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Importance, Contributors, Research Needs and Assessment Options

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POLICY INFORMATION REPORT

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RESEARCH REPORT

Preschoolers' Executive Function: Importance, Contributors, Research Needs and Assessment Options

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The early education field increasingly is recognizing the key role played by young children's executive function (EF) skills, generally defined as the cognitive abilities that consciously support goal-directed behaviors. To provide the field with an overview of research conducted on this topic over the past 15 years, we review research on the traits and skills that fall under the broader umbrella of preschool EF and the role it plays in young children's developmental and academic outcomes. Also addressed are the child, environmental, activity-related, and curricular factors potentially impacting the development of EF and some EF-related topics for which additional research is needed. Finally, we provide practical and psychometric information regarding six examples of measures that focus on assessing preschoolers' EF skills. This report can serve as a resource for early childhood researchers and practitioners who are interested in understanding EF development during the early years. By highlighting some topics for which additional research is needed and providing information regarding examples of valid and reliable measures to assess EF in children ages 3–5 years, we hope this report also will serve as a springboard for future studies related to preschool EF.

Keywords Executive function; preschool; assessment

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The early education field is increasingly recognizing the key role played by young children's executive function (EF) skills, generally defined as the cognitive abilities that consciously support goal-directed behaviors (Diamond, 2006; Garon, Bryson, & Smith, 2008). This recognition is important given the continued policy emphasis on expanding at-risk children's access to publicly funded prekindergarten (Barnett et al., 2016) and the central role that EF skills play in children's learning and overall school readiness (Blair, 2002; Blair & Razza, 2007; Obradovic, Portilla, & Boyce, 2012; Zelazo, Blair, & Willoughby, 2016). The extent to which EF may serve as a critical contributor to children's early education outcomes may be particularly salient in light of recent data on the out-of-school suspension rates of preschool children, the percentage of kindergarten students who are retained in grade (U.S. Department of Education Office for Civil Rights, 2014), and research on the relationship between exposure to poverty and financial hardship and EF skills at age 4 years (Raver, Blair, Willoughby, & Family Life Project Key Investigators, 2013).

Perhaps not surprisingly, a wealth of preschool EF-related research has been conducted over the past 15 years, ranging from how EF is related to other cognitive skills to how children's experiences and environments contribute to EF development. In addition, attention has been paid to how EF might be validly and reliably assessed in 3-, 4-, and 5-year-olds. Given the importance of EF to young children's cognitive and social–emotional development, school-related behavior, and school success, we provide a broad overview of this research base, including the traits and skills that fall under the broad umbrella of EF and the role EF plays in preschoolers' developmental and academic outcomes. Also addressed are the child, environmental, activity-related, and curricular factors potentially impacting the development of EF and some related topics for which additional research is needed. Finally, to support future research, we provide practical and psychometric information regarding six examples of measures that focus on assessing EF in children ages 3–5 years.

What Is Executive Function?

Although *executive function* may sound like a topic that pertains exclusively to a corporate CEO, the term actually refers to an interrelated and complex set of high-level cognitive and behavioral processes that all employees should possess,

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regardless of their professional field or place on the career ladder. These qualities, which begin to develop early in life, include the ability to anticipate and initiate actions; appropriately direct and sustain one's short-term attention; inhibit inappropriate behaviors; problem solve, incorporate relevant feedback, and selectively make revisions to original plans; and retrieve rules and ideas from long-term memory to develop and implement appropriate strategies. EF also involves the capacity to use working memory and inhibit and control thoughts and actions (Zelazo et al., 2016).

Similarly, in children, EF skills consist of mental processes that help them control their behavior and attention, delay gratification, resist impulses, and engage in goal-directed behaviors (Blair & Ursache, 2011; Center on the Developing Child at Harvard University, 2011). Examples of important early EF classroom skills include the capacity to resist distractions; shift and maintain focus on the teacher or task at hand; and remember and follow directions, such as "raise your hand" and "wait your turn" (Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008; Cuevas, Hubble, & Bell, 2012; Garon et al., 2008; McClelland et al., 2007; Ursache, Blair, & Raver, 2011).

Most adults can easily identify toddlers and preschoolers who have not yet developed the capacity to resist distractions and follow directions. Yet, the larger education and developmental psychology fields have many (albeit overlapping) theories regarding EF, each stemming from a slightly different perspective. For example, EF is considered to be one aspect of the broader construct of self-regulation, which is the ability to manage attention, behavior, and emotional arousal to achieve a goal (Blair & Ursache, 2011; Posner & Rothbart, 2000). Self-regulation is typically divided into four subcomponents: emotion regulation, effortful control, executive attention, and EF. EF is considered the cognitive component of self-regulation and thus also to be primarily within a person's voluntary control (Blair & Ursache, 2011; Carlson, Mandell, & Williams, 2004).

Reflecting this perspective, one theory of EF collapses its related skills into three categories. As can be seen in Figure 1, these categories are *inhibitory control* (also referred to as self-control or impulse control), *cognitive or mental flexibility* (or what might be termed attention switching or set shifting), and *working memory* (or the ability to hold information in one's mind and use that information; Bedrova & Leong, n.d.; Blair & Ursache, 2011; Blair, Zelazo, & Greenberg, 2005; Diamond, 2006; Diamond & Lee, 2011; Espy, Bull, Martin, & Stroup, 2006; Garon et al., 2008; Miyake, Friedman, Emerson, Witzki, & Howerter, 2000).

As can be seen also in Figure 1, another related theory characterizes EF as a domain with four distinct regions. The first two categories overlap with the three-category model and include *attentional control* (the capacity to selectively focus on a particular task for a set amount of time, while also remembering or resisting what *not* to do) and *cognitive flexibility* (or the capacity to "switch gears," reflect on mistakes, and use one's working memory to strategize on next steps). However, from this perspective, goal setting—defined as reasoning and formulating a plan of sequential steps toward reaching a specific end point—and information processing, or the extent to which an individual can organize his or her thoughts and weed through the bits of information that may or may not help the individual complete a task, also are included.

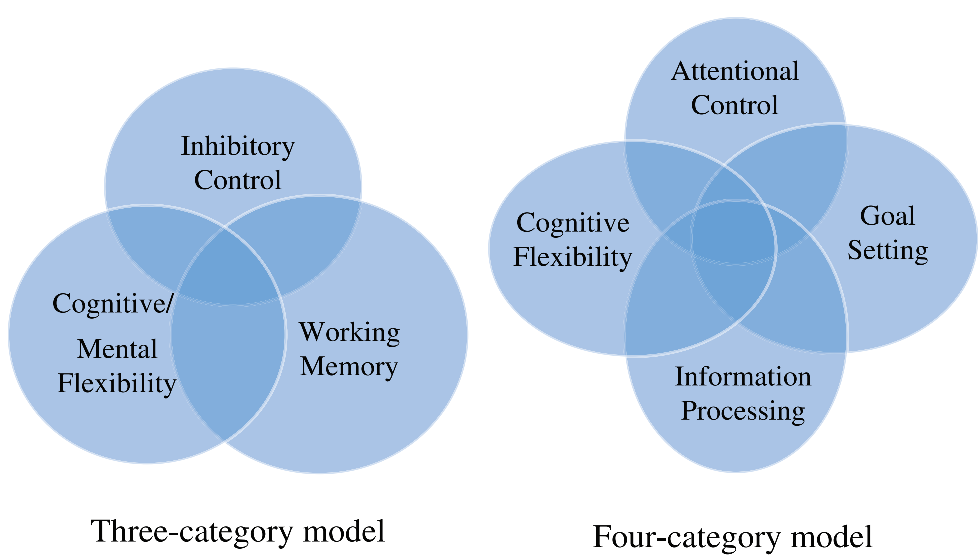

Figure 1 Three- and four-category models of executive function.

Although certain tasks will demand higher levels of input from specific EF domains, the processes within each domain are highly integrated, and all of the domains are bidirectionally related and thus must work together for optimal functioning (Anderson, 2002; Anderson & Reidy, 2012).

In addition, some researchers have separated these EF processes into those that can and cannot be influenced by emotion (Liew, 2011; Rueda, Posner, & Rothbart, 2005). As a result, another theory about EF divides it into *hot* and *cool* categories. Tasks that involve hot EF typically involve some type of emotional component, such as a reward or fear. Conversely, tasks that involve cool EF are considered to be decontextualized and thus more emotionally neutral (Beck, Schaefer, Pang, & Carlson, 2011; Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Carlson, 2005; Denham, Warren-Khot, Bassett, Wyatt, & Perna, 2012; Hongwanishkul, Happaney, Lee, & Zelazo, 2005; Willoughby, Kupersmidt, Voegler-Lee, & Bryant, 2011; Zelazo & Carlson, 2012). Thinking about EF in this way also makes sense in light of research finding a strong positive correlation between preschoolers' inhibitory control and emotion regulation (Carlson & Wang, 2007) as well as a positive impact of a promised reward on inhibitory control (Qu, Finestone, Qin, & Reena, 2012), both of which connote hot EF. Even healthy adults' capacity to focus, exercise self-control, and use their working memory can be impaired in situations that produce anxiety or other negative emotions (Robinson, Vytal, Cornwell, & Grillon, 2013).

Adding to this lack of consensus, one body of research has suggested that EF in 3- and 4-year-olds may be difficult to separate into individual categories and instead may best be thought of as a single overall construct that is displayed differently depending on the cognitive demand within any specific context (Allan, Allan, Lerner, Farrington, & Lonigan, 2015; Bull, Espy, Wiebe, Sheffield, & Nelson, 2011; Chevalier et al., 2012; Clark, Sheffield, Wiebe, & Espy, 2013; Nelson, James, Chevalier, Clark, & Espy, 2016; Wiebe, Espy, & Charak, 2008; Willoughby & Blair, 2016). However, additional research has suggested that the different EF constructs described previously may begin to emerge separately in preschool-aged children. That is, each EF component may follow a somewhat different developmental trajectory (Lerner & Lonigan, 2014; Lonigan, Lerner, Goodrich, Farrington, & Allan, 2016). Perhaps not surprisingly, a recent research synthesis cautioned early childhood policy makers and other stakeholders to be clear about the research tradition (e.g., cognitive vs. emotional) on which they are drawing when conceptualizing EF. Otherwise, their instructional or programmatic efforts to enhance children's EF skills, as well as attempts to measure EF in a valid way, may not be relevant (S. M. Jones, Bailey, Barnes, & Partee, 2016).

Though EF can be characterized in multiple ways, it is clear that all of its interdependent aspects are needed for everyday tasks (e.g., choosing which clothes to wear based on the weather) as well as decisions that may be even more consequential (e.g., choosing where to live, which career path to take, or the best way to respond to an unanticipated crisis). For young children, EF competencies are also needed for successful participation in, and learning skills from, early education programs (Blair, 2002; Center on the Developing Child at Harvard University, 2011). As is discussed next, these behaviors likely support young children's positive interactions with teachers and their peers and the learning of new concepts and skills.

The Relationship Between Executive Function and Young Children's Cognitive Development

Early education researchers have been particularly interested in the visible effects of young children's EF in terms of their behavioral regulation and learning-related skills as well as EF's contribution to school readiness and subsequent academic achievement (Cartwright, 2012; McClelland, Acock, & Morrison, 2006; Morrison, Cameron Ponitz, & McClelland, 2009; Stipek, Newton, & Chudgar, 2010). On one hand, more rigorous research is needed to provide evidence of a causal relationship between the different aspects of children's EF and their cognitive outcomes (Jacob & Parkinson, 2015; S. M. Jones et al., 2016). Yet, a growing research base, both in the United States and internationally, and including children from both low- and higher income families, has demonstrated the correlational relationship between inhibitory control, cognitive flexibility, and/or working memory and early academic skills.

For example, a study of 66 typically developing children ages 2–5 years found that their math competency could be predicted by their concurrent level of inhibitory control (Espy et al., 2004). In a different study of 310 preschoolers, children who experienced greater growth in their behavioral regulation over the prekindergarten school year also demonstrated better gains in their emergent literacy, vocabulary, and math skills (McClelland et al., 2007). A study of 152 Taiwanese preschoolers also found that scores on an EF measure predicted their early math and vocabulary skills (Wanless, McClelland, Acock, Chen, & Chen, 2011). Preschoolers' scores on a measure of inhibitory control are correlated with their vocabulary scores, as well (Lonigan, Allan, Goodrich, Farrington, & Phillips, 2015). Research conducted in Canadian preschools suggested that children's working memory is associated with their letter identification and early mathematics skills (Miller, Muller, Giesbrecht, Carpendale, & Kerns, 2013).

Analysis of data from a large-scale prekindergarten curriculum evaluation echoed the relationship between EF and preschoolers' early literacy and math outcomes (Fuhs, Farran, & Nesbitt, 2015). In addition, this research has suggested that children's working memory, inhibition, and ability to "switch gears" are positively related to such learning-related behaviors as level of engagement in sequential task-related activities, interacting with peers and the teacher, and refraining from being disruptive, which, in turn, can lead to better academic outcomes (Nesbitt, Farran, & Fuhs, 2015). Other data examined as part of research on Head Start enrollees in the Miami area also found a significant relationship between children's cognitive flexibility and the development of the type of learning-related behaviors that contribute to children's school readiness, including engagement, motivation, and positive attitudes toward learning (Vitiello, 2009; Vitiello, Greenfield, Munis, & George, 2011), as well as their math, literacy, and science outcomes (Nayfeld, Fuccillo, & Greenfield, 2013). Another study of 757 4-year-old Head Start and child care enrollees also reported an association between children's inhibitory control and three measures of academic achievement (Willoughby, Kupersmidt, & Voegler-Lee, 2012).

