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Measuring executive function in Indian mothers and their 4-year-old daughters

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Abstract: Executive function (EF), including cognitive flexibility, attention shifting, and inhibitory control, has been linked to a range of outcomes across the lifespan, such as school readiness and academic functioning, job performance, health, and social-emotional well-being. Yet, research investigating links between parent EF and child EF is still limited. This is partly due to challenges in measuring the same EF abilities in parents and their children. The current study investigated the applicability of a computer-based battery of various EF tasks for use with both mothers and children. The battery included the following EF tasks: Dimensional Change Card Sort, Hearts and Flowers, and Fish Flanker. Participants were 80 Indian mothers and their 4-year-old daughters. EF was measured with regard to accuracy scores, response time, and inverse efficiency (IE) scores of the most complex blocks of each task. Scoring patterns indicated that children's task performance appeared to be determined by their ability to recognize the cue indicating which task to perform at any given trial and to inhibit an incorrect response. In contrast, mothers' performance appeared to be determined by response time, that is, their ability to be quick in giving the correct response. However, for both children and mothers, IE scores best captured individual differences in EF performance between participants. Furthermore, confirmatory factor analyses found that, for both children and mothers, all EF measures loaded on a latent factor, suggesting that the measures shared common variance in EF. There appeared to be no significant association between mothers' and children's EF scores, controlling for several background variables. Directions for further research include examining the applicability of the EF task battery to reliably describe developmental trajectories of EF abilities over time, and further examining variability in the parent–child EF association across the lifespan.

Keywords: computer-based EF task battery; executive function (EF); mother–child EF association

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Executive function (EF) is a set of higher-order cognitive processes that are essential to optimal cognitive and social-emotional functioning from early childhood into adulthood (Best & Miller, 2010; Blair, 2002; Duckworth & Steinberg, 2015; Miyake et al., 2000). Although EF is not synonymous with self-regulation, both constructs are intricately linked with one another (Blair & Ursache, 2011; Hofmann, Schmeichel, & Baddeley, 2012). The cognitive processes involved in EF assist the individual in self-regulation, that is, one's purposeful behavior to successfully complete goal-directed action (Blair & Ursache, 2011). The relationship between EF and self-regulation becomes particularly obvious when experiencing failure of self-regulation. Hofmann et al. (2012) argue that impairments in an individual's self-regulation can be best explained "via state reductions in EF as the underlying conceptual mechanism" (p. 177).

It is well documented that EF undergoes significant developmental changes during the early childhood years that are linked to changes in the structural organization of the brain, the prefrontal cortex in particular (Best & Miller, 2010). Thereafter, EF improves linearly from middle childhood into adulthood (Best & Miller, 2010; Duckworth &

Steinberg, 2015). At all stages of life, EF is linked to goal-directed behavior by keeping an active mental representation of an abstract goal, by facilitating goal-related actions in the presence of temptations, and by suppressing undesired impulses (Duckworth & Steinberg, 2015). During early and middle childhood, EF has been linked to school readiness, academic performance, and social-emotional competence (Blair & Razza, 2007; Fabes et al., 1999; Gestsdottir et al., 2014; McClelland et al., 2007). Among adults, EF has been associated with a range of outcomes, including schooling decisions, employment status, physical and mental health, and violent/delinquent behaviors (Heckman, Stixrud, & Urzua, 2006; Ogilvie, Stewart, Chan, & Shum, 2011; Snyder, Miyake, & Hankin, 2015). Given the importance of EF across the lifespan and the consequences for successful and adaptive behavior, it is important to enhance our understanding of factors related to children's EF.

Although empirical evidence for the importance of EF for a range of outcomes across the lifespan has increased dramatically over the past two decades, research investigating associations between parent EF and child EF is still limited (Bridgett, Burt, Edwards, & Deater-Deckard, 2015). One reason for the lack of research on associations between mothers' EF and their children's EF might be due to measurement problems (Cuevas, Deater-Deckard, Kim-Spoon, Wang, et al., 2014). As a result, previous studies have almost exclusively used different tasks for assessing parent EF and child EF (Cuevas, Deater-Deckard, Kim-Spoon, Wang, et al., 2014; Cuevas, Deater-Deckard, Kim-Spoon, Watson, et al., 2014), mostly because adult EF tasks are too difficult for children. However, the use of different tasks for mothers and children may be problematic because different tasks might not measure the same EF abilities (Cuevas, Deater-Deckard, Kim-Spoon, Wang, et al., 2014). Recently developed computer-based tasks might present a potential alternative as previous research has shown that simple key-press tasks work equally well for participants between ages 3 and 99 years. In this paper, we test the applicability of a computer-based battery using the same EF tasks for both mothers and their 4-year-old daughters. More specifically, we first describe similarities and differences for scoring patterns and examine a latent EF factor structure. By testing concurrent associations between mothers' EF and their daughters' EF we add to a so far limited research base on the contribution of maternal EF in young children's EF.

Structure and measurement of EF

EF refers to multiple, higher-order cognitive, and self-regulatory processes relevant to goal-directed behavior (Blair & Ursache, 2011; Fuhs, Nesbitt, Farran, & Dong, 2014; Wiebe et al., 2011). EF includes working memory, inhibitory control, and attention shifting (Blair & Ursache, 2011; Miyake et al., 2000). Research suggests age-related changes in the structure of EF during childhood and early adolescence (K. Lee, Bull, & Ho, 2013). In young children, a unitary, single latent EF factor has been identified (Wiebe, Espy, & Charak, 2008). As children grow older, EF task performance seems to be best represented by a two-factor EF structure, with working memory emerging as a separate factor (K. Lee et al., 2013). The process of differentiation into a three-factor EF structure continues into the teenage years (K. Lee et al., 2013). Among adult populations, the EF structure consists of three core components, that is, working memory, inhibitory control, and attention shifting (Miyake et al., 2000). However, despite the fact that past research has established the diversity of the EF construct in distinct components (Miyake et al., 2000), there is growing evidence for "considerable similarity if not actual overlap" between various EF processes (Bridgett et al., 2015, p. 604). This is reflected in recent shifts in conceptual frameworks of EF (such as the unity/diversity framework) arguing that there are underlying cognitive processes common across all EF (Friedman & Miyake, 2016; Miyake & Friedman, 2012). Given an increased consensus that the neurobiological origins of various EF processes are concentrated in the frontal lobe, the prefrontal cortex in particular, overlap between EF processes has not only been suggested at the behavioral level, but also at the neurobiological level (Best & Miller, 2010; Bridgett et al., 2015; Duckworth & Steinberg, 2015).

