 months (Clearfield et al., 2006; Thelen et al., 2001).

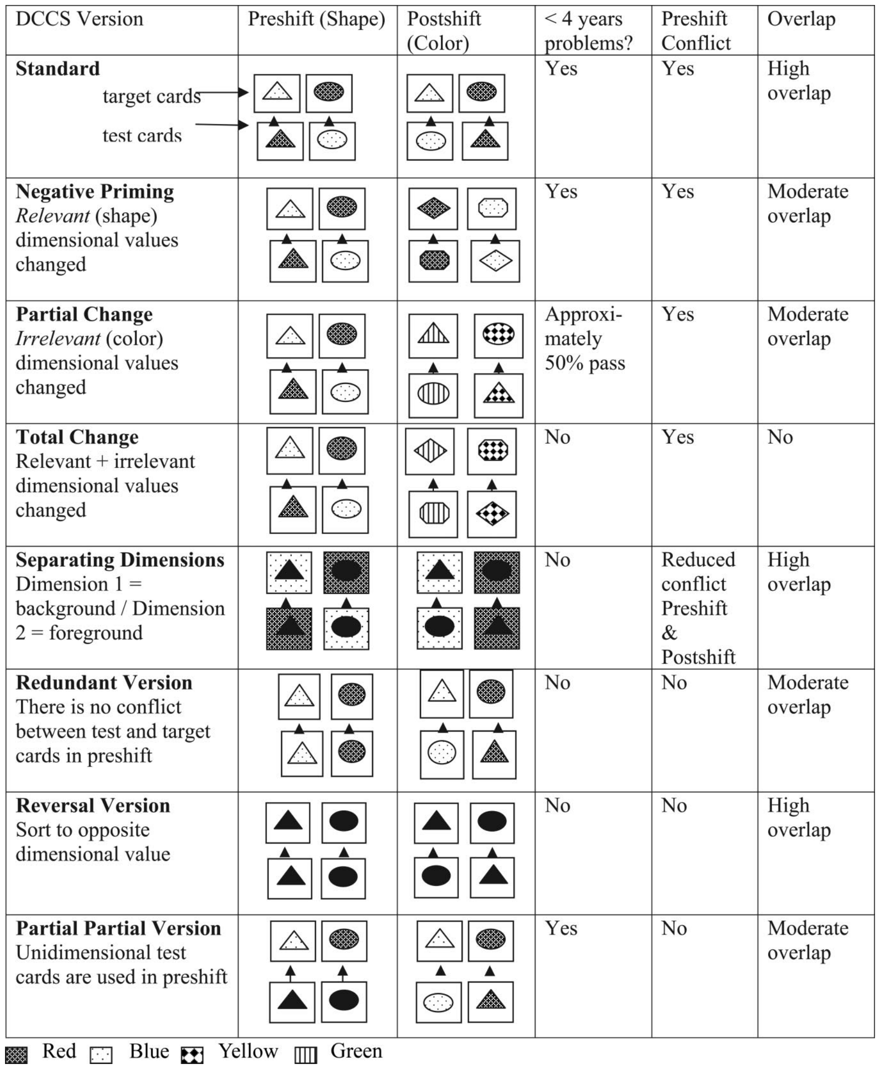
By approximately 12 months, infants are able to shift from an old to a new response set, with a 10-s delay between hiding and search (Diamond & Goldman-Rakic, 1989). However, children continue to make perseverative errors on the standard A-not-B task until approximately 5 years of age. Another development during the later part of the preschool period is an increasing ability to deal with similarity between the A and B locations (Schutte et al., 2003). More similar locations result in increased overlap, and therefore increased conflict, between the first and second response sets. As children approach the end of the preschool period, they become increasingly able to shift to a new response set that more strongly conflicts with the preshift response set. It should be noted that this type of conflict differs from that present in delay and complex response inhibition tasks. Whereas conflict in a complex response inhibition task is between dominant and subdominant responses, the conflict in response set shifting is between the two representations (response sets) held in mind.

There are a variety of important directions for this area of research. Studies on the reversal tasks and the A-not-B tasks indicate that there may be two dissociable aspects to response shifting, with different developmental paths. One skill, S-R learning and remapping, which is emphasized in the reversal tasks, seems to develop quickly, with research indicating most of the developments occurring by 3 years. The other skill, coping with conflicting mental representations held in mind, which is emphasized in A-not-B tasks, seems to develop more slowly and to be more dependent on attention control. At present there are no longitudinal data comparing developmental trajectories of children on these two tasks.

As we learned from the previous section, the ability to delay a response and impose top-down control during a complex response inhibition task develops considerably later, during the latter part of the preschool period (3 to 5 years). This new ability allows children to form stronger response sets, even those involving inhibition of a prepotent response. Because initially establishing such a response set is more difficult, does this affect children's ability to shift to a new response set? Research using the detour-reaching box indicates that there is improvement from 3 to 5 years of age on this task. However, given the paucity of research, we know very little about the nature of this change.

*Attention shifting.* Probably the most popular attention shift task for preschoolers is the dimensional change card sort (DCCS; Frye et al., 1995). Children sort test cards that vary on two dimensions (e.g., shape and color) into two trays with two target cards that also vary on the same two dimensions (see Figure 1). The test cards and target cards conflict on dimensional values (e.g., test cards: red triangle and blue circle; target cards: red circle and blue triangle), so that they can be sorted by either dimension. In the first phase, children are asked to sort the two types of test cards according to one dimension (e.g., color: red triangle card goes with red circle target, and blue circle card goes with blue triangle target). In the second phase, children need to shift and sort according to a new dimension (e.g., shape: red triangle card goes with blue triangle target, and blue circle card goes with red circle target).

