Relations between Executive Function, Behavioral Regulation, and Achievement: Moderation by Family Income

Robert J. Duncan[a1]

duncanrj@uci.edu

Megan M. McClelland[a]

megan.mcclelland@oregonstate.edu

Alan C. Acock[a]

alan.acock@oregonstate.edu

[a]Human Development and Family Sciences

Oregon State University

Corvallis, OR, USA 97331

Published: January 25, 2017
Grant support: IES Grant R305A100566 (PI: M. McClelland) and Grant R305B120013 (PI: G. Duncan)
Citation: Duncan, R. J., McClelland, M. M., & Acock, A. C. (2017). Relations between executive function, behavioral regulation, and achievement: Moderation by family income. *Journal of Applied Developmental Psychology, 49*, 21-30. doi: 10.1016/j.appdev.2017.01.004

[1]Robert J. Duncan is now at the School of Education, University of California, Irvine.

Correspondence concerning this article should be addressed to Robert J. Duncan, University of California, Irvine, School of Education, 2066 Education, Irvine, CA 92697.

Contact: duncanrj@uci.edu

Phone: +1 (949) 824-3068

Abstract

Children's executive function (EF) and behavioral regulation skills are robust predictors of academic success. The current study examines differential associations between measures of EF, classroom behavioral regulation, and academic achievement by children's family income in a sample of 100 prekindergarten children. In correlational analyses, EF and classroom behavioral regulation were more strongly associated for children *not* in low-income families, although only one comparison between correlations reached statistical significance. In regression models controlling for age, gender, and maternal education, EF and classroom behavioral regulation were generally similarly related to achievement regardless of family income. However, inhibitory control was significantly less associated with mathematics and vocabulary for children in low-income families than for children not. These findings suggest similarities in associations between EF, behavioral regulation, and academic achievement regardless of family income, with evidence of only a few exceptions. Potential implications for early childhood interventions in low-income populations are considered.

Keywords: Executive Function, Behavioral Regulation, Academic Achievement, Head Start

Relations between Executive Function, Behavioral Regulation, and Achievement: Moderation by Family Income

Children's early development has important implications for a host of outcomes throughout their life. One developmental period of importance is the transition from early childhood environments to formal schooling, where executive function (EF) and behavioral regulation help children take advantage of learning opportunities in the classroom (McClelland & Cameron Ponitz, 2012). Specifically, children's EF and behavioral regulation are observed in their ability to sit still in classrooms, pay attention to teachers, problem solve, and be goal-directive (Blair & Diamond, 2008; McClelland & Cameron Ponitz, 2012; Morrison, Cameron Ponitz, & McClelland, 2010). Considerable evidence using a variety of methods supports the notion that EF and behavioral regulation are strong predictors of academic achievement in early childhood (e.g., Blair & Razza, 2007; Espy et al., 2004; Gathercole & Pickering, 2000), with predictive relations maintaining through college completion (McClelland, Acock, Piccinin, Rhea, & Stallings, 2013).

Given these theoretical and empirical connections, early childhood interventions have targeted EF and behavioral regulation as a mechanism to boost children's academic success (e.g., Blair & Raver, 2014; Schmitt, McClelland, Acock, & Tominey, 2015). However, it is unclear if the underlying connections between EF, behavioral regulation, and academic achievement are the same across diverse populations of children. That is, research is needed to clarify whether demographic factors (i.e., family income) moderate relations between EF and behavioral regulation measures, and if they moderate relations between these skills and academic achievement. Clarifying this issue has potential implications for the skills that early childhood interventions should target in diverse populations. The current study examines differential associations between EF, behavioral regulation, and academic skills by family income in a sample of prekindergarten children. To accomplish this goal, children were compared who were enrolled in Head Start to those who were not enrolled in, or eligible for, Head Start. However, all children were in combined Head Start and non-Head Start preschool classrooms.

Executive Function (EF) and Behavioral Regulation

Executive function, including attention shifting, working memory, and inhibitory control, helps children regulate their thoughts and behavior (e.g., plan, organize, and problem solve; Blair, Zelazo, & Greenberg, 2005; McClelland, Cameron Ponitz, Messersmith, & Tominey, 2010). Behavioral regulation has been defined as inclusive of cognitive (e.g., EF) and emotional regulatory skills that help children stop, think, and then act in order to achieve a goal (Blair & Raver, 2015; McClelland & Tominey, 2015; Ursache, Blair & Raver, 2011). In other words, children use EF skills along with other regulatory skills when they pay attention to teachers, follow instructions, and complete or persist on tasks and activities (McClelland & Cameron Ponitz, 2012; Morrison et al., 2010). We view EF skills as necessary for children to regulate their behaviors in the classroom along with other skills, such as emotional regulation (McClelland et al., 2010; Ursache et al., 2011).