Despite overlapping and highly interrelated processes, methodologically it is not possible to assess EF in one individual measure (Carlson, Mandell, & Williams, 2004; Wiebe et al., 2011; Willoughby, Wirth, Blair, & Family Life Project Investigators, 2012) for at least two important reasons. First, it is not possible to assess performance only on a given EF task, as the performance is also affected by non-EF demands (e.g., variance due to measurement error). Second, it is not possible to single out and measure one aspect of EF (e.g., attention shifting) in a single task as tests also tap into other EF processes, such as inhibitory control, which is known as the impurity problem (Miyake et al., 2000; Toplak, West, & Stanovich, 2013). Therefore, it is essential to obtain multiple measures of latent constructs, such as EF (Carlson et al., 2004). Consequently, precision in the measurement of EF is improved by aggregating performance across multiple tasks (Willoughby et al., 2012). A variety of performance-based tasks to measure EF exist, for example, the Stroop test (Jensen & Rohwer, 1966), Flanker task (Eriksen & Eriksen, 1974), Stop-Signal task (Logan, 1994), and task-switching tests such as the Dimensional Change Card Sort (Zelazo, 2006). Such tasks allow for a highly standardized assessment, with regard to both stimulus presentation and response completion (Duckworth & Kern, 2011; Garon, Bryson, & Smith, 2008; Toplak et al., 2013). However, most tasks demonstrate sufficient variability in EF performance in only relatively narrow age ranges (Willoughby et al., 2012). To facilitate the investigation of EF at different stages of the lifespan and across age groups, computer-based versions of various EF tasks have been developed for use with both children and adults (Blankson & Blair, 2016; Duckworth & Kern, 2011).

Although the majority of computer-based tasks provide data on accuracy and response time, many previous studies have relied on accuracy scores only (Blankson & Blair, 2016; Zelazo et al., 2013). However, accuracy scores do not account for speed–accuracy trade-offs, that is, slow responses but fewer errors and vice versa. To address this problem, inverse efficiency (IE) scores have been introduced, initially in experimental brain research (Holmes, Calvert, & Spence, 2007; Kitagawa & Spence, 2005; Schicke, Bauer, & Röder, 2009; Spence, Kingstone, Shore, & Gazzaniga, 2001) but more recently also in EF research (Ding et al., 2014; Yang, Yang, & Kang, 2014). IE scores are calculated by dividing the average response time for correct trials by accuracy scores. The underlying assumption is that “differences in reaction time performance would decrease if differences in accuracy [were] large but would remain the same if accuracy [were] identical” (Ding et al., 2014, p. 91). Compared to using accuracy (i.e., the proportion of correct responses) and response time as separate variables, IE scores thus provide a more psychometrically accurate representation of processing efficiency (Yang et al., 2014).

Associations between maternal EF and child EF

Recent research has begun to identify the link between parent EF and child EF (Bridgett et al., 2015; Cuevas, Deater-Deckard, Kim-Spoon, Wang, et al., 2014; Cuevas, Deater-Deckard, Kim-Spoon, Watson, et al., 2014). Yet, results suggest variability in the timing as well as the strength of associations. While there is evidence for an intergenerational transmission of EF within the family for older children (Jester et al., 2009; Valiente, Lemery-Chalfant, & Reiser, 2007), less is known about the early childhood years and studies have demonstrated mixed results. For example, one study demonstrated that maternal EF was related to infant EF at 4, 8, and 10 months of age (Bridgett et al., 2011). However, the associations were no longer evident when infants were 12 months old, thus suggesting that associations might change when children move into toddlerhood. Although that study provides important information on the role of maternal EF for emerging child EF very early in life, conclusions are limited by the fact that maternal reports were used to measure both maternal EF and infant EF. Results from a recent study using different performance-based tasks to measure maternal EF and child EF demonstrated stable mother–child EF associations when children were older, at 24, 36, and 48 months, respectively (Cuevas, Deater-Deckard, Kim-Spoon, Wang, et al., 2014; Cuevas, Deater-Deckard, Kim-Spoon, Watson, et al., 2014). However, another study showed that mother EF was unrelated to child EF at 27 months of age (Leve et al., 2013).

Possible explanations for the link between parent EF and child EF have been discussed in the context of the nature–nurture debate. For example, substantial genetic contributions have been demonstrated at the level of latent variables. One study with 293 same-sex twin pairs showed large genetic but almost no significant environmental influences on performance on EF tasks (Friedman et al., 2008). The results let the authors conclude that variance common across various EF components is highly heritable. In other words, the overlap of EF components is due to shared genetic influences (Friedman et al., 2008; Miyake & Friedman, 2012). Other researchers suggest that individual differences in EF are due to environmental influences, in particular caregiving behaviors (Bridgett et al., 2015; Bridgett et al., 2011; Cuevas, Deater-Deckard, Kim-Spoon, Watson, et al., 2014). They argue that impaired parent EF is related to negative (i.e., reactive and hostile) parenting (Deater-Deckard, Sewell, Petrill, & Thompson, 2010) that in turn results in poor child EF (Bridgett et al., 2015; Gonzalez, 2015). Despite different assumptions regarding the mechanisms by which EF is transmitted across generations, the malleability of EF is not questioned (Bridgett et al., 2015; Friedman et al., 2008). Targeted intervention programs have the potential to improve EF abilities (Diamond, 2013; Friedman et al., 2008).

Although there is initial evidence supporting mother–child EF associations in samples from the United States, further research is needed to replicate and extend existing findings to different sociocultural contexts to improve understanding about regularities in diverse patterns of human development, such as EF development (Arnett, 2008; Rogoff, 2003). Recent years have seen an increasing number of studies on EF outside the United States (Gestsdottir et al., 2014; Mulder, Hoofs, Verhagen, van der Veen, & Leseman, 2014; von Suchodoletz, Uka, & Larsen, 2015; Wanless et al., 2011). Results suggest that the cultural context shapes goal-directed behavior and EF functioning (Gestsdottir et al., 2014; Trommsdorff, 2009). One study with Chinese and American preschoolers suggests cultural differences in children's EF task performance (Lan, Legare, Ponitz, Li, & Morrison, 2011). While Chinese children showed higher performance in inhibitory control and attention-shifting tasks than their American counterparts, no differences were found on the working memory task. It has been argued that cultures differ in the extent to which the context provides opportunities to repeatedly engage in certain tasks relevant to the development of EF (Imada, Carlson, & Itakura, 2013; Trommsdorff, 2009). For example, in Asian cultures, children are expected to adjust their behavior to situational and social demands by adjusting one's goals to the expectations of others, such as inhibiting the expression of negative emotions in order to maintain interpersonal harmony (Trommsdorff, 2009). In contrast, there is an emphasis on the individual's goals in the American culture. Consequently, children's behavior that demonstrates their autonomy and independence is encouraged (Trommsdorff, 2009). Such differences in the cultural context may explain cultural variability in EF performance (Imada et al., 2013; Trommsdorff, 2009). The present study aims to extend the existing international literature on EF to India. Research on EF is still in its infancy in India and cultural factors can play a significant role in determining links between mother and child characteristics, including mother–child EF associations. For example, a recent study suggests culture-specific priorities in mother–child interactions that may affect caregiving behavior and, in turn, set different pathways for child development (Kärtner, Crafa, Chaudhary, & Keller, 2016). To the best of our knowledge, there is only one study that examined EF in a sample of 8-year-old children from India (Bialystok & Viswanathan, 2009). Although the focus of the study was on the effects of bilingualism on EF, it provides important information on the applicability of commonly used measures of EF, which have been developed and validated in the United States, for use in the Indian context.