The number of cards correctly sorted after the shift phase is the dependent measure. This task does not initially involve learning the abstract rule, as both sets of rules (preshift and shift) are provided by the experimenter. Typically, a child is considered to have passed the task if the majority of postswitch cards are sorted correctly. The pattern of findings for the standard DCCS task is that most 3-year-olds can sort according to the first rule (e.g., color) but cannot shift to a new rule (e.g., shape). After age 4, children are able to shift to a new rule (Carlson, 2005; Carlson & Moses, 2001; Cole & Mitchell, 2000; Dick, Overton, & Kovacs, 2005; Frye et al., 1995; Hongwanishkul et al., 2005; Jacques & Zelazo, 2001; Kirkham et al., 2003; Kloo & Perner, 2005; Müller, Dick, Gela, Overton, & Zelazo, 2006; Perner & Lang, 2002; Perner



| DCCS Version | Preshift (Shape) | Postshift (Color) | < 4 years problems? | Preshift Conflict | Overlap |
|---|---|---|---|---|---|
| **Standard** target cards test cards | | | Yes | Yes | High overlap |
| **Negative Priming** *Relevant* (shape) dimensional values changed | | | Yes | Yes | Moderate overlap |
| **Partial Change** *Irrelevant* (color) dimensional values changed | | | Approxi-mately 50% pass | Yes | Moderate overlap |
| **Total Change** Relevant + irrelevant dimensional values changed | | | No | Yes | No |
| **Separating Dimensions** Dimension 1 = background / Dimension 2 = foreground | | | No | Reduced conflict Preshift & Postshift | High overlap |
| **Redundant Version** There is no conflict between test and target cards in preshift | | | No | No | Moderate overlap |
| **Reversal Version** Sort to opposite dimensional value | | | No | No | High overlap |
| **Partial Partial Version** Unidimensional test cards are used in preshift | | | Yes | No | Moderate overlap |

Red Blue Yellow Green

*Figure 1.* Different versions of the dimensional change card sort (DCCS) task and their characteristics.

et al., 2002; Zelazo, Frye, & Rapus, 1996; see Zelazo et al., 2003, for a review). Studies using other dimension shift tasks have also found improved performance from 3 to 4 years of age (Cepeda, Deák, Sedlik, & Weisser, 2005; Deák, 2000; Deák & Narasimham, 2003; Deák, Ray, & Pick, 2004; Dowsett & Livesey, 2000; Legare & Deák, 2005).

Currently, there are four major interpretations of the deficits of 3-year-olds on the DCCS. Zelazo and Frye (1998) have proposed the cognitive complexity and control theory, arguing that 3-year-olds perseverate on the old dimension because they cannot use higher order, embedded "if–if–then" rules for directing behavior. Kloo and Perner (2005) have proposed the conceptual redescription hypothesis, which explains the 3-year-old failure in terms of difficulty in redescribing the same thing in a different way. Munakata (2001) has offered a graded memory interpretation, arguing that 3-year-olds may fail to shift because their working memory capacity is not strong enough to overcome the conflict between the latent S-R associations formed during the preshift phase. Finally, Kirkham and Diamond (2003) have proposed that 3-year-olds fail because of attentional inertia; that is, they fail to disengage their attention from the previous attention set. Although a resolution of this theoretical debate is beyond the scope of this review, it should be noted that these interpretations have some commonalities. All four interpretations acknowledge that the failure of 3-year-olds stems from a difficulty overcoming conflict. The attentional inertia and redescription accounts emphasize the difficulty 3-year-olds have thinking about something in two different ways. Finally, both the attentional inertia hypothesis and a revised version of the cognitive complexity and control hypothesis (Zelazo et al., 2003) emphasize the importance of selective attention processes.

The debate among these theoretical perspectives has inspired a number of clever studies using the DCCS task. As is the case with A-not-B, the search for cognitive processes underlying performance has led to a number of task variants. For example, researchers have created DCCS versions that have minimized the perceptual conflict and enhanced the response conflict from the pre- to postshift phase. In Perner and Lang's (2002) reversal version (see Figure 1), the first phase requires that children sort cards to targets according to one dimension (e.g., triangle and circle test cards go with their corresponding triangle and circle target cards). In the second phase, children sort test cards to the "opposite" dimensional value (e.g., circle card now goes with triangle target, and triangle card now goes with circle target). Despite the fact that this version contains similar complex rules and working memory demands as the original DCCS, 3-year-olds easily succeed (Brooks et al., 2003, Experiment 1; Kloo, Perner, & Dabernig, 2007; Perner & Lang, 2002). Other studies have shown that response inhibition does not underlie the failure of 3-year-olds on the DCCS (Jacques, Zelazo, Kirkham, & Semcesen, 1999; Perner et al., 2002; Zelazo et al., 1996, Experiment 3). Similarly, working memory alone does not appear to be the critical factor, as children pass various versions that have working memory requirements comparable to those of the standard version (Frye et al., 1995; Perner & Lang, 2002; Zelazo et al., 2003).

Across the various studies, there have been two consistent findings in this literature. Three-year-olds tend to fail the DCCS when (a) there is a perceptual conflict in the preshift phase between test cards and targets and (b) there is overlap or conflict between the mental set formed in the preshift and the mental set required during the postshift phase. The bulk of the findings on the DCCS suggest that these two conditions must be present for 3-year-olds to experience difficulty. We first look at the research on perceptual conflict and then consider the research on mental set overlap.

