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Relations Between Inhibitory Control and the Development of Academic Skills in Preschool and Kindergarten: A Meta-Analysis

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Although there is evidence that young children's inhibitory control (IC) is related to their academic skills, the nature of this relation and the role of potential moderators of it are not well understood. In this meta-analytic study, we summarized results from 75 peer-reviewed studies of preschool and kindergarten children (14,424 children; 32–80 months old [$M = 54.71$ months; $SD = 9.70$]) across a wide range of socioeconomic status. The mean effect size (*r*) across studies was .27 (95% confidence interval [.24, .29]), indicating a moderate and statistically significant association between self-regulation and academic skills. The association between IC and academic skills was moderated by type of IC behavior task (i.e., hot vs. cool behavior task), by method of assessing IC (i.e., behavior task vs. parent report), and by academic subject (i.e., literacy vs. math), but not by other methods of assessing IC (i.e., behavior task vs. teacher report, parent report vs. teacher report) or by grade (i.e., preschool vs. kindergarten). The results of this meta-analysis suggest that there are preferred methods for assessing IC (i.e., cool behavior tasks, teacher reports) that should be considered when examining the relations between IC and academic skills in young children.

Keywords: self-regulation, meta-analysis, prekindergarten/preschool, kindergarten, education

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The importance of acquiring academic skills and the perils of early failure are well-documented (e.g., Duncan et al., 2007; McGee, Prior, Williams, Smart, & Sanson, 2002; Spreen, 1988; Stone & LaGreca, 1990). For example, early reading and math skills are the strongest predictors of later academic achievement (e.g., Duncan et al., 2007). Further, children's academic skills trajectories appear to remain fairly stable after first grade (e.g., Entwisle & Hayduk, 1988). Therefore, it is crucial to understand and assimilate research on factors that influence the acquisition of academic skills prior to first grade (i.e., during the preschool and kindergarten years). Researchers have begun to recognize the importance of self-regulation for transitioning into and early success in the structured classroom environment (e.g., Blair & Razza, 2007; Espy et al., 2004). However, the literature lacks a comprehensive review of the associations between self-regulatory skills such as inhibitory control (IC) or effortful control (EC) and early academic skills. The current study provides a quantitative review of existing research on the concurrent relation between IC/EC and early academic skills in preschool and kindergarten.

Self-regulation refers to the internal and transactional processes that individuals use to guide their goal-directed behavior over time and in varying contexts (Karoly, 1993). Whereas some researchers have used this term when conducting research exploring the relation between self-regulation and early academic skills (e.g., Howse, Lange, Farran, & Boyles, 2003; Matthews, Ponitz, & Morrison, 2009), researchers traditionally use terms derived from their respective field of research. For example, cognitive psychologists typically use the broad construct of executive functioning (EF) when discussing self-regulation and related cognitive aspects associated with self-regulation (e.g., Carlson, 2005; Garon, Bryson, & Smith, 2008). Developmental psychologists refer to EC and the executive attention system that underlies EC (e.g., Rothbart & Bates, 2006). The primary difference between EF and EC is that EF is a broader construct than EC, encompassing several distinct cognitive constructs, including working memory and shifting, which are distinct from an IC component in adults and children (McAuley & White, 2011; Miyake et al., 2000).

There is accumulating evidence that the divide between the disparate self-regulatory terms of IC and EC is not substantive. These terms are defined as the ability to inhibit prepotent thoughts or actions flexibly, often in favor of a subdominant action, typically in goal-directed behavior (e.g., Blair, Zelazo, & Greenberg, 2005; Carlson & Moses, 2001; Rothbart, 2004; Rothbart & Bates, 2006). From a neural structures perspective, overlapping neural substrates, involving the prefrontal and anterior cingulate cortex, are associated with both IC and EC (e.g., Fan, Flombaum, McCandliss, Thomas, & Posner, 2003; Garavan, Ross, Murphy, Roche, & Stein, 2002; Zelazo & Müller, 2002).

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Researchers have argued that there are empirical differences between IC and EC, based on the modest to moderate correlations that have been reported between these constructs (Blair & Razza, 2007).[1] However, the magnitudes of these correlations are likely due to the different measurement tools used when assessing these constructs. Studies ostensibly examining the relations between IC and EC typically compare direct assessment behavior tasks (i.e., peg-tapping; Diamond & Taylor, 1996) to questionnaire measures (i.e., subscales from the EC scale of the Children's Behavior Questionnaire [CBQ], Putnam & Rothbart, 2006; e.g., Blair & Razza, 2007; Rothbart, Ellis, Rueda, & Posner, 2003). Although researchers interested in EC have historically used temperament questionnaires and researchers interested in IC have employed more behavioral tasks, temperament researchers have begun to use behavior tasks (e.g., Kochanska, Murray, & Harlan, 2000) and EF researchers interested in IC have begun to employ questionnaire measures (e.g., Clark, Pritchard, & Woodward, 2010). When behavior tasks and questionnaires have been included within discipline (i.e., as either EC or IC measures), the correlations are similar and sometimes lower than those reported between behavioral tasks defined as IC tasks and EC questionnaires (e.g., Clark et al., 2010; Kochanska, Murray, & Coy, 1997). In a series of studies examining the factor structure of several tasks that were a combination of EC and IC tasks, Allan and Lonigan (2011, 2014) reported that all the tasks were best represented as a single factor. Because of this accumulating evidence, many researchers now acknowledge that EC, IC, and related terms, such as *action control* and *response modulation*, are virtually interchangeable (Allan & Lonigan, 2011, 2014; Block, 1996; Diamond, 2006; Nelson, de Haan, & Thomas, 2006; see Zhou, Chen, & Main, 2012, for review). Due to the commonalities among these terms (and for the sake of clarity), we refer to them as *IC*.

The preschool and kindergarten years are crucial and transitional years for both IC and early academic skills. The preschool and kindergarten years have been implicated as a period of rapid self-regulation development (Rothbart & Bates, 2006; Zelazo & Carlson, 2012). A successful transition into increasingly structured environments as children progress from early childhood settings into early elementary school, including basic academic skills acquisition, requires the development and refinement of self-regulatory skills such as IC. Whereas many children transition successfully into this environment, a substantial percentage of children struggle because of difficulties in regulating their behavior. For example, a large, national sample of teachers ($N = 3{,}595$) reported that 16% of children had difficulties with the transition into formal schooling (Rimm-Kaufman, Pianta, & Cox, 2000). Further, 46% of teachers reported that more than half of the children in their classroom had specific behavior problems that affected these children's ability to succeed in kindergarten. Researchers examining the association between IC and early academic skills have reported modest to moderate associations across multiple methods of assessment (e.g., Allan & Lonigan, 2011; Blair & Razza, 2007; Valiente, Lemery-Chalfant, & Swanson, 2010). It is increasingly apparent that an understanding of children's success in the early years of formal schooling requires an understanding of the relation between IC and early academic skills (Blair, 2002; Howse, Calkins, Anastopoulos, Keane, & Shelton, 2003).

An understanding of the relation between IC and early academic skills requires some specification of the possible mechanisms by which self-regulation may impact these emerging academic skills. An executive attention system is said to underlie IC (Posner & Rothbart, 2007). Behaviorally, this system allows young children to "progressively exert more voluntary control over their thoughts and behavior" (Garon et al., 2008, p. 35). Thus, the executive attention system allows children to orient toward classroom learning activities more efficiently as this system develops from the preschool through the kindergarten years. More specific relations between IC and certain academic skills have been suggested. Specifically, it has been suggested that IC is more associated with math skills than with literacy skills, given the presumed role of the prefrontal cortex in IC and other aspects of self-regulation and math (e.g., Willoughby, Kupersmidt, & Voegler-Lee, 2012). More complex relations between IC and academic skills also have been proposed in which IC, by virtue of regulating children's emotional responses, influences academic achievement by facilitating positive teacher-child interactions (e.g., Hamre & Pianta, 2001; Ursache, Blair, & Raver, 2012).