Although there is conceptual and statistical overlap between EF and behavioral regulation, research supports the notion that EF processes are foundational for children to develop regulatory skills (Blair & Raver, 2012; McClelland & Tominey, 2015; Urasche et al., 2011). The current study uses the two terms to distinguish between EF tasks that are directly assessed (i.e., Day-Night Stroop, a Card Sort task, and the Head-Toes-Knees-Shoulders [HTKS]), and teacher-ratings of children's behavioral regulation in the classroom (which may capture EF along with other skills, such as emotional regulation or persistence). We use a multisource approach of direct assessments of EF and teacher ratings of classroom behavioral regulation to gain a more comprehensive understanding of these skills in early childhood. Teacher ratings of children's classroom behavioral regulation complement direct assessment information by assessing children's ability to demonstrate EF-related skills in early learning environments (Cameron Ponitz, McClelland, Matthews, & Morrison, 2009; McClelland, Acock, & Morrison, 2006). Although teacher ratings may be affected by biases absent in direct assessments (Waterman, McDermott, Fantuzzo, & Gadsden, 2011), a meta-analysis shows they are significantly associated with children's academic outcomes, and this association is not significantly different from the one between direct assessments and academic outcomes (Allan, Hume, Allan, Farrington, & Lonigan, 2014).

The current study focuses on whether the observed associations between different EF tasks and behavioral regulation are the same across diverse populations of children (Caughy, Mills, Owen, & Hurst, 2013; Rhoades, Greenberg, Lanza, & Blair, 2011). If environmental and demographic factors differentially influence EF and behavioral regulation development (e.g., Barrage et al., 2008), could they also influence relations among tasks and their relations to achievement? Understanding relations among EF, behavioral regulation, and academic skills is critical to informing the development of successful early childhood interventions that target these skills, especially for children in lower-income families who are at greater risk of falling behind in schooling achievement (Reardon, 2011). In other words, our study is unique because it supports the need for a greater understanding of how school readiness skills are associated (i.e., EF, behavioral regulation, academic achievement) in diverse populations of children.

Theoretical Perspective

Our theoretical perspective is that transactional processes of biological maturation and environmental contexts influence children's development of EF and behavioral regulation. That is, children improve on EF and behavioral regulation as they age (Best & Miller, 2010; Lee, Bull, & Ho, 2013; Wiebe, Espy, & Charak, 2008), but the rate of growth is dependent on both children's characteristics and the environmental context (Blair & Diamond, 2008; Blair & Raver, 2012). For example, studies show EF and regulatory skills are malleable to intervention effects (e.g., Blair & Raver, 2014; Schmitt et al., 2015), with other work showing that these skills also demonstrate a maturational unfolding with brain development (Garon, Bryson, & Smith, 2008). Correlational studies also show there are differences in children's development of EF and behavioral regulation based on demographic risk factors (Caughy et al., 2013; Razza, Martin, Brooks-Gunn, 2010; Rhoades et al., 2011; Sektnan, McClelland, Acock, & Morrison, 2010). Thus, these skills likely develop at different rates, and possibly, in different ways depending on children's early environments. However, it is unclear if these processes could also influence how the aspects of EF and behavioral regulation are associated. The current study extends previous research by examining if variation in family income is related to differential relations between aspects of EF and behavioral regulation in the classroom. Answering this question is important for our understanding of how children's environments may be related to different, but related, components of EF and behavioral regulation.

Family Income and the Associations between EF and Behavioral Regulation in Early Childhood

Poverty is one important context in which to understand EF and behavioral regulation because it is associated with lower quality home learning environments (McLoyd, 1998). Additionally, experiencing poverty is associated with elevated levels of chronic stress, which influence the EF and regulatory processes of the brain (Blair, 2010; Blair & Raver, 2012; Evans

& English, 2002; Kishiyama, Boyce, Jimenez, Perry, & Knight, 2009). Highly stressful environments cause increased neural reactivity in children, and without the necessary supportive resources (i.e., high quality childcare or home environments), can contribute to lower levels of EF and behavioral regulation (Blair, 2010). It is important to note that neural reactivity may be adaptive in some contexts, although research suggests that greater reactivity combined with fewer environmental supports is negatively associated with the development of regulatory skills and this has been linked to negative outcomes (including school achievement) in children (Blair & Raver, 2012; Blair & Raver, 2015). Therefore, there are likely multiple mechanisms through which poverty influences the development of these skills (e.g., stress, lower quality home learning environment, worse physical health), but it is unknown whether growing up in poverty might influence the relations *among* these skills. In other words, although poverty has been linked to lower EF and behavioral regulation, it is unclear if it also influences the relations between EF and behavioral regulation tasks in low-income samples. Addressing this issue provides important insights for better understanding the development of, and the relations between, these skills in lower-income populations.