Similar results have been demonstrated as children move into kindergarten and the early primary grades. For example, researchers examined 3- and 4-year-olds' working memory and inhibitory control and found a positive relationship with their general mathematics proficiency at age 5 years (Clark et al., 2014, 2013). A second study of low-income preschoolers found that their kindergarten math outcomes correlated with their capacity to inhibit irrelevant information from their working memory. This also was the case for children's phonemic awareness outcomes (Blair & Razza, 2007). In a study set in Iceland, preschoolers' scores on two EF measures predicted their Grade 1 reading comprehension scores (Birgisdottir, Gestsdottir, & Thorsdottir, 2015). A longitudinal study found that growth in 4-year-olds' working memory and attention skills while enrolled in Head Start was associated with their reading and math achievement in kindergarten (Welsh, Nix, Blair, Bierman, & Nelson, 2010). Similarly, researchers found that 4-year-old Head Start students' EF skills predicted their math skills and learning-related behaviors in third grade (Sasser, Bierman, & Heinrichs, 2015).

Kindergartners' performance on an EF measure in the beginning of the school year also predicted their scores on six academic measures (Cameron et al., 2012). Secondary analysis of the National Institute of Child Health and Human Development study of Early Child Care and Youth Development data set found that children's behavior regulation (defined as the ability to apply attention, working memory, and inhibitory control to behavior), a construct related to EF, at 4.5 years and in kindergarten predicted their academic achievement in Grade 1 (Sektnan, McClelland, Acock, & Morrison, 2010). Furthermore, the performance of 459 Swiss 4- to 8-year-olds on tasks measuring working memory, inhibitory control, and cognitive flexibility predicted their performance on standardized measures of both mathematics and reading (Neuenschwander, Rothlisberger, Cimeli, & Roebers, 2012).

Additional research has focused specifically on the role EF plays in children's mathematics outcomes. Kindergartners' performance on tests focusing on the cool (nonemotional) aspects of EF predicted higher achievement in their spring math scores (Brock et al., 2009). Another study documented correlations between 4-year-olds' planning, set shifting, and inhibitory control and their mathematical achievement at age 6 years (Clark, Pritchard, & Woodward, 2010) and in kindergarten through second grade (Blair, McKinnon, & Family Life Project Investigators, 2016; Blair, Ursache, Greenberg, Vernon-Feagans, & Family Life Project Investigators, 2015).

An additional study assessed changes in math skills over time by following a group of preschool-aged children in the United Kingdom into the first 3 years of primary school. In this study, children who exhibited higher levels of visual–spatial working memory experienced better mathematics outcomes (Bull, Espy, & Wiebe, 2008). Another study of children in a U.K. early primary school found that lower mathematical ability is correlated with the inability to inhibit a learned strategy and instead switch to the more appropriate strategy (Bull & Scerif, 2001). Research taking place in Italian preschools and primary schools has also demonstrated the relationship between EF skills at age 5 years and math achievement in first and third grades (Viterbori, Usai, Traverso, & De Franchis, 2015).

These results echo the results of a small research study suggesting that inhibitory control (as compared to working memory and cognitive flexibility) is the strongest predictor of 2.5- to 4-year-olds' complex problem-solving skills. However, this same study suggested that working memory may play a larger role in complex problem solving at ages 5 and 6 years (Senn, Espy, & Kaufmann, 2004). And, parental report regarding 4-year-olds' persistence in attending to relevant information and staying on task has been correlated with math achievement at age 21 years (McClelland, Acock, Piccinin, Rhea, & Stallings, 2013).

Simply put, a significant research base has demonstrated the robust, positive relationship between young children's EF skills and their academic outcomes in preschool through third grade. Given this research, it can be helpful to understand which factors contribute to the development of EF. Such an understanding is useful also for thinking about the different options for enhancing this set of skills. Although this topic is complex and thus deserving of its own report, highlighted next is a brief review of the research on the factors that can affect the development of EF from birth through the early primary grades.

Which Factors Affect the Development of Executive Function in Young Children?

As the previous section outlined, a growing research base has documented the important relationship between EF and young children's early academic outcomes. As a result, parents, teachers, and policy makers may wonder what they can do to improve preschoolers' EF skills. Like other complex skills, EF not only follows an age-related, developmental trajectory but is influenced by individual child characteristics, environmental factors, and exposure to specific activities and early learning curricula.

Child Factors

EF is highly dependent on human brain development (Anderson & Reidy, 2012; Cartwright, 2012; Mahone, Pillion, Hoffman, Hiemenz, & Denkla, 2005). In particular, although infants display emerging EF (Hughes, 2011), the growth of EF during the period of age 3–6 years is mirrored by rapid development of the prefrontal cortex (Kagan & Herschkowitz, 2005; Thompson & Nelson, 2001), an area of the brain thought to underlie EF (Blair & Ursache, 2011; Zelazo et al., 2016). Although the development of EF continues into the adolescent and early adult years, a substantial research base has also suggested that the early childhood period may represent the most dramatic growth in EF skills (Center on the Developing Child at Harvard University, 2011; Hughes, 2011; L. B. Jones, Rothbart, & Posner, 2003; Thompson & Nelson, 2001; Zelazo & Jacques, 1996).

Development of inhibition and working memory is particularly pronounced from ages 3 to 4 years (Rothlisberger, Neuenschwander, Cimeli, & Roebers, 2013). Preschoolers also tend to experience growth in their attention system and, in turn, their capacity to control their thoughts and behavior (Garon et al., 2008). In typically developing children, the expansion of EF skills during the ages of 3–6 years is demonstrated through older preschoolers' improved performance on EF tasks that are designed to evaluate EF across a wide age range (Buss & Spencer, 2014; Carlson, 2005; Clark et al., 2012; Diamond, Carlson, & Beck, 2005; Hongwanishkul et al., 2005; Hughes, 1998; Rennie, Bull, & Diamond, 2004; Wiebe, Sheffield, & Espy, 2012).

The development of the different dimensions of EF may be interdependent, as well. For example, a study of 103 3- to 6-year-olds found that higher levels of sustained attention predicted children's inhibitory control (Reck & Hund, 2011). Response inhibition is also related to children's age and the development of working memory (Wiebe et al., 2012). Yet, its different dimensions do not develop at the same pace, and some aspects reach maturity more quickly than others (Best & Miller, 2010; Brocki & Bohlin, 2004; Zelazo, Muller, Frye, & Marcovitch, 2003).

In addition, although there are individual differences in children's EF at any given age, as might be expected, age plays a role in the development of EF capacity (Kochanska, Coy, & Murray, 2001; Loeher & Roebers, 2013). Indeed, the degree to which children exhibit various EF skills prior to kindergarten predicts their EF levels 2 years later (Cuevas et al., 2012). Some research has also suggested that there may be gender differences in how quickly young children develop certain EF skills (Fuhs, Farran, & Nesbitt, 2013; Gestsdottir et al., 2014; Kochanska et al., 2001; Matthews, Cameron Ponitz, & Morrison, 2009; Son, Lee, & Sung, 2013; Storksen, Ellingsen, Wanless, & McClelland, 2015; von Suchodoletz et al., 2013). However, additional research has suggested that these gender differences may be culturally dependent (Oh & Lewis, 2008; Wanless et al., 2013).

Not surprisingly, various prenatal and child health issues can negatively affect the development of EF. For example, 3-year-olds who had extremely low birth weights perform worse on complex working memory and inhibition tasks in comparison to their full-term peers (Baron, Kerns, Muller, Ahronovich, & Litman, 2012). Premature birth is also related to lower EF skills in preschoolers (Espy et al., 2002; Loe, Chatav, & Alduncin, 2014; Loe, Feldman, & Huffman, 2014; Mulder, Pitchford, Hagger, & Marlow, 2009), as is the combination of extreme preterm and low birth weight status when these children later enter kindergarten (Orchinik et al., 2011).

Children with fetal alcohol syndrome also can experience deficits in EF (P. D. Connor, Sampson, Bookstein, Barr, & Streissguth, 2000; Fuglestad et al., 2015; Rasmussen & Bisanz, 2011), as do those with higher chronic levels of lead exposure (Canfield, Gendle, & Cory-Slechta, 2004). Even the degree to which infants and toddlers get a greater proportion of their total sleep time during the night (rather than during naps) is linked to their subsequent EF development (Bernier, Carlson, Bordeleau, & Carrier, 2010). Accordingly, preschoolers who have higher levels of parent-reported risk for sleep-disordered breathing exhibited lower performance on measures of EF in comparison to peers with low reported levels of risk (Karpinski, Scullin, & Montgomery-Downs, 2008).

Another line of research has investigated the relationship between preschoolers' receptive and expressive language skills and the development of EF. For example, the extent to which children's vocabulary grows between the ages of 15 and 36 months is associated with both the development of their EF skills between ages 3 and 5 years and their EF capacity at age 5 years (Kuhn, Willoughby, Vernon-Feagans, Blair, & Family Life Project Key Investigators, 2016). A different study of 191 children at ages 4 and 6 years suggested that lower verbal ability can predict lower levels of performance on several EF tasks at age 4 years (Hughes, Ensor, Wilson, & Graham, 2010). Another small study of 39 3- to 5-year-olds found that children's oral language skills predicted their verbal working memory abilities (Ezrine, 2010). A study of the verbal ability of Head Start enrollees found a correlation between their development in this area and EF skills (Fuhs & Day, 2011). Low-income preschoolers' EF gains over the course of the school year were related to their start-of-school language skills, as well (Anthony, 2013).

In addition, preschoolers who experience severe delays in their speech and language development demonstrate lower levels of working memory, inhibition, and cognitive shifting (Vissers, Koolen, Hermans, Scheper, & Knoors, 2015). Three- to 6-year-olds with cochlear implants due to severe to profound hearing loss exhibited poorer performance on tasks designed to assess inhibitory control and working memory as compared to a comparison group of normal hearing peers (Beer et al., 2014). Finally, preschoolers' more frequent use of "private speech," or talking to themselves, as they engage in a challenging task also has been correlated with better performance on an assessment of EF (Alarcon-Rubio, Sanchez-Medina, & Prieto-Garcia, 2014).

Extending the impact of language skills on the development of EF, other research compared EF in young children who are monolingual versus bilingual or trilingual. For example, bilingual French/English 2-year-olds exhibited better inhibitory response performance as compared to a monolingual group (Poulin-Dubois, Blaye, Coutya, & Bialystok, 2011). In a set of two (Martin-Rhee & Bialystok, 2008) and three (Bialystok & Martin, 2004) small studies comparing inhibitory control in monolingual and bilingual 4- and 5-year-olds, researchers also found an advantage for the bilingual sample. Another study of 50 kindergarteners compared native Spanish/English bilingual students with children who only spoke English as well as native English speakers who were enrolled in a Spanish or Japanese immersion class. After controlling for children's age, verbal ability, and family socioeconomic status, researchers found that the bilingual students performed significantly better on tests of EF as compared to the monolingual and immersion kindergartners (Carlson & Meltzoff, 2008).

In another small study of 5-year-old monolingual and bilingual children, those speaking two languages had faster and more accurate responses to a test of working memory compared to the monolingual group (Morales, Calvo, & Bialystok, 2013). Similarly, bilingual 6- and 7-year- olds performed better on a test of working memory and inhibitory control than their monolingual peers (Calvo & Bialystok, 2014). A final study looked at the EF abilities of 5- to 8-year-old German native speakers who were learning English, German and English bilinguals, and German/English/another language trilinguals. In this study, the bilingual and trilingual students had an advantage over the learning English group on attention-shifting tasks (Poarch & van Hell, 2012). The idea here is that children learning two (or more) languages must shift back and forth between languages and learn how to inhibit the impulse to speak in one language when speaking the other language is more appropriate, thereby exercising their EF skills.

Environmental Influences: Contexts and Caregivers

The development of EF skills is related also to children's broader environmental influences, including their social interactions with their parents, other caregivers, and teachers. For example, the parenting style experienced by infants has been shown to predict EF levels at 18 and 26 months (Bernier, Carlson, & Whipple, 2010), age 3 years (Bernier, Carlson, Deschenes, & Matte-Gagne, 2012), and age 4 years (Kraybill & Bell, 2013). Similarly, higher levels of parental sensitivity and responsiveness when children are 2 and 3 years old are related to higher levels of EF when children reach ages 4 and

5 years (Blair, Raver, Berry, & Family Life Project Investigators, 2014; Landry, Smith, Swank, & Miller-Loncar, 2000). Yet, having a mother who exhibits depressive symptoms when children are 2 years old may be correlated with lower levels of EF (Hughes, Roman, Hart, & Ensor, 2013). However, the influence of parental sensitivity experienced when children are infants and toddlers on EF may vary by family ethnicity (Holochwost et al., 2016).

Related to the language research highlighted earlier, additional studies have demonstrated that the degree to which parents provide autonomy support at 15 months (Matte-Gagne & Bernier, 2011) and deliberately scaffold children's problem solving at ages 2 and 3 years (Bibok, 2007; Bibok, Carpendale, & Muller, 2009; Hammond, Muller, Carpendale, Bibok, & Liebermann-Finestone, 2012) is related to the development of children's expressive vocabulary and EF skills. Middle- and upper-middle-class parents' use of "management language" also has been shown to be related to 3-year-olds' EF. In this study, language that provided children with choices and strategies for thinking about their behavior versus direct commands regarding what to do was correlated with better performance on tests of EF (Bindman, Hindman, Bowles, & Morrison, 2013). Similarly, a different study of college-educated, middle-class mothers and their children found that efforts to help children maintain or redirect their attention at age 2 years predicted children's conflict inhibition at age 4.5 years, and particularly for those children who also tended to be attracted to novel experiences (Conway & Stifter, 2012). More sensitive parenting at age 3 years also has an effect on children's EF skills at ages 4 and 5 years and, in turn, on the extent to which children exhibit externalizing behavior problems (Sulik et al., 2015).