In the standard version of the DCCS, perceptual conflict occurs because of a mismatch between test cards and targets (e.g., test cards: red triangle and blue circle; targets: blue triangle and red circle). In versions in which there is no mismatch, the performance of 3-year-olds improves dramatically (Perner & Lang, 2002; Rennie, Bull, & Diamond, 2004; Zelazo et al., 2003). For instance, 3-year-olds can easily shift dimensions when they sort test cards without target cards present (Perner & Lang, 2002). Similarly, most 3-year-olds pass the redundant DCCS (see Figure 1), a version in which children sort test cards that are identical to the target card in the preshift phase but conflict in the postshift phase (Zelazo et al., 2003, Experiment 9). Another way to reduce the perceptual conflict between test cards and targets is to separate the dimensions. Separating the two dimensions (see Figure 1), either by placing them side by side on the test card (Kloo & Perner, 2005) or by placing one dimension in the foreground and the other in the background on the test card (Diamond, Carlson, & Beck, 2005), improves performance significantly in young children (although see Zelazo et al., 2003, Experiment 5).

As in adults, increased perceptual conflict in the preshift phase is likely to increase selective attention to the stimulus (Allport & Wylie, 2000). An accepted belief in the literature is that selective attention increases attention focus by inhibiting the activation of irrelevant stimuli and increasing the activation of relevant stimuli (see Tipper, 2001, for a review). Inhibition of attention to a previously irrelevant stimulus value is assessed through negative priming. Negative priming is said to occur when a response to a previously ignored stimulus value is slowed or disrupted on a subsequent trial. Accumulating evidence indicates that inhibition of the irrelevant dimensional value plays a role in the DCCS (Dick, Müller, & Overton, 2003; Gela & Müller, 2003; Müller et al., 2006; Zelazo et al., 2003). To specifically test whether negative priming plays a role in the DCCS, Zelazo et al. (2003, Experiments 8 and 9) created a version in which the previously relevant dimensional value was not used in the shift phase (see Figure 1). Even without the previously relevant dimensional value in the postshift phase, the majority of 3-year-olds failed this version, suggesting that they were having trouble responding to the previously ignored dimensional value. Hence, rather than having trouble with negative priming (ignoring the irrelevant dimensional value), the results suggest that young children have difficulty releasing the negative priming (inhibition of the dimensional value) from the preshift set. More important, perceptual conflict between target and test cards in the preshift phase appears necessary for negative priming to interfere with 3-year-olds' performance, as a majority of young children pass a negative priming version of the DCCS when there is no conflict in the preswitch phase (Müller et al., 2006; Zelazo et al., 2003). Finally, young children also have difficulty releasing "activation" of the previously relevant dimensional value when shifting. Zelazo et al. (2003, Experiments 7 and 8) found that about half of the young children failed a DCCS version even when the previously irrelevant dimensional values were changed, suggesting that the problem is one of disengaging from previously activated dimensional values (see Figure 1, partial change version).

In addition to perceptual conflict, overlap between the two mental sets appears to be the second ingredient necessary to cause problems for 3-year-olds. In the total change DCCS, the same dimensions (e.g., color and shape) are retained, but the specific dimensional values change in the postshift phase (e.g., preshift: red triangle and blue circle test cards sorted onto blue triangle and red circle targets; postshift: yellow diamond and green octagon test cards sorted onto green diamond and yellow octagon targets; see Figure 1). Zelazo et al. (2003, Experiment 7 and 8) found that the majority of 3-year-olds passed a "total change" version of the DCCS. It is important to note that although there is still a perceptual conflict (mismatch) in the preshift phase, the specific dimensional values change in the postshift phase. The mental sets, therefore, overlap less than in the standard, negative priming, and partial versions (see Figure 1). Recall that mental set overlap is an important factor in response shifting as well.

Hence, the evidence reviewed thus far indicates that young preschoolers have difficulty disengaging from a set (i.e., dimensional values that were activated and dimensional values that were inhibited) when (a) they have had to overcome perceptual conflict in order to form the mental set in preshift phase *and* (b) there is at least moderate overlap between mental sets. However, there is at least one exception to this in the literature. In partial partial change (PPC) versions of the DCCS, there is no conflict between test cards and targets in the preshift phase (Zelazo et al., 2003, Experiment 8). In this version, children sort test cards that vary on only one dimension (e.g., black triangle and black circle) onto targets that vary in two dimensions (e.g., blue triangle and red circle; see Figure 1). In the postshift phase, test cards now vary on two dimensions, and there is a mismatch between target and test cards (e.g., test cards: red triangle and blue circle; target cards: blue triangle and red circle). Despite the lack of perceptual conflict in the preshift phase (cards can be sorted in only one way), the majority of 3-year-olds fail this version.

One possible explanation for this discrepancy is that it is the strength of the initial mental set that is important rather than (or in addition to) perceptual conflict per se. Furthermore, the strength of the initial mental set specifically relative to the second mental set may be crucial, as suggested by Munakata and her colleagues (Morton & Munakata, 2002; Munakata, 2001; Munakata & McClelland, 2003). To overcome perceptual conflict, children would have to create an even stronger mental set. Similarly, in the PPC version, having test cards that vary only according to the relevant dimension might actually increase focus on the color values, strengthening the initial mental set. Indeed, a recent study by Yerys and Munakata (2006) provides strong support for this possibility. This study used three versions of the DCCS: the PPC, novel stimuli, and uninformative label. In the first phase of the novel stimuli DCCS, children sorted according to novel dimensional values (e.g., cloudlike shapes). The authors hypothesized that using novel dimensional values would reduce the strength of the initial S-R representation. In the uninformative label condition, they showed children how to sort using the same cards as in the PPC but did not tell them the dimension they were sorting by, again hypothetically leading to weaker initial representations. Indeed, Yerys and Munakata found that more 3-year-old children were able to sort correctly in these two conditions than in the PPC, providing evidence that the strength of the initial mental representation is important.

