Neuropsychol Rev (2012) 22:345–360
DOI 10.1007/s11065-012-9220-3

REVIEW

Assessing Executive Function in Preschoolers

Peter J. Anderson · Natalie Reidy

Received: 2 August 2012 / Accepted: 19 October 2012 / Published online: 30 October 2012

Abstract Executive function develops at an unprecedented rate during the preschool period, yet few clinicians attempt to assess executive processes in young children. The primary objective of this article is to demonstrate that executive function can be assessed in preschoolers, and to highlight the importance of detecting executive dysfunction as early as possible. Following a description of executive function and the underlying neural systems, this article outlines some of the challenges in assessing executive function in young children. The various assessment paradigms used for assessing executive function in preschoolers are presented, and based on studies that have applied these measurement tools normal development of executive domains is described. Finally, the benefits and opportunities for executive function intervention in the preschool period are considered.

Keywords Executive function · Development · Assessment · Preschool · Children

It was only 30 years ago that it was assumed that cognitive processes underpinning executive function emerged in early adolescence, at which point the frontal lobes reached an adequate level of maturity to facilitate these higher-order cognitive abilities (Golden 1981). It is now well established that executive function emerges much earlier than this, and that primitive signs of inhibition and working memory can be observed in infancy (Diamond 1985; Diamond and Doar 1989; Diamond and Goldman-Rakic 1989). An appreciation of the goal directed behaviors of infants and toddlers in the 1980s initiated a substantial body of research examining the development of executive function in early childhood, predominantly from developmental psychology and developmental neuroscience fields. Certainly our understanding of executive function development in preschoolers is now far more advanced than it was a few decades ago.

Despite these advances in knowledge, pediatric neuropsychologists continue to avoid detailed assessments of executive function until clients reach school-age. Even in research of brain injured clinical populations, executive function is rarely a focus before children are deemed school ready. This is at least partly due to the lack of validated standardized assessment batteries, but also related to a perception that preschoolers don't have the attention, inhibitory control and communication capacities to adequately assess higher-order processes that are collectively referred to as executive function. The primary objective of this review is to demonstrate that executive function can be assessed in preschoolers (3 to 6 years of age), and that it is important to identify executive dysfunction as early as possible in order to intervene and minimize the associated academic, emotional, behavioral and social consequences. It is irresponsible to wait for problems to become pervasive if it is possible to detect and intervene at an early age.

Executive Function

Executive function is a construct composed of multiple inter-related high-level cognitive skills responsible for formulating goals, planning how to achieve them, and carrying out these plans effectively (Lezak 1982; Welsh and Pennington 1988). The key elements of executive function include a) anticipation and deployment of attention, b) impulse control and self-regulation, c) initiation of activity, d) working memory, e) mental flexibility and utilization of

P. J. Anderson (✉) · N. Reidy
Victorian Infant Brain Studies (VIBeS),
Murdoch Childrens Research Institute,
Royal Children's Hospital, Flemington Road,
Parkville, 3052 Victoria, Australia
e-mail: peter.anderson@mcri.edu.au

P. J. Anderson
Department of Paediatrics, The University of Melbourne,
Melbourne, VIC 3010, Australia

feedback, f) planning ability and organization, g) selection of efficient problem-solving strategies, and h) monitoring of performance (Anderson 2002, 2008). These executive processes develop throughout childhood and for preschoolers the focus has been on self-regulation, impulse control, working memory and mental flexibility, however there is evidence that young children also exhibit planning, organization and decision making skills (Welsh et al. 1991). While critical for academic performance (Bull et al. 2004; Clark et al. 2010; Espy et al. 2004; Willoughby et al. 2011), executive processes are also intimately linked to emotional, behavioral and social functioning (Blair 2002; Espy et al. 2011; Kochanska et al. 2000; Schoemaker et al. 2012). In fact, it has been proposed that the construct can be dichotomised into "cool" processes that are cognitive and tapped during abstract, decontextualized situations or "hot" processes that represent affective responses to situations that are meaningful and involve regulation of affect and motivation (Zelazo et al. 2004).

Numerous cognitive processes are labeled as "executive", but some of these processes overlap and are highly interdependent. Thus, theoretical models of this complex multidimensional construct are required to provide a framework for the selection of assessment tools, interpreting test performance and everyday behavior, and understanding executive function development (Anderson 2002; Garon et al. 2008). Various conceptual models of executive function have been proposed, although none has been universally adopted. Early conceptualizations of executive function were unitary models such as the "central executive"(Baddeley 1986) or "supervisory activating system"(Norman and Shallice 1986), however it has been demonstrated that a modular unit is too simplistic and that this construct is composed of distinct but inter-related components (Baddeley 1998; Parkin 1998). Evidence for the fractionation of executive function includes findings that patients rarely exhibit global executive dysfunction (Bigler 1988; Grattan and Eslinger 1991; Pennington and Ozonoff 1996); specific executive processes can be localised within the prefrontal cortex (Courtney et al. 1998; Rezai et al. 1993; Stuss et al. 2002); measures of executive processes correlate poorly (Cripe 1996; Della Sala et al. 1998); factor analytic studies identify multiple factors (Lehto et al. 2003; Miyake et al. 2000); and the developmental trajectories of specific executive processes vary (Anderson 2002; Welsh et al. 1991). As a consequence, concepts such as the "central executive" and "supervisory system" have been modified including an attempt to fractionate subcomponents of the various control systems (Baddeley 1996; Shallice and Burgess 1996). However, while executive function may comprise several distinct processes, they are inter-related and could still be conceptualized, and referred to, as an integrated supervisory or control system (Alexander and Stuss 2000; Stuss and Alexander 2000). It should be noted that certain preschool executive function factor analytic studies have revealed a single latent variable (Hughes et al. 2009; Wiebe et al. 2008), although this is at least partly related to the measures and variables included in the analysis and does not necessarily challenge the view that executive function includes distinct components (Hughes et al. 2009).

In the developmental literature the executive function framework proposed by Miyake et al. (2000) has been very influential. In their factor analytic study of commonly employed executive function measures administered to young adults, Miyake et al. identified three core factors—inhibition, working memory and shifting. This model is appealing for developmental psychologists as these components of executive function are assessable from a young age. Furthermore, studies with children broadly support the view that executive function comprises similar components (Lehto et al. 2003; Huizinga et al. 2006). While it could be argued that inhibition, working memory and shifting are "core" executive processes, this framework excludes functions commonly considered "executive" such as conceptual reasoning, planning ability, and organizational skills. Therefore, for the purposes of this review, the Executive Control System (Anderson 2002, 2008) will be employed, which is a conceptual framework based principally from the developmental neuropsychology literature and largely influenced by factor analytic and developmental studies (Brocki and Bohlin 2004; Kelly 2000; Lehto et al. 2003; Levin et al. 1991; Miyake et al. 2000; O'Donnell et al. 1994; Welsh et al. 1991). The Executive Control System conceptualizes executive function as an overall control system that comprises four distinct domains, attentional control, cognitive flexibility, goal setting, and information processing (see Fig. 1). Processes within domains are considered to be highly integrated. Each receives and processes stimuli from various sources including subcortical, motor, and posterior brain regions, thus are dependent on similar prefrontal networks, and they exhibit comparable developmental trajectories (Anderson 2002). To operate in a functional manner these domains interact and have bidirectional relationships, and together function as an overall control system. The mechanisms operating the executive control system are task-dependent, that is, the nature of the task determines the level of input from each.

Attentional control refers to the capacity to selectively attend to specific stimuli, remain attentive for a prolonged period, regulate and monitor actions and behavior, and control impulses. The cognitive flexibility domain includes the ability to transition to new activities, cope with changes in routine, switch between response sets, learn from mistakes and devise alternative strategies, multi-task, and process temporarily stored information (working memory). Goal setting refers to initiative, conceptual reasoning, planning ability (anticipation of future events, formulation of a

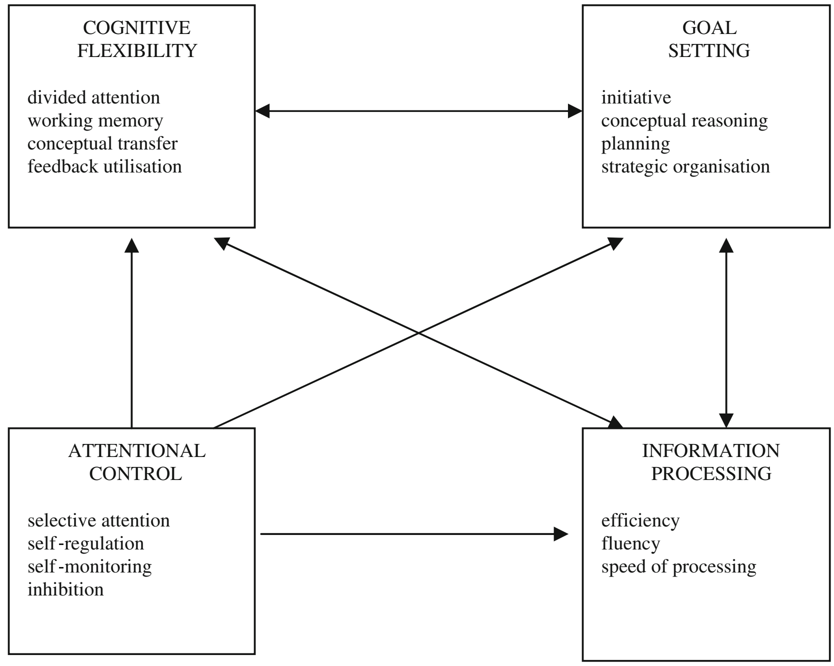

Fig. 1 The executive control system (Anderson 2002, 2008)

goal or endpoint, and development of steps or actions required to achieve the goal), and organization (ability to arrange complex information or a sequence of steps in a logical, systematic, and strategic manner). The information processing domain focuses on the speed, fluency and efficiency to complete novel, problem-solving tasks. It is included as a separate domain due to findings from factor analytic studies that reveal a separate factor for fluency/response speed variables from executive function tasks (Kelly 2000; Welsh et al. 1991). This framework will be utilized when categorizing the different executive function measures that are available and when describing executive function development.