A study of Mexican and Colombian students ages 5–14 years found that children whose parents had attended college had higher levels of EF. Although the researchers were not able to determine why this was the case, they hypothesized that it was due to parents' academic orientation and thus also their emphasis on the types of tasks that contribute to optimal EF in their home environments (Ardila, Rosselli, Matute, & Guajardo, 2005). Additional research suggested that higher levels of EF in young children are related to having the opportunity to observe others making correct behavioral choices and then actually practicing making such choices (Carlson, 2009; Hughes & Ensor, 2009). Conversely, a potential negative influence of poverty on EF may be fewer opportunities to observe and practice the skills that promote EF (Sektnan et al., 2010).

Echoing the research on parents' potential contributions, several studies highlighted the role that teachers can play in shaping children's EF development. One study found that the extent to which kindergarten teachers can redirect children's misbehavior and manage instructional time and routines to promote opportunities for learning is related to kindergartners' behavioral and cognitive self-control (Cameron Ponitz, Rimm-Kaufman, Grimm, & Curby, 2009; Rimm-Kaufman, Curby, Grimm, Nathanson, & Brock, 2009). In a similar study, Head Start enrollees' working memory and inhibitory control skills improved through teacher-based classroom management intervention. These effects also translated into better child outcomes in terms of end-of-year receptive vocabulary, letter naming, and early math skills (Raver, 2012; Raver et al., 2008, 2011).

Other environmental factors that appear to be related to EF development include the degree to which the classroom climate is organized (Morrison et al., 2009) and teachers provide explanations regarding why classroom activities are taking place and demonstrate what to do while engaged in these activities (Cameron & Morrison, 2011). Also beneficial to the development of children's EF skills is teachers' use of more open-ended questions and letting children know their efforts to learn and behave well are appreciated (Fuhs et al., 2013). Preschoolers also experience gains in EF when they are positively engaged with both classroom activities and interactions with their teachers (Williford, Vick Whittaker, Vitiello, & Downer, 2013). Teacher sensitivity, as well as the absence of a negative classroom climate, may be particularly important for preschoolers with the lowest levels of inhibitory control (Choi et al., 2016). In addition, teachers' use of classroom management techniques may serve as a critical support for children who begin first grade with the lowest scores on a measure of working memory, inhibitory control, and cognitive flexibility skills (C. M. Connor et al., 2010).

Growing up in home environments involving poverty or low socioeconomic status, abuse and neglect, or violence, as well as less access to educational resources, is correlated with deficits in children's EF as compared to children growing up in more optimal environments (Blair & Ursache, 2011; Noble, McCandliss, & Farah, 2007; Noble, Norman, & Farah, 2005; Raver, 2004; Raver et al., 2013; Rhoades, Greenberg, Lanza, & Blair, 2011; Sarsour et al., 2011; Waber, Gerber, Turcios, Wagner, & Forbes, 2006; Wanless, McClelland, Tominey, & Acock, 2011). The number of times a preschooler's family has moved is related to poor performance on measures of inhibitory control, early mathematics skills, and letter identification, as well (Schmitt, Finders, & McClelland, 2015). The relationship between housing instability and attention problems can be particularly acute for poor preschoolers (Ziol-Guest & McKenna, 2013). Research has suggested that chronic exposure to stress (often poverty related) can alter brain structure and function, particularly affecting the prefrontal cortex (Arnsten, 2000, 2009; Blair, 2010; Blair, Granger, & Razza, 2005; Blair & Raver, 2012; R. J. Duncan, 2012; Twardosz, 2012). Yerkes and Dodson's (1908) well-known psychology principle states that performance on cognitively complex tasks – such as EF – is impaired under conditions of high stress (such as poverty).

An additional limited research base has suggested the protective role EF skills may play in the outcomes of children who might otherwise be expected to "fail" academically due to stressful environmental factors. For example, a study of kindergarten and first-grade children residing in a homeless shelter found that their EF levels were related to their academic achievement such that children with higher EF demonstrated higher academic achievement (Masten et al., 2012). Two separate studies found that preschoolers' levels of EF can mediate expected associations between low family socioeconomic status and emerging math skills (Dilworth-Bart, 2012; Fitzpatrick, McKinnon, Blair, & Willoughby, 2014). An additional longitudinal study of 206 ethnically and racially diverse children through first grade demonstrated similar results (Nesbitt, Baker-Ward, & Willoughby, 2013). Finally, researchers found that children's EF skills at age 3 years can mediate the relationship between exposure to their mothers' self-reported depression symptoms at age 2 years and teacher-reported problem behaviors at age 6 years (Roman, Ensor, & Hughes, 2016).

Children's Activities

Another research base has examined the relationship between different activities in which young children might participate and their EF development. For example, for some young children, the combination of both increased age and participation in school may be sufficient for expanding their working memory skills (Burrage et al., 2008). Research conducted on the impact of Boston's publicly funded prekindergarten program for 4-year-olds also demonstrated its positive effects on children's EF skills. Interestingly, the curriculum used in this program had a strong emphasis on children's early language, literacy, and mathematical skills, and the researchers hypothesized that such an emphasis may have had a "spillover" effect on enrollees' EF levels (Weiland & Yoshikawa, 2013). This topic is explored in more detail later.

Additional research has explored the relationships between children's television viewing and use of other types of media and their EF. This research does not yet appear to be conclusive, with studies suggesting that media use (including television) can both positively and negatively affect children's language, attention, and other aspects of EF. However, the influence of media on children's EF appears to be dependent on the content, pacing, and quantity of exposure as well as children's age (Lillard & Peterson, 2011; Nathanson, Alade, Sharp, Rasmussen, & Christy, 2014; Zimmerman & Christakis, 2007). Researchers also hypothesized that if children need to "use up" their current short-term working memory, inhibitory control, or cognitive shifting skills simply to process the content of what they are viewing (and due to an overabundance of new information or fantastical or unrealistic events, or information that is presented too quickly), their short-term EF skills may be negatively affected (Lillard, Li, & Boguszewski, 2015). And viewing media may incidentally place an infant, toddler, or preschooler at risk for attention problems if the time spent in front of a screen replaces live interactions with sensitive and responsive adults (Courage & Setliff, 2009).

Preschoolers' participation in physical activity during the day also is associated with better performance on measures of self-regulation and inhibitory control (Becker, McClelland, Loprinzi, & Trost, 2014; Campbell, Eaton, & McKeen, 2002). However, it is unclear if physical activity results in better self-regulation and inhibitory control or instead higher levels of skills in these areas leads to more physical activity. Alternatively, reviews of EF interventions (Bierman & Torres, 2016; Diamond & Ling, 2016) suggested that physical activity in and of itself may not directly lead to improvements in EF skills. Rather, because physical activity can improve sleep and the amount of oxygen and blood flow to the brain, as well as reduce stress and depression, it may mitigate the negative effects on EF of these factors. Given the decreasing amount of school recess time (Council on School Health, 2013; Jarrett & Waite-Stupiansky, 2009), more research in this area is warranted.

Research on the contribution of children's spontaneous pretend play to the development of EF has generally shown a positive correlation, as well (Berk & Meyers, 2013; Chung & de Silva, 2013; Pierucci, O'Brien, McInnis, Gilpin, & Barber, 2014). Linking casual pretend play with growth in children's skills related to attention, rulemaking, and planning also makes intuitive sense (Bedrova, Germeroth, & Leong, 2013; Berk, Mann, & Ogan, 2006; Hoffman & Russ, 2012; Walker & Gopnik, 2013). As Bierman and Torres (2016) noted, it is through such play that young children learn self-control (e.g., taking turns and thinking before acting) and cognitive flexibility (e.g., role-playing and considering the perspective of the other child) and develop their working memory (e.g., remembering how to play a game). The methodological limitations of these studies in terms of their sample demographics, study design, and measures used means their results are insufficient for demonstrating a direct causal link between specific types or levels of play and the degree to which young children's EF is impacted (Lillard et al., 2012). However, the results of a more recent randomized-control trial involving 100 preschoolers are intriguing, as this research found that children randomly assigned with the task of creating a fantastical script and then encouraged to act it out exhibited greater gains in their EF performance as compared to children randomly assigned to the nonimaginative play and control groups (Thibodeau, Gilpin, Brown, & Meyer, 2016).

The Potential Role of Early Education Curricula and Other Interventions

Preschoolers' EF development also may benefit from more intentional interventions that are offered as part of early education programs. A study situated in Head Start found that children in classrooms implementing the Promoting Alternative Thinking Strategies intervention, which was aimed at developing children's social–emotional skills, experienced better improvements in these skills as compared to children in control classrooms. This study did not find that the intervention produced significant differences in children's inhibitory control or sustained attention (Domitrovich, Cortes, & Greenberg, 2007). However, additional research on the effects of this curriculum demonstrated small but statistically significant improvements in assessments of children's working memory, inhibitory control, and attention-shifting skills. The intervention was particularly beneficial for children who exhibited lower levels of motor inhibitory control at the beginning of the school year (Bierman et al., 2008).

Another promising avenue for supporting the development of children's inhibitory control, cognitive flexibility, and working memory is through the use of specific curricula designed to promote children's academic development. For example, 3- to 6-year-olds enrolled in programs that used only "classic Montessori" materials, and in the prescribed Montessori manner (i.e., building a tower with a set of sequentially sized blocks), exhibited better EF skills as compared to similarly aged children enrolled in Supplemented Montessori (e.g., classic Montessori materials plus conventional puzzles, games, blocks, or toys) and non-Montessori classrooms. The researcher conducting this study hypothesized that these gains were due to the Montessori activities' demands on children's working memory, inhibition, and cognitive flexibility (Lillard, 2012). In a randomized-control trial set in classrooms serving 5-year-olds in Brazil, students exposed to a special curriculum designed to promote the development of their organizational, collaborative, and emotional skills also experienced more improvement in their EF skills as compared to students in the control group (Dias & Seabra, 2015). In addition, preschoolers who received once-per-week lessons promoting mindfulness received better teacher ratings of their working memory in comparison to students who did not receive such lessons. However, this study was limited by its small sample size and nonrandomized study design (Thierry, Bryant, Nobles, & Norris, 2016).

One additional curricular approach is Tools of the Mind, which aims to improve preschoolers' and kindergartners' EF through intentional teaching and classroom strategies. In addition to 40 prescribed activities, these strategies include children's formulation of play (preschool) and learning (kindergarten) plans that are designed to help them self-monitor and evaluate their performance as well as reflect on how their plans might be modified (Bedrova & Leong, n.d.). In a small study of the effects of the Tools curriculum in preschool classrooms in New Jersey, researchers found improved EF skills in children randomly assigned to classrooms implementing the curriculum as compared to children in classrooms using the typical district curriculum (Diamond, Barnett, Thomas, & Munro, 2007). These findings were not replicated in a different study taking place in Tennessee (Farran & Lipsey, 2012). Yet, a more recent randomized trial evaluating the Tools kindergarten curriculum in Massachusetts found significant positive impacts on measures of children's working memory, inhibitory control, and cognitive flexibility (Blair & Raver, 2014).

Finally, research has demonstrated that preschoolers' performance in EF tasks can be enhanced after participating in interventions specifically designed to increase these skills (Center on the Developing Child at Harvard University, 2011). For example, providing 4- and 4.5-year-olds with reflection training on the rules of a card-switching game was related to fewer errors made when playing the game as well as the ability to successfully play a more complicated version of the game (Espinet, Anderson, & Zelazo, 2013). In two additional (and independent) studies, researchers found that they could improve the performance of 3- to 5-year-olds (Segretin et al., 2014) and 5- and 6-year-olds (Rothlisberger, Neuenschwander, Cimeli, Michel, & Roebers, 2011) on a set of EF tasks by training them on the tasks themselves. Research has also suggested that young children's working memory can be improved through playing computer games that tap this skill (Blakey & Carroll, 2015; Diamond & Lee, 2011; Thorell, Lindqvist, Bergman, Bohlin, & Klingberg, 2009). Having regular opportunities to participate in behavioral games that involve paying attention to changing rules also may be helpful to preschoolers with very low levels of EF (Tominey & McClelland, 2011).

In summary, a growing research base has demonstrated the negative effects of a variety of prenatal and child health issues, as well as stressful environments, on young children's EF development. Other research has suggested that children's home and school environments and experiences can support EF development. However, research on the potential contribution of certain activities (e.g., recess) and early learning experiences (e.g., curricula) is not yet definitive. As a result, although policy makers and early education stakeholders may have a clear sense of the issues and environments that can be detrimental to young children's development, it remains difficult to draw concrete conclusions about the ways in which EF development might best be supported in specific populations of preschoolers. Given the important role EF plays in children's early academic outcomes, in the next section, we summarize some of the additional research needed.

Executive Function-Related Research Needs

Although we know a great deal about the importance of preschoolers' EF, as was described in the preceding review, there are some topics for which additional research is needed. These topics include the role played by recess and other opportunities to participate in play and physical activity in shaping young children's EF abilities. And, given the use of digital media in homes and early education settings, it also would be useful to have a better understanding of the effects of exposure to television and these media.

Also needed is additional research on the potential bidirectional relationship between children's EF skills and their early academic outcomes. As was cited previously, a significant research base has shown a correlation between young children's EF skills and their subsequent mathematics outcomes. However, Clements, Sarama, and Germeroth (2016) hypothesized that learning and use of mathematical skills may also help develop and strengthen young children's EF. More specifically, because learning how to "do math" involves working memory, attention, and inhibiting an automatic response, it also may contribute to the development of these skills. This bidirectional hypothesis is supported by the association between prekindergarten students' beginning math scores and their EF gains found by Welsh et al. (2010) as well as by additional research that found a bidirectional association between prekindergarten math and EF scores (Fuhs, Nesbitt, Farran, & Dong, 2014; Prager, Sera, & Carlson, 2016). However, further research is needed to adequately test this hypothesis.

Similarly, additional information is needed about the direction of the relationship between EF and language skills. Do early language skills help children develop stronger EF skills? Or do higher early EF skills help children acquire language skills? More likely there is a bidirectional relationship between children's EF and language skills, whereby each set of skills scaffolds children's development of the other skill.