Multiple methods of assessment, with different associated benefits and drawbacks, have been used to study the relation between IC and early academic skills. Questionnaires such as the CBQ (Rothbart, Ahadi, Hershey, & Fisher, 2001) and the Inhibition subscale from the Behavior Rating Inventory of Executive Function–Preschool Version (BRIEF–P; Gioia, Espy, & Isquith, 2002) are usually completed by parents or teachers. The focus of these measures is on typically occurring behaviors within the classroom or the home environment conceptualized across a wide spectrum of occurrence (i.e., from *extremely untrue of the child* to *extremely true of the child*). However, questionnaires are hampered by rater subjectivity, the influence of past history (or lack thereof) between the rater and the child, and variations in the expression of behaviors across environments and with raters. In contrast, direct assessments of IC using behavior tasks (i.e., grass/snow, peg tapping; Carlson & Moses, 2001; Diamond & Taylor, 1996) are assumed to measure children's IC objectively and are more likely to assess cognitive processes involved in IC. However, because behavior tasks are usually administered at a single time, patterns of behavior cannot be captured and factors related but not central to IC (e.g., processing speed) and factors unrelated to a child's general self-regulatory abilities (e.g., time of testing, child fatigue) may influence results. Further, because early childhood is a period of rapid self-regulatory development (Rothbart & Bates, 2006), tasks that are appropriate for younger children may not be appropriate for older children and vice versa (Garon et al., 2008; Ponitz, McClelland, Matthews, & Morrison, 2009). As there are no summative reviews including both questionnaires and behavior task methods of assessment, it is difficult to determine whether there are differences between measures and their relations to academic skills that might make one approach preferable to another.

There are also potential differences in the relation between IC and academic skills within methods of assessment. Regarding questionnaires, it might be expected that teacher-ratings of IC

[1] Modest, moderate, and large correlations are defined at .10, .30, and .50, respectively, by convention (Cohen, 1992).

would be more associated with measures of academic skills than would be parent ratings, given that teachers observe children's behavior in relation to academic tasks. There is mixed evidence for this expectation. For example, Blair and Razza (2007) reported that teacher-rated IC measured in preschool was moderately associated with math and letter knowledge measured in kindergarten, but parent-rated IC was not associated with any academic skills. Eisenberg et al. (2010) reported that mother-rated IC was not associated with preschool children's vocabulary skills. In contrast, Valiente et al. (2010) found modest correlations between parent-rated IC and math and literacy abilities of kindergarten children. Whereas the evidence suggests that teacher-rated IC is moderately associated with children's early academic skills, it is unclear whether this association is present between parent-rated IC and children's early academic skills as well.

In recent years, researchers have suggested that academic measures are differentially associated with behavior tasks designed to measure IC, depending on the level of emotional valence associated with the task (e.g., Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Willoughby, Kupersmidt, Voegler-Lee, & Bryant, 2011). This distinction parallels the argument that emotion regulation is controlled by "bottom-up" processes, distinct from the "top-down" processes controlling more decontextualized regulation (Zelazo & Carlson, 2012) "Hot" IC is purported to be necessary when children are involved in tasks or activities that involve affect or emotion regulation. In contrast, "cool" IC is purported to be necessary in tasks or activities that are decontextualized and abstract. In assessment of IC-using behavior tasks, the distinction has been most clearly drawn in that tasks that reward or punish a child (through giving or taking away prizes or giving larger prizes for longer periods of IC) are considered hot and tasks that do not include rewards or punishments for performance are considered cool (Zelazo, Qu, & Kesek, 2009). An example of a hot IC task is snack delay, in which a child is presented with the option of receiving a small portion of a snack immediately or a larger portion after a certain period of time (Mischel, Shoda, & Rodriguez, 1989). An example of a cool IC task is the head-to-toes task, in which children are issued commands to touch either their head or toes, and they have to do the opposite of this command (Ponitz et al., 2008).

Researchers have suggested that cool IC is more associated with academic skills than is hot IC because of the similarity in emotional valence in cool tasks and academically oriented activities (Brock et al., 2009); however, findings are equivocal regarding this distinction. In a sample of 173 kindergarten children, Brock et al. (2009) reported moderate correlations between cool IC and fall and spring math and reading skills (*r*s from .37 to .46) and nonsignificant to modest correlations between hot IC and fall and spring math and reading skills (*r*s from .12 to .19). Further, Brock et al. and others (e.g., Willoughby et al., 2011) have reported that only cool IC uniquely predicted the academic skills of preschool and kindergarten children. However, in a factor analysis involving hot and cool tasks, Allan and Lonigan (2011) did not find the two types of tasks to be separable. Further, other researchers have found modest to moderate correlations between tasks that would be considered hot and early academic skills (e.g., Carlson, Mandell, & Williams, 2004; Howse, Lange, et al., 2003). Although it is clear that there are relations between IC as measured by behavior tasks and preschool and kindergarten academic skills, it is unclear whether the emotional valence of the task moderates these associations.

The Current Study

Numerous researchers have demonstrated that IC is important in the development of early academic skills; however, the best methods of assessing IC when exploring this relation are as of yet unclear. This lack of clarity hinders the ability to target effectively IC in teaching strategies, curricula, and interventions to improve young children's academic skills. The purpose of this meta-analytic study was to provide an estimate of the overall relation between IC and academic skills in preschool and kindergarten children and to examine the influence of the method of assessing IC on this relation. Based on past research (e.g., Allan & Lonigan, 2011; Blair & Razza, 2007; Valiente et al., 2010),we expected that a modest to moderate effect size would emerge. Regarding method of assessment, it was expected that (a) behavior tasks (i.e., direct assessment) would be more strongly associated with academic measures than would be questionnaires, (b) teacher questionnaires would be more associated with academic measures than would be parent questionnaires, and (c) cool tasks would be more associated with academic measures than would be hot tasks. Although few studies have included examination of whether there are differences in the relation between IC and early math and literacy skills, it has been suggested that IC may be more strongly associated with math skills than with literacy skills (Willoughby, Blair, Wirth, Greenberg, 2012). Because no studies have explored this dissociation between IC and type of outcome directly, it was examined as an exploratory question in this study.

Method

Literature Search and Coding

A broad search of the literature was conducted using ERIC and PsycINFO for articles published prior to September, 2013. Articles were sought that included a term related to IC (i.e., "executive function," "executive control," executive attention," cognitive control," attention control," temperament," "self-regulation," and "inhibit") along with a term related to academic skills (i.e., "academic," "math," "literacy," "reading," "vocabulary," and "numeracy"). The search was restricted to preschool age (i.e., children 2–5 years old) and school age (i.e., children 6–12 years old). To be included in this meta-analysis, a study had to include reports of at least one zero-order correlation between an IC measure and an academic measure in preschool- or kindergarten-age children (typically between the ages of 3 and 6 years).

An initial search resulted in 776 references identified. After removing duplicate articles, 737 references remained. Articles were then examined to ensure that they met our criteria. First, studies that were specific to populations with neurological or biological disorders were removed, resulting in 41 studies ruled out. This criterion was used because it is likely that the relations between IC and academic skills would be moderated by the specific characteristics of these populations. Studies that did not include preschool- or kindergarten-age children were removed, resulting in 64 studies ruled out. Qualitative reviews were removed, resulting in 44 studies ruled out. Studies had to have at least one IC measure. Behavior tasks were included if they required children to delay or inhibit a response to a stimulus. The first author reviewed all articles to ensure that this criterion was met. Parent and teacher-report measures were included if they targeted IC. There were 184 studies that were ruled out because they did not meet this criterion. Studies also had to have at least one academic measure. There were 111 studies ruled out because they did not meet this criterion. Studies had to include correlations, resulting in 110 studies ruled out, and these correlations had to be specific to preschool or kindergarten children. This criterion resulted in 104 studies ruled out. The review of studies across criteria resulted in a total of 79 studies. However, four studies were eventually removed because the correlations provided were also provided in another study included in this meta-analysis. In all, this process resulted in a total of 75 studies that included 14,424 participants. Each study was independently coded by two of the co-authors on demographic variables, effect sizes and information pertaining to effect sizes (i.e., names of measures, sample size per effect size), and moderator variables of interest. Demographic variables included ethnicity, age, and country in which the study took place. Effect size and related variables included the inhibitory control and academic measures used, individual effects, and sample size per effect. Moderators included type of inhibitory control measure (i.e., teacher report, parent report, behavior task), type of academic measure (i.e., literacy, math), and grade level (i.e., preschool or kindergarten). Raters agreed on codes 92.5% of the time. Discussion among the raters, with the ultimate decision being made by the first author, resolved any coding conflicts.

Inhibitory Control Measures

IC measures were either other-report measures or behavior tasks. Other-report measures were completed by either parents or teachers or, in one instance, by a trained research assistant who had observed the child's behavior. Behavior tasks were completed by the child, either in a lab setting, in the child's school, or at the child's home. Behavior tasks were classified as hot if there was an external motivator for performance, typically consisting of a reward (i.e., snack, stickers, money) and as cool if there were no external motivators for performance. Performance rewards included being given a prize for a correct response, having to wait for a larger prize, or having to delay a behavior while awaiting a reward or prize, although nearly all hot tasks were delay tasks. Performance rewards did not include the typical small prizes given to children just for participating. In most studies, hot tasks were identified as such by the authors. Tasks used in each study are listed by study in Table S1 in the online supplemental material.