If strength of the initial mental set relative to the new mental set is important, any manipulation that increases the strength of the new mental set should help children succeed on the DCCS. Indeed, this notion is consistent with the literature. Providing children with feedback on responses in the postshift phase improves performance (Bohlmann & Fenson, 2005). Similarly, increasing focus on the new dimensional values has been found to be very important (Kirkham et al., 2003; Towse, Redbond, Houston-Price, & Cook, 2000; Wall & Morton, 2005). For example, Kirkham et al. (2003) found that asking 3-year-olds to label the test card according to the new dimensional value in the postshift phase improved performance. Finally, Brace, Morton, and Munakata (2006) found that young preschoolers could shift to the second dimension set when test cards were slowly "morphed" from one to two dimensions. They argued that this increased the strength of the new mental set by providing experience sorting to the new dimension without conflict from the previously relevant dimension. Hence, the improvement that occurs between 3 and 4 years of age may be in releasing or disengaging from a strong mental set, with stronger perceptual conflict in the preshift phase leading to a stronger mental set.

Alternatively, the difference between performance at 3 and 4 years on the DCCS may be the result of an improvement in forming the initial attention set, leaving more central attention capacity for shifting. For instance, filtering distractors that are presented on either side of a target stimulus, as occurs in the flanker task (Eriksen & Eriksen, 1974), is challenging even for older preschoolers (Enns & Cameron, 1987). It is widely accepted that the ability to respond quickly to a target is dependent on successful inhibition of these irrelevant distractors (Tipper, 1985). Although emerging evidence indicates that preschoolers (Enns, 1990; Pritchard & Neumann, 2004; Simone & McCormick, 1999; Tipper & McLaren, 1990) and even infants (Amso & Johnson, 2005) show negative priming (i.e., do inhibit irrelevant distractors), this process appears to be less precise in preschoolers (Enns, 1990). Whereas school-age children inhibit only the specific distractors presented, 4-year-olds show negative priming effects to stimuli that are either similar to or within the same category as previous distractors (Enns, 1990). A recent study by Hanania and Smith (2007) found evidence connecting selective attention ability and DCCS performance. Preschool children who were better at a selective attention task were also better at the DCCS. Moreover, Hanania and Smith found that training children on the DCCS improved their performance on a test of selective attention, suggesting that selective attention is an important factor in DCCS performance.

In summary, attention-shifting tasks such as the DCCS build upon other EF components. In this respect, development of the ability to perform this type of task is intimately tied to the development of attention and other EF components. Two factors appear important in understanding the challenges posed by the DCCS. First, preschool children have difficulty passing the DCCS when the mental sets overlap. Three-year-olds are able to perform tasks with a low degree of overlap, such as the total change version, but they fail on tasks with even moderate overlap, such as the negative priming version. Presumably the more overlap exists, the higher the conflict will be. This parallels findings from the response-shifting tasks discussed earlier. For instance, in the sandbox A-not-B variant, when A and B locations are very close together, even 6-year-olds demonstrate difficulty with this task.

Another important factor is the strength of the first mental set. As we saw in response shifting, development of flexible behavior may follow a U-shaped path (Munakata, Morton, & Yerys, 2003). As children mature, they create a stronger initial mental set. Perhaps the 3-year-olds' failure on the standard DCCS actually reflects this developmental progression in flexible thought, whereby a strong mental set and perseveration precedes the ability to shift to a similar but new mental set. A wealth of data from DCCS studies indicate that reducing the perceptual conflict leads to improved performance on this task. One possible reason for this finding is that perceptual conflict may actually lead to a stronger mental set and therefore make shifting from it more difficult. Alternatively, it may be that creation of a strong mental set, as required by the standard DCCS, competes for limited attention in young preschoolers, leaving fewer attentional resources for set-shifting processes.

Many outstanding questions remain regarding dimension shifting during the early preschool years. The work done in this area thus far has focused on children 3 years old and over, and all of the studies thus far have been cross-sectional. As a result, we do not know the developmental course of this complex task. There is very little research on the factors that affect dimension shifting in toddlers. Preliminary DCCS findings from older 2-year-olds suggest that factors such as perceptual conflict affect their performance as well (Rennie et al., 2004). A related unanswered question is whether development of attention shifting follows a U-shaped distribution, with very young preschoolers showing less perseveration, similar to the pattern demonstrated by infants in A-not-B tasks.

Finally, as we saw in the *response shifting* section, another issue that needs further exploration is the ability of young preschoolers to learn the actual rule, as occurs in the Wisconsin Card Sorting Test . In contrast, children do not have to learn the rules in the DCCS. In fact, they are frequently reminded of the rules throughout the task. The ability to learn an abstract rule on the basis of feedback from the environment is an important skill that is crucial to language learning (Diamond, 2006a), yet we have little data on how this ability develops in preschoolers. Research on the delayed nonmatch-to-sample (DNMS) task suggests that this ability develops at approximately 21 months (Diamond, 1990c). Diamond (2006a) argued that difficulty associating an abstract rule with a response underlies toddlers' difficulty with the DNMS task. In this task, children must always choose the novel toy in a toy pair. Furthermore, the pair always contains the toy that was chosen and rewarded in the previous trial. According to Diamond (2006a), children must deduce an abstract rule (i.e., choose the new one) and associate this with the reward. Typically, children cannot succeed on the DNMS until 21 months, even with short delays (Diamond, 1990c). Furthermore, data suggest that even 3- and 4-year-olds have some ability to integrate learning rules and flexibly shift their responses on the basis of environmental feedback. Hughes (1998a, 1998b) created the teddy bear shifting task, which is similar to the DCCS with two exceptions: Children must deduce the rules, and the dimensional values change in the second phase. Her data suggest that children can coordinate these two abilities at 3 years and show age improvements until 4.5 years (Hughes, 1998b). Comparison to the data available from the standard DCCS suggests that deducing the rules may actually be easier for preschoolers than overcoming perceptual conflicts. Further work in this area would provide information on the mechanisms underlying language development and flexibility.