The present study

The aims of the present study were twofold. First, we tested whether the same computer-based battery of various EF tasks can be applied to measure EF in an Indian sample of mothers and their 4-year-old daughters. Second, we aimed to provide a first analysis of concurrent associations between mothers' EF and children's EF outside the United States. We decided to focus on measures of attention shifting and inhibitory control because these two EF processes were found to be undifferentiated among children in previous research (K. Lee et al., 2013; Shing, Lindenberger, Diamond, Li, & Davidson, 2010), while, at the same time, the nature of shared variance among these components remains unresolved (K. Lee et al., 2013). Based on previous research documenting developmental changes in EF performance (Diamond, 2013), we hypothesized differences in scoring patterns of mothers and their daughters, with mothers outperforming their daughters. Recent shifts in theoretical frameworks of EF propose shared cognitive processes across all EF (Friedman & Miyake, 2016; Miyake & Friedman, 2012). For example, for inhibitory control, no unique variance has been found after accounting for unity of EF, that is, common processes involved across all EF (Friedman et al., 2008). Moreover, studies with children found support for a combined attention shifting/inhibitory control factor (K. Lee et al., 2013). Therefore, we aimed to test whether attention shifting and inhibitory control share common variance. Specifically, we expected to find that the EF measures for both mothers and children would load on a latent EF factor. Finally, we hypothesized that latent variable scores of mothers' EF and their children's EF would show a positive association, thus providing support for the assumption of familial transmission of EF.

The present study included 4-year-old children as previous research has shown that individual differences in EF can be reliably assessed in this age group (Cuevas, Deater-Deckard, Kim-Spoon, Wang, et al., 2014; McClelland et al., 2007; Willoughby et al., 2012). A growing number of studies has provided evidence that several child- and family-level characteristics (including child age, family socioeconomic status, and maternal education) are associated with EF (Hackman, Gallop, Evans, & Farah, 2015; Rhoades, Greenberg, Lanza, & Blair, 2011). Consistent with prior research (Cuevas, Deater-Deckard, Kim-Spoon, Watson, et al., 2014), we included these variables as covariates in the analysis to determine whether the hypothesized association between mothers' EF and their children's EF was robust.

Method

Participants

The data for the present study were collected from kindergarten children (all girls) and their mothers in a large town in the southeast of India. In total, 80 mother–child dyads participated. Children's mean age was 55 months (*SD* =4.9); mothers were, on average, 32 years old (*SD* =3.9). All children and mothers were Indian nationals. Most families' home language was Tamil (73%). Other languages spoken at home were Telugu (9%), English (8%), Urdu (4%), Hindi (3%), and Malayalam (3%). All children were enrolled in English-medium schools for girls, and the majority of them (89%) had been at their school for 1 year or longer (*M* = 54 weeks, *SD* = 23.3). On average, children started learning English when they were 3 years old (*SD* =10.1 months). Mothers rated their child's ability to understand English on a 4-point scale (1 = *poor* to 4 = *excellent*) as good (*M* = 2.9, *SD* = 0.7). The majority of mothers (78%) had at least a college degree. Forty-three percent of mothers and most fathers (90%) were employed. All but one mother described themselves as from a middle-class socioeconomic background.

Procedure

Prior to the data collection, the study was approved by the Institutional Review Board at New York University Abu Dhabi and by Hislop College, Nagpur, India. Parents of kindergarten children were contacted via their children's schools. Permission of school principals to conduct the study was requested prior to contacting parents of children in the targeted age range (4–5 years of age). Permission was granted from the principals of three private schools. It is important to note that the majority of private schools in the city where the data were collected are sex-segregated. The schools where participants for the present study were recruited were girls' schools, resulting in a sample of only girls. In each school, parents of kindergarten children received a letter describing the aims and procedure of the study. They then stated their interest to participate in the study by signing the consent form, which was collected prior to the data collection. Recruitment stopped after the targeted sample size of 80 mother–child dyads was reached.

Data were collected at the beginning of the school year during school hours in a quiet area of the school. Mother and child were seated in the same room to respect the routines of the local culture. A computer-based battery of three tasks was used to assess children's and mothers' EF (Blankson & Blair, 2016). The battery consisted of the Dimensional Change Card Sorting (DCCS) task (Zelazo, 2006), the Hearts and Flowers task (Davidson, Amso, Anderson, & Diamond, 2006), and the Fish Flanker task (Rueda et al., 2004). The tasks were presented in a random order. On average, it took mothers about 20 min and children about 30 min to complete the tasks. Instructions appeared visually on the computer screen. For children, a local research assistant seated to the child's side additionally explained the tasks verbally and walked them through the practice trials to ensure they understood the instructions. Generally, instructions were given in English but if needed they were repeated in the local language. To avoid ceiling effects, in particular regarding mothers' performance, the most difficult block of each task was used to measure EF in the present study. At the end of the session, mothers were asked to complete a questionnaire about basic demographic background information.

Measures

DCCS task

The DCCS task measured cognitive flexibility and attention shifting (Zelazo, 2006). The version of the DCCS used in the present study followed the protocol used by Frye, Zelazo, and Palfai (1995), but presented the stimuli on a laptop screen. The task required participants to match a target stimulus presented at the top of the screen with two pictures that varied along two dimensions (i.e., color and shape) and appeared at the bottom corners of the screen. To match the pictures, participants were instructed to press one of two yellow-marked keys on opposite sides of the laptop keyboard to indicate the location of their selection. In addition, a word (either color or shape) was presented at the top of the screen and spoken by a prerecorded voice to cue participants to match the target picture with the correct corresponding picture on the bottom of the screen. Following the practice trials, participants were first asked to correctly sort the stimuli by one dimension (e.g., sort by shape; pre-switch block) and then to switch and sort the stimuli by the other dimension (e.g., color; post-switch block). The final block consisted of mixed trials. Participants' accuracy (i.e., percent correct) and response time of correct trials were measured across 50 mixed trials.

Hearts and Flowers task

The Hearts and Flowers task was used as a measure of attention shifting and inhibitory control (Blankson & Blair, 2016; Davidson et al., 2006). In the task, one of two target pictures (heart or flower) appeared on either the left or right side of the laptop screen and participants were told that when a heart appeared on the screen, they should press the yellow-marked button on the keyboard that was on the same side as the heart, and when a flower appeared on the screen, they should press the yellow-marked button that was on the opposite side as the flower. Following the practice trials, the first block consisted of heart-trials and the second block of flower-trials. The final block consisted of mixed trials. Participants' accuracy (i.e., percent correct) and response times of correct trials were measured across 33 mixed trials.