Impaired executive functioning, or executive dysfunction, can be characterized by a variety of presentations, however it is important to recognize that some of the behaviors considered concerning in an older child maybe developmentally appropriate for an infant or preschooler (Anderson 2002). Thus, everyday behaviors and performance on clinical tests for preschoolers need to be interpreted in the context of the child's age and developmental expectations in order to avoid mislabeling a normally developing child as impaired or delayed (Baron 2004). Executive dysfunction in young children may include an inability to focus and maintain attention, extreme impulsivity, incapacity to inhibit established behaviors, difficulties transitioning to new activities or situations, inability to switch between conflicting demands, and difficulties monitoring or regulating performance. Executive dysfunction is a common observation in young children and has been reported in many developmental and acquired disorders of the central nervous system (CNS) including attention deficit/hyperactivity disorder (Barkley 1997), autism (Ozonoff et al. 1991), traumatic brain injury (Anderson et al. 2012), prematurity (Anderson et al. 2004), and phenylketonuria (Welsh et al. 1990).

Executive Function Neural Systems

Historically the anterior regions of the brain, specifically the prefrontal cortex, have been considered to subsume executive processes. This premise was largely based on observations of patients following damage to the prefrontal cortex (Benton, 1968; Grattan and Eslinger 1991; Stuss, 1992), but also early functional neuroimaging studies that reported significant activation of the prefrontal cortex during performance on established executive function measures (Baker et al., 1996; Morris et al., 1993; Rezai et al. 1993). However, prefrontal cortex functioning is dependent on extensive efferent and afferent connections with most brain regions (Heyder et al. 2004), and consequently damage at any level of these prefrontal networks could potentially result in impairments commonly associated with executive dysfunction (Alexander and Stuss 2000). Thus, it may be argued that the integrity of the prefrontal cortex is a necessary but not a sufficient condition for intact executive functioning (Della Sala et al. 1998), and that executive dysfunction may not always reflect prefrontal pathology and instead reflect compromised neural networks across the brain.

Cognitive development is thought to reflect brain development (Casey et al. 2000; Casey et al 2005). Given that cognitive processes are emerging and developing at a rapid rate in early childhood, it comes as no surprise that this is also a period of rapid brain development (Fig. 2). During early childhood primary cortical areas such as the auditory and visual cortex, and association areas such as the medial prefrontal cortex, have high levels of synaptic density and undergo a dynamic period of synaptic elimination at differing trajectories (Huttenlocher, 1990; Huttenlocher & Dabholkar, 1997). Concurrently, total brain volume increases and reaches 95 % of its adult size by age 6 years (Lenroot & Giedd, 2006); however, brain volume trajectories differ according to region and tissue type. Giedd et al., (1999) conducted serial MRI scanning, and demonstrated that from age 4, white matter volume increases steadily, but gray matter volumes in the frontal and parietal regions increase and peak during mid-childhood before reducing. During infancy and early childhood, total white matter is increasing in volume at a greater rate than total gray matter (Matsuzawa et al., 2001). Taki et al., (2012) examined white matter volume change in children from age 5, and demonstrated that increasing white matter volume with age is linear in many regions across the brain. The increase in white matter volume may be related to an increase in myelination (Tsujimoto, 2008). Myelination of the major cerebral tracts begins in the post-natal period, with greatest development in the first 2 years of life, continuing throughout childhood and adolescence (Gao et al., 2009; Paus et al., 2001). The maturation of white matter, including myelination and the increasing complexity of neural circuits, are thought to support the development of cognitive functions in addition to changes to the gray matter (Johnson, 2001; Tau & Peterson, 2010).

A widely held view in brain development is that the frontal lobes develop much later in childhood and adolescence than other brain regions, and although this region undergoes a period of protracted development, infancy and early childhood still sees rapid growth in this anterior area of the brain. In addition to the changes at the microscopic level as mentioned above, further structural development has been observed. Gogtay et al., (2004) demonstrated that primary and secondary areas of the frontal lobes mature earlier than the association area of the prefrontal cortex, as measured by a reduction in gray matter thickness. Despite this cortical thinning, the prefrontal region expands in size with age, more so than areas surrounding the central sulcus or the posterior medial surface (Sowell et al., 2004). These concomitant changes have been explained as partly reflecting an increase in myelination of the lower cortical layers with age, causing both regional brain expansion and apparent cortical thinning (Sowell et al. 2004). Individual tracts that are present in the frontal white matter are identifiable early in the post-natal period and continue to develop throughout the preschool years (Hermoye et al., 2006).

Comparatively few functional imaging studies have been conducted in preschool children due to the difficulties with scanning young children and getting them to attend to tasks during imaging sessions. Even so, areas of the prefrontal cortex have been shown to be active during tasks of executive function in this population. For example, Tsujimoto et al., (2004) examined activation in the lateral prefrontal cortex during a working memory task in children aged 5 and 6 years, and found that the patterns of activation were similar to those in adult participants. Using EEG, Wolfe and Bell (2004) demonstrated the medial prefrontal cortex is active while children aged 4.5 years perform working memory and inhibitory control tasks. In examining the maturation of prefrontal cortex function, Moriguchi and Hiraki (2011) demonstrated using near infra-red spectroscopy that from age 3 to age 4, children improve their performance on a conceptual switching task, and show a concomitant increase in activation in the inferior prefrontal region. Different executive processes are supported by widespread

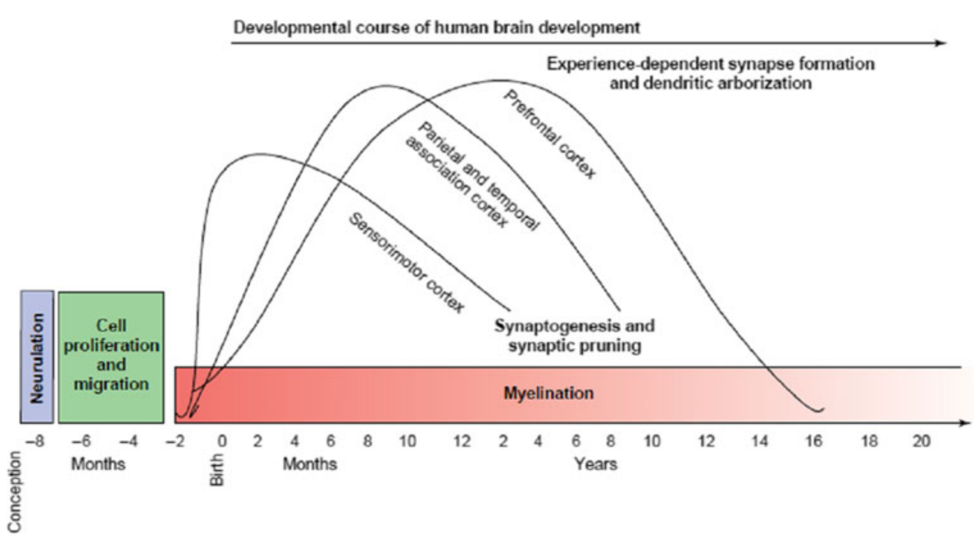

Fig. 2 Development course of human brain development (Casey et al. 2005)

neural circuits that mature and change with age (see Tau & Peterson, 2010 for a review). While it is not clear in preschool children, activation in areas of the prefrontal cortex during cognitively demanding tasks has been shown to occur in school aged children and reduce into adolescence and adulthood as the functional networks become more efficient (Brauer & Friederici, 2007; Durston et al., 2006). At the same time, functional neuroimaging studies demonstrate that the maturation of neural networks involves a move from interconnected local regions, to the connectivity of distributed regions that work together to subserve the same function, and this may mirror maturation of cognitive skills (Fair et al., 2009).

Assessment Challenges

Even for adults what constituents a measure of executive function is not entirely clear, and this is less clear in young children given the substantial inter-individual variability observed in infants and preschoolers. Traditionally, executive function measures have been considered assessment tasks that are novel, complex, and involved the integration of information (Walsh 1978) as these require the individual to focus, formulate a plan and strategy, and self-regulate. Tasks that are simple and routinized are performed more instinctively and as such are thought to require minimal attentional resources and planning (Shallice 1990). However, it has been noted that defining an activity as routine, overlearned, complex, or novel is not always straightforward, as what may be complex or novel for one person may be rather simple or routine for another (Alexander and Stuss 2000; Gioia et al. 2001; Stuss and Alexander 2000), especially in the case of the young child. Moreover, as models of executive function have increasingly focused on self-regulatory processes, it has been argued that all cognitive tests involve executive functioning to some extent (Alexander and Stuss 2000; Della Sala et al. 1998).