## Integrative EF Model Within a Developmental Framework

Brain development involves a continual process of building, organizing, and sculpting of brain networks in response to environmental inputs (Casey et al., 2005; Nelson et al., 2006; Thatcher, 1994), directly paralleling the increasing complexity of mental structures (Fischer & Rose, 1994, 1996; Piaget, 1954). With reference to general cognitive development, Fischer and Rose (1994) argued that when a new skill is added, there is initially a competition between this skill and others. Gradually, however, as the new skill becomes integrated into the existing cognitive systems, this skill becomes increasingly coordinated with existing skills. They argue further that major developmental changes involve the coordination of component skills into higher order systems, with these systems being more than the sum of their parts. Our review of the literature on the development of component EFs illustrates this process. EF components are built upon simpler cognitive skills and can be said to be the result of a coordination of simpler skills.

Miyake et al. (2000) have provided evidence that in adults, EFs are organized into components that have common and unique variance. This, coupled with evidence for a similar organization in children 8 to 13 years old (Lehto et al., 2003), suggests a hierarchical organization to EF, which is very much in keeping with what is known about the development of EF. Findings that we have reviewed suggest that by the end of the preschool period, EF organization is also characterized by partially dissociable components. For instance, factor analysis of data from children 2 to 5 years of age indicates that measures of EF cluster into distinct factors (Carlson, 2005; Espy et al., 2001). However, the data also suggest that the development of this hierarchical structure is not a linear process.

Figure 2 gives a visual overview of the development of component EF skills and how they build upon one another. Darker areas in the bars reflect times of increased growth. For the sake of simplicity, we have chosen not to include very basic skills, such as reaching and object recognition, although it is understood that these are foundational for component EFs. Instead, we have focused on skills that we consider critical for EF development. Some of these skills, such as the ability to hold in mind and delay responses, may not be considered actual EF components by some researchers, but it is generally agreed that they are necessary for successfully performing various EF tasks (Baddeley, 2002; Diamond, 2001). The "combination skills" are the ones that have been more closely linked with actual components of EF, as well as the central executive. For instance, the tasks used by Miyake and his colleagues (2000) to assess working memory involved attention processes (updating and manipulating information) in addition to simple holding in mind.

As we reviewed earlier, the ability to selectively attend is a prerequisite skill in any EF task. Selective attention allows children to focus on relevant aspects of the task and to disengage attention when warranted. Further developments in the superior parietal and frontal cortices allow for more voluntary shifts of attention so that infants can direct behavior according to internal rather than external factors (Posner & Fan, in press). Development of the anterior attention network and its connection to lower level attention subsystems allows infants to sustain attention for longer periods during the first 6 months of life. Finally, children are able to detect and deal with low levels of conflict during the latter half of the 1st year. Although the groundwork for internally mediated attention control is established toward the end of the 1st year, there are further developments in attention that allow preschoolers to increase the length of time spent in focused attention and to increasingly deal with tasks that have a high level of conflict. Another development, upon which we have briefly touched, is that attention and its various processes gradually become more integrated during the preschool period and middle childhood as the anterior attention system develops.

These developments in attention set the stage for EF components to develop. The first EF component to develop is working memory. There is evidence that children can hold simple representations in mind during the first 6 months of life. More complex skills, such as updating and manipulating information, which require coordination with the attention system, become apparent by 15 months.

Simple forms of response inhibition develop within the latter half of the 1st year, reflecting the infant's growing ability to impose cognitive control over behavior. Once infants are able to delay responses, the ability to reduce conflict between dominant and subdominant responses develops. Dealing with simple conflict, such as controlling a direct reach, develops at approximately 12 months of age. Coordination of working memory and response inhibition develops around 2 years of age, when children are able to use a rule held in mind to inhibit a prepotent response and execute a subdominant response.

Set shifting is the most complex EF component. Owing to its nature, there is no pure set-shifting task, as shifting naturally builds upon the first two EF components (response inhibition and working memory). Shifting tasks require children to shift from a mental set that has been formed. Moreover, we can distinguish it from the other two EF components (response inhibition and working memory), which involve the coordination of simpler skills. Shifting is