Fish Flanker task

The Fish Flanker task is a measure of inhibitory control (Blankson & Blair, 2016; Rueda et al., 2004). In the first block of the task, a row of five fish appeared in the center of the screen and participants were asked to press the yellow-marked button on the keyboard that corresponded to the direction in which the middle fish was pointing. On half the trials, the flanker fish were pointing in the same direction as the target fish (congruent trials); on the other half, the flanker fish were pointing in the opposite direction (incongruent trials). The second block of the task presented arrows instead of fish: A row of five arrows appeared in the center of the screen and participants were asked to press the yellow-marked button on the keyboard that corresponded to the direction in which the middle arrow was pointing. On half the trials, the flanker arrows were pointing in the same direction as the target arrow (congruent trials); on the other half, the flanker arrows were pointing in the opposite direction (incongruent trials). Within each block, the trials were presented in random order. Participants' accuracy (i.e., percent correct) and response times of correct trials were measured across 17 incongruent switch trials.

Background (control) variables

Mothers completed a questionnaire on family demographic background information. Because direct questions on a family's income are perceived as inappropriate in the local culture, we used the Family Affluence Scale (Andersen et al., 2008) to evaluate family socioeconomic status. The scale includes four items that are conceptually related to consumption indices of material deprivation and on home affluence, such as "Does your family own a car, van, or tuck?" Following previous research (Andersen et al., 2008), a composite score was calculated based on the mother's responses to all four items, with higher values indicating higher socioeconomic status. In addition, mothers evaluated their child's English-language comprehension.

Data preparation and analysis strategy

Accuracy scores were calculated if 60% of trials were available for the aggregate, otherwise scores were set to zero (thus indicating low levels of EF). This was only the case for children's data. Response time was averaged across the trials for each task. We first investigated descriptive statistics for both accuracy scores and response time. Next, we calculated IE scores by dividing the mean response time of correct trials by accuracy scores to account for speed–accuracy trade-offs (Spence et al., 2001). To test the latent EF factor structure, confirmatory factor analyses using IE scores were conducted in Mplus (Version 7), applying the MLR estimator.[1] As these were saturated models, no model fit statistics could be obtained. Missing data were handled with using full maximum likelihood estimation (Enders, 2010). Finally, the latent factor models for mothers and children were used to investigate the hypothesized mother–child EF association in Mplus. Following previous research (Cuevas, Deater-Deckard, Kim-Spoon, Watson, et al., 2014), analysis testing mother–child EF associations included the following control variables: child's age, socioeconomic status of the family, and maternal education. Because instructions were given in English, we additionally controlled for children's English-language comprehension. Model trimming was applied in a step-by-step fashion by eliminating non-significant paths with $p > .10$ and with a $|\beta| < .05$ to obtain the most parsimonious model (Wuensch, 2012).

Results

Descriptive information on the EF tasks for mothers and their children is presented in Table 1. Bivariate correlations between the different EF tasks are reported in Table 2. The results indicated moderate, significant correlations between the three tasks for both mothers and children and only the DCCS and the Hearts and Flowers task were unrelated in the child sample. Below the results will first be described for accuracy, response time, and IE scores separately. Furthermore, the results of the confirmatory factor analysis will be reported for mothers and their daughters. Finally, the relation between mother EF and child EF will be described.

Describing scoring patterns of mothers and their daughters

Accuracy scores

For children, the range of accuracy scores covered almost the full possible distribution, except for the DCCS task. The highest mean accuracy score was observed for the Hearts and Flowers task and the lowest for the DCCS task. Standard deviations on all three EF tasks indicated a substantial variation in children's accuracy scores. Mothers' accuracy scores showed a different picture. The highest mean accuracy for mothers was observed on the Fish Flanker task and the lowest on the Hearts and Flowers task. Although the range of accuracy scores covered almost the full range, standard deviations for all tasks were small. A comparison of children's and mothers' scores shows that, on average, mothers scored almost thrice as high on the DCCS and the Fish Flanker task, whereas the scores for the Hearts and Flowers task were slightly more than twice as high. Given the low variation in combination with a high mean score, it appeared that mothers outperformed children the most on the DCCS.

Response time scores

Children showed the lowest mean response time (i.e., fastest responses) on the DCCS, with a small standard deviation and variation in the range of scores. The mean response time was highest for the Fish Flanker task, which

Table 1
Descriptive Statistics for the Accuracy, Response Time, and IE Scores of all EF Tasks for Children and Mothers.

	N	*M*	*SD*	Range	Kurtosis	Skewness
Children						
DCCS accuracy	80	0.31	0.24	0–0.78	–1.27	–0.27
DCCS response time	39	1,053.88	159.02	725.45–1,453.88	0.21	–0.01
IE DCCS	80	1,051.82	1,130.18	0–3,100	–1.68	0.29
Fish Flanker accuracy	80	0.37	0.30	0–0.94	–1.33	0.09
Fish Flanker response time	41	1,306.68	218.03	731.29–1,786.63	0.23	–0.25
IE Fish Flanker	80	1,128.72	1,198.18	0–3,796.58	–1.29	0.41
Hearts and Flowers accuracy	80	0.40	0.21	0–0.91	0.27	–0.44
Hearts and Flowers response time	47	1,230.62	231.09	844.47–1,697.36	–1.07	0.30
IE Hearts and Flowers	80	1,409.89	1,269.42	0–4,000.91	–1.45	0.05
Mothers						
DCCS accuracy	76	0.90	0.10	0.47–0.98	7.56	–2.54
DCCS response time	76	927.28	158.69	550.39–1,306.15	–0.34	0.07
IE DCCS	76	1,051.71	260.32	598.25–2,239.27	5.89	1.85
Fish Flanker accuracy	77	0.95	0.12	0–1.00	46.77	–6.27
Fish Flanker response time	77	846.57	213.28	444.75–1,401.41	–0.19	0.51
IE Fish Flanker	76	886.04	261.63	472.55–1,723.14	1.27	1.07
Hearts and Flowers accuracy	80	0.87	0.17	0.03–0.97	10.72	–3.14
Hearts and Flowers response time	77	948.97	147.29	608.87–1,295.12	–0.43	0.20
IE Hearts and Flowers	77	1,084.59	1,269.42	669.75–2,279.69	4.40	1.61

Note. DCCS = Dimensional Change Card Sorting; EF = executive function; IE = inverse efficiency.

Table 2
Bivariate Correlations between IE Scores of the EF Tasks for Children and Mothers.