Academic Measures

Academic measures were typically administered in the child's classroom or in a lab setting by trained research assistants. Academic measures consisted of commonly used academic assessment tools (i.e., several Woodcock–Johnson–III Academic Achievement subtests, Wechsler Preschool and Primary Scale of Intelligence subtests; Wechsler, 1989; Woodcock, McGrew, & Mather, 2001) or were modified versions of common assessment tools. There was a single task that was not administered by research assistants. Eisenberg et al. (2010) used mother-completed vocabulary checklists from the MacArthur Communicative Development Inventories (CDI; Dale, Price, Bishop, & Plomin, 2003; Fenson et al., 2000). Academic measures used in each study are listed by study in Table S1 in the supplemental online material.

Ethnicity and Age

Of the 14,424 participants, 43% of children were reported to be White, 14% African American, 6% Hispanic/Latino, 8% Asian, and 4% of other or of mixed race. Race/ethnicity was not reported for 24% of participants. Children's reported within-study mean ages ranged from 32 to 80 months. Across studies, the average age of children was 54.71 months ($SD = 9.70$).

Computing Effect Sizes

Bivariate correlations between IC and academic measures served as effect sizes (r). Prior to combining effects, all correlations were converted to Fisher's z scores to reduce the impact of the correlation on the effect size variance calculation (see Borenstein, Hedges, Higgins, & Rothstein, 2009). After analysis, all effects were converted back to correlations.

Many studies included multiple measures of IC, academic skills, or both. Because multiple correlations within the same study are based on the same children, they are not independent and share variance or error present in the study. To compute a more precise measure of effect sizes, if more than one correlation was included in a study, we combined the correlations to yield one effect size per study. However, when studies provided correlations on unique samples of children (e.g., Lan, Legare, Ponitz, Li, & Morrison, 2011), one effect size was calculated per group. This occurred in seven of the 75 studies included in this meta-analysis, resulting in a total of 85 individual effects.

In each moderator analysis, correlations were combined to yield one effect size per study based on the variables being examined such that each sample contributed one effect size per variable of interest to the analysis. For example, when examining the type of IC task (hot or cool) as a moderator, all correlations relating to hot tasks within a sample were combined. This approach was outlined by Cooper (1989) and allows the researcher to maximize information present within a study and, at the same time, minimize violations of the assumptions of independence of effect sizes (see also Degner & Dalege, 2013). Each study could produce a different number of effect sizes based on the variables present within the study resulting in a different number of effect sizes being compared in each moderator analysis. For example, in the study by Bull, Espy, Wiebe, Sheffield, & Nelson (2011), multiple IC outcomes were combined to contribute one effect size in the moderator analysis examining the type (hot or cool) of IC task (i.e., all IC measures were cool), but Bull et al.'s outcomes were combined to contribute two effect sizes in the moderator analysis examining the type of academic tasks (i.e., some academic measures assessed literacy, whereas others assessed math).

To combine effect sizes, the procedures outlined by Gleser and Olkin (1994) were followed. Correlations between multiple measures of IC (and multiple measures of academic skill) were incorporated into variance estimates for each study's average effect size, which provided confidence intervals that were robust to multiple correlations within studies (see also Borenstein et al., 2009). If correlations among IC measures (or among academic measures) were not reported, the average correlation between IC measures (or between academic measures) across all the studies included in the meta-analysis was used in the variance equation. Study effects were assumed to differ across studies; therefore, random-effects models were used in all analyses. Consequently, mean effect size estimations and their confidence intervals accounted both for differences within studies and for differences between studies.

Results

As can be seen in Table 1, the overall effect of IC on academic skills was modest, positive, and significant ($r = .27$), with a 95% confidence interval (CI) indicating that 95% of true study-average effects ranged from 0.24 to 0.29. A forest plot (see Figure 1) shows the vast majority of effect sizes (and their confidence intervals) are to the right of the vertical line of no effect ($r = .00$), indicating a positive relation between self-regulation and academic skills.

The heterogeneity of effect sizes (Q; Cochran, 1954) was calculated to examine how effect size estimations varied between studies. The Q value is calculated by summing square deviations of study effect size estimates while weighting each effect size estimates by its inverse variance. The value of Q was 347.70 ($p <$ .001), and 75.84% of the observed variance reflected actual differences in study effects (Higgins, Thompson, Deeks, & Altman, 2003). These calculations suggested that study-effect estimations varied significantly and accounted for only a moderate amount of true variance. The forest plot (see Figure 1) depicts how much effect sizes (and corresponding confidence intervals) varied within this meta-analysis.

Subgroup Analyses Examining Moderators

Results of all moderator analyses are presented in Table 1. Mean effect sizes were computed for groups of studies that shared certain characteristics (e.g., behavior task or questionnaire). These subgroups were compared to determine if effect sizes differed between the groups. The effect of IC on academic outcomes varied significantly based on whether the task was classified as hot or cool. The summary effect of cool tasks ($r = .28$, 95% CI [.25, .31]) was larger than the summary effect of hot tasks ($r = .17$, 95% CI [.12, .24]; $p < .01$). The mean effect from behavior tasks of self-regulation on academic outcomes ($r = .28$, 95% CI [.25, .31]) was significantly higher than the mean effect from parent ($r = .16$, 95% CI [.08, .25]; $p = .01$) but not teacher reports of self-regulation ($r = .22$, 95% CI [.13, .30]; $p = .15$). The mean effects from parent versus teacher reports of self-regulation, however, did not differ significantly from each other.

Moderator analyses also were conducted to examine whether effect sizes varied based on the type of academic skills that were assessed and the grade-level (e.g., preschool or kindergarten) of participants. The effect of IC on academic skills differed significantly as a function of whether the academic skills were literacy-

Table 1
Meta and Subgroup Analyses

Variable	Q_B (*df*)	*k*	*r*	95% CI LL	95% CI UL	*p*
Overall	347.70	85	.27	.24	.29	<.001
Inhibitory control measure	8.63 (1)	81				.003
Hot		20	.17	.12	.24	<.001
Cool		61	.28	.25	.31	<.001
Behavioral task vs. parent report	6.81(1)	87				.010
Behavioral task		75	.28	.25	.31	<.001
Parent report		12	.16	.08	.25	<.001
Behavioral task vs. teacher report	2.10 (1)	85				.147
Behavioral task		75	.28	.25	.31	<.001
Teacher report		10	.22	.13	.30	<.001
Type of reporter	.81 (1)	22				.369
Parent		12	.16	.08	.25	<.001
Teacher		10	.22	.13	.30	<.001
Academic subject	8.16 (1)	112				.004
Literacy		80	.25	.22	.28	<.001
Math		32	.34	.29	.39	<.001
Within literacy measures	5.68 (1)	91				.017
Behavioral task		72	.25	.22	.28	<.001
Reporter		19	.17	.10	.23	<.001
Within math measures	4.64 (1)	36				.031
Behavioral task		28	.35	.30	.41	<.001
Reporter		8	.22	.11	.33	<.001
Grade	.10 (1)	67				.748
Preschool		46	.29	.24	.32	<.001
Kindergarten		21	.27	.22	.33	<.001

Note. Q_B = the weighted sum of square deviations of the subgroup means about the grand mean; *df* = degrees of freedom; *k* = number of individual effects; *r* = mean effect size; CI = confidence interval; LL = lower limit; UL = upper limit. Total *k* per analysis differed because each study could contribute a different number of effect sizes based on the collection of variables present within the study.