One useful theoretical framework for investigating these relations is the ability differentiation hypothesis put forth by Tucker-Drob (2009). This hypothesis says that children with lower ability levels rely more on domain general skills (e.g., working memory) across cognitive tasks resulting in larger correlations among them. Empirically, this hypothesis was supported with longitudinal data across the lifespan (Tucker-Drob, 2009). In the present study, it would predict stronger relations between EF tasks and classroom behavioral regulation for children experiencing poverty (i.e., previous research has documented lower mean performance). In other words, children growing up in poverty might rely more on underlying domain general skills across EF and behavioral measures (e.g., working memory capacities have more of an impact on performance across tasks). However, it is unknown whether economic hardship would contribute to differential relations between EF tasks and behavioral regulation because these skills are all closely related to domain general abilities. Therefore, other factors (such as maturational rate and environmental experiences) could drive differential associations between these skills, or differential association among these skills might not exist. We compare multiple direct assessment EF tasks and teacher ratings of children's classroom behavior for children enrolled in Head Start and those not to address this question.

Family Income and the Associations between EF, Behavioral Regulation, and Academic Achievement

Children's EF and behavioral regulation skills are consistently strong predictors of academic achievement, with the strongest connections typically found with mathematics (Blair & Razza, 2007; Blair, Ursache, Greenberg, Veron-Feagans, & The Family Life Project Investigators, 2015; Bull, Espy, & Wiebe, 2008; Bull & Scerif, 2001; Cameron Ponitz et al., 2009; Espy et al., 2004; Fuhs, Nesbitt, Farran, & Dong, 2014; Gathercole & Pickering, 2000; Hongwanishkul, Happaney, Lee, & Zelazo, 2005; McClelland et al., 2007; McClelland et al., 2014). Children's EF and behavioral regulation are argued to facilitate growth in academic skills because they allow children to take greater advantage of learning opportunities (Morrison et al., 2010). For example, when children are presented with learning opportunities, children who focus on the task, hold multiple pieces of information in mind, and persist through challenges likely gain the most academically. Moreover, these skills may be particularly useful for early mathematics development, which requires manipulating pertinent information and ignoring distracting information (Blair et al., 2015). Few empirical studies, however, have explicitly explored if associations between different EF tasks and classroom behavioral regulation with academic achievement are moderated by family income, which was the purpose of this study.

There are theoretical reasons to predict that these associations would not be the same across diverse populations. The ability differentiation hypothesis would predict stronger associations among EF, behavioral regulation, and academic achievement for children experiencing greater economic hardships because of a larger dependence on domain general skills (e.g., working memory) across measures (Tucker-Drob, 2009). Therefore, we would expect stronger relations between EF and behavioral regulation with academic achievement for children enrolled in Head Start. It is also possible that children's EF and behavioral regulation skills may influence how well they are able to take advantage of learning opportunities for academic skills (Morrison et al., 2010). However, it is unclear how this might affect differential relations between EF, behavioral regulation, and academic achievement by family income.

Previous research has found mixed evidence for whether demographic risk factors moderate the relations between EF, behavioral regulation, and academic achievement. For example, one study found that risk factors (including Head Start status) did not moderate the associations between EF and academic achievement (McClelland & Wanless, 2012). However, other research has found that a lack of impulsivity was significantly related to vocabulary in a group of poor children, but not related to vocabulary in a group of near-poor children (Razza et al., 2010). Although these studies are informative, the current study adds to this work in three unique ways. First, it examines multiple direct EF assessments and teacher ratings of classroom behavioral regulation to see if these measures are differentially related to academic achievement. Second, it examines three different types of academic achievement, including mathematics, emergent literacy, and vocabulary based on prior research findings that effects vary by academic outcome (e.g., Blair & Razza, 2007). Finally, it examines differences between children enrolled in Head Start and those not in Head Start, but who are experiencing the same classroom environment (i.e., are in combined classrooms). Thus, it examines if family income moderates associations between children's EF and behavioral regulation skills and academic achievement controlling for preschool classroom quality.