Another related issue that does not yet appear to have a robust research base is the relationship between the use of children's home language in the classroom and the development of their EF skills. As was noted earlier, young children who are bilingual appear to have higher levels of working memory and inhibitory control than monolingual children. However, is the extent to which early education teachers use children's home language, as well as switch back and forth between languages, correlated with the development of EF among young dual language learners (DLLs)? The need for such a study is also supported when considering a 2-year longitudinal study that followed 93 children from the beginning of preschool to the end of the kindergarten year. In this study, growth in children's attention, working memory, and inhibitory control was slower for low-income DLLs as compared to their low-income, English-speaking peers. Although this study did not examine the reason behind this slower growth, the authors hypothesized that it could be due to the DLLs' limited capacity to speak and understand English and thus take advantage of all of the learning experiences being offered in their mainly monolingual preschool and kindergarten classrooms (Wanless, McClelland, Tominey et al., 2011). Analysis of data from state-funded preschool education classrooms in 11 states also showed that DLLs' reading and math scores were higher when they received greater amounts of instruction in Spanish and were in classrooms with more sensitive and responsive teachers (Burchinal, Field, Lopez, Howes, & Pianta, 2012; Vitiello, Downer, & Williford, 2011). Further analysis of these same data also suggests that when teachers spoke some Spanish, DLLs demonstrated better social skills (Chang et al., 2007).

Also deserving of further research is the degree to which disruptive behavior exhibited by one or more children in a classroom affects the development of EF in the other children in that classroom (Raver et al., 2012). A related issue that warrants additional exploration is the role an early education classroom's physical environment plays in supporting—or detracting from—the development of young children's EF skills. In this case, environment does not refer to the nature of the interactions students have with their teacher or peers, classroom organization, or type of learning centers or materials available to children. Instead, the focus is on such classroom inputs as light, noise, temperature, the size of the room, the number of children and adults in the space at the same time, and even the type and number of wall decorations. The potential disruptive impact of these environmental factors on EF makes sense when examining the limited research base on young children's varying access to healthy indoor early care and education environments (Saterlee, Molavi, & Williams, 2015) as well as the negative effects of noise (Klatte, Bergstrom, & Lachmann, 2013), space and color (Read, Sugawara, & Brandt, 1999), and the quantity of visual displays (Fisher, Godwin, & Seltman, 2014) on children's learning and/or classroom behavior.

Finally, there is a continued policy emphasis on expanding at-risk 4-year-olds' access to publicly funded prekindergarten as a means for improving children's school readiness (Barnett et al., 2016) and, in turn, reducing achievement gaps between students of different races or ethnicities and socioeconomic groups (Bassok & Loeb, 2014; Cannon & Karoly, 2007; G. J. Duncan & Sojourner, 2013). Longer term achievement gaps through elementary, middle, and high school have typically focused on students' academic outcomes (e.g., Bohrnstedt, Kitmitto, Ogut, Sherman, & Chan, 2015). Although there is emerging research that children growing up in poverty demonstrate lower EF than their more advantaged peers (e.g., Noble et al., 2005, 2007), it would be interesting to understand the extent to which these later achievement gaps also represent differences in older students' EF.

Six Preschool Executive Function Assessment Examples

Given the importance of EF in young children's development, as well as what is left to learn about how it might be enhanced, it would be helpful for future early education-related studies to include measures of children's EF skills. Our review of the research suggests that at least 83 measures have been used to assess EF-related skills in preschoolers. Owing to space constraints, we are unable to adequately describe each of these measures here. However, to provide researchers with a brief overview of their assessment options, in this section, we highlight six preschool-relevant examples. These examples were chosen in part because they represent different approaches to assessment (including two single-task measures, three performance-based task batteries, and one teacher rating scale) as well as variations in equipment and supplies needed and in costs. In addition, all six examples have a strong psychometric research base supporting their use with 3- to 5-year-olds. At the same time, these measures are by no means the only options for assessing EF in preschool-age children, and thus researchers are encouraged to choose the assessments that are the best fit for their specific research questions.

Head–Toes–Knees–Shoulders Task

Our first measure example is the Head–Toes–Knees–Shoulders (HTKS) task (McClelland et al., 2014), which is a single-task assessment and was initially developed as the Head to Toes task with the support of the Institute for Education Sciences (Cameron Ponitz et al., 2008). HTKS is a 5- to 7-minute game that asks a child to touch his or her head versus toes as well as his or her knees versus shoulders. However, in the follow-on round, the child needs to use working memory to recall the original rule but also inhibit his or her natural response and touch his or her head when the assessor asks the child to touch his or her toes (and vice versa). The only materials needed are the script, which is available in more than 15 languages and has been used all over the world, including North and South America, Australia, Africa, Europe, and Asia. The assessor's role is limited to reading the script and scoring each event.

A growing body of research has demonstrated HTKS's convergent validity (Cameron Ponitz et al., 2008; Cameron Ponitz, McClelland, Matthews, & Morrison, 2009; C. M. Connor et al., 2010; Lipsey et al., 2014; McClelland et al., 2014; Wanless, McClelland, Acock, Ponitz et al., 2011) and predictive validity (Cameron Ponitz, Rimm-Kaufman et al., 2009; R. J. Duncan, 2012; Matthews et al., 2009; McClelland et al., 2007; McClelland et al., 2014; Schmitt, Pratt, & McClelland, 2014). Researchers also have investigated the measure's validity for non-English-speaking children (Gestsdottir et al., 2014; von Suchodoletz et al., 2013; Wanless, McClelland, Acock, Chen et al., 2011). In addition, studies have demonstrated the measure's interrater reliability (Cameron Ponitz et al., 2008) and test–retest reliability (Fuhs et al., 2014; Wanless, McClelland, Tominey et al., 2011). HTKS is available from its authors at no cost, but for research purposes only (Oregon State University, 2011).

Minnesota Executive Function Scale

Our second assessment example is the Minnesota Executive Function Scale (MEFS; Carlson & Zelazo, 2014), which is a touchscreen computer-based adaptive sorting game. The MEFS is based on the Dimensional Change Card Sort

(DCCS; Zelazo, 2006), which has been characterized as "the most widely used executive function task in early childhood" (Willoughby & Blair, 2016, p. 92). In both the DCCS and the MEFS, children are instructed to sort pictures first by color and then by shape. Administration of the MEFS takes approximately 4 minutes and requires an Android tablet or an iPad and downloadable app. It is available in English, Dutch, Mandarin Chinese, and Spanish. The developers offer a 3-hour in-person or webinar-based training and web-based certification for assessors (Reflection Sciences, 2017).

Researchers have demonstrated the validity of the DCCS with children ages 3–5 years (Beck et al., 2011) as well as its convergent validity (Carlson, Faja, & Beck, 2016) and test–retest reliability (Beck et al., 2011; Fuhs et al., 2014). Recent research also has examined the validity and reliability of the MEFS (Carlson & Harrod, 2013; Fuhs et al., 2014). The cost of purchasing the MEFS is dependent on the number of individuals to be assessed (Reflection Sciences, 2017).

Cognition Battery of the National Institutes of Health Toolbox for the Assessment of Neurological and Behavioral Function

Our first task battery example is the Cognition Battery of the NIH Toolbox for the Assessment of Neurological and Behavioral Function (Bauer & Zelazo, 2014). The battery was developed using funds from the Blueprint for Neuroscience Research and the Office of Behavioral and Social Sciences Research of the National Institutes of Health (NIH) and is available in English and Spanish. It includes two EF tasks: the DCCS (Zelazo, 2006), which, as was highlighted in the previous section, is the basis for the MEFS (Carlson & Zelazo, 2014), and the Flanker Inhibitory Control and Attention Test, which requires children to pay attention to the direction in which a stimulus fish is pointing while ignoring the direction of the surrounding fish. Both tasks are administered via a computer platform but NIH Toolbox administrators may use either a laptop with Microsoft's Windows 7 operating system and a 19-inch monitor or an iPad Air 2 and the NIH Toolbox app. Scoring takes place automatically in this battery, as well, so assessor tasks are limited to completing two e-learning training modules and reading, clicking on, and pointing to objects on the screen (Health Measures, 2017).

In addition to the research already conducted on the DCCS, recent studies have demonstrated the convergent validity of the NIH Toolbox for preschoolers as well as the measure's test–retest reliability (Weintraub, Bauer et al., 2013; Weintraub, Dikmen et al. 2013; Zelazo et al., 2013). Web-based access to the NIH Toolbox is available for $5,000 annually due to the cost of maintaining the Web site. A subscription for 10 iPads is $499 per year after a free 60-day trial (NIH Toolbox, n.d.).

Executive Function Touch

Another task battery example is Executive Function Touch (EF Touch; Willoughby & Blair, 2016), which was developed with the financial support of the Eunice Shriver Kennedy National Institute of Child Health and Human Development and the Institute for Education Sciences. The battery consists of seven computer-based modular tasks: Spatial Conflict Arrows, Working Memory Span, Silly Sounds Stroop, Something's the Same, Animal Go/No-Go, Pick the Picture, and Farmer. Each task takes 3–7 minutes to complete. Because the assessment uses a touchscreen format, administrators need a laptop or computer using Microsoft's Windows 7 operating system as well as a touch monitor. The measure is scored automatically, so assessors' tasks are limited to opening the program, noting information about the child being assessed, and reading the instructions to the child.

Research conducted thus far on this measure has demonstrated its validity for children ages 3–5 years (Willoughby, Wirth, Blair, & Family Life Project Investigators, 2011) and for low- versus upper-income children across several racial/ethnic groups (Willoughby & Blair, 2016). Additional research has demonstrated its convergent validity (Willoughby & Blair, 2016; Willoughby, Blair, Wirth, Greenberg, & Family Life Project Investigators, 2012) and test–retest reliability (Willoughby & Blair, 2011, 2016; Willoughby, Kuhn, Blair, Samek, & List, 2016). To support its continued development, EF Touch is freely available to researchers who will use it "as is" but also are willing to sign a memorandum of understanding regarding their use (Frank Porter Graham Child Development Institute, n.d.).

Preschool Self-Regulation Assessment

A third battery example is the Preschool Self-Regulation Assessment (PSRA; Smith-Donald, Raver, Hayes, & Richardson, 2007; Raver et al., 2011), which also was developed with the financial support of the Eunice Shriver Kennedy National Institute of Child Health and Human Development. The PSRA is available in English and Spanish and is designed to measure impulse control, effortful control, emotional regulation, and compliance. It consists of a total of nine performance-based tasks, four of which (Balance Beam, Pencil Tap, Toy Sort, and Toy Wrap) have a particularly strong research base related to measuring aspects of preschoolers' EF. In addition to the paper-based script, the materials needed for these four tasks include masking tape, pencils, blocks, sorting bins, toys, and gift wrapping material. The assessor must organize the materials for each task, read the instructions and demonstrate the trial task, and score each task. The PSRA is freely available (NYU Institute of Human Development and Social Change, 2016).

Extensive research using samples of Head Start enrollees and Hispanic and African American preschoolers has demonstrated the construct and concurrent validity of the PSRA (Raver et al., 2012; Smith-Donald et al., 2007). Additional research has demonstrated the convergent and predictive validity of the Pencil Tap task (Blair & Razza, 2007; Lipsey et al., 2014; Rhoades et al., 2011). Finally, researchers have determined the measure's interrater reliability and test–retest reliability (Bassett, Denham, Wyatt, & Warren-Khot, 2012; Denham, Bassett, & Zinsser, 2012; Raver et al., 2012).

Child Behavior Rating Scale

Our final measure example is the Child Behavior Rating Scale (CBRS; Bronson, Goodson, Layzer, & Love, 1990; Bronson, Tivnan, & Seppanen, 1995), which is designed to capture teachers' perspectives of children's exhibited behavior with adults and other children in a classroom setting. The paper-based measure has a total of 15 items, the first 10 of which focus on self-regulation in the classroom. (The last five questions measure interpersonal skills.) All 15 items are scored on a 5-point Likert scale ranging from 1 (*never*) to 5 (*always*).

The CBRS was initially developed by Martha Bronson and colleagues at Boston College and was based on an observational measure called the Bronson Social and Task Skills Profile (Bronson, 1991, 1994). The current version of the assessment is available in at least seven languages and for use in research studies and school districts from Dr. Megan McClelland (personal communication, August 8, 2016). It also has been used in a number of studies for demonstrating the HTKS task's convergent validity (McClelland et al., 2014; von Suchodoletz et al., 2013; Wanless, McClelland, Acock, Chen et al., 2011; Wanless, McClelland, Acock, Ponitz et al., 2011; Wanless et al., 2013) and predictive validity (R. J. Duncan, 2012; Matthews et al., 2009; Schmitt et al., 2014; von Suchodoletz et al., 2013; Wanless, McClelland, Tominey et al., 2011). Researchers also have demonstrated the CBRS's reliability across U.S. samples and in other countries (Matthews et al., 2009; Wanless, McClelland, Acock, Ponitz et al., 2011).

Interestingly, the state of Oregon is using the CBRS as part of its statewide Oregon Kindergarten Assessment (Oregon Early Learning Division, n.d.; Rowley, 2015). Though not the focus of this report, a quick online search suggests that aspects of EF have been included in other states' plans for kindergarten entry assessments (Children's Learning Institute, n.d.; K–3 North Carolina Assessment Think Tank, 2013; National Conference of State Legislatures, 2014). However, to the best of our knowledge, researchers have not yet compiled information regarding the specific measures—or items—used to assess EF in entering kindergartners as well as the extent to which each measure or group of items has a strong validity and reliability research base. This is especially important given the array of purposes for which early childhood assessment data are used (Goldstein & Flake, 2015).