Most executive function measures are multi-dimensional and as such tap multiple cognitive processes, executive and non-executive (Anderson 2002; Espy et al. 2008). Thus, executive function tasks generally suffer from task impurity (Miyake et al. 2000), in that they are considered to evaluate a specific executive process yet performance is also dependent on other cognitive processes. While this can make the test sensitive to cognitive impairment, determining the underlying reason for sub-optimal performance can be difficult, limiting the capacity to differentiate specific cognitive deficits. One approach to overcome this limitation that is sometimes adopted is to gradually increase task demand or complexity; this enhances the capacity to isolate the cognitive deficit contributing to poor test performance. Summary scores are often used to assess performance but these may mask personal and situational factors that could explain impaired performance, especially for young children who are more distractible, have shorter attention spans, require greater novelty and have less awareness of the requirements of the testing situation (“test sense”). A more comprehensive interpretative approach incorporating quantitative (e.g., success/failure, latency, number of errors, etc.), qualitative (e.g., motivation, energy, attention, distractions, etc.) and cognitive-process (e.g., process, strategies, actions, etc.) methodologies is likely to provide a more meaningful picture of the child’s performance and improve the diagnostic utility of these measures (Anderson 2002; Baron 2004).

Executive dysfunction can present in many forms, and impairment in one domain does not necessarily imply impairment in other executive domains. While it is well known that interest and motivation levels affect performance on cognitive tasks, fluctuations in motivation and interest levels is greater in young children and can be observed both across and within testing sessions. Accordingly, a comprehensive assessment of executive function requires the administration of multiple measures, that collectively assess all executive domains and preferably across different modalities. It is worth noting that established measures do not necessarily assess what they are claimed to assess (Baron 2004), and purported measures of executive function are unlikely to be sensitive to impairments in all domains of executive function. Some measures are more tailored towards evaluating inhibitory control, others towards working memory and cognitive flexibility, while complex problem solving tasks generally tap planning and organizational ability, and strategic decision-making.

The ecological validity of many traditional executive function measures has been questioned due to the novel nature of the tasks and reported discrepancies between performance on traditional executive function measures and real life behavior (Eslinger and Damasio 1985; Hughes 2011; Levine et al. 1998; Lezak et al. 2012). This discrepancy may also reflect the assessment environment, which is generally a quiet, one-on-one, structured setting with minimal distractions (Anderson 1998; Lezak et al. 2012) and very different to most home, classroom, or social environments. Furthermore, during assessments examiners generally provide children with support and encouragement, initiate activities, provide structure, and help to keep the child on task (Anderson 1998; Lezak et al. 2012), and it has been suggested act as the “frontal lobes” of the child (Stuss and Alexander 2000).

Other sources of information should be attained in addition to direct cognitive assessment, especially given that assessment tasks do not always predict everyday behaviors. As well as behavioral observations during the assessment, in the waiting area, at school and other settings, information from parents and preschool/child care workers can help shape the assessment, clarify assessment findings, and assist in determining what remediation and compensatory strategies are most likely to be effective. There are now validated questionnaires that can assist with acquiring this information from various sources (Isquith et al. 2004).

Young children get tired quickly, struggle to sustain attention during cognitive assessments, often fail to comply with non-appealing tasks, and have immature receptive and expressive communication skills. Thus, it is hard work assessing preschoolers. To improve compliance, a range of practical approaches can be beneficial such as timing assessments at a time when the child is most alert, arrange multiple short appointments, alternate activities regularly but fluently to maintain interest and attention, provide structure so the child knows what is expected, and very importantly, provide age-appropriate and gender-specific reinforcement.

Most executive function measures used with school-aged children were designed and validated in adult populations. It is clearly an advantage to have a suite of measures that can be employed across a wide age range, however the practice of administering adult-derived tests or scaled-down versions in children should be done with caution as 1) these tests may be of little interest or relevance to children, 2) the novelty factor and level of complexity of such tests are likely to be greater in children, 3) there is a strong possibility that these tests tap different skills (and neural networks) in children or at least require greater cognitive resources, and 4) they often lack adequate normative data necessary to differentiate normal and abnormal performance within a developmental context (Anderson 1998; Baron 2004; Fletcher and Taylor 1984). Recent attempts to design measures for preschoolers appreciate the need for age appropriate or child friendly measures, and have specifically designed tests that are appealing to young children (Hughes 2011). Child friendly tasks will reduce the high refusal rate experienced when assessing preschoolers (Beck et al. 2011). A major challenge, however, is the attainment of good norms as determining age appropriate behavior is very difficult when children are young and developing at a rapid rate (Baron 2004). Thus, measures with good age norms are important for accurate clinical interpretations.

Specific neuropsychological measures for this age group are not easily accessed, and research and preparation is required to organize a battery of tests that cover the spectrum of cognitive abilities and have adequate normative data. Most executive function tests designed for preschoolers maybe considered "experimental", in that they are not commercially available, have limited information on their reliability and validity, and norms may be limited or based on small convenience samples or a local geographic region. For these reasons practitioners need to be cautious in interpreting test performance, and consider generating local norms and reliability estimates. Encouragingly, a recent study reported that same-day test-retest reliability for certain preschool executive function measures was good (ICCs$\geq$0.75) and that minimal learning effects were observed; instead slightly poorer performance was observed on second testing which was interpreted to reflect fatigue (Beck et al. 2011). Other papers reveal reasonable reliability for most experimental tests with estimates consistent with those reported with older childhood and adult populations (Willoughby and Blair 2011) and published subtests in the NEPSY battery (Espy et al. 2008). Reliability estimates vary across tasks and it may be that assessing certain executive processes may be more stable than others. For example a recent report showed that test-retest reliability was good for working memory and planning tasks but moderate to poor for response inhibition tasks (Muller et al. 2012). It is not yet known whether preschool executive function measures are predictive of executive functioning in later childhood.

Measures

There are some general cognitive assessment batteries that are suitable for assessing IQ or general cognitive ability in preschoolers such as the Wechsler Preschool and Primary Intelligence Scale (WPPSI-III; (Wechsler 2002)), Stanford-Binet Intelligence Scales (SB5; (Roid 2003)), Differential Ability Scales (DAS-II; (Elliott 2007)), and the Kaufman Assessment Battery for Children (KABC-II; (Kaufman and Kaufman 2004)). While these general cognitive batteries were not designed to specifically assess executive functioning, all include subtests that tap executive processes. The NEPSY (now updated to NEPSY-II; (Korkman et al. 2007)) is a neuropsychological battery designed to provide a comprehensive assessment of major cognitive domains from 3 to 16 years, including attention and executive functioning. While the NEPSY is an important and popular tool for pediatric neuropsychologists, it has few subtests that assess executive functioning in the lower ranges of the preschool period (Espy and Cwik 2004). There is currently no commercially available, norm-referenced test battery that enables a comprehensive assessment of executive function in preschoolers. Following is a review of some measures that are reported in the literature (see Table 1). The intention of the following section is to demonstrate that a range of measures are available rather than review all the executive function measures that have been developed for preschoolers. This section will focus on measures for the attentional control, cognitive flexibility and goal setting domains, as the assessment of information processing is generally based on latency, efficiency and fluency parameters measured during these tasks. Further, there

Table 1 Selection of executive function measures developed for preschoolers

Executive domain	Type of measure	Test name
Attentional control	Delay of Gratification	Snack Delay; Gift Delay
	Impulse Control	Statue
	Go/No-Go	Bear/Dragon; Simon Says
	Response Inhibition (motor)	Hand Tapping; Hand Game; Knock & Tap
	Response Inhibition (verbal)	Day-Night; Grass-Snow; Silly Sounds Stroop
Cognitive Flexibility	Working Memory (updating)	Delayed Alternation
	Working Memory (self-ordered searching)	Self-ordered Pointing; Pick the Pictures; Six Boxes; Spin the Pots; Spatial Working Memory (CANTAB)
	Working Memory (manipulation)	Backward Digit Span; Backward Block Span
	Switching	Shape School; Trails-P
	Shifting Attention	Dimensional Change Card Sort
Goal Setting	Planning	Tower of Hanoi
	Conceptual Reasoning	Object Classification Task for Children

are well-established approaches for assessing information processing speed, with research demonstrating significant improvement in reaction/response time during the preschool period and that response speed varies as a function of complexity (Kiselev et al. 2009).

Attentional Control

There are generally three approaches to assessing attentional control in preschoolers: 1) delay of gratification tasks that require the child to resist (for a specific period of time) a tempting response such as eating a treat, playing with an attractive tool or opening a present, 2) Go/No-Go paradigms that require a child to respond to target stimuli but refrain from responding to non-targets, and 3) complex response inhibition tasks in which the child needs to learn a new rule that involves responding in a way that conflicts with a dominant behavior.

Delay of gratification or self-control tasks can be administered in young preschool children, with the delay period adjusted according to child's age. *Snack Delay* (Carlson 2005) involves the child resisting the temptation to eat a treat placed in front of them during a period in which the tester has left the room. Including rewards of different value can increase the complexity of the task. For example, two bowls of treats, one with a small amount and one with a larger amount, can be placed in front the child who is told that if they wait for the tester to return they are rewarded with the large bowl of treats but if they can't wait they are rewarded with the small bowl of treats. Temptations other than snacks can be used such as gifts. In *Gift Delay* (Carlson 2005; Kochanska et al. 2000), a wrapped gift is placed in front of the child who is asked not to open it until the tester comes back into the room. The child is observed during this period and opening the present or peeping through the wrapping is considered a failure. For older children a variation on this task can be considered, such as asking the child to look away and not peep while the tester wraps a prize for the child. The child is videotaped or observed through a one-way screen for peeping behavior (Carlson 2005; Kochanska et al. 2000). The NEPSY-II includes a self-control subtest, called *Statue*, which does not involve delay of gratification (Korkman et al. 2007). In this task children attempt to maintain a body position and remain silent, eyes closed for 75 s while the examiner attempts to attract the child's attention by making sounds (Klenberg et al. 2001).