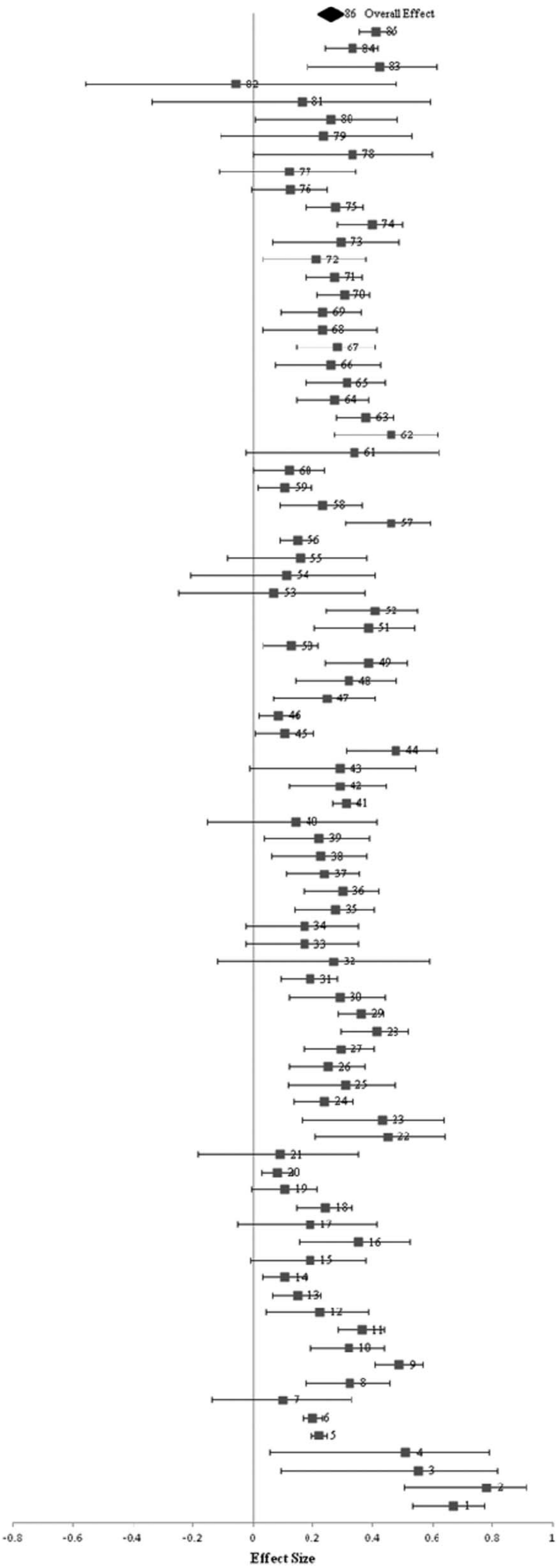

Figure 1. Forest plot for inhibitory control and academic skills meta-analysis derived from a random effects model. Each line and tick mark represents an individual effect size for between-subjects comparisons. Top to bottom presentation order is consistent with Table 1. The diamond shape at the top plot is the overall effect size (.27) for all 85 average weighted effects.

related (r = .25, 95% CI [.22, .28]) or math-related (r = .34, 95% CI [.29, .39]; $p < .01$). Compared to literacy-related skills, math-related skills exhibited higher correlations with measures of IC. The effect of IC was further examined within literacy and math skills separately. The summary effect of behavior tasks on literacy skills (r = .25, 95% CI [.22, .28]) was higher than the summary effect of other-report questionnaires on literacy skills (r = .17, 95% CI [.10, .23]; p = .02). Likewise, the summary effect of behavior tasks on math skills (r = .35, 95% CI [.30, .41]) was higher than the summary effect of other-report questionnaires on math skills (r = .22, 95% CI [.11, .33]; p = .03). The effect of IC on academic skills was not significantly different between preschool (r = .29, 95% CI [.24, .32]) and kindergarten (r = .27, 95% CI [.22, .33]; p = .75) populations.

Evaluating Possible Bias

Although a thorough review of the literature was conducted, the pool of studies that were included in this meta-analysis may not represent all studies conducted in this field of research. It is possible that studies evaluating the relation between IC and academic skills in young children have gone unpublished or were not located for this meta-analysis. Studies with significant results are more likely to get published than are studies with nonsignificant results, suggesting that the mean effects calculated in this meta-analysis may have been higher than the true mean effect (Rosenthal, 1979). To determine if the mean effect-size calculated was robust against this potential bias, we computed Orwin's (1983) Fail-Safe *N*. To reduce the mean effect to .20, only 29 studies with null findings (r = .00) would be needed. However, to reduce the mean effect to near zero (r = .01), 2,210 studies with null findings would be needed.

The possibility of publication bias was also assessed with a funnel plot (see Figure 2). Because studies were fairly symmetrically spaced around the overall mean effect size, it is unlikely that publication bias was present. Effect sizes near zero appear to be occurring in studies with both large and small sample sizes, indicating it is unlikely that there is a bias toward nonpublication of

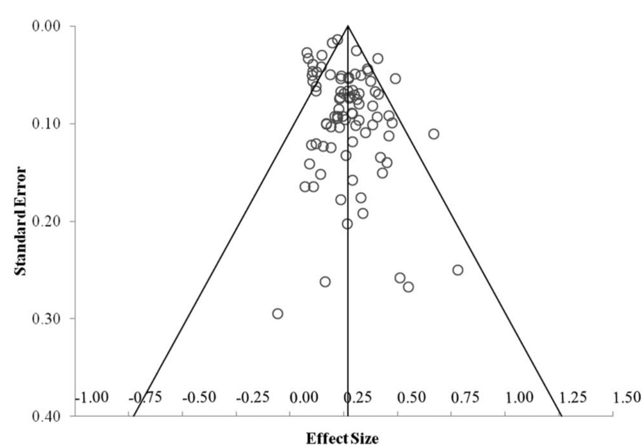

Figure 2. Funnel plot of the correlations used to evaluate the overall effect in the random effects model. The *x* axis is the study average weighted effects (r), and the *y* axis is the weighted standard error associated with each effect. The center vertical line represents the overall mean effect.

studies with very small effects. Therefore, selection is unlikely to have biased the results of the current meta-analysis.

Discussion

The results of this meta-analysis indicated that there was a modest overall relation between IC and academic skills of preschool and kindergarten children. Academic skills were more associated with behavior tasks designed to measure cool IC than with behavior tasks designed to measure hot IC, consistent with several explanations of differences between hot and cool behavior tasks. Behavior tasks were more strongly related to academic outcomes than were parent-questionnaire measures of IC, but behavior tasks were not more strongly related to academic outcomes than were teacher-questionnaire measures of IC. This finding suggests that important information regarding the relation between IC and academic skills can be obtained using both behavior tasks and teacher reports. Behavior tasks were more strongly associated with both literacy and math measures than were other reports. Finally, IC in general was more strongly associated with early math skills than with early literacy skills.

Cool Versus Hot Inhibitory Control

The results of this meta-analysis supported the hypothesis that cool IC tasks are more related to academic skills than are hot self-regulation tasks. These results are consistent with the few studies in which investigators directly compared associations between academic skills in young children and hot versus cool IC (e.g., Brock et al., 2009; Willoughby et al., 2011), although there is ongoing debate as to whether hot and cool EC are separate constructs as well as how best to define hot EC (e.g., Allan & Lonigan, 2011, 2014; Brock et al., 2009; Willoughby et al., 2011). There are several possibilities as to why cool IC is more associated with academic skills than is hot IC. The primary distinction between hot and cool IC is that cool tasks are decontextualized, with limited emotional or motivational significance, whereas hot tasks are typically characterized by their emotional or motivational significance (Zelazo & Müller, 2002). This lack of affective or motivational significance is consistent with the lack of affective or motivational significance involved in testing of young children's academic skills, which typically require more intrinsic motivation to do well. Therefore, it is possible that hot tasks capture children's optimal performance because even children who are not motivated intrinsically are willing to put forth their best efforts for the prizes or rewards. This suggestion is consistent with previous research that has compared the performances of children with attention-deficit/hyperactivity disorder (ADHD) to the performances of typically developing children and has determined that although typically developing children outperform children with ADHD on tasks with no rewards, children with ADHD perform similarly to typically developing children when rewards are given for task performance (e.g., Carlson & Tamm, 2000; Konrad, Gauggel, Manz, & Scholl, 2000; see Luman, Oosterlaan, Knol, & Sergeant, 2005, for review). Although there is some debate, researchers have found that rewarding children for academic performance leads to improvements in academic performance (e.g., J. Cameron & Pierce, 1994; Deci, Koestner, & Ryan, 2001). If rewards do increase academic and self-regulatory performance to capture children's more optimal performance, then using more decontextualized IC tasks and academic measures may capture children's average, limited motivation potential and using more affective or motivationally salient IC tasks and academic measures may capture their true potential in these domains.

It is also possible that the developmental nature of self-regulation in young children is partially responsible for the stronger relation between cool IC and academic skills, in comparison to the relation between hot IC and academic skills. The capacity for self-regulation undergoes a protracted development, with significant development occurring in the preschool years (Rothbart et al., 2003). For example, tasks designed to measure IC in preschoolers are often too easy for kindergarten children (Carlson, 2005). Diamond (2006) and Zelazo et al. (2009) argued that emotional and behavioral regulation are not yet fully integrated in young children, suggesting that the added level of difficulty in regulating emotional responses to hot tasks interferes with children's ability to regulate their behavior. Carlson, Davis, and Leach (2005) provided evidence for this argument in a series of experiments involving a hot IC task, *less-is-more*, in which children were asked to point to a smaller reward so that they would receive the larger reward. In the first experiment, 4-year-old children performed significantly better than did 3-year-old children on the task. In the second experiment, which used a less emotionally salient condition (i.e., symbols instead of real rewards were used), 3-year-old children were more likely to point correctly than were the 3-year-old children in the condition using real rewards. Therefore, emotional and behavioral self-regulation may become more integrated as children grow older.