Conclusion

In this report, we reviewed research on the traits and skills that fall under the broader umbrella of preschool EF. Although EF can be characterized in many ways, the research reviewed here has demonstrated that its interdependent aspects are critical for supporting young children's developmental and academic outcomes. More specifically, EF is not only important for successfully completing everyday tasks but is a necessary skill for language, literacy, and mathematics learning. In turn, our review suggests that it is important for both policy makers and early education stakeholders to be mindful of the child and of environmental factors that play a role in the development of EF. Yet, there still is much to learn about the specific activities, interventions, curricula, and instructional approaches that might best promote preschoolers' EF.

These topics are timely given the policy emphasis over the past 15 years on expanding at-risk 4-year-olds' access to publicly funded prekindergarten (Barnett et al., 2016) and improving the quality of early learning and development programs (U.S. Department of Health and Human Services & U.S. Department of Education, 2016). Given this context, we hope this report will serve as a resource for early childhood researchers and practitioners who are interested in understanding EF development during the early years. In addition, by highlighting some topics for which additional research is needed and providing information regarding examples of measures that focus on assessing EF in children ages 3 – 5 years, we hope this report will serve as a springboard for future investigations related to preschool EF.

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References

Alarcon-Rubio, D., Sanchez-Medina, J. A., & Prieto-Garcia, J. R. (2014). Executive function and verbal self-regulation in childhood: Development linkages between partially internalized private speech and cognitive flexibility. *Early Childhood Research Quarterly, 29*, 95 – 105.

Allan, D. M., Allan, N. P., Lerner, M. D., Farrington, A. L., & Lonigan, C. J. (2015). Identifying unique components of preschool children's self-regulatory skills using executive function tasks and continuous performance tests. *Early Childhood Research Quarterly, 32*, 40 – 50.

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

Anderson, P. J., & Reidy, N. (2012). Assessing executive function in preschoolers. *Neuropsychological Review, 22*, 345 – 360.

Anthony, K. (2013). *Self-regulation development in early childhood: The role of language skills and pre-kindergarten learning behaviors* (Unpublished doctoral dissertation). Vanderbilt University, Nashville, TN.

Ardila, A., Rosselli, M., Matute, E., & Guajardo, S. (2005). The influence of parents' educational level on the development of executive functions. *Developmental Neuropsychology, 28*, 539 – 560.

Arnsten, A. F. T. (2000). Through the looking glass: Differential noradrenergic modulation of prefrontal cortical function. *Neural Plasticity, 7*, 133 – 146.

Arnsten, A. F. T. (2009). Stress signaling pathways that impair prefrontal cortex structure and function. *Nature Reviews. Neuroscience, 10*, 410 – 422.

Barnett, W. S., Friedman-Krauss, A. H., Gomez, R., Horowitz, M., Weisenfeld, G. G., Clarke Brown, K., & Squires, J. H. (2016). *The state of preschool 2015: State preschool yearbook*. New Brunswick, NJ: National Institute for Early Education Research.

Baron, I. S., Kerns, K. A., Muller, U., Ahronovich, M. D., & Litman, F. R. (2012). Executive functions in extremely low birth weight and late-term preschoolers: Effects on working memory and inhibition. *Child Neuropsychology, 18*, 586 – 599.

Bassett, H. H., Denham, S., Wyatt, T. M., & Warren-Khot, H. K. (2012). Refining the Preschool Self-Regulation Assessment for use in preschool classrooms. *Infant and Child Development, 21*, 596 – 616.

Bassok, D., & Loeb, S. (2014). Early childhood and the achievement gap. In H. F. Ladd & M. E. Goertz (Eds.), *Handbook of research in education finance and policy* (2nd ed., Chapter 29). New York, NY: Routledge.

Bauer, P. J., & Zelazo, P. D. (2014). The National Institutes of Health Toolbox for the assessment of neurological and behavioral function: A tool for developmental science. *Child Development Perspectives, 8*, 119 – 124.

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

Becker, D. R., McClelland, M. M., Loprinzi, P., & Trost, S. G. (2014). Physical activity, self-regulation, and early academic achievement in preschool children. *Early Education and Development, 25*, 56 – 70.

Bedrova, E., Germeroth, C., & Leong, D. J. (2013). Play and self-regulation: Lessons from Vygotsky. *American Journal of Play, 6*, 111 – 123.

Bedrova, E., & Leong, D. (n.d.). *Tools of the mind*. Retrieved from http://www.bostonchildrensmuseum.org/sites/default/files/pdfs/5-Tools-of-the-Mind-Curriculum.pdf.

Beer, J., Kronenberger, W. G., Castellanos, I., Colson, B. G., Henning, S. C., & Pisoni, D. B. (2014). Executive functioning skills in preschool-age children with cochlear implants. *Journal of Speech, Language, and Hearing Research, 57*, 1521 – 1534.

Berk, L. E., Mann, T. D., & Ogan, A. T. (2006). Make-believe play: Wellspring for development of self-regulation. In D. G. Singer, R. M. Golinkoff, and K. Hirsh-Pasek (Eds.), *Play = Learning: How play motivates and enhances cognitive and social-emotional growth* (pp. 74 – 100). New York, NY: Oxford University Press.

Berk, L. E., & Meyers, A. B. (2013). The role of make-believe play in the development of executive function: Status of research and future directions. *American Journal of Play, 6*, 98 – 110.

Bernier, A., Carlson, S. M., Bordeleau, S., & Carrier, J. (2010). Relations between physiological and cognitive regulatory systems: Infant sleep regulation and subsequent executive functioning. *Child Development, 81*, 1739 – 1752.

Bernier, A., Carlson, S. M., Deschenes, M., & Matte-Gagne, C. (2012). Social factors in the development of early executive functioning: A closer look at the caregiving environment. *Developmental Science, 15*, 12 – 24.

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

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

Bialystok, E., & Martin, M. (2004). Attention and inhibition in bilingual children: Evidence from the Dimensional Change Card Sort task. *Developmental Science, 7*, 325 – 339.

Bibok, M. B. (2007). *Social interactive quality of parent – child scaffolding as a predictor of children's executive function* (Unpublished master's thesis). Simon Fraser University, Burnaby, BC.

Bibok, M. B., Carpendale, J. I., & Muller, U. (2009). Parental scaffolding and the development of executive function. *New Directions in Child and Adolescent Development, 123*, 17 – 34.

Bierman, K. L., Nix, R. L., Greenberg, M. T., Blair, C., & Domitrovich, C. E. (2008). Executive functions and school readiness intervention: Impact, moderation, and mediation in the Head Start REDI program. *Developmental Psychopathology, 20*, 821 – 843.

Bierman, K. L., & Torres, M. (2016). Promoting the development of executive functions through early education and prevention programs. In J. A. Griffin, P. McCardle, & L. S. Fruend (Eds.), *Executive function in preschool-age children: Integrating measurement, neurodevelopment, and translational research* (pp. 299 – 326). Washington, DC: American Psychological Association.

Bindman, S. W., Hindman, A. H., Bowles, R. P., & Morrison, F. J. (2013). The contributions of parental management language to executive function in preschool children. *Early Childhood Research Quarterly, 28*, 529 – 539.

Birgisdottir, F., Gestsdottir, S., & Thorsdottir, F. (2015). The role of behavioral self-regulation in learning to read: A 2-year longitudinal study of Icelandic preschool children. *Early Education and Development, 26*, 807 – 828.

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

Blair, C. (2010). Stress and the development of self-regulation in context. *Child Development Perspectives, 4*, 181 – 188.

Blair, C., Granger, D., & Razza, R. P. (2005). Cortisol reactivity is positively related to executive function in preschool children attending Head Start. *Child Development, 76*, 554 – 567.

Blair, C., McKinnon, R. D., & Family Life Project Investigators. (2016). Moderating effects of executive functions and the teacher – child relationship on the development of mathematics ability in kindergarten. *Learning and Instruction, 41*, 85 – 93.

Blair, C., & Raver, C. C. (2012). Child development in the context of adversity: Experiential canalization of brain and behavior. *American Psychologist, 67*, 309 – 318.

Blair, C., & Raver, C. C. (2014). Closing the achievement gap through modification of neurocognitive and neuroendocrine function: Results from a cluster randomized controlled trial of an innovative approach to the education of children in kindergarten. *PloS ONE, 9*(11), e112393.

Blair, C., Raver, C. C., Berry, D. J., & Family Life Project Investigators. (2014). Two approaches to estimating the effect of parenting on the development of executive function in early childhood. *Developmental Psychology, 50*, 554 – 565.

Blair, C., & Razza, R. P. (2007). Relating effortful control, executive function, and false belief understanding to emerging math and literacy ability in kindergarten. *Child Development, 78*, 647 – 663.

Blair, C., & Ursache, A. (2011). A bidirectional model of executive functions and self-regulation. In K. D. Vohs & R. F. Baumeister (Eds.), *Handbook of self-regulation: Research, theory, and applications* (2nd ed., pp. 300 – 320). New York, NY: Guilford Press.

Blair, C., Ursache, A., Greenberg, M., Vernon-Feagans, L., & Family Life Project Investigators. (2015). Multiple aspects of self-regulation uniquely predict mathematics but not letter-word knowledge in the early elementary grades. *Developmental Psychology, 51*, 459 – 472.

Blair, C., Zelazo, P. D., & Greenberg, M. T. (2005). The measurement of executive function in early childhood. *Developmental Neuropsychology, 28*, 561 – 571.

Blakey, E., & Carroll, D. J. (2015). A short executive function training program improves preschoolers' working memory. *Frontiers in Psychology, 6*, Article 1827.

Bohrnstedt, G., Kitmitto, S., Ogut, B., Sherman, D., & Chan, D. (2015). *School composition and the Black – White achievement gap* (Report No. NCES 2015-018). Washington, DC: U.S. Department of Education, National Center for Education Statistics.

Brock, L. L., Rimm-Kaufman, S. E., Nathanson, L., & Grimm, K. J. (2009). The contributions of "hot" and "cool" executive function to children's academic achievement, learning-related behaviors, and engagement in kindergarten. *Early Childhood Research Quarterly, 24*, 337 – 349.

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

Bronson, M. B. (1991, April). *Longitudinal evaluation of a collaborative public school and day care intervention program in preschool and kindergarten*. Paper presented at the annual meeting of the American Educational Research Association, Chicago, IL.

Bronson, M. B. (1994). The usefulness of an observational measure of young children's social and mastery behaviors in early childhood classrooms. *Early Childhood Research Quarterly, 9*, 19 – 43.

Bronson, M. B., Goodson, B. D., Layzer, J. I., & Love, J. M. (1990). *Child Behavior Rating Scale*. Cambridge, MA: Abt Associates.

Bronson, M. B., Tivnan, T., & Seppanen, P. S. (1995). Relations between teacher and classroom activity variables and the classroom behaviors of preschool children in Chapter 1 funded programs. *Journal of Applied Developmental Psychology, 16*, 253–282.

Bull, R., Espy, K. A., & Wiebe, S. A. (2008). Short-term memory, working memory, and executive functioning in preschoolers: Longitudinal predictors of mathematical achievement at age 7 years. *Developmental Neuropsychology, 33*, 205–228.

Bull, R., Espy, K. A., Wiebe, S. A., Sheffield, T. D., & Nelson, J. M. (2011). Using confirmatory factor analysis to understand executive control in preschool children: Sources of variation in emergent mathematic achievement. *Developmental Science, 14*, 679–692.

Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. *Developmental Neuropsychology, 19*, 273–293.

Burchinal, M., Field, S., Lopez, M. L., Howes, C., & Pianta, R. (2012). Instruction in Spanish in pre-kindergarten classrooms and child outcomes for English language learners. *Early Childhood Research Quarterly, 27*, 188–197.

Burrage, M., Cameron Ponitz, C., McCready, E. A., Shah, P. R., Sims, B. C., Jewkes, A. M., & Morrison, F. J. (2008). Age and schooling-related effects on executive functions in young children: A natural experiment. *Child Neuropsychology, 14*, 510–524.

Buss, A. T., & Spencer, J. P. (2014). The emergent executive: A dynamic field theory of the development of executive function. *Monographs of the Society for Research in Child Development, 79*(2), 104–115.

Calvo, A., & Bialystok, E. (2014). Independent effects of bilingualism and socioeconomic status on language ability and executive functioning. *Cognition, 130*, 278–288.

Cameron, C. E., Brock, L. L., Murrah, W. M., Bell, L. H., Worzalla, S. L., Grissmer, D., & Morrison, F. J. (2012). Fine motor skills and executive function both contribute to kindergarten achievement. *Child Development, 83*, 1229–1244.

Cameron, C. E., & Morrison, F. J. (2011). Teacher activity orienting predicts preschoolers' academic and self-regulatory skills. *Early Education and Development, 22*, 620–648.

Cameron Ponitz, C. E., McClelland, M. M., Jewkes, A. M., Connor, C. M., Farris, C. L., & Morrison, F. J. (2008). Touch your toes! Developing a direct measure of behavioral regulation in early childhood. *Early Childhood Research Quarterly, 23*, 141–158.

Cameron Ponitz, C., McClelland, M. M., Matthews, J. S., & Morrison, F. J. (2009). A structured observation of behavioral self-regulation and its contribution to kindergarten outcomes. *Developmental Psychology, 45*, 605–619.

Cameron Ponitz, C., Rimm-Kaufman, S. E., Grimm, K. J., & Curby, T. W. (2009). Kindergarten classroom quality, behavioral engagement, and reading achievement. *School Psychology Review, 38*, 102–120.

Campbell, D. W., Eaton, W. O., & McKeen, N. A. (2002). Motor activity level and behavioral control in young children. *International Journal of Behavioral Development, 26*, 289–296.

Canfield, R. L., Gendle, M. H., & Cory-Slechta, D. A. (2004). Impaired neuropsychological functioning in lead-exposed children. *Developmental Neuropsychology, 26*, 513–540.

Cannon, J. S., & Karoly, L. A. (2007). *Who is ahead and who is behind? Gaps in school readiness and student achievement in the early grades for California's children*. Santa Monica, CA: RAND.

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

Carlson, S. M. (2009). Social origins of executive function development. *New Directions in Child and Adolescent Development, 123*, 87–98.