Many different Go/No-Go paradigms have been developed for young children. Depending on the nature of the task and the degree of inhibitory control required, Go/No-Go tasks can be administered to children as young as 3 years (Willoughby et al. 2010). Factors that may influence complexity, and therefore age appropriateness, include the stimuli used, the speed that stimuli are presented, and the response modality (verbal or motor). One paradigm that has been shown to be age appropriate across the preschool period is the *Bear*/*Dragon* task (Carlson 2005). The child is instructed to follow the instructions of the "nice" bear puppet (i.e. hand movements) but refrain from following the instructions of the "naughty" dragon puppet. Another Go/No-Go task is the well-known game *Simon Says* (Carlson 2005). In this imitation game the tester gives a command and performs the action, and the child is requested to follow the commands and imitate the actions of the tester but only when the command is prefaced with "Simon says", otherwise the child must remain still. The *Simon Says* task is significantly more difficult for children than the *Bear*/*Dragon* task, despite both being Go/No-Go paradigms. In *Simon Says* the No-Go cue is a verbal statement embedded with the command, while the Go and No-Go cues in the *Bear*/*Dragon* task are commands from different puppets and much easier to differentiate. *Simon Says* is also more challenging as it involves active imitation, which is difficult for young children to inhibit.

Complex response inhibition tasks require the child to learn two (i.e. alternate) response sets that conflict with either an established or instinctive behavior. A commonly employed approach is anti-imitation games, such as the *Hand Tapping* task. In this task the child is instructed to tap once when the tester taps twice or tap twice when the examiner taps once (Diamond and Taylor 1996). Other variations are the *Hand Game* in which the child does the opposite gesture to the tester (fist or pointed finger) (Carlson 2005; Hughes 1998) and the *Knock and Tap* subtest from the NEPSY (Korkman et al. 1998). These anti-imitation tasks are suitable across the preschool age range, although young 3-year-olds may struggle. Instead of inhibiting an instinctive motor response, the *Day-Night* task requires children to inhibit a dominant verbal response. Children are instructed to say “day” when presented with the black card with a moon and stars and “night” when presented with the white card with a yellow sun (Gerstadt et al. 1994; Montgomery and Koeltzow 2010). A number of tasks along the same concept of the *Day-Night* task have been developed such as *Silly Sounds Stroop* (Willoughby et al. 2010) and *Grass/Snow* (Carlson 2005) tasks. Again, developmental trajectories across these response inhibition tasks can vary, and it is assumed that the strength of the dominant behavior that needs to be resisted differs influencing task difficulty (Espy et al. 2006; Prevor and Diamond 2005). Supporting this premise, young children perform significantly better when the response rule to the *Day/Night* cards is completely unrelated to the stimuli such as “dog” and “pig” (Diamond et al. 2002) or when the child is instructed to say “night” and “day” to neutral cards (Gerstadt et al. 1994).

Cognitive Flexibility

The key processes in the cognitive flexibility domain, especially when assessing young children, are working memory (capacity to update or manipulate information in short-term storage), switching between response sets, and shifting attention.

Delayed Alternation is a task used to assess working memory in young children, and can be administered to toddlers as well as throughout the preschool period (Espy et al. 1999). The child searches for a reward under one of two wells or cups; if the child searches correctly the location of the reward is alternated to the other well/cup but otherwise the location of the reward remains in the original location (Espy et al. 1999). In addition to assessing working memory, good performance on the *Delayed Alternation* requires the capacity to shift search strategy and, for older kids, to learn the alternating pattern of the search location. Another working memory paradigm used with preschoolers is self-ordered searching tasks, which requires information, usually visual-spatial, to be maintained and updated in short-term memory. Examples of this approach are the *Self-ordered Pointing* and *Pick the Picture* tests (Hongwanishkul et al. 2005; Willoughby et al. 2011). In both tests the child is shown a page of pictures and asked to select one by pointing to it. A new page with the same pictures but in different locations is then presented, and the child is instructed to point to a picture not previously selected. The task gradually increases with complexity as a function of the number of pictures presented, and for young children can start with as few as 2 or 3 pictures. The Cambridge Neuropsychological Test Automated Battery (CANTAB) has a computerized version of self-ordered searching referred to as *Spatial Working Memory*. Identical boxes are presented on the computer screen with the objective to search the boxes for tokens without returning to a previously searched box (Luciana and Nelson 1998). Another updating working memory task described for use with preschoolers is the *Six Boxes* test (Diamond et al. 1997). The task involves 6 visually-unique boxes in which rewards are placed. The child selects a box, and after each search there is a brief delay during which the boxes are scrambled. Following the delay the child is required to select a different box; one not previously searched. The task can also be administered without scrambling the boxes, and for younger or more delayed children can be restricted to fewer boxes. A variation on the *Six Boxes* test is the *Spin the Pots* test (Hughes 1998) in which 8 visually-unique pots are used instead of 6 boxes. Traditional working memory tasks can also be administered to preschoolers including backward digit span and backward block span. In these tests the child is presented with a sequence of numbers or pattern of tapped blocks and instructed to repeat the sequence/pattern in the reverse order (Carlson 2005; Garon et al. 2008). These tasks are challenging even for older children and preschoolers are rarely able to reverse sequences of 4 or greater. Furthermore, a prerequisite is an understanding of the “backward” concept, and this should be demonstrated prior to administering reversal recall tasks.

Switching is the ability to fluently switch between multiple rule sets. Performance on switching tasks generally requires 1) inhibition to suppress previously applied rule set, and 2) working memory to maintain the alternating rules and when to shift (Chevalier et al. 2012). The child needs to inhibit a previously applied behavior to enable fluent switching, otherwise perseverative errors will be observed (Best and Miller 2010). The *Shape School* test (Espy 1997; Espy et al. 2006) assesses both inhibition and switching. It is designed in the context of a storybook, involving students in the playground, and has four trials or conditions. The first trial is considered a control or baseline condition and involves naming the color of figures (circles and squares which represent students lined up in the playground) as quickly as possible. In the second trial the child is also instructed to name the color of the students as quickly as possible, but this time only those with a happy face. Thus, this trial applies a Go/No-Go paradigm and is considered the inhibition condition. The third trial is more complex and involves the child switching between two rules: 1) name the color of the students without hats, or 2) name the shape of the students with hats. The final trial involves switching plus response inhibition. Children are instructed to apply the switching rule as in the previous trial, but this time only for those students with a happy face. The inhibition trial is considered appropriate for preschoolers aged 3-years and older, while the more complex switch and combined (switch & inhibit) trials are considered appropriate for children aged 3:6 years and older. *Trails-P* is a preschool adaptation of the child and adult version of the Trail Making Test (Espy and Cwik 2004), and is another measure of switching. As with most of the measures designed by Espy and colleagues, the task is administered in the context of an age appropriate story (i.e. family of dogs that differed in size) and colorful stimuli are used. In the control condition children are required to stamp the members of the dog family in order of increasing size. The switch condition includes the dog family and matching bones that increase in size, and children are required to switch between stamping the dogs and bones in order of increasing size. A third condition is administered which involves inhibition. Again the children are presented with a page with the dog family and matching bones, however this time they must only stamp the dogs in order of increasing size and ignore the bones. In the final condition the children switch between stamping the dogs and bones in order of increasing size, but this time ignore distractors, which in this case, are cat stimuli.

Some tasks assess the ability to shift attention to a new response set after establishing a specific behavioral pattern. The *Dimensional Change Card Sort* task has been used extensively to evaluate shifting attention in preschoolers (Zelazo 2006; Zelazo et al. 2003). It is a sorting task in which the child is shown two target cards (e.g. blue rabbit or red boat) and told that they must sort subsequent cards (e.g. 3 red rabbit cards and 3 blue boat cards) according to the object's color. After six trials the child is told that they are going to play a new game, and that they now need to sort the same six cards according to shape. The child's capacity to shift their attention from color to shape and sort the cards accordingly is the primary interest.

Goal Setting

Few executive function measures designed for preschoolers focus on the goal setting domain, such as conceptual reasoning, planning ability, organizational skills, and strategic decision-making. While not specifically designed for young children, one test that has been successfully employed with preschoolers is the *Tower of Hanoi* (Espy et al. 2001; Welsh et al. 1991). This test is purported to tap planning ability, and requires the child to move three different sized disks across three pegs to achieve a specific configuration. A number of trials is administered which increase in difficulty. In order to help young children understand the instructions Espy et al. (2001) administered the task in the context of a story involving three monkeys (dad, mum, and child) who need to jump across the trees (pegs). Other Tower tasks have been developed to assess planning ability such as the various versions of the *Tower of London* (Shallice 1982) and the *Tower* in the NEPSY (Korkman et al. 1998). The *Tower of London* involves rearranging 3 different colored balls on 3 pegs of different height to match specific configurations in the minimum number of moves. This task is generally considered too difficult for preschoolers, as demonstrated by Luciana and Nelson (1998) who found that less than half of their 4-year-old sample understood task requirements despite extensive training. The assessment of conceptual reasoning in preschoolers can be attempted with the *Object Classification Task for Children* (Smidts et al. 2004). In this test children are presented with six different toys that can be sorted into two groups across three different dimensions (i.e. color, size, function). For younger children who cannot successfully sort the six toys, the task can be re-administered with four toys sorted across two dimensions. Additional steps such as explicit cuing can also be utilized to further examine conceptual reasoning in children who failed to sort using all three dimensions.