	2	3	4	5	6
1 DCCS child	.48** (*N* = 80)	.14 (*N* = 80)	−.04 (*N* = 76)	−.01 (*N* = 76)	.06 (*N* = 76)
2 Fish Flanker child		.25* (*N* = 80)	−.01 (*N* = 76)	−.15 (*N* = 77)	−.10 (*N* = 80)
3 Hearts and Flowers child			.06 (*N* = 76)	−.18 (*N* = 77)	−.25* (*N* = 77)
4 DCCS mother				.53** (*N* = 72)	.49** (*N* = 73)
5 Fish Flanker mother					.57** (*N* = 73)
6 Hearts and Flowers mother					

Note. DCCS = Dimensional Change Card Sorting; EF = executive function; IE = inverse efficiency.
*$p < .05$. **$p < .01$.

also showed the largest variation in the range of response times. Mothers' mean response time, in contrast, was lowest for the Fish Flanker task, but they also showed the largest variation in this task both in terms of standard deviation and range. Overall, mothers showed lower response times for all tasks (i.e., responded faster). The difference in response time between children and mothers was smallest for the DCCS and largest for the Fish Flanker task.

IE scores

For children, the IE score was the lowest for the DCCS, suggesting that in this task the time needed to respond and give the correct answer was the best trade-off. Although the highest accuracy score for children was observed on the Hearts and Flowers task, the mean IE score indicated that this was at the expense of their response time in that task. Mothers, on the contrary, showed the highest accuracy and the lowest response time on the Fish Flanker. Interestingly, IE scores for children and mothers were the same for the DCCS, although there was much less variation among the mothers. Differences between children and mothers were largest on the Hearts and Flowers task.

Confirmatory factor analyses

Next, confirmatory factor analyses were conducted for children and mothers separately to test the latent EF factor structure (Table 3). All EF tasks contributed significantly to the latent EF variable for both children and mothers. Internal consistency for the latent EF variable was sufficient, with a Cronbach's alpha of .77 for mothers and of .55 for children. For children, the DCCS contributed the most to the latent construct, whereas it was the Fish Flanker task for mothers.

Relations between mother and child EF

As shown in Table 2, no significant correlations were found between mothers' and their child's individual IE scores on all EF measures, with the exception of a negative correlation on the Hearts and Flowers task. A latent factor model was estimated to further investigate the relations between mothers' and children's EF while controlling for background variables. The model showed good model fit: $\chi^2(27) = 34.17$, $p = .16$; root mean square error of approximation = .06; comparative fit index = .90; standardized root mean square residual = .06. The results are presented in Table 4. With a nonsignificant effect between mother and child latent EF variables, our hypothesis of a positive mother–child EF association was not supported.

Discussion

The present data provide initial evidence for the applicability of a computer-based battery of various EF tasks in a sample of mothers and their children outside the United States. The selected tasks represented the EF components cognitive flexibility, attention shifting, and inhibitory control. In contrast to previous studies (Cuevas, Deater-Deckard, Kim-Spoon, Wang, et al., 2014; Cuevas, Deater-Deckard, Kim-Spoon, Watson, et al., 2014), we used the

Table 3
Factor Loadings of the EF Tasks for Children and Mothers (Using Inverse Efficiency Scores).

	Child	Mother
DCCS	.55**	.70***
Fish Flanker	.49*	.83***
Hearts and Flowers	.38*	.70***

Note. The pattern of results was replicated in Bayesian analyses. DCCS = Dimensional Change Card Sorting; EF = executive function.
*$p < .05$. **$p < .01$. ***$p < .001$.

Table 4
Concurrent Associations between Mother and Child Latent EF Variables.

	Child EF		
	B	*SE*	β
Child age	–.02	.06	–.09
Family SES	.03	.19	.05
Maternal education	–.07	.08	-.24
Child English comprehension	–.48	.29	–.28
Mother EF	.35	.33	.31

Note. DCCS = Dimensional Change Card Sorting; EF = executive function; SES = socioeconomic status.

same EF tasks for both mothers and children, thus addressing challenges raised in prior work in measuring the same EF abilities in parents and their children. As hypothesized, measures of mothers' and children's attention shifting and inhibitory control loaded on a latent EF factor. In other words, all measures seemed to be influenced by the same latent construct. A possible explanation for the finding, in particular for mothers, could be that the EF tasks used in our study measured shared cognitive processes that are relevant across all EF components (Friedman & Miyake, 2016; Miyake & Friedman, 2012). This would speak to the unity hypothesis, that is, common processes involved in all core EF (Miyake & Friedman, 2012). As such, our results are in line with the recent EF literature suggesting a substantial overlap between EF processes at both the behavioral and neurobiological level (Blankson & Blair, 2016; Bridgett et al., 2015; Friedman & Miyake, 2016; Miyake & Friedman, 2012; Wiebe et al., 2011; Willoughby et al., 2012). Alternatively, however, the results could have been due to the fact that we did not include a measure of working memory, the component of EF that emerges first as a separate factor in development (K. Lee et al., 2013). It is therefore up to future research to test the applicability of the unity–diversity EF framework in different countries and populations.

Overall, the task battery did a relatively good job of measuring EF ability across the full proficiency range, that is, demonstrating sufficient variability in performance. Using the most complex block of each task, children's task performance seemed to be determined by their ability to recognize the cue indicating which task to perform at any given trial and to inhibit an incorrect response in switch trials. In contrast, mothers' performances seemed to be driven by response time, that is, their ability to be quick in giving the correct response. Importantly for both children and mothers, IE scores best captured individual differences in EF performance between participants whereas our results showed the lowest variability in accuracy scores. This finding is consistent with a recent argument that, when analyzed separately, accuracy and response time data might reduce the reliability and validity of measurement of EF (M. M. Hughes, Linck, Bowles, Koeth, & Bunting, 2014). Thus, alternative scoring methods that incorporate response time and accuracy information into a single score have the potential to improve the precision of measurement of EF, in particular when examining individual differences in EF task performance (M. M. Hughes et al., 2014).

Although it has been suggested that origins of the link between parent EF and child EF emerge very early in life and remain stable over the toddler and preschool periods (Bridgett et al., 2011; Cuevas, Deater-Deckard, Kim-Spoon, Wang, et al., 2014), our results did not support mother–child EF associations. The lack of significant findings could point to variability in timing and strength of the parent–child EF association. For example, a longitudinal study reported the weakest associations between parent EF and child EF at the last measurement point of their study, when children were almost as old as the children in our sample (Cuevas, Deater-Deckard, Kim-Spoon, Wang, et al., 2014). It could thus be that the link between parent EF and child EF decreases when children become kindergarteners. A potential explanation for such a decline in the strength of association could be that around the age of 4 years, with the transition to formal schooling, factors outside the family become increasingly important for children's EF. For example, the school provides children with a new social environment where they practice and improve their EF skills (van Lier & Deater-Deckard, 2016). Recent studies demonstrating associations between the quality of teacher–child interactions and children's EF highlight the importance of developmental contexts other than familial for EF skills beyond the early childhood years (Hamre, Hatfield, Pianta, & Jamil, 2014; Hatfield, Burchinal, Pianta, & Sideris, 2016). A possible alternative explanation for the null finding in our study could be that other parent characteristics might have impacted their child's EF more strongly than parent EF. Support for this assumption comes from a study finding that mother verbal IQ was the predominant pathway to child EF, not mother EF (Leve et al., 2013). Overall, research on mother–child EF associations has so far provided contradictory results, and where significant results have been reported, effect sizes were small (Cuevas, Deater-Deckard, Kim-Spoon, Wang, et al., 2014; Cuevas, Deater-Deckard, Kim-Spoon, Watson, et al., 2014). This could be due to different approaches in EF assessment that need to be addressed in future studies. It is up to further research to provide a more comprehensive understanding of links between parent EF and child EF at different stages of the lifespan using consistent measures of EF across the developmental span.