Carlson, S. M., Faja, S., & Beck, D. M. (2016). Incorporating early development into the measurement of executive function: The need for a continuum of measures across development. In J. A. Griffin, P. McCardle, & L. S. Fruend (Eds.), *Executive function in preschool-age children: Integrating measurement, neurodevelopment, and translational research* (pp. 45–64). Washington, DC: American Psychological Association.

Carlson, S. M., & Harrod, J. (2013). *The executive function scale for preschoolers: Validation phase.* Paper presented at the annual meeting of the Society for Research in Child Development, Seattle, WA.

Carlson, S., Mandell, D., & Williams, L. (2004). Executive function and theory of mind: Stability and prediction from ages 2 to 3. *Developmental Psychology, 40*, 1105–1122.

Carlson, S. M., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science, 11*, 282–298.

Carlson, S. M., & Wang, T. S. (2007). Inhibitory control and emotion regulation in preschool children. *Cognitive Development, 22*, 489–510.

Carlson, S. M., & Zelazo, P. D. (2014). *Minnesota Executive Function Scale: Test manual*. St. Paul, MN: Reflection Sciences.

Cartwright, K. B. (2012). Insights from cognitive neuroscience: The importance of executive function for early reading development and education. *Early Education and Development, 23*, 24–36.

Center on the Developing Child at Harvard University. (2011). *Building the brain's "air traffic control" system: How early experiences shape the development of executive function* (Working Paper No. 11). Cambridge, MA: Author.

Chang, F., Crawford, G., Early, D., Bryant, D., Howes, C., Burchinal, M., … Pianta, R. (2007). Spanish-speaking children's social and language development in pre-kindergarten classrooms. *Early Education and Development, 18*, 243–269.

Chevalier, N., Sheffield, T. D., Nelson, J. M., Clark, C. A. C., 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*, 99–118.

Children's Learning Institute. (n.d.). *Texas Kindergarten Entry Assessment (TX-KEA)*. Retrieved from https://www.childrenslearninginstitute.org/research/texas-kindergarten-entry-assessment-tx-kea/

Choi, J. Y., Castle, S., Williamson, A. C., Young, E., Worley, L., Long, M., & Horm, D. M. (2016). Teacher–child interactions and the development of executive function in preschool-age children attending Head Start. *Early Education and Development, 27*, 751–769.

Chung, K. K., & de Silva, A. D. (2013). *Effects of a pretend play intervention on executive functioning tasks* (Unpublished manuscript). Wellesley College, Wellesley, MA.

Clark, C. A. C., Nelson, J. M., Garza, J., Sheffield, T. D., Wiebe, S. A., & Espy, K. A. (2014). Gaining control: Changing relations between executive control and processing speed and their relevance for mathematics achievement over course of the preschool period. *Frontiers in Psychology, 5*(107), 1–15.

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

Clark, C. A. C., Sheffield, T. D., Chevalier, N., Nelson, J. M., Wiebe, S. A., & Espy, K. A. (2012). Charting early trajectories of executive control with the Shape School. *Developmental Psychology, 49*, 1481–1493.

Clark, C. A. C., Sheffield, T. D., Wiebe, S. A., & Espy, K. A. (2013). Longitudinal associations between executive control and developing mathematical competence in preschool boys and girls. *Child Development, 84*, 662–677.

Clements, D. H., Sarama, J., & Germeroth, C. (2016). Learning executive function and early mathematics: Directions of causal relations. *Early Childhood Research Quarterly, 36*, 79–90.

Connor, C. M., Cameron Ponitz, C., Phillips, B. M., Travis, Q. M., Glasney, S., & Morrison, F. J. (2010). First graders' literacy and self-regulation gains: The effect of individualizing student instruction. *Journal of School Psychology, 48*, 433–455.

Connor, P. D., Sampson, P. D., Bookstein, F. L., Barr, H. M., & Streissguth, A. P. (2000). Direct and indirect effects of prenatal alcohol damage on executive function. *Developmental Neuropsychology, 18*, 331–354.

Conway, A., & Stifter, C. (2012). Longitudinal antecedents of executive function in preschoolers. *Child Development, 83*, 1022–1036.

Council on School Health. (2013). The crucial role of recess in school. *Pediatrics*, *131*, 183–188.

Courage, M. L., & Setliff, A. E. (2009). Debating the impact of television and video material on very young children: Attention, learning, and the developing brain. *Child Development Perspectives, 3*, 72–78.

Cuevas, K., Hubble, M., & Bell, M. A. (2012). Early childhood predictors of post-kindergarten executive function: Behavior, parent-report, and psychophysiology. *Early Education and Development, 23*, 59–73.

Denham, S. A., Bassett, H. H., & Zinsser, K. (2012). Computerizing social–emotional assessment for school readiness: First steps toward an assessment battery for early childhood settings. *Journal of Applied Research on Children: Informing Policy for Children at Risk*, *3*(2), Article 3.

Denham, S. A., Warren-Khot, H. K., Bassett, H. H., Wyatt, T., & Perna, A. (2012). Factor structure of self-regulation in preschoolers: Testing models of field-based assessment for predicting early school readiness. *Journal of Experimental Child Psychology, 111*, 386–404.

Diamond, A. (2006). The early development of executive functions. In E. Bialystok & F. I. M. Craik (Eds.), *Lifespan cognition: Mechanisms of change* (pp. 70–95). New York, NY: Oxford University Press.

Diamond, A., Barnett, W. S., Thomas, J., & Munro, S. (2007). Preschool program improves cognitive control. *Science, 318*, 1387–1388.

Diamond, A., Carlson, S. M., & Beck, D. M. (2005). Preschool children's performance in task switching on the Dimensional Change Card Sort task: Separating the dimensions aids the ability to switch. *Developmental Neuropsychology, 28*, 689–729.

Diamond, A., & Lee, K. (2011). Interventions shown to aid executive function development in children 4–12 years old. *Science, 333*, 959–963.

Diamond, A., & Ling, D. S. (2016). Conclusions about interventions, programs, and approaches for improving executive functions that appear justified and those that, despite much hype, do not. *Developmental Cognitive Neuroscience, 18*, 34–48.

Dias, N. M., & Seabra, A. G. (2015). Is it possible to promote executive functions in preschoolers? A case study in Brazil. *International Journal of Child Care and Education Policy, 9*(6). https://doi.org/10.1186/s40723-015-0010-2

Dilworth-Bart, J. E. (2012). Does executive function mediate SES and home quality associations with academic readiness? *Early Childhood Research Quarterly, 27*, 416–425.

Domitrovich, C. E., Cortes, R. C., & Greenberg, M. T. (2007). Improving young children's social and emotional competence: A randomized trial of the Preschool "PATHS" curriculum. *Journal of Primary Prevention, 28*, 67–91.

Duncan, G. J., & Sojourner, A. J. (2013). Can intensive early childhood intervention programs eliminate income-based cognitive and achievement gaps? *Journal of Human Resources, 48*, 945–968.

Duncan, R. J. (2012). *Measures of executive function: Convergent validity and links to academic achievement in preschool* (Unpublished master's thesis). Oregon State University, Corvallis, OR.

Espinet, S. D., Anderson, J. E., & Zelazo, P. D. (2013). Reflection training improves executive function in preschool-age children: Behavioral and neural effects. *Developmental Cognitive Neuroscience, 4*, 3 – 15.

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

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 mathematics skills in preschool children. *Developmental Neuropsychology, 26*, 465 – 486.

Espy, K. A., Stalets, M. M., McDiarmid, M. M., Senn, T. E., Cwik, M. F., & Hamby, A. (2002). Executive functions in preschool children born preterm: Application of cognitive neuroscience paradigms. *Child Neuropsychology, 8*, 83 – 92.

Ezrine, G. A. (2010). *Effects of language on the development of executive functions in preschool children* (Unpublished doctoral dissertation). Georgia State University, Atlanta, GA.

Farran, D. C., & Lipsey, M. W. (2012). *Experimental evaluation of the Tools of the Mind pre-K curriculum: Mid-study report fall 2012.* Nashville, TN: Peabody Research Institute.

Fisher, A. V., Godwin, K. E., & Seltman, H. (2014). Visual environment, attention allocation, and learning in young children: When too much of a good thing may be bad. *Psychological Science, 25*(7), 1362 – 1370. https://doi.org/10.1177/0956797614533801

Fitzpatrick, C., McKinnon, R. D., Blair, C. B., & Willoughby, M. T. (2014). Do preschool executive function skills explain the school readiness gap between advantaged and disadvantaged children? *Learning and Instruction, 30*, 25 – 31.

Frank Porter Graham Child Development Institute. (n.d.). *Executive functions (EF) touch: Brief history of task development*. Retrieved from http://eftouch.fpg.unc.edu/content/brief-history-task-development

Fuglestad, A. J., Whitley, M. L., Carlson, S. M., Boys, C. J., Eckerley, J. K., Fink, B. A., & Wozniak, J. R. (2015). Executive functioning deficits in preschool children with fetal alcohol spectrum disorders. *Child Neuropsychology, 21*, 716 – 731.

Fuhs, M. W., & Day, J. D. (2011). Verbal ability and executive functioning development in preschoolers at Head Start. *Developmental Psychology, 47*, 404 – 416.

Fuhs, M. W., Farran, D. C., & Nesbitt, K. T. (2013). Preschool classroom processes as predictors of children's cognitive self-regulation skills development. *School Psychology Quarterly, 28*, 347 – 359.

Fuhs, M. W., Farran, D. C., & Nesbitt, K. T. (2015). Prekindergarten children's executive functioning skills and achievement gains: The utility of direct assessment and teacher ratings. *Journal of Educational Psychology, 107*, 207 – 221.

Fuhs, M. W., Nesbitt, K. T., Farran, D. C., & Dong, N. (2014). Longitudinal associations between executive functioning and academic skills across content areas. *Developmental Psychology, 50*, 1698 – 1709.

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

Gestsdottir, S., von Suchodoletz, A., Wanless, S. B., Hubert, B., Guimard, P., Birgisdottir, F., … McClelland, M. (2014). Early behavioral self-regulation, academic achievement, and gender: Longitudinal findings from France, Germany, and Iceland. *Applied Developmental Science, 18*, 90 – 109.

Goldstein, J., & Flake, J. K. (2015). Towards a framework for the validation of early childhood assessment systems. *Educational Assessment, Evaluation and Accountability, 28*, 273 – 293.

Hammond, S. I., Muller, U., Carpendale, J. I. M., Bibok, M. B., & Liebermann-Finestone, D. P. (2012). The effects of parental scaffolding on preschoolers' executive functioning. *Developmental Psychology, 48*, 271 – 281.

Health Measures. (2017). *NIH Toolbox Early Childhood Cognition Battery: Ages 3 – 6*. Retrieved from http://www.healthmeasures.net/explore-measurement-systems/nih-toolbox/intro-to-nih-toolbox/cognition

Hoffman, J., & Russ, S. (2012). Pretend play, creativity, and emotion regulation in children. *Psychology of Aesthetics, Creativity, and the Arts, 6*, 175 – 184.

Holochwost, S. J., Gariepy, J.-L., Propper, C. B., Gardner-Neblett, N., Volpe, V., Neblett, E., & Mills-Koonce, W. R. (2016). Sociodemographic risk, parenting, and executive functions in early childhood: The role of ethnicity. *Early Childhood Research Quarterly, 36*, 537 – 549.

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

Hughes, C. (1998). Finding your marbles: Does preschoolers' strategic behavior predict later understanding of mind? *Developmental Psychology, 34*, 1326 – 1339.

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

Hughes, C., & Ensor, R. (2009). How do families help or hinder the development of executive function? *New Directions in Child and Adolescent Psychiatry, 2009*(123), 35 – 50.

Hughes, C., Ensor, R., Wilson, A., & Graham, A. (2010). Tracking executive function across the transition to school: A latent variable approach. *Developmental Neuropsychology, 35*, 20 – 36.

Hughes, C., Roman, G., Hart, M. J., & Ensor, R. (2013). Does maternal depression predict young children's executive function? A 4-year longitudinal study. *Journal of Child Psychology & Psychiatry, 54*, 169–177.

Jacob, R., & Parkinson, J. (2015). The potential for school-based interventions that target executive function to improve academic achievement: A review. *Review of Educational Research, 85*, 512–552.

Jarrett, O., & Waite-Stupiansky, S. (2009, September). Recess: It's indispensable! *Young Children*, pp. 66–69.

Jones, L. B., Rothbart, M. K., & Posner, M. I. (2003). Development of executive attention in preschool children. *Developmental Science, 6*, 498–504.

Jones, S. M., Bailey, R., Barnes, S. P., & Partee, A. (2016). *Executive function mapping project: Untangling the terms and skills related to executive function and self-regulation in early childhood* (Report No. OPRE 2016-88). Washington, DC: Office of Planning, Research, and Evaluation, Administration for Children and Families, U.S. Department of Health and Human Services.

K–3 North Carolina Assessment Think Tank. (2013). *Assessment for learning and development in K–3*. Retrieved from https://elc.grads360.org/services/PDCService.svc/GetPDCDocumentFile?fileId=10247

Kagan, J., & Herschkowitz, N. (2005). *A young mind in a growing brain*. New York, NY: Lawrence Erlbaum Associates.

Karpinski, A. C., Scullin, M. H., & Montgomery-Downs, H. E. (2008). Risk for sleep-disordered breathing and executive function in preschoolers. *Sleep Medicine, 9*, 418–424.

Klatte, M., Bergstrom, K., & Lachmann, T. (2013). Does noise affect learning? A short review on noise effects on cognitive performance in children. *Frontiers in Psychology, 4*(578), 1–6.

Kochanska, G., Coy, K. C., & Murray, K. T. (2001). The development of self-regulation in the first four years of life. *Child Development, 72*, 1091–1111.