Behavioral and Social Manifestations of Executive Function

As performance on clinic based cognitive measures does not always correspond with behavior in real-life settings such as school and home, it is important to acquire as much information as possible about the child's functioning and behavior in these environments. Behavioral inventories, such as the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000), are a useful adjunct to cognitive assessments as they sample a range of behaviors in children and enable qualitative information to be collected and interpreted in a standardized format. A preschool version of the BRIEF is available, called the BRIEF-P (Isquith et al. 2004), with forms for parents and preschool/childcare teachers. The BRIEF-P has five scales labeled Inhibit, Shift, Emotional Control, Working Memory and Plan/Organise, which produces three indices called Inhibitory Self Control, Flexibility, and Emergent Metacognition. The level of agreement between the BRIEF and well-established EF cognitive tasks is at best modest (Anderson et al. 2002), supporting the view that each form of assessment provides unique information.

Testing Platforms

Preschoolers of today have access to a large range of child friendly activities available on computers, tablets, gaming and other devices. As a result, most young children are now very familiar with these IT platforms, and many are drawn to these activities. As contemporary preschoolers are more technologically sophisticated then preschoolers of previous generations, the way many traditional preschool assessment tasks are presented may need to be updated if they are to continue to be appealing for this age group. Fortunately, most of the tasks described above can be easily designed for tablets and touch screen computers, and these platforms can enhance flexibility and the presentation experience as well as ensuring standardization of administration. Another obvious advantage is the detailed information on task performance that can be recorded and evaluated using these platforms (Hughes 2011). Kimberly Kerns and colleagues have successfully designed computer based tasks suitable for preschoolers based on previously validated measures of attention and executive function including appealing and interactive Go/No-Go, response inhibition, delayed alternation, self-ordered pointing and working memory tasks (Hrabok et al. 2007; Muller et al. 2012).

Executive Function Development in the Preschool Period

The preschool period is associated with rapid development in motor, language, cognitive, and social skills, and the availability of age appropriate executive function measures for preschoolers enables executive function development during this critical period to be investigated. Research utilizing measures described above demonstrates that preschool is a period during which executive processes develop at an unprecedented rate; consider the capacity of a 6-year-old in contrast to a 3-year-old. Following is a brief summary of developmental trajectories for attentional control, cognitive flexibility and goal setting domains, however it is important to note that there is enormous inter-individual variability in developmental trajectories and this is particularly obvious in young children. Developmental spurts are commonly observed in individual children, and can also be observed on a population level (Anderson 2002). While development will be described separately for executive domains, it is worth highlighting again that these domains don't operate independently, instead function within an integrated cognitive and neural system that comprises the different component systems (Garon et al. 2008). The ongoing maturation of executive domains and their associated neural networks is dependent on refinement of other executive and non-executive skills, as well as the enhanced coordination and integration of these systems.

Attentional Control

Substantial improvement in inhibitory control is observed in the preschool period (Carlson 2005). On the *Bear/Dragon* task (Go/No-Go task), only about half of young 3-year-olds (<3½ yrs) are able to resist responding to the instructions of the Dragon puppet, however this increases to 75 % for older 3-year-olds (>3½ yrs) and by age 5 years most children are successfully completing this task (Carlson 2005). Accuracy of responding improved only marginally for children aged between 3 and 5 years on the Inhibit condition (Go/No-Go) on the *Shape School* test, but speed increased dramatically during this developmental period (Espy 1997; Espy et al. 2001). In contrast, even 4- and 5-year-olds struggled to remain still on the No-Go items of the *Simon Says* task, demonstrating that the context of the task makes some behaviors more difficult to resist than others. While Carlson (2005) also showed continued maturation of inhibitory control across 3 to 5 years on delayed gratification tasks, performance again varied and the discrepancy may be explained by the intrinsic value of the gift. For example, approximately 60 % of children aged 3 to 4½ could wait 5 min before eating snacks positioned in front of them, however this age group had more difficulty resisting the urge to peep when their surprise prize was being wrapped. When there is a choice between an immediate or delayed gratification, 3-year-olds are unlikely to wait even when the delayed reward is significantly more appealing than the immediate reward (Lemmon and Moore 2007). In contrast, 4-year-olds are able to resist immediate gratification for a greater reward.

Preschoolers have difficulty on complex response inhibition tasks. Carlson (2005) found that only about half of the children aged between 3 and 4½ years were able to pass tasks that required a response that conflict with their instinctive or dominant response (e.g. *Day-Night*). Similarly, Gerstadt et al. (1994) found the *Day-Night* test to be too difficult for children younger than 3½ years, and about half of the children aged 3½ to 4½ years struggled on the task. In contrast, children aged 5 years and older performed well both in terms of accuracy and speed. In terms of accuracy, the most significant improvement in performance was observed between 4½ and 5 years, although performance gains continued to age 7 years. Children younger than 4½ years were slow on the *Day-Night* test, while the average latency for the older age groups did not differ. Interestingly, all preschool age groups perform better at the start than at the end of the *Day-Night* test, suggesting that the task requires considerable cognitive effort that is difficult to sustain (Gerstadt et al. 1994). On average children as young as 3½ years are able to get nearly two-thirds of the trials correct on the Luria hand tapping test, but performance improves significantly throughout the preschool period both in terms of accuracy and speed (Diamond and Taylor 1996). Thus, the developmental trajectories for the *Day-Night* and *Hand Tapping* tasks differ, even though they both require the retention of two rules and inhibition of a dominant response (Diamond and Taylor 1996). The *Day-Night* task may be more difficult as it involves the inhibition of an instinctive verbal response rather than a motor response, as is the case in the *Hand Tapping* task.

In summary, enormous development of inhibitory control is observed between 3- and 6-years of age with continued maturation beyond the preschool period. Young preschoolers have limited impulse control and delay of gratification and simple Go/No-Go tasks are the most suitable for evaluating developmental status. Older preschoolers have greater inhibitory control, and more complex inhibitory control measures are probably necessary to detect subtle impairments in these children.

Cognitive Flexibility

Working memory, switching and shifting attention tasks have been administered in numerous developmental studies and provide evidence that cognitive flexibility increases greatly during the preschool period. On *Delayed Alternation* (Espy et al. 1999) even very young children are able to shift search strategy between alternate wells. Some children as young as 3-years apply an alternating search strategy at least some of the time, however there are also some older children (e.g. 5-years) who struggle with this concept (Espy et al. 1999). Performance improves with age across the preschool period on measures of self-ordered pointing tasks (Hongwanishkul et al. 2005; Luciana and Nelson 1998). Hongwanishkul et al. (2005) reported significant developmental increments between 3 and 5-years of age with their *Self-ordered Pointing* task, with a particular spurt observed between 3- and 4- years. With an older sample and a computerized self-ordered search task, Luciana and Nelson (1998) reported that 4-year-olds make more perseverative errors than older preschoolers, which likely reflects less mature working memory. Consistent with these findings, younger preschoolers tend to make their first perseverative error prior to older preschoolers on the *Six Boxes* test, although the total number of searches needed to find all six boxes decreases only marginally with increasing age (Diamond et al. 1997). More complex working memory tasks that require explicit manipulation of information in short-term memory store are generally too difficult for young preschoolers. For example, very few 3-year-olds are able to correctly reverse the sequence of three digits but by 5-years of age most children have this capacity (Carlson 2005).

Before a child can successfully switch between rule sets, they must be able to hold the multiple rules in working memory and have the capacity to inhibit other previously applied rules (Garon et al. 2008). The switch condition of the *Shape School* is successfully completed by most 4-year-olds, and while accuracy increases slightly, improved performance in older preschoolers is predominantly reflected in better switching fluency and reduced time needed to complete the task (Espy 1997). While 3-year-olds can complete the switch condition on the *Trails-P*, they are substantially slower in completing the task than 4-year-olds and require almost twice the time needed by 5-year-olds (Espy and Cwik 2004). Accuracy of switching on *Trails-P* also improves between 3- and 5-years of age, although generally speaking preschoolers make few errors on this task. In terms of shifting attention, 3-year-olds really struggle to shift sorting categories on the Dimensional Change Card Sort test, but this perseverative behavior is far less common in older 4-year-olds (Carlson 2005).

Goal Setting

In contrast to attentional control and cognitive flexibility, less research has investigated the early development of goal setting processes such as planning and organizational ability, and conceptual reasoning. On the *Tower of Hanoi*, a measure that taps planning ability, steady improvement in performance is observed across the preschool period (Espy et al. 2001; Welsh et al. 1991). It should be noted however, that children younger than 4-years of age get very few trials correct and a significant increase in performance is observed between 3- and 4-years. Considerable development of conceptual reasoning is observed in the preschool period, particularly between 4- and 5-years of age. Using the *Object Classification Task for Children* 3-year-olds struggle to identify a common feature within a group of six objects (i.e. toys), but in contrast, children aged 4-years and older find it relatively easy to sort different objects according to a single dimension. It is not until children are aged 5-years that they can identify and sort according to a second and third dimension. In summary, problem solving tasks that require forward planning and conceptual reasoning can be administered to preschoolers, and this is potentially worthwhile.