Although a strength of our study was the use of the same battery of EF tasks to measure both mother EF and child EF, potential limitations have to be considered when interpreting our results. First, due to the small sample size and other sample characteristics, significant relations may not have been detected. In contrast to previous studies reporting associations between mother EF and child EF, our sample consisted of only girls. This was caused by the fact that participants could only be recruited in girls' schools. However, it has been suggested that child sex might play a role in the development of EF during the early years and thus mother–child EF associations might differ among boys and girls (Carlson & Wang, 2007; C. Hughes & Ensor, 2005). Previous research has provided considerable evidence for sex differences in young children's EF, with girls outperforming boys on various EF tasks (Matthews, Ponitz, & Morrison, 2009; Rimm-Kaufman, Curby, Grimm, Nathanson, & Brock, 2009; Sabbagh, Xu, Carlson, Moses, & Lee, 2006; Wanless et al., 2013). In future studies, it will be important to include boys and girls in the sample to test the assumption of sex differences in the strength of mother–child EF associations. Moreover, participants were predominately from a middle-class socioeconomic family background with highly educated mothers. Before generalizing our results, future studies need to replicate the findings in a larger sample representing the full socioeconomic spectrum. Second, the study did not include other variables of the home environment (such as caregiving behaviors) that may influence the familial association in EF (Bridgett et al., 2015). Third, comparing our results with previous studies is limited by the fact that children in our sample were not of the same age as children in previous studies that included either infants/toddlers or children in primary and secondary school. And finally, although the results provide initial evidence for the applicability of the computer-based EF task battery to assess EF in different age groups, the cross-sectional design of the study does not allow for conclusions on whether our task battery can be used to reliably describe developmental trajectories of EF abilities over time.

The present study suggests that computer-based versions of commonly used EF tasks are appropriate for use with different age groups, thus contributing to the literature on the measurement of EF by providing important information on how to facilitate the investigation of EF development at different stages of the lifespan. Moreover, the results indicate the applicability of the EF tasks in samples outside the United States. Such knowledge is needed to better understand cross-cultural consistency and variability in EF performance in future studies. Results suggest that EF measures of attention shifting and inhibitory control for both children and mothers share common variance and load on a latent EF factor. However, mother EF was unrelated to child EF. This lack of association has also been reported in other studies, highlighting the importance of further understanding the links by which EF is transmitted across generations.

Disclosure of conflict of interest

The authors declare that there are no conflicts of interest.

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Note

[1]The CFA models were also estimated using the Bayesian estimator with non-informative priors. Bayesian estimation is robust to distributional assumptions of the estimated parameters of interest and to relatively small sample sizes (S. Lee & Song, 2004; Muthén, 2010; Song & Lee, 2008).

References

Andersen, A., Krølner, R., Currie, C., Dallago, L., Due, P., Richter, M., … Holstein, B. E. (2008). High agreement on family affluence between children's and parents' reports: International study of 11-year-old children. *Journal of Epidemiology and Community Health*, *62*, 1092–1094. doi:10.1136/jech.2007.065169

Arnett, J. J. (2008). The neglected 95%: Why American psychology needs to become less American. *American Psychologist*, *63*, 602–614. doi:10.1037/0003-066X.63.7.602

Best, J. R., & Miller, P. H. (2010). A developmental perspective on executive function. *Child Development*, *81*, 1641–1660. doi:10.1111/j.1467-8624.2010.01499.x

Bialystok, E., & Viswanathan, M. (2009). Components of executive control with advantages for bilingual children in two cultures. *Cognition*, *112*, 494–500. doi:10.1016/j.cognition.2009.06.014

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. doi:10.1037/0003-066X.57.2.111

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. doi:10.1111/j.1467-8624.2007.01019.x

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.

Blankson, A. N., & Blair, C. (2016). Cognition and classroom quality as predictors of math achievement in the kindergarten year. *Learning and Instruction*, *41*, 32–40. doi:10.1016/j.learninstruc.2015.09.004

Bridgett, D. J., Burt, N. M., Edwards, E. S., & Deater-Deckard, K. (2015). Intergenerational transmission of self-regulation: A multidisciplinary review and integrative conceptual framework. *Psychological Bulletin*, *141*, 602–654. doi:10.1037/a0038662

Bridgett, D. J., Gartstein, M. A., Putnam, S. P., Lance, K. O., Iddins, E., Waits, R., … Lee, L. (2011). Emerging effortful control in toddlerhood: The role of infant orienting/regulation, maternal effortful control, and maternal time spent in caregiving activities. *Infant Behavior and Development*, *34*, 189–199. doi:10.1016/j.infbeh.2010.12.008

Carlson, S. M., Mandell, D. J., & Williams, L. (2004). Executive function and theory of mind: Stability and prediction from ages 2 to 3. *Developmental Psychology*, *40*, 1105–1122. doi:10.1037/0012-1649.40.6.1105

Carlson, S. M., & Wang, T. S. (2007). Inhibitory control and emotion regulation in preschool children. *Cognitive Development*, *22*, 489–510. doi:10.1016/j.cogdev.2007.08.002

Cuevas, K., Deater-Deckard, K., Kim-Spoon, J., Wang, Z., Morasch, K. C., & Bell, M. A. (2014). A longitudinal intergenerational analysis of executive functions during early childhood. *British Journal of Developmental Psychology*, *32*, 50–64. doi:10.1111/bjdp.12021

Cuevas, K., Deater-Deckard, K., Kim-Spoon, J., Watson, A. J., Morasch, K. C., & Bell, M. A. (2014). What's mom got to do with it? Contributions of maternal executive function and caregiving to the development of executive function across early childhood. *Developmental Science*, *17*, 224–238. doi:10.1111/desc.12073

Davidson, M. C., Amso, D., Anderson, L. C., & Diamond, A. (2006). Development of cognitive control and executive functions from 4 to 13 years: Evidence from manipulations of memory, inhibition, and task switching. *Neuropsychologia*, *44*, 2037–2078. doi:10.1016/j.neuropsychologia.2006.02.006

Deater-Deckard, K., Sewell, M. D., Petrill, S. A., & Thompson, L. A. (2010). Maternal working memory and reactive negativity in parenting. *Psychological Science*, *21*, 75–79. doi:10.1177/0956797609354073

Diamond, A. (2013). Executive functions. *Annual Review of Psychology*, *64*, 135–168. doi:10.1146/annurev-psych-113011-143750

Ding, X. P., Omrin, D. S., Evans, A. D., Fu, G., Chen, G., & Lee, K. (2014). Elementary school children's cheating behavior and its cognitive correlates. *Journal of Experimental Child Psychology*, *121*, 85–95. doi:10.1016/j.jecp.2013.12.005

Duckworth, A. L., & Kern, M. L. (2011). A meta-analysis of the convergent validity of self-control measures. *Journal of Research in Personality*, *45*, 259–268. doi:10.1016/j.jrp.2011.02.004

Duckworth, A. L., & Steinberg, L. (2015). Unpacking self-control. *Child Development Perspectives*, *9*, 32–37. doi:10.1111/cdep.12107

Enders, C. K. (2010). *Applied missing data analysis*. New York, NY: Guilford Press.