Behavior Tasks Versus Questionnaires

There was no statistically significant difference in the association between IC and academic skills when IC was measured using behavior tasks or teacher reports. However, IC as measured by behavior tasks was significantly more associated with early academic skills than was IC as measured by parent report. Studies that have included multiple methods of rating IC (i.e., behavior tasks, parent reports, teacher reports) have generally reported significant modest to moderate associations between academic skills and IC as measured by behavior tasks and teacher reports but nonsignificant to modest associations between academic skills and IC as measured by parent reports (e.g., Blair & Razza, 2007; Leerkes, Paradise, Calkins, O'Brien, & Lange, 2008; Thorell & Nyberg, 2008). The findings of this meta-analysis as well as the finding that both teacher reports and behavior tasks were significantly associated with academic skills does not provide support for the argument that direct measures are preferable to questionnaire measures (e.g., McClelland et al., 2007; Rimm-Kaufman et al., 2000). It does suggest, however, that either behavior tasks or teacher reports of IC are preferable to parent reports of IC when one is examining the relation between academic skills and IC.

Because there was no statistically significant difference in the relation between IC and academic skills when behavior tasks or teacher reports were used to measure IC, both methods may be useful in understanding this association. Further, because academic skills in these studies were assessed predominantly by trained research assistants, the relation between teacher reports of IC and academic skills was not due to teachers rating children's IC based on children's performance on the academic measures used as outcome variables. Although few researchers have included both teacher reports and behavior tasks when measuring IC, there is some evidence that each type of measure captures unique and important aspects of IC (e.g., Allan, Lonigan, & Wilson, 2013; Valiente et al., 2010). For example, Allan, Lonigan, and Wilson (2013) reported that the overlap between a teacher-report and a latent IC construct was only moderate in a sample of preschool children. Matthews et al. (2009) used a behavior task and a teacher questionnaire to examine the effects of IC on academic gains across 1 year for 156 kindergarten children. They found that teacher-reported IC and the behavior task both uniquely and significantly predicted gains in math but that only the behavior task predicted literacy gains. Blair and Razza (2007) reported that both a teacher report and behavior task were uniquely associated with math and letter knowledge skills in a sample of low-income kindergarten children.

It is possible that the unique association behavior tasks and teacher reports of IC each share with academic skills is due to the context specificity of each method of assessing IC. Because behavior tasks assess behavior under specific circumstances and teacher reports assess everyday behavior, (Liebermann, Giesbrecht, & Müller, 2007). It appears that teacher reports, which capture average levels of classroom IC, and behavior tasks, which capture IC more objectively, both identify important and unique information regarding the relation between IC and early academic skills, suggesting that direct measures and other-report measures of IC are likely not interchangeable or useful to combine in a multimethod framework given that they appear to represent different aspects of IC (e.g., Toplak, West, & Stanovich, 2013).

Math Versus Literacy Skills

Across all methods of measuring IC, the IC construct was more strongly associated with math skills than with literacy skills. Researchers have speculated that IC might be more strongly associated with early math skills than with early literacy skills (e.g., Willoughby, Blair, et al., 2012) because similar brain regions (i.e., the prefrontal cortex) have been implicated in solving math problems and completing IC tasks (Blair & Razza, 2007; Bull, Espy, & Wiebe, 2008; Espy et al., 2004). However, although IC was more strongly related to math, IC also was related to literacy skills, indicating that IC is not a domain-specific, but rather a domain-general, skill, associated with all learning-related activities.

Preschool Versus Kindergarten Relations

The relation between IC and academic skills was similar in preschool and kindergarten children. Whereas the preschool and kindergarten years have been identified as a period of rapid development for IC skills (Rothbart & Bates, 2006), few studies have explicitly examined whether the relations IC shares with academic skills are different across this time frame. The assumption, albeit implicit, seems to be that although IC skills develop rapidly during the preschool and kindergarten years, this developmental process does not influence the relation between IC and other developmental outcomes. Support for this assumption, at least with respect to academic skills, was provided in the current study.

Limitations

There were several important moderators that could not be examined in this meta-analysis. For example, gender differences have been report on both direct and indirect assessments of IC (e.g., Else-Quest, Hyde, Goldsmith, & Van Hulle, 2006; Matthews et al., 2009). However, because no studies included in this meta-analysis reported correlations separately by gender, it could not be included as a moderator. Additionally, because we were interested in establishing the concurrent correlations between IC and academic skills, we could not disentangle causality. It might be that the relation between academic skills and IC occurs because having well-developed academic skills leads to the development of IC. To our knowledge, no studies have examined whether academic skills influence IC growth in young children. Another variable could also account for the relation between IC and early academic skills. For example, socioeconomic status and home–environment quality, which are associated with both IC and academic ability (e.g., Dilworth-Bart, 2012; Sarsour et al., 2011), may account for the association between IC and academic skills. Given that Willoughby, Kupersmidt, et al. (2012) found no relations between difference scores of IC and difference scores of academic measures in preschool children when fixed-effects models were used to model the effects of unmeasured confounding variables, further consideration of potential confounding variables is needed.

Implications and Conclusion

IC appears to be a domain-general skill associated with both math and literacy skills in young children. The strength of the relation between IC and academic skills is similar across preschool and kindergarten children. Cool behavior tasks are most associated with academic measures and should be used for both research and screening purposes, especially if time and resources are limited. Teacher-reported IC is also associated with academic skills. When feasible, researchers should include both behavior tasks and teacher reports to assess IC as there appears to be unique information associated with the type of measure used. Future research should be conducted to establish the causal influence of IC on early academic skills.

References

References marked with an asterisk indicate studies included in the meta-analysis.

*Allan, N. P., & Lonigan, C. J. (2011). Examining the dimensionality of effortful control in preschool children and its relation to academic and socioemotional indicators. *Developmental Psychology, 47,* 905–915. doi:10.1037/a0023748

Allan, N. P., & Lonigan, C. J. (2014). Exploring dimensionality of effortful control using hot and cool tasks in a sample of preschool children. *Journal of Experimental Child Psychology, 122,* 33–47. doi:10.1016/j.jecp.2013.11.013

Allan, N. P., Lonigan, C. J., & Wilson, S. B. (2013). Psychometric evaluation of the Children's Behavior Questionnaire–Very Short Form in preschool children using parent and teacher report. *Early Childhood Research Quarterly, 28,* 302–313. doi:10.1016/j.ecresq.2012.07.009

*Altamura, V. O. (2012). Influences of attachment, temperament, and emotional development on preschool children's behavior. *Dissertation Abstracts International, Section B: Sciences and Engineering, 72*(10), 3467897.

*Baker, S. T., Gjersoe, N. L., Sibielska-Woch, K., Leslie, A. M., & Hood, B. M. (2011). Inhibitory control interacts with core knowledge in toddlers' manual search for an occluded object. *Developmental Science, 14,* 270–279. doi:10.1111/j.1467-7687.2010.00972.x

*Barr, R., Lauricella, A., Zack, E., & Calvert, S. L. (2010). Infant and early childhood exposure to adult-directed and child-directed television programming: Relations with cognitive skills at age four. *Merrill-Palmer Quarterly, 56,* 21–48. doi:10.1353/mpq.0.0038

*Barra, G. (2009). Oral narrative skills for Chilean preschool children. *Dissertation Abstracts International, Section A: Humanities and Social Sciences, 70*(3), 3351368.