Intervention

An objective of this review was to demonstrate that it is possible to assess executive function in preschoolers by providing examples of tasks that are suitable for this age group and evidence that executive processes undergo considerable maturation during the preschool period. However, just as importantly, we wanted to convince pediatric clinicians that the preschool period is a critical time to perform comprehensive neuropsychological assessments. Early intervention is an effective approach for minimizing the long-term consequences of cognitive impairments, and detailed assessments of young children are the best way to detect children in need for early intervention and for tailoring interventions for the child's specific needs.

It is well recognized that brain and cognitive development are greatly determined by environmental factors. Consistent with this notion, research has demonstrated that the family environment, in particular parenting styles, has important implications to executive function development (Hughes 2011; Rhoades et al. 2011). While various elements of parenting have been associated with executive function development, supporting autonomy and maternal scaffolding appear to be the most critical aspects of parenting (Bernier et al. 2010; Hughes and Ensor 2009). Unfortunately, this positive association between parenting and executive function development means that certain negative parenting characteristics such as disorganization and unpredictability hinders early development of these skills in young children (Hughes and Ensor 2009; Rhoades et al. 2011). This knowledge provides hope that early intervention programs focusing on maternal scaffolding and support may be effective in enhancing executive development in high-risk children and those exhibiting early delays.

Cognitive training involves intensive practice (and sometimes intentional instruction) of a specific cognitive skill such as working memory. While this is a controversial area of research and practice, a couple of studies have shown cognitive training in preschoolers focusing on attentional control and working memory to be effective, at least in the short-term. For example, a series of small randomized controlled trials of a 5-day training program involving child friendly computer exercises tapping attentional control processes achieved significant improvements in aspects of attentional control as well as spatial reasoning (Rueda et al. 2005). Of interest, the effectiveness of this training program was greater for 4-year-olds than 6-year-olds. Another study with preschoolers examined the effectiveness of two 5-week training programs, one focusing on working memory and the other inhibition (Thorell et al. 2009). In contrast to children in control conditions, children who received the working memory intervention showed improvements in trained and non-trained working memory tasks as well as in attentional control tasks, but no effects in non-trained inhibitory control tasks. The children who received the inhibition intervention only showed improved functioning in trained inhibitory control tasks. Far more research is needed to demonstrate that cognitive training programs have long-term effects and the effects translate to everyday functioning. Also, research is needed to determine when training should be delivered, the dose of training, and whether booster sessions are needed. However, early studies in this area suggest that cognitive training may be an avenue for enhancing the development of executive processes as well as assisting those who are impaired. Given that the preschool period is associated with dramatic brain and cognitive development, one could assume that this is a period in which cognitive training may be most effective.

Conclusions

In conclusion, executive function develops rapidly during the preschool period. While there is a perception that preschoolers are difficult to assess, with the right assessment tasks and testing environment it is feasible to conduct a detailed assessment of executive function. There are numerous executive function measures that are age appropriate for preschoolers, although none have adequate normative data and no commercially norm-referenced battery is currently available. Given the importance of detecting problems in executive function at an early age, further refinement of preschool executive function measures is needed, especially with regards to collating good test norms and generating age-standardized scores.

Acknowledgements Financial support was provided by the National Health & Medical Research Council (PJA - Senior Research Fellowship #628371) and the Victorian Government's Operational Infrastructure Support Program.

References

Alexander, M., & Stuss, D. (2000). Disorders of frontal lobe functioning. *Seminars in Neurology, 20*(4), 427–437.

Anderson, P. (2002). Assessment and development of executive function (EF) during childhood. *Child Neuropsychology, 8*(2), 71–82.

Anderson, P., Doyle, L., & Victorian Infant Collaborative Group. (2004). Executive functioning in school-aged children who were born very preterm or with extremely low birth weight in the 1990s. *Pediatrics, 114*(1), 50–57.

Anderson, P. J. (2008). Towards a developmental model of executive function. In V. Anderson, R. Jacobs, & P. J. Anderson (Eds.), *Executive functions and the frontal lobes: A lifespan perspective* (pp. 3–22). New York: Psychology Press.

Anderson, V. (1998). Assessing executive functions in children: biological, psychological, and developmental considerations. *Neuropsychological Rehabilitation, 8*(3), 319–349.

Anderson, V., Godfrey, C., Rosenfeld, J. V., & Catroppa, C. (2012). 10 years outcome from childhood traumatic brain injury. *International Journal of Developmental Neuroscience, 30*(3), 217–224.

Anderson, V. A., Anderson, P., Northam, E., Jacobs, R., & Mikiewicz, O. (2002). Relationships between cognitive and behavioral measures of executive function in children with brain disease. *Child Neuropsychology, 8*(4), 231–240.

Baddeley, A. (1996). Exploring the central executive. *The Quarterly Journal of Experimental Psychology, 49A*, 5–28.

Baddeley, A. (1998). The central executive: a concept and some misconceptions. *Journal of the International Neuropsychological Society, 4*(5), 523–526.

Baddeley, A. D. (1986). *Working memory*. Oxford: Oxford University Press.

Baker, S. C., Rogers, R. D., Owen, A. M., Frith, C. D., Dolan, R. J., Frackowiak, R. S. J., & Robbins, T. W. (1996). Neural systems engaged by planning: A PET study of the Tower of London task. *Neuropsychologia, 34*(6), 515–526.

Barkley, R. (1997). Behavioral inhibition, sustained attention, and executive functions: constructing a unifying theory of ADHD. *Psychological Bulletin, 121*(1), 65–94.

Baron, I. (2004). *Neuropsychological evaluation of the child*. New York: Oxford University Press.

Beck, D. M., Schaefer, C., Pang, K., & Carlson, S. M. (2011). Executive function in preschool children: test-retest reliability. *Journal of Cognition and Development, 12*(2), 169–193.

Benton, A. L. (1968). Differential Behavioral Effects in Frontal Lobe Disease. *Neuropsychologia, 6*(1), 53–60.

Bernier, A., Carlson, S. M., & Whipple, N. (2010). From external regulation to self-regulation: early parenting precursors of young children's executive functioning. *Child Development, 81*(1), 326–339.

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development, 81*(6), 1641–1660.

Bigler, E. (1988). Frontal lobe damage and neuropsychological assessment. *Archives of Clinical Neuropsychology, 3*, 279–297.

Blair, C. (2002). School readiness—integrating cognition and emotion in a neurobiological conceptualization of children's functioning at school entry. *The American Psychologist, 57*(2), 111–127.

Brauer, J., & Friederici, A. D. (2007). Functional neural networks of semantic and syntactic processes in the developing brain. *Journal of cognitive neuroscience, 19*(10), 1609-1623.

Brocki, K., & Bohlin, G. (2004). Executive functions in children aged 6 to 13: a dimensional and developmental study. *Developmental Neuropsychology, 26*(2), 571–593.

Bull, R., Espy, K. A., & Senn, T. E. (2004). A comparison of performance on the Towers of London and Hanoi in young children. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 45*(4), 743–754.

Carlson, S. M. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology, 28*(2), 595–616.

Casey, B.J., Giedd, J.N., & Thomas, K.M. (2000). Structural and functional brain development and its relation to cognitive development. *Biological psychology, 54*(1-3), 241–257.

Casey, B. J., Tottenham, N., Liston, C., & Durston, S. (2005). Imaging the developing brain: what have we learned about cognitive development? *Trends in cognitive sciences, 9*(3), 104–110.

Chevalier, N., Sheffield, T. D., Nelson, J. M., Clark, C. A., Wiebe, S. A., & Espy, K. A. (2012). Underpinnings of the costs of flexibility in preschool children: the roles of inhibition and working memory. *Developmental Neuropsychology, 37*(2), 99–118.

Clark, C. A. C., Pritchard, V. E., & Woodward, L. J. (2010). Preschool executive functioning abilities predict early mathematics achievement. *Developmental Psychology, 46*(5), 1176–1191.

Courtney, S., Petit, L., Maisong, J., Ungerleider, L., & Haxby, J. (1998). An area specialized for spatial working memory in human frontal cortex. *Science, 279*, 1347–1350.

Cripe, L. I. (1996). The ecological validity of executive function testing. In R. J. Sbordone & J. Long (Eds.), *Ecological validity of neuropsychological testing* (pp. 171–202). England: Gr Press/St Lucie Press, Inc.

Della Sala, S., Gray, C., Spinnler, H., & Trivelli, C. (1998). Frontal lobe functioning in man: the riddle revisited. *Archives of Clinical Neuropsychology, 13*(8), 663–682.

Diamond, A. (1985). Development of the ability to use recall to guide action, as indicated by infants' performance on AB. *Child Development, 56*(4), 868–883.

Diamond, A., & Doar, B. (1989). The performance of human infants on a measure of frontal cortex function, the delayed response task. *Developmental Psychobiology, 22*(3), 271–294.

Diamond, A., & Goldman-Rakic, P. S. (1989). Comparison of human infants and rhesus monkeys on piaget's AB task: evidence for dependence on dorsolateral prefrontal cortex. *Experimental Brain Research, 74*(1), 24–40.

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: development of the abilities to remember what I said and to "do as I say, not as I do". *Developmental Psychobiology, 29*(4), 315–334.

Diamond, A., Prevor, M., Callender, G., & Druin, D. (1997). Prefrontal cortex cognitive deficits in children treated early and continuously for PKU—introduction. *Monographs of the Society for Research in Child Development, 62*(4).

Diamond, A., Kirkham, N., & Amso, D. (2002). Conditions under which young children can hold two rules in mind and inhibit a prepotent response. *Developmental Psychology, 38*(3), 352–362.