Goals of the Present Study

The current study has two goals for gaining a deeper understanding of differential associations between EF, behavioral regulation, and academic skills by children's family income in early childhood. The *first goal* is to explore differences in relations between *EF measures and classroom behavioral regulation* by Head Start status. According to the ability differentiation hypothesis (Tucker-Drob, 2009), we expect stronger relations between the measures for the group experiencing greater economic hardship (i.e., children in Head Start) because of a larger dependence on domain general skills across tasks (e.g., working memory). The *second goal* is to assess if the relations between the *EF measures and classroom behavioral regulation with academic achievement* differ based on Head Start status. Based on the ability differentiation hypothesis again, we predict stronger relations among the group experiencing greater economic hardship (i.e., children in Head Start) because of a larger dependence on domain general skills.

Method

Participants

The study consisted of 100 children (51% enrolled in Head Start), with a mean age of 58.81 months (*SD* = 4.23; see Table 1 for descriptive statistics). Participants were recruited from a preschool in a small city in the Pacific Northwest, with roughly 45% of children reported White, 26% Latino, 11% Asian/Pacific Islander, and 18% other. Children and families were recruited by sending letters home (in English or Spanish) with an explanation of the study and consent information. The preschool had combined classrooms that included children enrolled in Head Start and children not enrolled in Head Start, a unique characteristic that is uncommon in most Head Start programs. This enabled us to control for program quality because all children received the same instruction based on the Creative Curriculum program. In total, participants were in 13 different classrooms (20 children per classroom on average), with roughly 8 children consenting to the study per classroom (i.e., consent rate was roughly 50%). Head Start enrollment criterion was based on whether the family income was below the poverty line, with eligible children able to attend the preschool at no charge (US DHHS, 2010). Therefore, Head Start enrollment versus non-enrollment was roughly equivalent to comparing children from families below the poverty line to children from families above the poverty line although we did not have a measure of family income. This is important because differences in classroom peers' socio-economic status is associated with children's growth in EF (Weiland & Yoshikawa, 2014), and children in this study had a mix of Head Start and non Head Start peers in their classroom. Of the children enrolled in Head Start, a small number were primarily Spanish speakers (n = 15) and received all the assessments in Spanish. The Spanish speaking children did not significantly differ from their English speaking peers enrolled in Head Start in age, gender, any EF assessment, behavioral regulation, or emergent literacy, but did significantly worse on mathematics and vocabulary. Overall differences between children enrolled in Head Start and those not are presented in the descriptive statistics table (see Table 1).

Procedure

After attaining consent, each child was administered all of the assessments over 2 – 3 sessions during the spring of the preschool year, with each session lasting 10 – 15 minutes. All analyses treated the data as concurrent. That is, even though assessments took place over 1 – 2 weeks, they were treated as one time point in analyses and not as longitudinal data. The administration of measures was counterbalanced to avoid order effects and trained research assistants administered all assessments. Research assistants were trained on how to successfully administer each assessment in the battery and certified for proficiency before collecting data in the field. Spanish-speaking children were identified by their teacher and received all of the measures in a Spanish version from a fluent Spanish speaker.

Measures

Direct assessments of executive function. A Card Sort task similar to the traditional Dimensional Change Card Sort measure was used to measure children's attention shifting and cognitive flexibility (Blackwell, Cepeda, & Munakata, 2009; Frye, Zelazo, & Palfai, 1995; Zelazo, 2006). The task requires children to sort cards based on three dimensions: size (i.e., small, medium, large), color (i.e., red, yellow, blue), and shape (i.e., dog, bird, fish). The game requires the child respond to rules by placing the card correctly in designated boxes. The task involves 18 trials, with the first 6 trials sorted by shape (no conflict), then 6 trials by color (all conflict), and then 6 trials by size (all conflict). Before each set of six trials, the child is instructed of the new rule. Incorrect responses received 0 points and correct responses received 1 point, for a range of scores from 0 – 18. We used the child's Card Sort task raw score in all analyses. Although no conflict trials were used in the scoring, almost all children received the full six points so no substantial differences occurred from including these trials in the scoring (i.e., scores between the two scoring methods were correlated at r = .98). Consistent with previous research showing that the task has high internal consistency in preschool children (Blackwell et al., 2009; Hongwanishkul et al., 2005), the Cronbach's alpha for the current sample was .85. Validity for the Card Sort task has been demonstrated in studies showing that it is related to but unique from, other measures of EF, as well as related to preschool academic achievement (McClelland et al., 2014).