Eriksen, B. A., & Eriksen, C. W. (1974). Effects of noise letters upon the identification of a target letter in a nonsearch task. *Perception and Psychophysics*, *16*, 143–149. doi:10.3758/BF03203267

Fabes, R. A., Eisenberg, N., Jones, S., Smith, M., Guthrie, I., Poulin, R., … Friedman, J. (1999). Regulation, emotionality, and preschoolers' socially competent peer interactions. *Child Development*, *70*, 432–442. doi:10.1111/1467-8624.00031

Friedman, N. P., & Miyake, A. (2016). Unity and diversity of executive functions: Individual differences as a window on cognitive structure. *Cortex*, Advance online publication. doi:10.1016/j.cortex.2016.04.023

Friedman, N. P., Miyake, A., Young, S. E., DeFries, J. C., Corley, R. P., & Hewitt, J. K. (2008). Individual differences in executive functions are almost entirely genetic in origin. *Journal of Experimental Psychology: General*, *137*, 201–225. doi:10.1037/0096-3445.137.2.201

Frye, D., Zelazo, P. D., & Palfai, T. (1995). Theory of mind and rule-based reasoning. *Cognitive Development*, *10*, 483–527. doi:10.1016/0885-2014(95)90024-1

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. doi:10.1037/a0036633

Garon, N., Bryson, S. E., & Smith, I. M. (2008). Executive function in preschoolers: A review using an integrative framework. *Psychological Bulletin*, *134*, 31–60. doi:10.1037/0033-2909.134.1.31

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. doi:10.1080/10888691.2014.894870

Gonzalez, A. (2015). The role of maternal executive function. *Canadian Psychology*, *65*, 46–53. doi:10.1037/cap0000019

Hackman, D. A., Gallop, R., Evans, G. W., & Farah, M. J. (2015). Socioeconomic status and executive function: Developmental trajectories and mediation. *Developmental Science*, *18*, 686–702. doi:10.1111/desc.12246

Hamre, B., Hatfield, B., Pianta, R., & Jamil, F. (2014). Evidence for general and domain-specific elements of teacher–child

interactions: Associations with preschool children's development. *Child Development*, *85*, 1257–1274. doi:10.1111/cdev.12184
Hatfield, B. E., Burchinal, M. R., Pianta, R. C., & Sideris, J. (2016). Thresholds in the association between quality of teacher–child interactions and preschool children's school readiness skills. *Early Childhood Research Quarterly*, *36*, 561–571. doi:10.1016/j.ecresq.2015.09.005
Heckman, J. J., Stixrud, J., & Urzua, S. (2006). The effects of cognitive and noncognitive abilities on labor market outcomes and social behavior. *Journal of Labor Economics*, *24*, 411–482. doi:10.1086/504455
Hofmann, W., Schmeichel, B. J., & Baddeley, A. D. (2012). Executive functions and self-regulation. *Trends in Cognitive Sciences*, *16*, 174–180. doi:10.1016/j.tics.2012.01.006
Holmes, N. P., Calvert, G. A., & Spence, C. (2007). Tool use changes multisensory interactions in seconds: Evidence from the crossmodal congruency task. *Experimental Brain Research*, *183*, 465–476. doi:10.1007/s00221-007-1060-7
Hughes, C., & Ensor, R. (2005). Executive function and theory of mind in 2 year olds: A family affair? *Developmental Neuropsychology*, *28*, 645–668. doi:10.1207/s15326942dn2802_5
Hughes, M. M., Linck, J. A., Bowles, A. R., Koeth, J. T., & Bunting, M. F. (2014). Alternatives to switch-cost scoring in the task-switching paradigm: Their reliability and increased validity. *Behavior Research Methods*, *46*, 702–721. doi:10.3758/s13428-013-0411-5
Imada, T., Carlson, S. M., & Itakura, S. (2013). East–West cultural differences in context-sensitivity are evident in early childhood. *Developmental Science*, *16*, 198–208. doi:10.1111/desc.12016
Jensen, A. R., & Rohwer, W. D., Jr. (1966). The Stroop color-word test: A review. *Acta Psychologica*, *25*, 36–93.
Jester, J. M., Nigg, J. T., Puttler, L. I., Long, J. C., Fitzgerald, H. E., & Zucker, R. A. (2009). Intergenerational transmission of neuropsychological executive functioning. *Brain and Cognition*, *70*, 145–153. doi:10.1016/j.bandc.2009.01.005
Kärtner, J., Crafa, D., Chaudhary, N., & Keller, H. (2016). Reactions to receiving a gift—Maternal scaffolding and cultural learning in Berlin and Delhi. *Child Development*, *87*, 712–722. doi:10.1111/cdev.12525
Kitagawa, N., & Spence, C. (2005). Investigating the effect of a transparent barrier on the crossmodal congruency effect. *Experimental Brain Research*, *161*, 62–71. doi:10.1007/s00221-004-2046-3
Lan, X., Legare, C. H., Ponitz, C. C., Li, S., & Morrison, F. J. (2011). Investigating the links between the subcomponents of executive function and academic achievement: A cross-cultural analysis of Chinese and American preschoolers. *Journal of Experimental Child Psychology*, *108*, 677–692. doi:10.1016/j.jecp.2010.11.001
Lee, K., Bull, R., & Ho, R. M. H. (2013). Developmental changes in executive functioning. *Child Development*, *84*, 1933–1953. doi:10.1111/cdev.12096
Lee, S.-Y., & Song, X.-Y. (2004). Evaluation of the Bayesian and maximum likelihood approaches in analyzing structural equation models with small sample sizes. *Multivariate Behavioral Research*, *39*, 653–686. doi:10.1207/s15327906mbr3904_4
Leve, L. D., DeGarmo, D. S., Bridgett, D. J., Neiderhiser, J. M., Shaw, D. S., Harold, G. T., … Reiss, D. (2013). Using an adoption design to separate genetic, prenatal, and temperament influences on toddler executive function. *Developmental Psychology*, *49*, 1045–1057. doi:10.1037/a0029390
Logan, G. D. (1994). On the ability to inhibit thought and action: A user's guide to the stop signal paradigm. In D. Dagenbach & T. H. Carr (Eds.), *Inhibitory processes in attention, memory, and language* (pp. 189–239). San Diego, CA: Academic Press.
Matthews, J. S., Ponitz, C. C., & Morrison, F. J. (2009). Early gender differences in self-regulation and academic achievement. *Journal of Educational Psychology*, *101*, 689–704. doi:10.1037/a0014240
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. doi:10.1037/0012-1649.43.4.947
Miyake, A., & Friedman, N. P. (2012). The nature and organization of individual differences in executive functions: Four general conclusions. *Current Directions in Psychological Science*, *21*, 8–14. doi:10.1177/0963721411429458
Miyake, A., Friedman, N. P., Emerson, M. J., Witzki, A. H., Howerter, A., & Wager, T. D. (2000). The unity and diversity of executive functions and their contributions to complex "frontal lobe" tasks: A latent variable analysis. *Cognitive Psychology*, *41*, 49–100. doi:10.1006/cogp.1999.0734
Mulder, H., Hoofs, H., Verhagen, J., van der Veen, I., & Leseman, P. P. M. (2014). Psychometric properties and convergent and predictive validity of an executive function test battery for two-year-olds. *Frontiers in Psychology*, *5*, 733. doi:10.3389/fpsyg.2014.00733
Muthén, B. (2010). *Bayesian analysis in Mplus: A brief introduction* (Technical Report Version 3). Retrieved from https://www.statmodel.com/download/IntroBayesVersion%203.pdf
Ogilvie, J. M., Stewart, A. L., Chan, R. C. K., & Shum, D. H. K. (2011). Neuropsychological measures of executive function and antisocial behavior: A meta-analysis. *Criminology*, *49*, 1063–1107. doi:10.1111/j.1745-9125.2011.00252.x
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. doi:10.1016/j.jecp.2010.08.004
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. doi:10.1037/a0015861
Rogoff, B. (2003). *The cultural nature of human development*. New York, NY: Oxford University Press.
Rueda, M. R., Fan, J., McCandliss, B. D., Halparin, J. D., Gruber, D. B., Lercari, L. P., & Posner, M. I. (2004). Development of attentional networks in childhood. *Neuropsychologia*, *42*, 1029–1040. doi:10.1016/j.neuropsychologia.2003.12.012
Sabbagh, M. A., Xu, F., Carlson, S. M., Moses, L. J., & Lee, K. (2006). The development of executive functioning and theory of mind. *Psychological Science*, *17*, 74–81. doi:10.1111/j.1467-9280.2005.01667.x