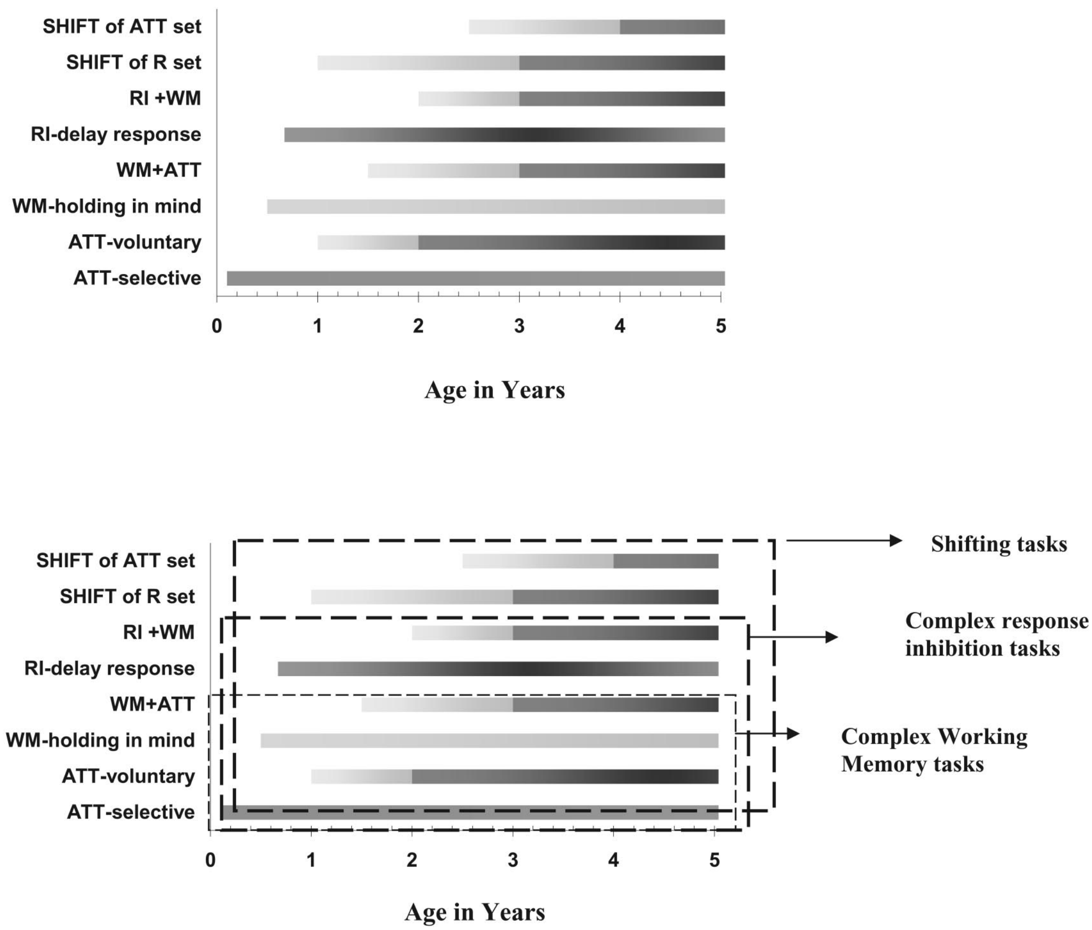



*Figure 2.* Development of skills underlying executive function components. Darker areas reflect periods of increased growth. SHIFT = shifting; ATT = attention; R = response set; RI = response inhibition; WM = working memory.

not simply the coordination of the other EF components. Rather, it can be seen as an EF process operating on another EF process. The first step (preshift) involves forming a representation in working memory of a rule (S-R associations). The second step, shifting, involves attention acting on this representation. The outcome of this component process is a modification of the original representation. This shift is made even more difficult when the original representation is strong and when there is a high degree of conflict between the original and modified representations.

A major distinction has been made between tasks that require a shift in response as opposed to a shift in the way a stimulus is perceived. One-year-old infants are able to shift from a simple —S-R set. Attention shifting, which involves shifting the way one perceives a stimulus, develops later on. When perceptual conflict is low and there is low overlap between the two mental sets (representations), some 2.5-year-old children can shift from one dimension to another (Rennie et al., 2004). However, for both response and attention shifting, tasks in which the first mental set (representation) is strong or the conflict between sets is high are difficult for children until the end of the preschool period.

Figure 2 shows that there are two main stages in EF development during the preschool period. Before 3 years of age, many of the basic skills needed to perform EF tasks are emerging. During this period, there is a developmental surge in which the infant gains more voluntary control over attention. Critical concomitant achievements that become possible include the capacities to hold and manipulate representations in mind, to inhibit a response using a rule held in mind, and to respond and allocate attention flexibly. It might appear from Figure 2 that nothing occurs after 3 years of age, yet we know that the period between 3 and 5 years is very important for EF development.

What critical EF developments take place from 3 to 5 years of age? The literature we reviewed indicates that there are significant age-related improvements in all three EF components during this period. These are well represented in Carlson's (2005) findings for a wide variety of EF tasks. Looking at Figure 2, developments in the 3- to 5-year-old period are indicated by the abrupt changes from light to dark areas on the bars. Notice that these changes take place primarily in complex skills that involve coordination of simpler skills. There are at least two possible interpretations of this pattern of development. First, it may be that the changes that occur in the latter half of the preschool period are merely quantitative for all EF components, with improvement reflecting fine-tuning of the basic circuitry for each component.

A second, non-mutually-exclusive possibility is that these parallel findings reflect an underlying factor that affects all aspects of EF development. A good candidate would be changes in the attention system and its connection to the EF networks. Rothbart and Posner (2001) have attributed the growth from 3 to 6 years to the development of the "executive control network" (p. 354). This network is made up of the anterior cingulate, dorsolateral prefrontal cortex, supplementary motor area, and basal ganglia, with the neurotransmitter dopamine being critically important for the integrity of this network (Posner & Fan, in press; Rothbart & Posner, 2001). Rothbart and Posner suggest that an important function of this network is to detect and resolve conflicts. Improvements after 3 years may reflect an integration of these developing attention networks with other brain areas underlying component EFs. Such developments in the attention system would enable children to overcome increasingly strong conflicts, to coordinate representations and response inhibition, and to flexibly adjust selective attention to fit the requirements of different EF tasks. Most important, this ability to flexibly use selective attention may underlie improvements in the ability to disengage from a mental set.