The Day-Night Stroop task (Gerstadt, Hong, & Diamond,1994) is an inhibitory control task where the child must inhibit the natural response by responding to a picture of a sun as “night” and a picture of a moon as “day.” Non-responses and incorrect responses are coded as 0, self-corrected and similar (to the correct) responses are coded as 1, and correct responses as 2, with scores ranging from 0 – 32. We used the child’s Day-Night Stroop task raw score in all analyses. Non-responses to specific items rarely occurred, and as with other assessments, non-responses to all items were counted as missing data and not a total score of 0. Consistent with previous research showing the Day-Night Stroop to have high internal consistency in preschool aged children (Gerstadt et al., 1994), the Cronbach’s alpha for the current sample was .93. The Day-Night Stroop task has been found to be related to other measures of EF, as well as to preschool academic achievement (McClelland et al., 2014).

The Head-Toes-Knees-Shoulders (HTKS) task is a more complex version of the original Head-to-Toes task (Cameron Ponitz et al., 2008). The task requires a gross motor response in which children must inhibit a natural behavior and do the opposite. Although the HTKS has been referred to as a behavioral regulation measure because of the gross motor component, conceptually it is more aligned with the other two EF assessments in the current study than the teacher ratings of classroom behavioral regulation, which are informed by children’s broader classroom behaviors. Each incorrect response is coded as 0, self-corrected response as 1 point, and correct response as 2 points; with 20 different commands there is a possible range of 0 – 40. We used the child’s HTKS task raw score in all analyses. The HTKS has been shown to have high inter-rater reliability (Cameron Ponitz et al., 2008), and to be reliable and valid in different cultures (Wanless, McClelland, Acock, Chen, & Chen, 2011; Wanless, McClelland, Acock, Cameron Ponitz et al., 2011), with the current sample having a Cronbach's alpha of .91. Part of the data (*n* = 14) used in this study was used in a larger analysis of the inter-rater reliability for the HTKS (*N* = 51) and results indicated a weighted κ = .80 with 92.59% agreement. Previous research has demonstrated validity for the HTKS task, where it has been significantly related to other measures of EF, as well as to preschool academic achievement (McClelland et al., 2014; Schmitt, Pratt, & McClelland, 2014).

Teacher ratings of classroom behavioral regulation. The CBRS was used to assess children's behavioral regulation in the classroom (Bronson, Tivnan, & Seppanen, 1995). We use the term "behavioral regulation" to describe the measure (Cameron Ponitz et al., 2009; Wanless, McClelland, Acock, Cameron Ponitz et al., 2011; Wanless et al., 2013), but note that it has also been referred to as "learning related social skills" (Lim, Rodger, & Brown, 2010) and "self-regulation" (Schmitt et al., 2015; von Suchodoletz et al., 2013). The same teachers assessed children enrolled in Head Start and those not. Although the original CBRS questionnaire includes more questions (Bronson et al., 1995), we used 10 items that previous research has shown tap a single dimension and are a reliable and valid measure of children's classroom behavior (Lim et al., 2010; Cameron Ponitz et al., 2009; von Suchodoletz et al., 2013; Wanless et al., 2011; Wanless et al., 2013). Example items from this subscale of the CBRS are: "Concentrates when working on a task; is not easily distracted by surrounding activities," "Observes rules and follows directions without requiring repeated reminders," and "Completes task successfully." We used the child's CBRS average Likert-score rating on the 10 items in all analyses (range 0 – 5). Consistent with the previous research on the 10-item scale characteristics, the CBRS had a Cronbach's alpha for the current sample of .96. The CBRS task has been found to be related to other measures of behavioral regulation and to preschool academic achievement (Schmitt et al., 2014).

Academic achievement. All children received either the Woodcock-Johnson Psycho-Educational Battery – III Tests of Achievement (WJ – III; Woodcock, McGrew, & Mather, 2001) or the Batería Woodcock-Muñoz (Muñoz-Sandoval, Woodcock, McGrew, & Mather, 2005). Woodcock-Johnson W-scores were used because they utilize Rasch-based measurement models to create equal-interval scale characteristics, with the W-score centered at 500 as the approximate average performance of a 10-year-old (Mather & Woodcock, 2001). Large-scale studies have equated the English and Spanish Woodcock-Johnson measures using item response theory and research suggests no significant differences on scores between the English and Spanish versions of the assessments (Hindman, Skibbe, Miller, & Zimmerman, 2010; Woodcock & Muñoz-Sandoval, 1993). Item level data were not available in the current sample to report sample specific alphas.

Mathematics skills were assessed with the Applied Problems subtest of the WJ – III that involves understanding quantities, simple calculations, and solving practical problems. The Applied Problems subtest is a well-validated, normed, and standardized measure (McGrew & Woodcock, 2001). For children ages two to seven, the Applied Problems subtest has a test-retest reliability of .90 for a less than 1-year interval and .85 for a 1- to 2-year interval, and a median split-half reliability of .92 for children 4 to 7 years old (McGrew & Woodcock, 2001).