Durston, S., Davidson, M. C., Tottenham, N., Galvan, A., Spicer, J., Fossella, J. A., & Casey, B. J. (2006). A shift from diffuse to focal cortical activity with development. *Developmental Science, 9*(1), 1–8.

Elliott, C. D. (2007). *Differential ability scales second edition: Introductory and technical handbook*. San Antonio: Harcourt Assessment.

Eslinger, P., & Damasio, A. (1985). Severe disturbance of higher cognition after bilateral frontal-lobe ablation—patient EVR. *Neurology, 35*(12), 1731–1741.

Espy, K. (1997). The shape school: assessing executive function in preschool children. *Developmental Neuropsychology, 13*(4), 495–499.

Espy, K. A., & Cwik, M. F. (2004). The development of a trial making test in young children: the TRAILS-P. *The Clinical Neuropsychologist, 18*(3), 411–422.

Espy, K. A., Kaufmann, P. M., McDiarmid, M. D., & Glisky, M. L. (1999). Executive functioning in preschool children: performance on A-not-B and other delayed response format tasks. *Brain and Cognition, 41*(2), 178–199.

Espy, K. A., Kaufmann, P. M., & Glisky, M. L. (2001). New procedures to assess executive functions in preschool children. *The Clinical Neuropsychologist, 15*(1), 46–58.

Espy, K. A., McDiarmid, M. M., Cwik, M. F., Stalets, M. M., Hamby, A., & Senn, T. E. (2004). The contribution of executive functions to emergent mathematic skills in preschool children. *Developmental Neuropsychology, 26*(1), 465–486.

Espy, K. A., Bull, R., Martin, J., & Stroup, W. (2006). Measuring the development, of executive control with the shape school. *Psychological Assessment, 18*(4), 373–381.

Espy, K. A., Bull, R., Kaiser, H., Martin, J., & Banet, M. (2008). Methodological and conceptual issues in understanding the development of executive control in the preschool period. In V. Anderson, R. Jacobs, & P. J. Anderson (Eds.), *Executive functions and the frontal lobes: A lifetime perspective* (pp. 105–122). New York: Psychology Press.

Espy, K. A., Sheffield, T. D., Wiebe, S. A., Clark, C. A. C., & Moehr, M. J. (2011). Executive control and dimensions of problem behaviors in preschool children. *Journal of Child Psychology and Psychiatry, 52*(1), 33–46.

Fair, D. A., Cohen, A. L., Power, J. D., Dosenbach, N. U., Church, J. A., Miezin, F. M., Schlagger, B.L., & Petersen, S. E. (2009). Functional brain networks develop from a "local to distributed" organization. *PLoS computational biology, 5*(5), e1000381.

Fletcher, J. M., & Taylor, H. G. (1984). Neuropsychological approaches to children: towards a developmental neuropsychology. *Journal of Clinical Neuropsychology, 6*(1), 39–56.

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: a review using an integrative framework. *Psychological Bulletin, 134*(1), 31–60.

Gao, W., Lin, W., Chen, Y., Gerig, G., Smith, J. K., Jewells, V., & Gilmore, J. H. (2009). Temporal and spatial development of axonal maturation and myelination of white matter in the developing brain. *American journal of neuroradiology, 30*(2), 290–296.

Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: performance of children 3 1/2–7 years old on a stroop-like day-night test. *Cognition, 53*(2), 129–153.

Giedd, J. N., Blumenthal, J., Jeffries, N. O., Castellanos, F. X., Liu, H., Zijdenbos, A., Paus, T., Evans, A.C., & Rapoport, J. L. (1999). Brain development during childhood and adolescence: a longitudinal MRI study. *Nature neuroscience, 2*(10), 861–863.

Gioia, G., Isquith, P., & Guy, S. (2001). Assessment of executive functions in children with neurological impairment. In R. Simeonsson & S. Rosenthal (Eds.), *Psychological and developmental assessment*: *Children with disabilities and chronic conditions* (pp. 317–356). New York: The Guildford Press.

Gioia, G.A., Isquith, P.K., Guy, S.C., & Kenworthy, L. (2000). *The behavior rating inventory of executive function*. Odessa, FL: Psychological Assessment Resources.

Gogtay, N., Giedd, J. N., Lusk, L., Hayashi, K. M., Greenstein, D., Vaituzis, A. C., Nugent, T.F., Herman, D.H., Clasen, L.S., Toga, A.W., Rapoport, J.L., & Thompson, P. M. (2004). Dynamic mapping of human cortical development during childhood through early adulthood. *Proceedings of the National Academy of Sciences of the United States of America, 101*(21), 8174–8179.

Golden, C. (1981). The Luria-Nebraska children's battery: Theory and formulation. In G. Hynd & J. Obrzut (Eds.), *Neuropsychological assessment of the school-aged child*. (pp. 277–302). New York: Grune & Stratton.

Grattan, L., & Eslinger, P. J. (1991). Frontal lobe damage in children and adults: a comparative review. *Developmental Neuropsychology, 7*(3), 283–326.

Hermoye, L., Saint-Martin, C., Cosnard, G., Lee, S. K., Kim, J., Nassogne, M. C., Menton, R., Clapuyt, P., Donohue, P.K., Hua, K., Wakana, S., Jiang, H., van Zijl, P.C. & Mori, S. (2006). Pediatric diffusion tensor imaging: normal database and observation of the white matter maturation in early childhood. *NeuroImage, 29*(2), 493–504.

Heyder, K., Suchan, B., & Daum, I. (2004). Cortico-subcortical contributions to executive control. *Acta Psychologica, 115*(2–3), 271–289.

Hongwanishkul, D., Happaney, K. R., Lee, W. S., & Zelazo, P. D. (2005). Assessment of hot and cool executive function in young children: age-related changes and individual differences. *Developmental Neuropsychology, 28*(2), 617–644.

Hrabok, M., Kerns, K. A., & Muller, U. (2007). The vigilance, orienting, and executive attention networks in 4-year-old children. *Child Neuropsychology, 13*(5), 408–421.

Hughes, C. (2011). Changes and challenges in 20 years of research into the development of executive functions. *Infant and Child Development, 20*(3), 251–271.

Hughes, C. (1998). Executive function in preschoolers: Links with theory of mind and verbal ability. *The British Journal of Developmental Psychology, 16*, 233–253.

Hughes, C. H., & Ensor, R. A. (2009). How do families help or hinder the emergence of early executive function? *New Directions for Child and Adolescent Development, 123*, 35–50.

Hughes, C., Ensor, R., Wilson, A., & Graham, A. (2009). Tracking executive function across the transition to school: a latent variable approach. *Developmental Neuropsychology, 35*(1), 20–36.

Huizinga, M., Dolan, C. V., & Van der Molen, M. W. (2006). Age-related change in executive function: developmental trends and a latent variable analysis. *Neuropsychologia, 44*, 2017–2036.

Huttenlocher, P. R. (1990). Morphometric study of human cerebral cortex development. *Neuropsychologia, 28*(6), 517–527.

Huttenlocher, P. R., & Dabholkar, A. S. (1997). Regional differences in synaptogenesis in human cerebral cortex. *The Journal of comparative neurology, 387*(2), 167–178.

Isquith, P. K., Gioia, G. A., & Espy, K. A. (2004). Executive function in preschool children: examination through everyday behavior. *Developmental Neuropsychology, 26*(1), 403–422.

Johnson, M. H. (2001). Functional brain development in humans. Nature reviews. *Neuroscience, 2*(7), 475–483.

Kaufman, A. S., & Kaufman, N. L. (2004). *Kaufman assessment battery for children-second edition (K-ABC-II)*. Circle Pines: American Guidance Service.

Kelly, T. (2000). The development of executive function in school-aged children. *Clinical Neuropsychological Assessment*, *1*, 38–55.

Kiselev, S., Espy, K. A., & Sheffield, T. (2009). Age-related differences in reaction time task performance in young children. *Journal of Experimental Child Psychology, 102*(2), 150–166.

Klenberg, L., Korkman, M., & Lahti-Nuuttila, P. (2001). Differential development of attention and executive functions in 3- to 12-year-old Finnish children. *Developmental Neuropsychology, 20*(1), 407–428.

Kochanska, G., Murray, K., & Harlan, E. (2000). Effortful control in early childhood: continuity and change, antecedents, and implications for social development. *Developmental Psychology, 36*(2), 220–232.

Korkman, M., Kirk, U., & Kemp, S. (1998). *NEPSY: A developmental neuropsychological assessment*. San Antonio: The Psychological Corporation.

Korkman, M., Kirk, U., & Kemp, S. (2007). *NEPSY-II second edition. Clinical and interpretive manual* (2nd ed.). San Antonio: PsychCorp.

Lehto, J., Juujarvi, P., Kooistra, L., & Pulkkinen, L. (2003). Dimensions of executive functioning: evidence from children. *The British Journal of Developmental Psychology, 21*, 59–80.

Lemmon, K., & Moore, C. (2007). The development of prudence in the face of varying future rewards. *Developmental Science, 10*(4), 502–511.

Lenroot, R. K., & Giedd, J. N. (2006). Brain development in children and adolescents: insights from anatomical magnetic resonance imaging. *Neuroscience and biobehavioral reviews, 30*(6), 718–729.

Levin, H., Culhane, K., Hartmann, J., Evankovich, K., Mattson, A., Harward, H., et al. (1991). Developmental-changes in performance on tests of purported frontal-lobe functioning. *Developmental Neuropsychology, 7*(3), 377–395.