The development of a more integrated central executive system suggests that EF may not initially be structured in the same way during the preschool period as it is during later childhood. Miyake et al. (2000) attribute the overlapping variance of the EF components to a common process such as attention. Logically, if attentional processes are not yet integrated, EF tasks that vary in their dependence on different attentional processes would not be strongly correlated during the early preschool period. It is interesting to note that Hughes's (1998b) longitudinal data provide support for this idea: Correlations between EF tasks increased from 3 years to 4 years, which she interpreted as evidence for increasing coherence of EF.

## Conclusions and Further Directions

The main goal of this article was to review EF development during the preschool period using an integrative EF framework in which EF is thought of as a unitary construct, with partially dissociable components (Miyake et al., 2000). In doing so, this review has provided a systematic analysis of a large and impressive body of research. Our analysis has revealed an interesting pattern of developments from infancy to 5 years, with individual EF components emerging before 3 years of age. Most researchers agree that the years from 3 to 5 constitute an important period in the development of EF. Our review suggests that the resolution of a high degree of conflict is common to tasks that are challenging for 3-year-olds. We propose that improved performance from 3 to 5 years reflects development of the attention system and its connectivity with other brain areas underlying component EFs. This is consistent with the view of Rothbart and Posner (2001) and others (e.g., Casey et al., 2005; Eigsti et al., 2006), who have argued that changes in the attention system are particularly critical in allowing the developing child to resolve various forms of conflict.

Although the present review highlights major advances in our understanding of EF development, many developmental issues have yet to be investigated. First, though there is a wealth of data on EF during the preschool period, most of our knowledge comes from cross-sectional data. Although this allows us to speculate on developmental changes in EF, we can draw only tentative conclusions. The major problem with comparing different age groups is that group differences are due to both age and individual differences among the participants within each group. Longitudinal research, on the other hand, controls for these individual differences, and so age differences can more purely be ascribed to development. Although we need more longitudinal data to confirm cross-sectional findings, it is encouraging that thus far the data emerging from the two approaches are consistent.

This brings us to the developmental aspect of EF, which has important theoretical and empirical implications. Investigating the development of EF is critical not only for understanding children but also for achieving a coherent theory of EF. Although there is evidence for Miyake et al.'s (2000) integrative EF model in older children as well as adults, the Miyake et al. model was developed to accommodate the structure of EF in adulthood. The model can be used as a guide for thinking about EF development, but it does not address developmental issues. For instance, it is unlikely that the initial EF structure during early infancy is the same as that evident in the later preschool years. We have mapped the emergence of simple and complex skills underlying EF components to illustrate how skills may combine at different ages to result in gradually more complex EF abilities, as constructive models of cognitive development assume (e.g., Case, 1991; Piaget, 1954). Possible mechanisms for these changes have been outlined in the developmental EF models described earlier (see Table 1). Whether the development of EF is framed as difficulty overcoming latent representations (Munakata, 2001), integrating conflicting rules (Zelazo et al., 2003), or overcoming a prepotent thought or behavior (Diamond et al., 2002), effortful control of attention and conflict resolution is the common thread that links these theories. Because attention is relevant to conflict resolution in all three of these theories, exploring attentional mechanisms in EF would be one way to assess how well these theories explain early changes in EF. In this respect, the use of structural equation modeling would serve as a valuable complement to other techniques that have been used in the past. Figure 3 illustrates how the role of attention in EF development could be tested using structural equation modeling. A model with an attention factor as a mediator of the association between the three EF components (Model A) could be compared with other models in which attention is not the source of common variance (e.g., Model B). Evidence that Model A is a good fit would provide support for attention as the source for the common EF factor. This would in turn pave the way for testing more specific predictions arising from the different developmental theories.

If attention is a basic building block for the EF system, the implication is that attention problems at any point in development may compromise emerging EF abilities. Children with attention problems should have deficits in many EF tasks when compared with typically developing children. Certainly attention problems have long been thought to be central to disorders such as attention-deficit/hyperactivity disorder, which is accompanied by deficits in many EF tasks (Barkley, 1998; Pennington, 1997). Furthermore, a hierarchical model of development would predict that very early brain damage would have a major impact on attention development, with more global or diffuse implications for later EF abilities. This prediction might be explored using animal models (e.g., Kolb & Gibb, 2001) and by following children who have experienced brain damage at different points in development. Indeed,