Kraybill, J. H., & Bell, M. A. (2013). Infancy predictors of preschool and post-kindergarten executive function. *Developmental Psychobiology, 55*, 530–538.

Kuhn, L. J., Willoughby, M. T., Vernon-Feagans, L., Blair, C. B., & Family Life Project Key Investigators. (2016). The contribution of children's time-specific and longitudinal expressive language skills on developmental trajectories of executive function. *Journal of Experimental Child Psychology, 148*, 20–34.

Landry, S. H., Smith, K. E., Swank, P. R., & Miller-Loncar, C. L. (2000). Early maternal and child influences on children's later independent cognitive and social functioning. *Child Development, 71*, 358–375.

Lerner, M. D., & Lonigan, C. J. (2014). Executive function among preschool children: Unitary versus distinct abilities. *Journal of Psychopathology and Behavior Assessment, 36*, 626–639.

Liew, J. (2011). Effortful control, executive functions, and education: Bringing self-regulatory and social–emotional competencies to the table. *Child Development Perspectives, 6*, 105–111.

Lillard, A. S. (2012). Preschool children's development in classic Montessori, supplemented Montessori, and conventional programs. *Journal of School Psychology, 50*, 379–401.

Lillard, A. S., Lerner, M. D., Hopkins, E. J., Dore, R. A., Smith, E. D., & Palmquist, C. M. (2012). The impact of pretend play on children's development: A review of the evidence. *Psychological Bulletin, 139*, 1–34.

Lillard, A. S., Li, H., & Boguszewski, K. (2015). Television and children's executive function. In J. B. Benson (Ed.), *Advances in child development and behavior* (Vol. *48*, pp. 209–248). San Diego, CA: Elsevier.

Lillard, A. S., & Peterson, J. (2011). The immediate impact of different types of television on young children's executive function. *Pediatrics, 128*(4). https://doi.org/10.1542/peds.2010-1919

Lipsey, M. W., Nesbitt, K. T., Farran, D. C., Dong, N., Fuhs, M. W., & Wilson, S. J. (2014). *Learning-related cognitive self-regulation measures for prekindergarten children with predictive validity for academic achievement* (Working paper). Nashville, TN: Vanderbilt University, Peabody Research Institute.

Loe, I. M., Chatav, M., & Alduncin, N. (2014). Complementary assessments of executive function in preterm and full-term preschoolers. *Child Neuropsychology: A Journal on Normal and Abnormal Development in Childhood and Adolescence, 21*, 331–353.

Loe, I. M., Feldman, H. M., & Huffman, L. C. (2014). Executive function mediates effects of gestational age on functional outcomes and behavior in preschoolers. *Journal of Developmental & Behavioral Pediatrics, 35*, 323–333.

Loeher, S., & Roebers, C. M. (2013). Executive functions and their differential contribution to sustained attention in 5- to 8-year-old children. *Journal of Educational and Developmental Psychology, 3*, 51–63.

Lonigan, C. J., Allan, D. M., Goodrich, J. M., Farrington, A. L., & Phillips, B. M. (2015). Inhibitory control of Spanish-speaking language-minority preschool children: Measurement and association with language, literacy, and math skills (Online first). *Journal of Learning Disabilities*. https://doi.org/10.1177/0022219415618498

Lonigan, C. J., Lerner, M. D., Goodrich, J. M., Farrington, A. L., & Allan, D. M. (2016). Executive function of Spanish-speaking language-minority preschoolers: Structure and relations with early literacy skills and behavioral outcomes. *Journal of Experimental Child Psychology, 144*, 46–65.

Mahone, E. M., Pillion, J. P., Hoffman, J., Hiemenz, J. R., & Denkla, M. B. (2005). Construct validity of the Auditory Continuous Performance Test for preschoolers. *Developmental Neuropsychology, 27*, 11–33.

Martin-Rhee, M. M., & Bialystok, E. (2008). The development of two types of inhibitory control in monolingual and bilingual children. *Bilingualism: Language and Cognition, 11*, 81 – 93.

Masten, S. A., Herbers, J. E., Desjardins, C. D., Cutuli, J. J., McCormick, C. M., Sapienza, J. K., … Zelazo, P. D. (2012). Executive function skills and school success in young children experiencing homelessness. *Educational Researcher, 41*, 375 – 384.

Matte-Gagne, C., & Bernier, A. (2011). Prospective relations between maternal autonomy support and child executive functioning: Investigating the mediating role of child language ability. *Journal of Experimental Child Psychology, 110*, 611 – 625.

Matthews, J. S., Cameron Ponitz, C., & Morrison, F. J. (2009). Early gender differences in self-regulation and academic achievement. *Journal of Educational Psychology, 101*, 689 – 704.

McClelland, M. M., Acock, A. C., & Morrison, F. J. (2006). The impact of kindergarten learning-related skills on academic trajectories at the end of elementary school. *Early Childhood Research Quarterly, 21*, 471 – 490.

McClelland, M. M., Acock, A. C., Piccinin, A., Rhea, S. A., & Stallings, M. C. (2013). Relations between preschool attention span-persistence and age 25 educational outcomes. *Early Childhood Research Quarterly, 28*, 314 – 324.

McClelland, M. M., Cameron, C. E., Connor, C. M., Farris, C. L., Jewkes, A. M., & Morrison, F. J. (2007). Links between behavioral regulation and preschoolers' literacy, vocabulary, and math skills. *Developmental Psychology, 43*, 947 – 959.

McClelland, M. M., Cameron, C. E., Duncan, R., Bowles, R. P., Acock, A. C., Miao, A., & Pratt, M. E. (2014). Predictors of early growth in academic achievement: The Head – Toes – Knees – Shoulders task. *Frontiers in Psychology, 5*, Article 599.

Miller, M. R., Muller, U., Giesbrecht, G. F., Carpendale, J. R., & Kerns, K. A. (2013). The contribution of executive function and social understanding to preschoolers' letter and math skills. *Cognitive Development, 28*, 331 – 349.

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

Morales, J., Calvo, A., & Bialystok, E. (2013). Working memory development in monolingual and bilingual children. *Journal of Experimental Child Psychology, 114*, 187 – 202.

Morrison, F. J., Cameron Ponitz, C., & McClelland, M. M. (2009). Self-regulation and academic achievement in the transition to school. In S. Calkins & M. Bell (Eds.), *Child development at the intersection of emotion and cognition* (pp. 203 – 224). Washington, DC: American Psychological Association.

Mulder, H., Pitchford, N., Hagger, M., & Marlow, N. (2009). Development of executive function and attention in preterm children: A systematic review. *Developmental Neuropsychology, 34*, 393 – 421.

Nathanson, A. I., Alade, F., Sharp, M. L., Rasmussen, E. E., & Christy, K. (2014). The relation between television exposure and executive function among preschoolers. *Developmental Psychology*, *50*(5), 1497 – 1506. https://doi.org/10.1037/a0035714

National Conference of State Legislatures. (2014). *State approaches to school readiness*. Retrieved from http://www.ncsl.org/Portals/1/Documents/educ/NCSL_Readiness_Assessment_2014_Update_Report_Chart.pdf

Nayfeld, I., Fuccillo, J., & Greenfield, D. B. (2013). Executive functions in early learning: Extending the relationship between executive functions and school readiness to science. *Learning and Individual Differences, 26*, 81 – 88.

Nelson, J. M., James, T. D., Chevalier, N., Clark, C. A. C., & Espy, K. A. (2016). Structure, measurement, and development of preschool executive function. In J. A. Griffin, P. McCardle, & L. S. Freund (Eds.), *Executive function in preschool-age children: Integrating measurement, neurodevelopment, and translational research* (pp. 65 – 89). Washington, DC: American Psychological Association.

Nesbitt, K. T., Baker-Ward, L., & Willoughby, M. T. (2013). Executive function mediates socio-economic and racial differences in early academic achievement. *Early Childhood Research Quarterly, 28*, 774 – 783.

Nesbitt, K. T., Farran, D. C., & Fuhs, M. W. (2015). Executive function skills and academic achievement gains in prekindergarten: Contributions of learning-related behaviors. *Developmental Psychology, 51*, 865 – 878.

Neuenschwander, R., Rothlisberger, M., Cimeli, P., & Roebers, C. M. (2012). How do different aspects of self-regulation predict successful adaptation to school? *Journal of Experimental Child Psychology, 113*, 353 – 371.

NIH Toolbox. (n.d.). *NIH Toolbox for the assessment of neurological and behavioral function*. Retrieved from http://www.nihtoolbox.org/Communications/NewsAndAnnouncements/Pages/NIH-Toolbox-iPad-App-launched.aspx

Noble, K. G., McCandliss, B. D., & Farah, M. J. (2007). Socioeconomic gradients predict individual differences in neurocognitive abilities. *Developmental Science, 10*, 464 – 480.

Noble, K. G., Norman, M. F., & Farah, M. J. (2005). Neurocognitive correlates of socioeconomic status in kindergarten children. *Developmental Science, 8*, 74 – 87.

NYU Institute of Human Development and Social Change. (2016). *Preschool Self-Regulation Assessment (PSRA)*. Retrieved from http://steinhardt.nyu.edu/ihdsc/csrp/psra

Obradovic, J., Portilla, X. A., & Boyce, W. T. (2012). Executive functioning and developmental neuroscience: Current progress and implications for early childhood education. In R. C. Pianta, W. S. Barnett, L. M. Justice, & S. M. Sheridan (Eds.), *Handbook of early childhood education* (pp. 324 – 351). New York, NY: Guilford Press.

Oh, S., & Lewis, C. (2008). Korean preschoolers' advanced inhibitory control and its relation to other executive skills and metal state understanding. *Child Development, 79*, 80 – 99.

Orchinik, L. J., Taylor, H. G., Espy, K. A., Minich, N., Klein, N., Sheffield, T., & Hack, M. (2011). Cognitive outcomes for extremely preterm/extremely low birth weight children in kindergarten. *Journal of the International Neuropsychological Society, 17*, 1067–1079.

Oregon Early Learning Division. (n.d.). *Kindergarten assessment*. Retrieved from https://oregonearlylearning.com/kindergarten-assessment/

Oregon State University. (2011). *Head–Toes–Knees–Shoulders research agreement*. Retrieved from http://oregonstate.qualtrics.com/jfe/form/SV_6leFzWtsGIXnUXP

Pierucci, J. M., O'Brien, C. T., McInnis, M. A., Gilpin, A. T., & Barber, A. B. (2014). Fantasy orientation constructs and related executive function development in preschool: Developmental benefits to executive functions by being a fantasy-oriented child. *International Journal of Behavioral Development, 38*, 62–69.

Poarch, G. J., & van Hell, J. G. (2012). Executive functions and inhibitory control in multilingual children: Evidence from second-language learners, bilinguals, and trilinguals. *Journal of Experimental Child Psychology, 113*, 535–551.

Posner, M., & Rothbart, M. (2000). Developing mechanisms of self-regulation. *Development and Psychopathology, 12,* 427–441.

Poulin-Dubois, D., Blaye, A., Coutya, J., & Bialystok, E. (2011). The effects of bilingualism on toddlers' executive functioning. *Journal of Experimental Child Psychology, 108*, 567–579.

Prager, E. O., Sera, M. D., & Carlson, S. M. (2016). Executive function and magnitude skills in preschool children. *Journal of Experimental Child Psychology, 147*, 126–139.

Qu, L., Finestone, D. L., Qin, L. J., & Reena, L. Z. (2012). Focused but fixed: The impact of expectation of external rewards on inhibitory control and flexibility in preschoolers. *Emotion, 13*, 562–572.

Rasmussen, C., & Bisanz, J. (2011). The relation between mathematics and working memory in young children with fetal alcohol spectrum disorders. *Journal of Special Education, 45*, 184–191.

Raver, C. C. (2004). Placing emotional self-regulation in sociocultural and socioeconomic contexts. *Child Development, 75*, 346–353.

Raver, C. C. (2012, November). Low-income children's self-regulation in the classroom: Scientific inquiry for social change. *American Psychologist*, pp. 681–689.

Raver, C. C., Blair, C., Willoughby, M., & Family Life Project Key Investigators. (2013). Poverty as a predictor of 4-year-olds' executive function: New perspectives on models of differential susceptibility. *Developmental Psychology, 49*, 292–304.

Raver, C. C., Carter, J. S., McCoy, D. C., Roy, A., Ursache, A., & Friedman, A. (2012). Testing models of children's self-regulation within educational contexts: Implications for measurement. *Advances in Child Development and Behavior, 42*, 245–270.

Raver, C. C., Jones, S. M., Li-Grining, C. P., Metzger, M., Champion, K. M., & Sardin, L. (2008). Improving preschool classroom processes: Preliminary findings from a randomized trial implemented in Head Start settings. *Early Childhood Research Quarterly, 23*, 10–26.

Raver, C. C., Jones, S. M., Li-Grining, C. P., Zhai, F., Bub, K., & Pressler, E. (2011). CSRP's impact on low-income preschoolers' pre-academic skills: Self-regulation and teacher-student relationships as two mediating mechanisms. *Child Development, 82*, 362–378.

Read, M. A., Sugawara, A. I., & Brandt, J. A. (1999). Impact of space and color in the physical environment on preschool children's cooperative behavior. *Environment and Behavior, 31*, 413–428.

Reck, S. G., & Hund, A. M. (2011). Sustained attention and age predict inhibitory control during early childhood. *Journal of Experimental Child Psychology, 108*, 504–512.

Reflection Sciences. (2017). *Frequently asked questions.* Retrieved from Reflection Sciences. Retrieved from http:/.refelectionsciences.com/resources/faqs/

Rennie, D. A. C., Bull, R., & Diamond, A. (2004). Executive functioning in preschoolers: Reducing the inhibitory demands of the Dimensional Change Card Sort task. *Developmental Neuropsychology, 26*, 423–443.

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*, 638–662.