Emergent literacy skills were assessed with the Letter-Word Identification subtest of the WJ – III, which requires the child to identify letters and pronounce words, increasing in difficulty (both receptive and expressive). As with the other subtests of the WJ – III, the measure has strong reliability and validity; for children ages 2 to 7, the Letter-Word Identification subtest has a test-retest reliability of .96 for a less than 1-year interval, .91 for a 1- to 2-year interval, and a median split-half reliability of .98 for children 4 to 7 years old (McGrew & Woodcock, 2001).

Vocabulary skills were assessed by the Picture Vocabulary subtest of the WJ – III (including both receptive and expressive responses), where the child must point to or name a target picture. As with the other subtests of the WJ – III, previous research has documented the reliability and validity of this subtest (McGrew & Woodcock, 2001). The Picture Vocabulary subtest has a median split-half reliability of .73 for children 4 to 7 years old (McGrew & Woodcock, 2001).

Analytic Strategy

Data analyses were run using Stata 12.1 (StataCorp, 2011). For the first research question, we examined the correlation matrix by Head Start status, and tested if any correlations significantly differed using a z-score test with a correction for the distributional properties of correlations (i.e., because correlations only range from -1.00 to 1.00; Fisher 1921; Soper, 2016).

For the second research question, we used multivariate regression models. Each model had one EF measure or classroom behavioral regulation entered and an interaction term with Head Start status to see if associations to academic skills differed by Head Start status. We entered EF and classroom behavioral regulation terms one at a time to reduce multi-collinearity among measures and interaction terms. In addition to Head Start status (i.e., because of the interaction term), the models included child age, gender, and maternal education as controls. We used the structural equation modeling function in Stata 12.1 in order to model all achievement outcomes simultaneously with correlated error terms (Acock, 2013). Thus, there were four structural equation models in total, each including the three achievement outcomes with correlated error terms and one of the EF measures or classroom behavioral regulation. These models used full information maximum likelihood (FIML) estimators in order to use all available data, which is shown to provide more accurate and reliable estimates than listwise deletion (Acock, 2005; Acock, 2012). Models that used listwise deletion did not provide any substantive differences in interpretations from models with FIML, but resulted in a loss of power and sample size (results available upon request but not presented). Children's language status was considered as a covariate, though because of the small number of Spanish speakers (n = 15), and limitation in overall power given total sample size (N = 100), it was not included (results are available upon request, though effects sizes did not differ substantively).

Clustering children by classroom was considered (classrooms were the only level of clustering because all children attended the same preschool center), however, the ICCs were small for each achievement measure (ICCs = .00 – .02), the number of clusters were small (13 classrooms; 7.69 children per classroom on average), and given the relatively small sample (N = 100), we did not account for clustering in the final models. Small ICCs were expected given that all children were attending the same preschool center and children were expected to be relatively similar between classrooms. In other words, and as found with other early childhood research (e.g., Waterman et al., 2011), children performed similarly to children in other classrooms as to children in their own classroom on direct assessments of academic achievement.

Given the relatively small sample size, we conducted post-hoc power analyses to estimate the probability of a significant result given the observed effects in our study and sample size (Cohen, 1988). For the two reported significant interactions with Day-Night Stroop in the multivariate regressions, our power was relatively small, .67 for mathematics and .67 for vocabulary (i.e., the change in R^2 due to the interaction term was the same across models). Therefore, if our observed effects are the same as the true effects, we would have found the significant interaction effects 67% of the time. However, we have no way of knowing the true effect sizes. Furthermore, we also considered the substantive importance of the results in our decision to report them. This line of rationale is consistent with the American Statistical Association on the misconception and misuse of the p-value (Wasserstein & Lazar, 2016). We acknowledge all differences for non statistically significant findings could be due to chance alone and limit the conclusions and generalizations that can be drawn from them.

Missing data. Overall, there was little missing data. Of the original sample of 100 children, child age, Head Start status, and teacher ratings (the CBRS) experienced no missing data. Five of the 100 children did not participate in any testing sessions and therefore did not receive any direct assessments. For the remaining 95 children, all direct assessments experienced less than 6% missing data, with the exception of Applied Problems (8% missing). Applied Problems was recoded, 1 if missing data occurred and 0 if no missing data occurred, and no covariate was related to missing data (nor was language status, which was not included as a covariate in the analyses for power reasons).