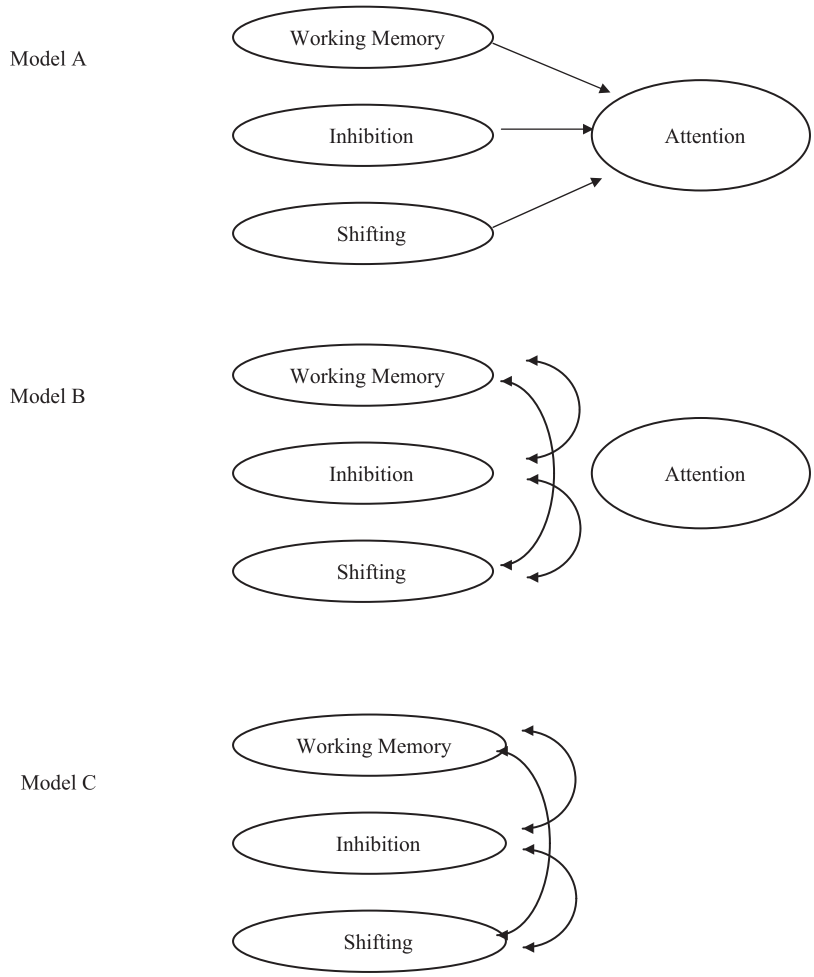



*Figure 3.* Executive function (EF) models that could be tested with structural equation modeling. Model A includes an attention latent factor that mediates the correlation between the three EF components. Model B includes an attention latent factor that does not account for the correlation between the EF components. Model C is from Miyake et al. (2000) and is shown for comparison; from "The Unity and Diversity of Executive Functions and Their Contributions to Complex 'Frontal Lobe' Tasks: A Latent Variable Analysis," by A. Miyake et al., 2000, *Cognitive Psychology, 41,* p. 60. Copyright 2000 by Elsevier. Adapted with permission.

early injuries to the brain have a major impact on attention (Dennis, Guger, Roncadin, Barnes, & Schachar, 2001) and more diffuse effects on EF development (Eslinger, Biddle, & Grattan, 1997; Scheibel & Levin, 1997). Further, the developmental stage at which disorders emerge may provide us with clues as to the nature of the EF impairment (Benes, 1997; Denckla & Reiss, 1997). In early emerging disorders such as autism (Bryson et al., 2007), for example, EF impairments may reflect disruption in early developing attention processes rather than a deficit in a specific EF component. This would perhaps lead to preservation of EF skills that rely less heavily on attention, such as holding information in mind or simple response inhibition, a pattern for which there is some evidence (Bryson, Landry, & Wainwright, 1997; Hill, 2004).

Finally, the slow maturation of the frontal cortex and its networks (Benes, 2001) suggests that it is heavily dependent on the environment for its development (Goldberg, 2002). The experience-expectant development of frontal networks is a double-edged sword. On the one hand, its slow pace, its dependence on the environmental stimulation, and its reliance on a variety of basic cognitive skills render executive development extremely vulnerable to dysfunction. It is no wonder that EF problems are found in a wide range of neurodevelopmental disorders and other disorders of childhood (e.g., Hills, 2004; Saint-Cyr, Bronstein, & Cummings, 2002). On the other hand, the very nature of EF that makes it vulnerable is also a source of untapped opportunities, suggesting that EF is amenable to environmental remediation. Some laboratories have already begun to investigate how training can improve EFs (Kloo & Perner, 2003; Posner & Rothbart, 2007; Rueda, Rothbart, McAndliss, Saccomanno, & Posner, 2005). This is an area ripe with possibilities, particularly for developmental disorders such as autism and attention-deficit/hyperactivity disorder.

From having only a handful of studies in the late 1980s and early 1990s to now having literally hundreds of studies on EF development during the preschool period, we are well positioned to make significant theoretical progress. We have enough data and the statistical tools to explore different models of early EF development. Although the integrative framework proposed by Miyake and his colleagues (2000) has been particularly useful in accomplishing the present goals, we need developmental models of EF to move the field forward. Our review suggests that skills underlying EF develop hierarchically, with two main stages of development. Before 3 years of age, basic skills needed for component EFs emerge, whereas development after age 3 appears to be an integrative period in which basic skills become coordinated. Using CFA to explore different EF models in preschoolers will be an important next step that will help advance the field. Another important step is to integrate neural imaging work with knowledge of cognitive development in order to clarify the relation between cognition and brain development. This work is already ongoing, and important parallels between cognition and brain development have been shown (Booth et al., 2003; Bunge, Dudukovic, Thomason, Vaidya, & Gabrieli, 2002; Casey et al., 1997; Lamm, Zelazo, & Lewis, 2006; Nagy, Westerberg, & Klingberg, 2004; Rueda, Posner, et al., 2004). Another emerging area that will have significant impact on our understanding of EF structure is the use of computer modeling of brain networks (Munakata, 2004; Munakata & McClelland, 2003; Rougier, Noelle, Braver, Cohen, & O'Reilly, 2005). This line of research promises to integrate knowledge of cognitive development, brain development, and how the environment interacts with emerging brain networks. For example, there is evidence that environmental input is critical for the development of flexible frontal lobe representations (Rougier et al., 2005). These emerging areas combined with the wealth of data we now have on early EF development hold real promise for furthering our understanding of both typical and atypical development.

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