Rimm-Kaufman, S. E., Curby, T. W., Grimm, K. J., Nathanson, L., & Brock, L. L. (2009). The contribution of children's self-regulation and classroom quality to children's adaptive behaviors in the kindergarten classroom. *Developmental Psychology, 45*, 958–972.

Robinson, O. J., Vytal, K., Cornwell, B. R., & Grillon, C. (2013, May 17). The impact of anxiety upon cognition: Perspectives from human threat of shock studies. *Frontiers in Human Neuroscience*. https://doi.org/10.3389/fnhum.2013.00203

Roman, G. D., Ensor, R., & Hughes, C. (2016). Does executive function mediate the path from mothers' depressive symptoms to young children's problem behaviors? *Journal of Experimental Child Psychology, 142*, 158–170.

Rothlisberger, M., Neuenschwander, R., Cimeli, P., Michel, E., & Roebers, C. M. (2011). Improving executive functions in 5- and 6-year olds: Evaluation of a small group intervention in prekindergarten and kindergarten children. *Infant and Child Development, 21*, 411–429.

Rothlisberger, M., Neuenschwander, R., Cimeli, P., & Roebers, C. M. (2013). Executive functions in 5- to 8-year olds: Developmental changes and relationship to academic achievement. *Journal of Educational and Developmental Psychology, 3*, 153–167.

Rowley, B. A. (2015). *Kindergarten assessment: Analysis of the Child Behavioral Rating Scale (CBRS)* (Unpublished doctoral dissertation). University of Oregon, Eugene, OR.

Rueda, M. R., Posner, M. I., & Rothbart, M. K. (2005). The development of executive attention: Contributions to the emergence of self-regulation. *Neuropsychology, 28*, 573–594.

Sarsour, K., Sheridan, M., Jutte, D., Nuru-Jeter, A., Hinshaw, S., & Boyce, W. T. (2011). Family socioeconomic status and child executive functions: The roles of language, home environment, and single parenthood. *Journal of the International Neuropsychological Society, 17*, 120–132.

Sasser, T. R., Bierman, K. L., & Heinrichs, B. (2015). Executive functioning and school adjustment: The mediational role of pre-kindergarten learning-related behaviors. *Early Childhood Research Quarterly, 30*, 70–79.

Saterlee, D. J., Molavi, J. M., & Williams, M. E. (2015, May 12). An evaluation of early education based on physical environmental guidelines. *SAGE Open*. Retrieved from http://sgo.sagepub.com/content/spsgo/5/2/2158244015586810.full.pdf

Schmitt, S. A., Finders, J. K., & McClelland, M. M. (2015). Residential mobility, inhibitory control, and academic achievement in preschool. *Early Education and Development, 26*, 189–208.

Schmitt, S. A., Pratt, M. E., & McClelland, M. M. (2014). Examining the validity of behavioral self-regulation tools in predicting preschoolers' academic achievement. *Early Education and Development, 25*, 641–660.

Segretin, M. S., Lipina, S. J., Hermida, M. J., Sheffield, T. D., Nelson, J. M., Espy, K. A., & Colombo, J. A. (2014). Predictors of cognitive enhancement after training in preschoolers from diverse socioeconomic backgrounds. *Frontiers in Psychology, 5*(205), 1–21.

Sektnan, M., McClelland, M. M., Acock, A., & Morrison, F. J. (2010). Relations between early family risk, children's behavioral regulation, and academic achievement. *Early Childhood Research Quarterly, 25*, 464–479.

Senn, T. E., Espy, K. A., & Kaufmann, P. M. (2004). Using path analysis to understand executive function organization in preschool children. *Developmental Neuropsychology, 26*, 445–464.

Smith-Donald, R., Raver, C. C., Hayes, T., & Richardson, B. (2007). Preliminary construct and concurrent validity of the Preschool Self-Regulation Assessment (PSRA) for field-based research. *Early Childhood Research Quarterly, 22*, 173–187.

Son, S.-H., Lee, K., & Sung, M. (2013). Links between preschoolers' behavioral regulation and school readiness skills: The role of child gender. *Early Education and Development, 24,* 1–23.

Stipek, D., Newton, S., & Chudgar, A. (2010). Learning-related behaviors and literacy achievement in elementary school–aged children. *Early Childhood Research Quarterly, 25*, 385–396.

Storksen, I., Ellingsen, I. T., Wanless, S. B., & McClelland, M. M. (2015). The influence of parental socioeconomic background and gender on self-regulation among 5-year-old children in Norway. *Early Education and Development, 26*, 663–684.

Sulik, M. J., Blair, C., Mills-Koonce, R., Berry, D., Greenberg, M., & Family Life Project Investigators. (2015). Early parenting and the development of externalizing behavior problems: Longitudinal mediation through children's executive function. *Child Development, 86*, 1588–1603.

Thibodeau, R. B., Gilpin, A. T., Brown, M. M., & Meyer, B. A. (2016). The effects of fantastical pretend-play on the development of executive functions: An intervention study. *Journal of Experimental Child Psychology, 145*, 120–138.

Thierry, K. L., Bryant, H. L., Nobles, S. S., & Norris, K. S. (2016). Two-year impact of a mindfulness-based program on preschoolers' self-regulation and academic performance. *Early Education and Development, 27*, 805–821.

Thompson, R. A., & Nelson, C. A. (2001). Developmental science and the media: Early brain development. *American Psychologist, 56*(1), 5–15.

Thorell, L. B., Lindqvist, S., Bergman, S., Bohlin, G., & Klingberg, T. (2009). Training and transfer effects of executive functions in preschool children. *Developmental Science, 11*, 969–976.

Tominey, S. L., & McClelland, M. M. (2011). Red light, purple light: Findings from a randomized trial using circle time games to improve behavioral self-regulation in preschool. *Early Education and Development, 22*, 489–519.

Twardosz, S. (2012). Effects of experience on the brain: The role of neuroscience in early development and education. *Early Education and Development, 23*, 96–119.

Ursache, A., Blair, C., & Raver, C. (2011). The promotion of self-regulation as a means of enhancing school readiness and early achievement in children at risk for school failure. *Child Development Perspectives, 6*, 122–128.

U.S. Department of Education Office for Civil Rights. (2014). *Civil rights data collection; Data snapshot: Early childhood education*. Washington, DC: Author.

U.S. Department of Health and Human Services & U.S. Department of Education. (2016). *Race to the top—early learning challenge: 2015 progress update.* Washington, DC: Author.

Vissers, C., Koolen, S., Hermans, D., Scheper, A., & Knoors, H. (2015). Executive functioning in preschoolers with specific language impairment. *Frontiers in Psychology, 6*, Article 1574.

Viterbori, P., Usai, M. C., Traverso, L., & De Franchis, V. (2015). How preschool executive functioning predicts several aspects of math achievement in Grades 1 and 3: A longitudinal study. *Journal of Experimental Child Psychology, 140*, 38–55.

Vitiello, V. E. (2009). *Executive functions and approaches to learning: Relationships to school readiness in Head Start preschoolers* (Unpublished doctoral dissertation). University of Miami, Coral Gables, FL.

Vitiello, V. E., Downer, J. T., & Williford, A. P. (2011). Preschool classroom experiences of dual language learners: Summary of findings from publicly funded programs in 11 states. In C. Howes, J. T. Downer, & R. C. Pianta (Eds.), *Dual language learners in the early childhood classroom* (pp. 69–91). Baltimore, MD: Paul H. Brookes.

Vitiello, V. E., Greenfield, D. B., Munis, P., & George, J. (2011). Cognitive flexibility, approaches to learning, and academic school readiness in Head Start preschool children. *Early Education and Development, 22*, 388–410.

von Suchodoletz, A., Gestsdottir, S., Wanless, S. B., McClelland, M. M., Birgisdottir, F., Gunzenhauser, C., & Ragnarsdottir, H. (2013). Behavioral self-regulation and relations to emergent academic skills among children in Germany and Iceland. *Early Childhood Research Quarterly, 28*, 62–73.

Waber, D. P., Gerber, E. B., Turcios, V. Y., Wagner, E. R., & Forbes, P. W. (2006). Executive functions and performance on high-stakes testing in children from urban schools. *Developmental Neuropsychology, 29*, 459–477.

Walker, C. M., & Gopnik, A. (2013). Pretense and possibility—A theoretical proposal about the effects of pretend play on development: Comment on Lillard et al. (2013). *Psychological Bulletin, 139*, 40–44.

Wanless, S. B., McClelland, M. M., Acock, A. C., Chen, F., & Chen, J. (2011). Behavioral regulation and early academic achievement in Taiwan. *Early Education and Development, 22*, 1–28.

Wanless, S. B., McClelland, M. M., Acock, A. C., Ponitz, C. C., Son, S., Lan, X., … Li, S. (2011). Measuring behavioral regulation in four societies. *Psychological Assessment, 23*, 364–378.

Wanless, S. B., McClelland, M. M., Lan, X., Son, S.-H., Cameron, C. E., Morrison, F. J., … Sung, M. (2013). Gender differences in behavioral regulation in four societies: The United States, Taiwan, South Korea, and China. *Early Childhood Research Quarterly, 28*, 621–633.

Wanless, S. B., McClelland, M. M., Tominey, S. L., & Acock, A. C. (2011). The influence of demographic risk factors on children's behavioral regulation in prekindergarten and kindergarten. *Early Education and Development, 22*, 461–488.

Weiland, C., & Yoshikawa, H. (2013). Impacts of a prekindergarten program on children's mathematics, language, literacy, executive function, and emotional skills. *Child Development, 84*, 2112–2130.

Weintraub, S., Bauer, P. J., Zelazo, P. D., Wallner-Allen, K., Dikmen, S. S., Heaton, R. K., … Gershon, R. C. (2013). NIH Toolbox Cognition Battery (CB): Introduction and pediatric data. *Monographs of the Society for Research in Child Development, 78*(4), 1–149.

Weintraub, S., Dikmen, S. S., Heaton, R. K., Tulsky, D. S., Zelazo, P. D., Bauer, P. J., … Gershon, R. C. (2013). Cognition assessment using the NIH Toolbox. *Neurology, 80*(Suppl. 3), S54–S64.

Welsh, J. A., Nix, R. L., Blair, C., Bierman, K. L., & Nelson, K. E. (2010). The development of cognitive skills and gains in academic school readiness for children from low-income families. *Journal of Education Psychology, 102*, 43–53.

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

Wiebe, S. A., Sheffield, T. D., & Espy, K. A. (2012). Separating the fish from the sharks: A longitudinal study of preschool response inhibition. *Child Development, 83*, 1245–1261.

Williford, A. P., Vick Whittaker, J. E., Vitiello, V. E., & Downer, J. T. (2013). Children's engagement within the preschool classroom and their development of self-regulation. *Early Education and Development, 24*, 162–187.

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

Willoughby, M. T., & Blair, C. B. (2016). Longitudinal measurement of executive function in preschoolers. In J. A. Griffin, P. McCardle, & L. S. Fruend (Eds.), *Executive function in preschool-age children: Integrating measurement, neurodevelopment, and translational research* (pp. 91–113). Washington, DC: American Psychological Association.

Willoughby, M. T., Blair, C. B., Wirth, R. J., Greenberg, M., & Family Life Project Investigators. (2012). The measurement of executive function at age 5: Psychometric properties and relationship to academic achievement. *Psychological Assessment, 24*, 226–239.

Willoughby, M. T., Kuhn, L. J., Blair, C. B., Samek, A., & List, J. A. (2016). The test–retest reliability of the latent construct of executive function depends on whether tasks are represented as formative or reflective indicators (Online first). *Child Neuropsychology*. https://doi.org/10.1080/09297049.2016.1205009

Willoughby, M. T., Kupersmidt, J. B., & Voegler-Lee, M. E. (2012). Is preschool executive function causally related to academic achievement? *Child Neuropsychology, 18*, 79–91.

Willoughby, M. T., Kupersmidt, J. B., Voegler-Lee, M. E., & Bryant, D. (2011). Contributions of hot and cool self-regulation to preschool disruptive behavior and academic achievement. *Developmental Neuropsychology*, *36*, 162–180.

Willoughby, M. T., Wirth, R. J., Blair, C. B., & Family Life Project Investigators. (2011). Executive function in early childhood: Longitudinal measurement invariance and developmental change. *Psychological Assessment, 24*, 418–431.

Yerkes, R. M., & Dodson, J. D. (1908). The relation of strength of stimulus to rapidity of habit formation. *Journal of Comparative Neurology and Psychology, 18*, 459–482.

Zelazo, P. D. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols, 1*, 297–301.

Zelazo, P. D., Anderson, J. E., Richler, J., Wallner-Allen, K., Beaumont, J. L., & Weintraub, S. (2013). NIH Toolbox Cognition Battery (CB): Measuring executive function and attention. *Monographs of the Society for Research in Child Development, 78*(4), 16–33.

Zelazo, P. D., Blair, C. B., & Willoughby, M. T. (2016). *Executive function: Implications for education* (Report No. NCER 2017–2000). Washington, DC: National Center for Education Research, Institute of Education Sciences, U.S. Department of Education.

Zelazo, P. D., & Carlson, S. M. (2012). Hot and cool executive function in childhood and adolescence: Development and plasticity. *Child Development Perspectives, 6*, 354–360.

Zelazo, P. D., & Jacques, S. (1996). Children's rule use: Representation, reflection, and cognitive control. In R. Vasta (Ed.), *Annals of child development: A research annual* (Vol. *12*, pp. 119–176). London, England: Jessica Kingsley.

Zelazo, P. D., Muller, U., Frye, D., & Marcovitch, S. (2003). The development of executive function in early childhood. *Monographs of the Society for Research in Child Development, 68*(3), vii – 137.

Zimmerman, F. J., & Christakis, D. A. (2007). Associations between content types of early media exposure and subsequent attentional problems. *Pediatrics, 120*, 986–992.

Ziol-Guest, K. M., & McKenna, C. C. (2013). Early childhood housing instability and school readiness. *Child Development, 85*, 103–113.

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