Schicke, T., Bauer, F., & Röder, B. (2009). Interactions of different body parts in peripersonal space: How vision of the foot influences tactile perception at the hand. *Experimental Brain Research*, *192*, 703–715. doi:10.1007/s00221-008-1587-2

Shing, Y. L., Lindenberger, U., Diamond, A., Li, S.-C., & Davidson, M. C. (2010). Memory maintenance and inhibitory control differentiate from early childhood to adolescence. *Developmental Neuropsychology*, *35*, 679–697. doi:10.1080/87565641.2010.508546

Snyder, H. R., Miyake, A., & Hankin, B. L. (2015). Advancing understanding of executive function impairments and psychopathology: Bridging the gap between clinical and cognitive approaches. *Frontiers in Psychology*, *6*, 328. doi:10.3389/fpsyg.2015.00328

Song, X.-Y., & Lee, S.-Y. (2008). A Bayesian approach for analyzing hierarchical data with missing outcomes through structural equation models. *Structural Equation Modeling: A Multidisciplinary Journal*, *15*, 272–300. doi:10.1080/10705510801922472

Spence, C., Kingstone, A., Shore, D. I., & Gazzaniga, M. S. (2001). Representation of visuotactile space in the split brain. *Psychological Science*, *12*, 90–93. doi:10.1111/1467-9280.00316

Toplak, M. E., West, R. F., & Stanovich, K. E. (2013). Practitioner review: Do performance-based measures and ratings of executive function assess the same construct? *Journal of Child Psychology and Psychiatry*, *54*, 131–143. doi:10.1111/jcpp.12001

Trommsdorff, G. (2009). Culture and development of self-regulation. *Social and Personality Psychology Compass*, *3*, 687–701. doi:10.1111/j.1751-9004.2009.00209.x

Valiente, C., Lemery-Chalfant, K., & Reiser, M. (2007). Pathways to problem behaviors: Chaotic homes, parent and child effortful control, and parenting. *Social Development*, *16*, 249–267. doi:10.1111/j.1467-9507.2007.00383.x

van Lier, P. A. C., & Deater-Deckard, K. (2016). Children's elementary school social experience and executive functions development: Introduction to a Special Section. *Journal of Abnormal Child Psychology*, *44*, 1–6. doi:10.1007/s10802-015-0113-9

von Suchodoletz, A., Uka, F., & Larsen, R. A. A. A. (2015). Self-regulation across different contexts: Findings in young Albanian children. *Early Education and Development*, *26*, 829–846. doi:10.1080/10409289.2015.1012189

Wanless, S. B., McClelland, M. M., Acock, A. C., Ponitz, C. C., Son, S.-H., Lan, X., … Li, S. (2011). Measuring behavioral regulation in four societies. *Psychological Assessment*, *23*, 364–378. doi:10.1037/a0021768

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. doi:10.1016/j.ecresq.2013.04.002

Wiebe, S. A., Espy, K. A., & Charak, D. (2008). Using confirmatory factor analysis to understand executive control in preschool children: I. Latent structure. *Developmental Psychology*, *44*, 575–587. doi:10.1037/0012-1649.44.2.575

Wiebe, S. A., Sheffield, T., Nelson, J. M., Clark, C. A. C., Chevalier, N., & Espy, K. A. (2011). The structure of executive function in 3-year-olds. *Journal of Experimental Child Psychology*, *108*, 436–452. doi:10.1016/j.jecp.2010.08.008

Willoughby, M. T., Wirth, R. J., Blair, C. B., & Family Life Project Investigators (2012). Executive function in early childhood: Longitudinal measurement invariance and developmental change. *Psychological Assessment*, *24*, 418–431. doi:10.1037/a0025779

Wuensch, K. L. (2012). *An introduction to path analysis.* Retrieved from http://core.ecu.edu/psyc/wuenschk/MV/SEM/Path.pdf

Yang, H., Yang, S., & Kang, C. (2014). The relationship between phonological awareness and executive attention in Chinese-English bilingual children. *Cognitive Development*, *30*, 65–80. doi:10.1016/j.cogdev.2013.11.003

Zelazo, P. D. (2006). The Dimensional Change Card Sort (DCCS): A method of assessing executive function in children. *Nature Protocols*, *1*, 297–301. doi:10.1038/nprot.2006.46

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*, 16–33. doi:10.1111/mono.12032