*Bernstein, D. M., Atance, C., Meltzoff, A. N., & Loftus, G. R. (2007). Hindsight bias and developing theories of mind. *Child Development, 78,* 1374–1394. doi:10.1111/j.1467-8624.2007.01071.x

*Bialystok, E., Barac, R., Blaye, A., & Poulin-Dubois, D. (2010). Word mapping and executive functioning in young monolingual and bilingual children. *Journal of Cognition and Development, 11,* 485–508. doi:10.1080/15248372.2010.516420

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., 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. doi:10.1111/j.1467-8624.2005.00863.x

*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., Zelazo, P. D., & Greenberg, M. T. (2005). The measurement of executive function in early childhood. *Developmental Neuropsychology, 28,* 561–571. doi:10.1207/s15326942dn2802_1

Block, J. (1996). Some jangly remarks on Baumeister and Heatherton. *Psychological Inquiry, 7,* 28–32. doi:10.1207/s15327965pli0701_5

Borenstein, M., Hedges, L. V., Higgins, J. P. T., & Rothstein, H. R. (2009). Front matter. In *Introduction to meta-analysis* (pp. i–xxix). Chichester, England: Wiley. Retrieved from http://onlinelibrary.wiley.com/doi/10.1002/9780470743386.fmatter/summary

*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. doi:10.1016/j.ecresq.2009.06.001

*Brown, E. D., Ackerman, B. P., & Moore, C. A. (2013). Family adversity and inhibitory control for economically disadvantaged children: Preschool relations and associations with school readiness. *Journal of Family Psychology, 27,* 443–452. doi:10.1037/a0032886

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. doi:10.1080/87565640801982312 doi:10.1080/87565640801982312

*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. doi:10.1111/j.1467-7687.2010.01012.x

*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. doi:10.1111/j.1467-8624.2012.01768.x

Cameron, J., & Pierce, W. D. (1994). Reinforcement, reward, and intrinsic motivation: A meta-analysis. *Review of Educational Research, 64,* 363–423. doi:10.3102/00346543064003363

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. doi:10.1016/j.ecresq.2007.01.004

Carlson, C. L., & Tamm, L. (2000). Responsiveness of children with attention-deficit/hyperactivity disorder to reward and response cost: Differential impact on performance and motivation. *Journal of Consulting and Clinical Psychology, 68,* 73–83. doi:10.1037/0022-006X.68.1.73

Carlson, S. M. (2005). Developmentally sensitive measures of executive function in preschool children. *Developmental Neuropsychology, 28,* 595–616. doi:10.1207/s15326942dn2802_3

Carlson, S. M., Davis, A. C., & Leach, J. G. (2005). Less is more: Executive function and symbolic representation in preschool children. *Psychological Science, 16,* 609–616. doi:10.1111/j.1467-9280.2005.01583.x

*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., & Meltzoff, A. N. (2008). Bilingual experience and executive functioning in young children. *Developmental Science, 11,* 282–298. doi:10.1111/j.1467-7687.2008.00675.x

Carlson, S. M., & Moses, L. J. (2001). Individual differences in inhibitory control and children's theory of mind. *Child Development, 72,* 1032–1053. doi:10.1111/1467-8624.00333

*Carlson, S. M., Moses, L. J., & Claxton, L. J. (2004). Individual differences in executive functioning and theory of mind: An investigation of inhibitory control and planning ability. *Journal of Experimental Child Psychology, 87,* 299–319. doi:10.1016/j.jecp.2004.01.002

*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

*Chung, K. K. H., & McBride-Chang, C. (2011). Executive functioning skills uniquely predict Chinese word reading. *Journal of Educational Psychology, 103,* 909–921. doi:10.1037/a0024744

Clark, C. A. C., Pritchard, V. E., & Woodward, L. J. (2010). Preschool executive functioning abilities predict early math achievement. *Developmental Psychology, 46,* 1176–1191. doi:10.1037/a0019672

Cochran, W. G. (1954). The combination of estimates from different experiments. *Biometrics, 10,* 101–129. doi:10.2307/3001666

Cohen, J. (1992). A power primer. *Psychological Bulletin, 112,* 155–159. doi:10.1037/0033-2909.112.1.155

Cooper, H. M. (1989). *Integrating research. A guide for literature reviews* (Applied Social Research Methods Series, Vol. 2). London, England: Sage.

*Corbo, M. N. (2012). Measuring behavioral regulation and its relation to early language skills and teacher-rated behavior in a culturally diverse school district. *Dissertation Abstracts International, Section A: Humanities and Social Sciences, 73*(12), 3518898.

Dale, P. S., Price, T. S., Bishop, D. V. M., & Plomin, R. (2003). Outcomes of early language delay: I. Predicting persistent and transient difficulties at 3 and 4 years. *Journal of Speech, Language, and Hearing Research, 46,* 544–560. doi:10.1044/1092-4388(2003/044)

*Davidse, N. J., de Jong, M. T., Bus, A. G., Huijbregts, S. C. J., & Swaab, H. (2011). Cognitive and environmental predictors of early literacy skills. *Reading and Writing, 24,* 395–412. doi:10.1007/s11145-010-9233-3

Deci, E. L., Koestner, R., & Ryan, R. M. (2001). Extrinsic rewards and intrinsic motivation in education: Reconsidered once again. *Review of Educational Research, 71,* 1–27. doi:10.3102/00346543071001001

Degner, J., & Dalege, J. (2013). The apple does not fall far from the tree, or does it? A meta-analysis of parent–child similarity in intergroup attitudes. *Psychological Bulletin, 139,* 1270–1304. doi:10.1037/a0031436

*Dennis, T. A., Hong, M., & Solomon, B. (2010). Do the associations between exuberance and emotion regulation depend on effortful control? *International Journal of Behavioral Development, 34,* 462–472. doi:10.1177/0165025409355514

Diamond, A. (2006). The early development of executive functions. In E. Bialystok & F. Craik (Eds.), *Lifespan cognition: Mechanisms of change* (pp. 70–95). New York, NY: Oxford University Press. doi:10.1093/acprof:oso/9780195169539.003.0006

Diamond, A., & Taylor, C. (1996). Development of an aspect of executive control: Development of the abilities to remember what I said and to "Do as I say, not as I do." *Developmental Psychobiology, 29,* 315–334. doi:10.1002/(SICI)1098-2302(199605)29:4<315::AID-DEV2>3.0.CO;2-T

Dilworth-Bart, J. E. (2012). Does executive function mediate SES and home quality associations with academic readiness? *Early Childhood Research Quarterly, 27,* 416–425. doi:10.1016/j.ecresq.2012.02.002

*Drobetz, R., Maercker, A., Spiess, C. K., Wagner, G. G., & Forstmeier, S. (2012). A household study of self-regulation in children: Intergenerational links and maternal antecedents. *Swiss Journal of Psychology, 71,* 215–226. doi:10.1024/1421-0185/a000090

Duncan, G. J., Dowsett, C. J., Claessens, A., Magnuson, K., Huston, A. C., Klebanov, P., & Crista, J. (2007). School readiness and later achievement. *Developmental Psychology, 43,* 1428–1446. doi:10.1037/0012-1649.43.6.1428

*Eisenberg, N., Vidmar, M., Spinrad, T. L., Eggum, N. D., Edwards, A., Gaertner, B., & Kupfer, A. (2010). Mothers' teaching strategies and children's effortful control: A longitudinal study. *Developmental Psychology, 46,* 1294–1308. doi:10.1037/a0020236

*El Nokali, N. E. (2011). The intersection of physical activity, self-regulation, and academic achievement: Implications for educational success. *Dissertation Abstracts International, Section B: Sciences and Engineering, 73*(7), 3501402.

Else-Quest, N. M., Hyde, J. S., Goldsmith, H. H., & Van Hulle, C. A. (2006). Gender differences in temperament: A meta-analysis. *Psychological Bulletin, 132,* 33–72. doi:10.1037/0033-2909.132.1.33

Entwisle, D., & Hayduk, L. A. (1988). Lasting effects of elementary school. *Sociology of Education, 61,* 147–159. doi:10.2307/2112624

*Espy, K. A., McDiarmid, M. M., Cwik, M. F., Stalets, M. M., Hamby, A., & Stern, T. E. (2004). The contribution of executive functions to emergent mathematic skills in preschool children. *Developmental Neuropsychology, 26,* 465–486. doi:10.1207/s15326942dn2601_6

*Evans, A. D., Xu, F., & Lee, K. (2011). When all signs point to you: Lies told in the face of evidence. *Developmental Psychology, 47,* 39–49. doi:10.1037/a0020787

*Ezrine, G. A. (2010). Effects of language on the development of executive functions in preschool children. *Dissertation Abstracts International, Section B: The Sciences and Engineering, 71*(12), 3431697.

Fan, J., Flombaum, J. I., McCandliss, B. D., Thomas, K. M., & Posner, M. I. (2003). Cognitive and brain consequences of conflict. *NeuroImage, 18,* 42–57. doi:10.1006/nimg.2002.1319

*Fantauzzo, C. A. (1997). Antecedents of shame in four- and five-year-old children. *Dissertation Abstracts International, Section B: Sciences and Engineering, 59*(9), 9703947.