Levine, B., Stuss, D., Milberg, W., Alexander, M., Schwartz, M., & MacDonald, R. (1998). The effects of focal and diffuse brain damage on strategy application: evidence from focal lesions, traumatic brain injury and normal aging. *Journal of the International Neuropsychological Society, 4*(3), 247–264.

Lezak, M. (1982). The problem of assessing executive functions. *International Journal of Psychology*, *17*(2-3), 281–297.

Lezak, M., Howieson, D., Bigler, E., & Tranel, D. (2012). *Neuropsychological assessment* (5th ed.). New York: Oxford University Press.

Luciana, M., & Nelson, C. (1998). The functional emergence of prefrontally-guided working memory systems in four- to eight-year-old children. *Neuropsychologia, 36*(3), 273–293.

Matsuzawa, J., Matsui, M., Konishi, T., Noguchi, K., Gur, R. C., Bilker, W., & Miyawaki, T. (2001). Age-related volumetric changes of brain gray and white matter in healthy infants and children. *Cerebral cortex, 11*(4), 335–342.

Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: a latent variable analysis. *Cognitive Psychology, 41*(1), 49–100.

Morris, R. G., Ahmed, S., Syed, G. M., & Toone, B. K. (1993). Neural correlates of planning ability - frontal-lobe activation during the tower-of-london-test. *Neuropsychologia, 31*(12), 1367–1378.

Montgomery, D. E., & Koeltzow, T. E. (2010). A review of the day-night task: the stroop paradigm and interference control in young children. *Developmental Review, 30*(3), 308–330.

Muller, U., Kerns, K. A., & Konkin, K. (2012). Test-retest reliability and practice effects of executive function tasks in preschool children. *The Clinical Neuropsychologist, 26*(2), 271–287.

Norman, D. A., & Shallice, T. (1986). Attention to action: willed and automatic control of behaviour. In R. J. Davidson, G. E. Schwartz, & D. E. Shapiro (Eds.), *Consciousness and self-regulation* (Vol. 4, pp. 1–14). New York: Plenum.

O'Donnell, J., Macgregor, L., Dabrowski, J., Oestreicher, J., & Romero, J. (1994). Construct-validity of neuropsychological tests of conceptual and attentional abilities. *Journal of Clinical Psychology, 50*(4), 596–600.

Ozonoff, S., Pennington, B., & Rogers, S. (1991). Executive function deficits in high-functioning autistic individuals - relationship to theory of mind. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 32*(7), 1081–1105.

Parkin, A. J. (1998). The central executive does not exist. *Journal of the International Neuropsychological Society, 4*(5), 518–522.

Paus, T., Collins, D. L., Evans, A. C., Leonard, G., Pike, B., & Zijdenbos, A. (2001). Maturation of white matter in the human brain: a review of magnetic resonance studies. *Brain research bulletin, 54*(3), 255–266.

Pennington, B. F., & Ozonoff, S. (1996). Executive functions and developmental psychopathology. *Journal of Child Psychology and Psychiatry, 37*(1), 51–87.

Prevor, M. B., & Diamond, A. (2005). Color-object interference in young children: a stroop effect in children 3(1/2)-6(1/2) years old. *Cognitive Development, 20*(2), 256–278.

Rezai, K., Andreasen, N., Alliger, R., Cohen, G., Swayze, V., & O'Leary, D. (1993). The neuropsychology of the prefrontal cortex. *Archives of Neurology, 50*, 636–642.

Rhoades, B. L., Greenberg, M. T., Lanza, S. T., & Blair, C. (2011). Demographic and familial predictors of early executive function development: contribution of a person-centered perspective. *Journal of Experimental Child Psychology, 108*(3), 638–662.

Roid, G. H. (2003). *Stanford-binet intelligence scales, fifth edition: Technical manual*. Itasca: Riverside.

Rueda, M., Rothbart, M., McCandliss, B., Saccomanno, L., & Posner, M. (2005). Training, maturation, and genetic influences on the development of executive attention. *Proceedings of the National Academy of Sciences of the United States of America, 102*(41), 14931–14936.

Schoemaker, K., Bunte, T., Wiebe, S. A., Espy, K. A., Dekovic, M., & Matthys, W. (2012). Executive function deficits in preschool children with ADHD and DBD. *Journal of Child Psychology and Psychiatry, and Allied Disciplines, 53*(2), 111–119.

Shallice, T. (1982). Specific impairments of planning. *Philosophical Transcripts of the Royal Society of London, 298*, 199–209.

Shallice, T. (1990). *From neuropsychology to mental structure*. New York: Oxford University Press.

Shallice, T., & Burgess, P. W. (1996). The domain of supervisory processes and temporal organisation of behaviour. *Philosophical Transactions of the Royal Society of London B: Biological Sciences, 351*, 1405–1412.

Smidts, D. P., Jacobs, R., & Anderson, V. (2004). The object classification task for children (OCTC): a measure of concept generation and mental flexibility in early childhood. *Developmental Neuropsychology, 26*(1), 385–401.

Sowell, E. R., Thompson, P. M., Leonard, C. M., Welcome, S. E., Kan, E., & Toga, A. W. (2004). Longitudinal mapping of cortical thickness and brain growth in normal children. The Journal of neuroscience: *the official journal of the Society for Neuroscience, 24(*38), 8223–8231.

Stuss, D. T. (1992). Biological and psychological-development of executive functions. *Brain and cognition, 20*(1), 8–23.

Stuss, D., & Alexander, M. (2000). Executive functions and the frontal lobes: a conceptual view. *Psychological Research, 63*(3–4), 289–298.

Stuss, D. T., Alexander, M. P., Floden, D., Binns, M. A., Levine, B., McIntosh, A. R., et al. (2002). Fractionation and localization of distinct frontal lobe processes: evidence from focal lesions in humans. In D. T. Stuss & R. T. Knight (Eds.), *Principles of frontal lobe function*. New York: Oxford University Press.

Taki, Y., Hashizume, H., Thyreau, B., Sassa, Y., Takeuchi, H., Wu, K., Kotozaki, Y., Nouchi, R., Asano, M., Asano, K., Fukuda, H., & Kawashima, R. (2012). Linear and curvilinear correlations of brain gray matter volume and density with age using voxel-based morphometry with the Akaike information criterion in 291 healthy children. *Human brain mapping*. doi:10.1002/hbm.22033.

Tau, G. Z., & Peterson, B. S. (2010). Normal development of brain circuits. *Neuropsychopharmacology, 35*(1), 147–168.

Thorell, L. B., Lindqvist, S., Bergman Nutley, S., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science, 12*(1), 106–113.

Tsujimoto, S. (2008). The prefrontal cortex: functional neural development during early childhood. The Neuroscientist : *a review journal bringing neurobiology, neurology and psychiatry, 14*(4), 345–358.

Tsujimoto, S., Yamamoto, T., Kawaguchi, H., Koizumi, H., & Sawaguchi, T. (2004). Prefrontal cortical activation associated with working memory in adults and preschool children: an event-related optical topography study. *Cerebral cortex, 14*(7), 703–712.

Walsh, K. (1978). *Neuropsychology: A clinical approach*. New York: Churchill Livingston.

Wechsler, D. (2002). *Wechsler preschool and primary scale of intelligence* (3rd ed.). San Antonio: Harcourt Assessment.

Welsh, M., & Pennington, B. (1988). Assessing frontal lobe functioning in children: views from developmental psychology. *Developmental Neuropsychology*, *4*(3), 199–230.

Welsh, M., Pennington, B., Ozonoff, S., Rouse, B., & McCabe, E. (1990). Neuropsychology of early-treated phenylketonuria - specific executive function deficits. *Child Development, 61*(6), 1697–1713.

Welsh, M., Pennington, B., & Groisser, D. (1991). A normative developmental-study of executive function—a window on prefrontal function in children. *Developmental Neuropsychology, 7* (2), 131–149.

Wiebe, S. A., Espy, K., & Charak, D. (2008). Using confirmatory factor analysis to understand executive control in preschool children: 1. Latent structure. *Developmental Psychology, 44*(2), 575–587.

Willoughby, M., & Blair, C. (2011). Test-retest reliability of a new executive function battery for use in early childhood. *Child Neuropsychology, 17*(6), 564–579.

Willoughby, M. T., Blair, C. B., Wirth, R. J., & Greenberg, M. (2010). The measurement of executive function at age 3 years: psychometric properties and criterion validity of a new battery of tasks. *Psychological Assessment, 22*(2), 306–317.

Willoughby, M. T., Wirth, R. J., & Blair, C. B. (2011). Contributions of modern measurement theory to measuring executive function in early childhood: an empirical demonstration. *Journal of Experimental Child Psychology, 108*(3), 414–435.

Wolfe, C. D., & Bell, M. A. (2004). Working memory and inhibitory control in early childhood: Contributions from physiology, temperament, and language. *Developmental psychobiology, 44*(1), 68–83.

Zelazo, P. D. (2006). The dimensional change card sort (DCCS): a method of assessing executive function in children. *Nature Protocols, 1*(1), 297–301.

Zelazo, P. D., Muller, U., Frye, D., & Marcovitch, S. (2003). The development of executive function. *Monographs of the Society for Research in Child Development, 68*(3).

Zelazo, P., Qu, L., & Muller, U. (2004). Hot and cool aspects of executive function: relations in early development. In W. Schneider, R. Schumann-Hengsteler, & B. Sodian (Eds.), *Young children's cognitive development: Interrelationships among executive functioning, working memory, verbal ability, and theory of mind* (pp. 71–93). Mahwah: Lawrence Eribaum Associates Publishers.