Results

Descriptive Statistics

Descriptive statistics for child age, maternal educational attainment, direct assessments, and teacher ratings are shown in Table 1. The counts, means, and standard deviations are shown for the total sample and by Head Start status. Additionally, t-tests and Cohen's *d* effect sizes are shown for the differences in scores for each assessment by Head Start status. As expected, children not in Head Start had parents who reported significantly more years of maternal educational attainment than children enrolled in Head Start. Age and gender were not significantly different between the two groups. Across all measures, children not in Head Start did significantly better than children enrolled in Head Start, except on the Day-Night Stroop task. Consistent with previous work on the distribution of children's scores on EF assessments (Carlson, 2005), all three of the EF tasks showed some degree of non-normality, or bimodal distribution (i.e., in general, children either did well or poorly on a given task). Therefore, the distributions were skewed right for the Day-Night Stroop and the Card Sort task (especially for children not in Head Start). Conversely, the distribution was skewed left for the HTKS (especially for children in Head Start). However, none of the assessments (i.e., EF, behavioral regulation, or academic achievement) violated skewness or kurtosis guidelines (e.g., Kline, 2005).

Bivariate correlations are presented between all of the measures and covariates (see Table 2). Children with mother's who reported more years of educational attainment were less likely to be in Head Start, $r = -.54$. Age was significantly associated with the HTKS, Day-Night Stroop, and CBRS scores, but not to Card Sort or any academic outcome. Gender was only significantly related to CBRS, with females receiving higher teacher ratings of classroom behavioral regulation than males on average. All correlations between EF tasks and the CBRS were significantly related at $p < .01$, and ranged from rs = .30 – .61. The HTKS and the Card Sort task were the EF tasks that were most strongly related to each other ($r = .61$, $p < .001$) and the Day-Night Stroop was generally the least related in magnitude to other EF tasks (rs = .30 – .36). Moreover, EF tasks and the CBRS were all significantly related to academic achievement at $p < .01$, and ranged from rs = .33 – .56. In general, these correlations are consistent with previous research on EF, behavioral regulation, and academic achievement in early childhood (e.g., McClelland et al., 2014; Wiebe et al., 2008).

Differences Between EF and Behavioral Regulation Associations by Family Income

For the first research question, we explored whether the relations between the direct assessments of EF and teacher ratings of classroom behavioral regulation varied as a function of Head Start status (see Table 3). In general, the findings were inconsistent with our hypothesis that the relations would be stronger for the children in Head Start. Although few statistically significant differences were found overall, tasks were generally more closely related for the children who were not in Head Start (i.e., below the diagonal in the table) than for children in Head Start (i.e., above the diagonal in the table). For example, the Day-Night Stroop was significantly related to other measures for children not in Head Start (rs = .36 – .56), but not significantly related to other measures for children in Head Start (rs = .14 – .18).

Only one of the comparisons between correlations by Head Start status reached statistical significance ($p < .05$), one reached marginal statistical significance ($p < .10$), and four were not close to statistical significance ($p > .10$). Specifically, the difference in the strength of association for the correlations between the Day-Night Stroop and the CBRS was .38 in magnitude and statistically significant (z [87] = 2.11, $p = .03$; $r = .56$ for children not in Head Start and $r = .18$ for children in Head Start), and .33 in magnitude and marginally significant for the Day-Night Stroop and the HTKS (z [86] = 1.73, $p = .08$; $r = .47$ for children not in Head Start and $r = .14$ for children in Head Start). All other comparisons did not approach statistical significance: the Day-Night Stroop and Card Sort (z [83] = 0.95, $p = .34$), the HTKS and Card Sort (z [82] = 1.26, $p = .21$), the HTKS and CBRS (z [86] = 1.27, $p = .20$), and the Card Sort and CBRS (z [84] = 0.44, $p = .66$). Overall, these findings suggest that most associations between tasks were not significantly different between children in Head Start and those not. Associations between the Day-Night Stroop and other measures of EF and the CBRS are potentially different by Head Start status, but conclusions are tempered due to the relatively small sample size and limited statistically significant differences in comparisons.