*Farrar, M. J., & Ashwell, S. (2012). Phonological awareness, executive functioning, and theory of mind. *Cognitive Development, 27,* 77–89. doi:10.1016/j.cogdev.2011.08.002

Fenson, L., Pethick, S., Renda, C., Cox, J., Dale, P., & Reznick, J. S. (2000). Short-form versions of the MacArthur Communicative Development Inventories. *Applied Psycholinguistics, 21,* 95–115. doi:10.1017/S0142716400001053

*Ford, R. M., Driscoll, T., Shum, D., & Macaulay, C. E. (2012). Executive and theory-of-mind contributions to event-based prospective memory in children: Exploring the self-projection hypothesis. *Journal of Experimental Child Psychology, 111,* 468–489. doi:10.1016/j.jecp.2011.10.006

*Fuhs, M. W., & Day, J. D. (2011). Verbal ability and executive functioning development in preschoolers at Head Start. *Developmental Psychology, 47,* 404–416. doi:10.1037/a0021065

*Fuhs, M. W., & McNeil, N. M. (2013). ANS acuity and math ability in preschoolers from low-income homes: Contributions of inhibitory control. *Developmental Science, 16,* 136–148. doi:10.1111/desc.12013

*Fuhs, M. W., Wyant, A. B., & Day, J. D. (2011). Unique contributions of impulsivity and inhibition to prereading skills in preschoolers at Head Start. *Journal of Research in Childhood Education, 25,* 145–159. doi:10.1080/02568543.2011.555497

Garavan, H., Ross, T. J., Murphy, K., Roche, R. A. P., & Stein, E. A. (2002). Dissociable executive functions in the dynamic control of behavior: Inhibition, error detection, and correction. *NeuroImage, 17,* 1820–1829.

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

*Georgiou, G. K., Tziraki, N., Manolitsis, G., & Fella, A. (2013). Is rapid automatized naming related to reading and math for the same reason(s)? A follow-up study from kindergarten to Grade 1. *Journal of Experimental Child Psychology, 115,* 481–496. doi:10.1016/j.jecp.2013.01.004

Gioia, G. A., Espy, K. A., & Isquith, P. K. (2002). *Behavior Rating Inventory of Executive Function-Preschool Version*. Odessa, FL: Psychological Assessment Resources.

Gleser, L. J., & Olkin, I. (1994). Stochastically dependent effect sizes. In H. Cooper & L. V. Hedges (Eds.), *The handbook of research synthesis* (pp. 339–355). New York, NY: Russell Sage Foundation.

*Gonik, I. (2008). Inhibitory control in preschool children: Does it predict academic achievement in kindergarten? *Dissertation Abstracts International, Section B: The Sciences and Engineering, 70*(8), 3370855.

Hamre, B. K., & Pianta, R. C. (2001). Early teacher–child relationships and the trajectory of children's school outcomes through eighth grade. *Child Development, 72,* 625–638. doi:10.1111/1467-8624.00301

*Harvey, H. A. (2011). Executive function development and early mathematics: Examination of dual language learners. *Dissertation Abstracts International, Section A: Humanities and Social Sciences, 73*(1), 3478234.

Higgins, J. P. T., Thompson, S. G., Deeks, J. J., & Altman, D. G. (2003). Measuring inconsistency in meta-analyses. *BMJ: British Medical Journal, 327,* 557–560. doi:10.1136/bmj.327.7414.557

*Howse, R. B., Calkins, S. D., Anastopoulos, A. D., Keane, S. P., & Shelton, T. L. (2003). Regulatory contributors to children's kindergarten achievement. *Early Education and Development, 14,* 101–120. doi:10.1207/s15566935eed1401_7

*Howse, R. B., Lange, G., Farran, D. C., & Boyles, C. D. (2003). Motivation and self-regulation as predictors of achievement in economically disadvantaged young children. *Journal of Experimental Education, 71,* 151–174. doi:10.1080/00220970309602061

*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 and Psychiatry, 54,* 169–177. doi:10.1111/jcpp.12014

Karoly, P. (1993). Mechanisms of self-regulation: A systems view. *Annual Review of Psychology, 44,* 23–52. doi:10.1146/annurev.ps.44.020193.000323

*Kilday, C. R. (2010). Factors affecting children's math achievement scores in preschool. *Dissertation Abstracts International, Section A: Humanities and Social Sciences, 72*(3), 3442301.

Kochanska, G., Murray, K., & Coy, K. C. (1997). Inhibitory control as a contributor to conscience in childhood: From toddler to early school age. *Child Development, 68,* 263–277. doi:10.2307/1131849

Kochanska, G., Murray, K. T., & Harlan, E. T. (2000). Effortful control in early childhood: Continuity and change, antecedents, and implications for social development. *Developmental Psychology, 36,* 220–232. doi:10.1037/0012-1649.36.2.220

*Kolkman, M. E., Hoijtink, H. J. A., Kroesbergen, E. H., & Leseman, P. P. M. (2013). The role of executive functions in numerical magnitude skills. *Learning and Individual Differences, 24,* 145–151. doi:10.1016/j.lindif.2013.01.004

Konrad, K., Gauggel, S., Manz, A., & Schöll, M. (2000). Lack of inhibition: A motivational deficit in children with attention deficit/hyperactivity disorder and children with traumatic brain injury. *Child Neuropsychology, 6,* 286–296. doi:10.1076/chin.6.4.286.3145

*Kroesbergen, E. H., Van Luit, J. E. H., Van Lieshout, E. C. D. M., Van Loosbroek, E., & Van de Rijt, B. A. M. (2009). Individual differences in early numeracy: The role of executive functions and subitizing. *Journal of Psychoeducational Assessment, 27,* 226–236. doi:10.1177/0734282908330586

*Lahat, A., Degnan, K. A., White, L. K., McDermott, J. M., Henderson, H. A., Lejuez, C. W., & Fox, N. A. (2012). Temperamental exuberance and executive function predict propensity for risk taking in childhood. *Development and Psychopathology, 24,* 847–856. doi:10.1017/S0954579412000405

*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

*Leerkes, E. M., Paradise, M., O'Brien, M., Calkins, S. D., & Lange, G. (2008). Emotion and cognition processes in preschool children. *Merrill-Palmer Quarterly, 54,* 102–124.

*Lengua, L. J., Honorado, E., & Bush, N. R. (2007). Contextual risk and parenting as predictors of effortful control and social competence in preschool children. *Journal of Applied Developmental Psychology, 28,* 40–55. doi:10.1016/j.appdev.2006.10.001

*Lewis, E. E., Dozier, M., Ackerman, J., & Sepulveda-Kozakowski, S. (2007). The effect of placement instability on adopted children's inhibitory control abilities and oppositional behavior. *Developmental Psychology, 43,* 1415–1427. doi:10.1037/0012-1649.43.6.1415

*Liebermann, D., Giesbrecht, G. F., & Müller, U. (2007). Cognitive and emotional aspects of self-regulation in preschoolers. *Cognitive Development, 22,* 511–529. doi:10.1016/j.cogdev.2007.08.005

Luman, M., Oosterlaan, J., Knol, D. L., & Sergeant, J. A. (2005). The impact of reinforcement contingencies on AD/HD: A review and theoretical appraisal. *Clinical Psychology Review, 25,* 183–213. doi:10.1016/j.cpr.2004.11.001

*Mann, T. D. (2012). Pathways to school readiness: Associations among parent scaffolding, executive functioning, and cognitive and social domains of development in early childhood. *Dissertation Abstracts International, Section A: Humanities and Social Sciences., 74*(1), 3529097.

*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

McAuley, T., & White, D. A. (2011). A latent variables examination of processing speed, response inhibition, and working memory during typical development. *Journal of Experimental Child Psychology, 108,* 453–468. doi:10.1016/j.jecp.2010.08.009

*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

*McClelland, M. M., & Wanless, S. B. (2012). Growing up with assets and risks: The importance of self-regulation for academic achievement. *Research in Human Development, 9,* 278–297. doi:10.1080/15427609.2012.729907

McGee, R., Prior, M., Williams, S., Smart, D., & Sanson, A. (2002). The long-term significance of teacher-rated hyperactivity and reading ability in childhood: Findings from two longitudinal studies. *Journal of Child Psychology and Psychiatry, 43,* 1004–1017. doi:10.1111/1469-7610.00228

*Miller, M. R., Giesbrecht, G. F., Müller, U., McInerney, R. J., & Kerns, K. A. (2012). A latent variable approach to determining the structure of executive function in preschool children. *Journal of Cognition and Development, 13,* 395–423. doi:10.1080/15248372.2011.585478

Mischel, W., Shoda, Y., & Rodriguez, M. I. (1989, May 26). Delay of gratification in children. *Science, 244,* 933–938. doi:10.1126/science.2658056

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. doi:10.1006/cogp.1999.0734

*Monette, S., Bigras, M., & Guay, M. (2011). The role of the executive functions in school achievement at the end of Grade 1. *Journal of Experimental Child Psychology, 109,* 158–173. doi:10.1016/j.jecp.2011.01.008

Nelson, C. A., De Haan, M., & Thomas, K. M. (2006). *Neuroscience of cognitive development: The role of experience and the developing brain*. Edison, NJ: Wiley.

*Nicolay, A. C., & Poncelet, M. (2013). Cognitive abilities underlying second-language vocabulary acquisition in an early second-language immersion education context: A longitudinal study. *Journal of Experimental Child Psychology, 115,* 655–671. doi:10.1016/j.jecp.2013.04.002

Orwin, R. G. (1983). A Fail-Safe *N* for effect size in meta-analysis. *Journal of Educational Statistics, 8,* 157–159. doi:10.2307/1164923

*Pears, K. C., Fisher, P. A., Kim, H. K., Bruce, J., Healey, C. V., & Yoerger, K. (2013). Immediate effects of a school readiness intervention for children in foster care. *Early Education and Development, 24,* 771–791. doi:10.1080/10409289.2013.736037

Ponitz, C. 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. doi:10.1037/a0015365

Posner, M. I., & Rothbart, M. K. (2007). Research on attention networks as a model for the integration of psychological science. *Annual Review of Psychology, 58,* 1–23. doi:10.1146/annurev.psych.58.110405.085516

Putnam, S. P., & Rothbart, M. K. (2006). Development of short and very short forms of the Children's Behavior Questionnaire. *Journal of Personality Assessment, 87,* 102–112. doi:10.1207/s15327752jpa8701_09

*Qu, L., Finestone, D. L., Qin, L. J., & Reena, L. Z. (2013). Focused but fixed: The impact of expectation of external rewards on inhibitory control and flexibility in preschoolers. *Emotion, 13,* 562–572. doi:10.1037/a0027263

*Rakoczy, H. (2010). Executive function and the development of belief desire psychology. *Developmental Science, 13,* 648–661. doi:10.1111/j.1467-7687.2009.00922.x

*Rhoades, B. L., Greenberg, M. T., & Domitrovich, C. E. (2009). The contribution of inhibitory control to preschoolers' social-emotional competence. *Journal of Applied Developmental Psychology, 30,* 310–320. doi:10.1016/j.appdev.2008.12.012

*Richland, L. E., & Burchinal, M. R. (2013). Early executive function predicts reasoning development. *Psychological Science, 24,* 87–92. doi:10.1177/0956797612450883

Rimm-Kaufman, S. E., Pianta, R. C., & Cox, M. J. (2000). Teachers' judgments of problems in the transition to kindergarten. *Early Childhood Research Quarterly, 15,* 147–166. doi:10.1016/S0885-2006(00)00049-1

Rosenthal, R. (1979). The file drawer problem and tolerance for null results. *Psychological Bulletin, 86,* 638–641. doi:10.1037/0033-2909.86.3.638

Rothbart, M. K. (2004). Commentary: Differentiated measures of temperament and multiple pathways to childhood disorders. *Journal of Clinical Child and Adolescent Psychology, 33,* 82–87. doi:10.1207/S15374424JCCP3301_8

Rothbart, M. K., Ahadi, S. A., Hershey, K. L., & Fisher, P. (2001). Investigations of temperament at three to seven years: The children's behavior questionnaire. *Child Development, 72,* 1394–1408. doi:10.1111/1467-8624.00355

Rothbart, M. K., & Bates, J. E. (2006). Temperament. In W. Damon, R. Lerner, & N. Eisenberg (Eds.), *Handbook of child psychology: Vol. 3. Social, emotional, and personality development* (6th ed., pp. 99–166). New York, NY: Wiley.

Rothbart, M. K., Ellis, L. K., Rueda, M., & Posner, M. I. (2003). Developing mechanisms of temperamental effortful control. *Journal of Personality, 71,* 1113–1144. doi:10.1111/1467-6494.7106009

*Sadeh, S. S., Burns, M. K., & Sullivan, A. L. (2012). Examining an executive function rating scale as a predictor of achievement in children at risk for behavior problems. *School Psychology Quarterly, 27,* 236–246. doi:10.1037/spq0000012

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. doi:10.1017/S1355617710001335

*Smith, H. J., Sheikh, H. I., Dyson, M. W., Olino, T. M., Laptook, R. S., Durbin, C. E., . . . Klein, D. N. (2012). Parenting and child DRD4 genotype interact to predict children's early emerging effortful control. *Child Development, 83,* 1932–1944. doi:10.1111/j.1467-8624.2012.01818.x

*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. doi:10.1016/j.ecresq.2007.01.002

*Snyder, E. H. (2004). Understanding the contributions of child and maternal temperament to reading and math achievement in children from poverty. *Dissertation Abstracts International, Section B: Sciences and Engineering, 66*(2), 3164657.

Spreen, O. (1988). Prognosis of learning disability. *Journal of Consulting and Clinical Psychology, 56,* 836–842. doi:10.1037/0022-006X.56.6.836

Stone, W. L., & LaGreca, A. M. (1990). The social status of children with learning disabilities: A reexamination. *Journal of Learning Disabilities, 23,* 32–37. doi:10.1177/002221949002300109

*Thorell, L. B. (2007). Do delay aversion and executive function deficits make distinct contributions to the functional impact of ADHD symptoms? A study of early academic skill deficits. *Journal of Child Psychology and Psychiatry, 48,* 1061–1070. doi:10.1111/j.1469-7610.2007.01777.x

*Thorell, L. B., & Nyberg, L. (2008). The Childhood Executive Functioning Inventory (CHEXI): A new rating instrument for parents and teachers. *Developmental Neuropsychology, 33,* 536–552. doi:10.1080/87565640802101516

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

Ursache, A., Blair, C., & Raver, C. C. (2012). 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. doi:10.1111/j.1750-8606.2011.00209.x

*Valiente, C., Lemery-Chalfant, K., & Swanson, J. (2010). Prediction of kindergartners' academic achievement from their effortful control and emotionality: Evidence for direct and moderated relations. *Journal of Educational Psychology, 102,* 550–560. doi:10.1037/a0018992

*Wanless, S. B., McClelland, M. M., Acock, A. C., Chen, F.-M., & Chen, J.-L. (2011). Behavioral regulation and early academic achievement in Taiwan. *Early Education and Development, 22,* 1–28. doi:10.1080/10409280903493306

*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. doi:10.1037/a0021768

*Weatherholt, T. N., Harris, R. C., Burns, B. M., & Clement, C. (2006). Analysis of attention and analogical reasoning in children of poverty. *Journal of Applied Developmental Psychology, 27,* 125–135. doi:10.1016/j.appdev.2005.12.010

Wechsler, D. (1989). *Wechsler Preschool and Primary Scale of Intelligence-Revised.* San Antonio, TX: Psychological Corporation.

*Willoughby, M. T., Blair, C. B., Wirth, R. J., Greenberg, M., & the 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. doi:10.1037/a0025361

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. doi:10.1080/09297049.2011.578572

*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. doi:10.1080/87565641.2010.549980

*Wolfe, C. D., & Bell, M. A. (2007). Sources of variability in working memory in early childhood: A consideration of age, temperament, language, and brain electrical activity. *Cognitive Development, 22,* 431–455. doi:10.1016/j.cogdev.2007.08.007

Woodcock, R. W., McGrew, K. S., & Mather, N. (2001). *Woodcock-Johnson III Tests of Achievement*. Itasca, IL: Riverside.

*Zelazo, P. D., Anderson, J. E., Richler, J., Wallner-Allen, K., Beaumont, J. L., & Weintraub, S. (2013). II. 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

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. doi:10.1111/j.1750-8606.2012.00246.x

Zelazo, P. D., & Müller, U. (2002). Executive function in typical and atypical development. In U. Goswami (Ed.), *Handbook of childhood cognitive development* (pp. 445–469). Oxford, England: Blackwell. doi:10.1002/9780470996652.ch20

Zelazo, P. D., Qu, L., & Kesek, A. (2009). Hot executive function: Emotion and development of cognitive control. In S. Calkins & M. A. Bell (Eds.), *Child development at the intersection of emotion and cognition* (pp. 97–111). Washington, DC: American Psychological Association.

Zhou, Q., Chen, S. H., & Main, A. (2012). Commonalities and differences in the research on children's effortful control and executive function: A call for an integrated model of self-regulation. *Child Development Perspectives, 6,* 112–121. doi:10.1111/j.1750-8606.2011.00176.x

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