Differences Between EF and Behavioral Regulation Associations with Academic Achievement by Family Income

For the second research question, differences in the relation to academic achievement for EF tasks and the CBRS were explored by Head Start status (see Table 4). Along with control variables, each model included a single measure of interest (i.e., the HTKS, the Card Sort task, the Day-Night Stroop, the CBRS) with an interaction term between it and Head Start status. Significant interactions emerged between the Day-Night Stroop and Head Start status associations with mathematics (see Figure 1) and vocabulary (see Figure 2). These interactions show that the Day-Night Stroop was significantly less associated with early mathematics and vocabulary for children enrolled in Head Start. Specifically, for each point increase on the Day-Night Stroop for children *not* in Head Start, their expected mathematics and vocabulary scores increased by 1.48 and 0.88 points, respectively, but for children in Head Start, their expected mathematics and vocabulary scores increased by 0.40 and 0.09 points, respectively. These findings suggest a possible differential association between inhibitory control (as measured by the Day-Night Stroop task) and early academic achievement, with inhibitory control less related to early mathematics and vocabulary for children in Head Start. In general, the other measures were similarly related to academic achievement (i.e., not significantly different) regardless of Head Start status. However, given the relatively weak power for detecting small effects (i.e., power = .67 for the two relatively large, significant effects found), we do not consider this definitive proof that other aspects of EF and behavioral regulation are not moderated by Head

Start status. In other words, true effects could exist and our study design was unpowered to detect them.

Discussion

The current study had two goals to gain a deeper understanding of potential differential associations between EF, behavioral regulation, and academic achievement by family income in early childhood. The first goal explored differences in relations between EF and behavioral regulation measures for children enrolled in Head Start versus those who were not enrolled in Head Start. In general, results indicated that few statistically significant differences were found for relations between EF measures and behavioral regulation by Head Start status. One exception was the Day-Night Stroop, a measure of inhibitory control, was not significantly related to the other measures for the children in Head Start, but was significantly related to all measures for the children *not* in Head Start. However, only one comparison of correlations between the groups was statistically significantly different (i.e., Day-Night Stroop and classroom behavioral regulation), suggesting that overall there were relatively few differences in relations based on Head Start status.

The second goal was to assess if the relations between EF and behavioral regulation with academic achievement were moderated by Head Start status. Overall, most tasks related to achievement similarly regardless of Head Start status. However, results indicated that inhibitory control (as measured by the Day-Night task) was significantly less associated with mathematics and vocabulary for children in Head Start compared to children not in Head Start.

Associations Between EF and Behavioral Regulation by Family Income

In general, the correlations observed in the overall sample between measures of EF and behavioral regulation were in the low-to-moderate range, which is largely consistent with previous research (e.g., Blair & Razza, 2007; Hongwanishkul et al., 2005; McClelland et al., 2014; Schmitt et al., 2014; Wiebe et al., 2008). Furthermore, the strong correlation between the HTKS and the Card Sort task is consistent with previous research showing close associations for these measures during early childhood (McClelland et al., 2014). It is possible that performance on these tasks is influenced by a common EF construct contributing to their relatively large bivariate correlations (Allan & Lonigan, 2011, 2014; Wiebe et al., 2008). However, substantial unshared variance still exists between the two tasks (i.e., 63%). In addition, the correlation between the HTKS and Day-Night Stroop was relatively low, which suggests that they may not both measure just inhibitory control. This is supported by recent research on the HTKS showing that it was significantly related to measures of cognitive flexibility and working memory in addition to inhibitory control (McClelland et al., 2014). It is worth noting that some correlations between EF measures were more closely related to academic achievement than to other measures of EF or behavioral regulation. In other words, there could be other factors influencing the relations among tasks than simply the constructs of interest. This suggests that more research is needed to unpack measurement and construct validity of EF and behavioral regulation assessments in early childhood research.

We found that teacher ratings of children's behavioral regulation in the classroom were moderately related to each EF assessment. This provides further support that teacher ratings capture some of the same skills as direct assessments of EF (all correlations over .35), though they did not have substantial shared variance with any one EF task. This finding is consistent with the broader set of skills that teachers likely observe children demonstrating in the classroom (Allan et al., 2014).

Inconsistent with our expectations based on the ability differentiation hypothesis (Tucker-

Drob, 2009), EF measures and behavioral regulation were generally more closely correlated for children not in Head Start. However, most of the statistical tests of differences between correlations by group did not reach significance (i.e., five of six). One exception was the Day-Night Stroop task of inhibitory control showed some evidence for differential associations. Previous research has found inhibitory control to have differential mean performance (i.e., compared to other EF skills) depending on demographic risk factors (e.g., race/ethnicity, poverty; Caughy et al., 2013; Rhoades et al., 2011), which could account for the findings in this study. The Day-Night Stroop measure of inhibitory control was not significantly related to other EF tasks and behavioral regulation for children in Head Start but was significantly related to all tasks for children not in Head Start. Furthermore, the comparison that reached statistical significance included the Day-Night Stroop (i.e., with teacher ratings of behavioral regulation), as did the comparison that reached marginal statistical significance (i.e., with the HTKS). Together, these findings suggest a need for a more in-depth understanding of the contribution of inhibitory control to the development of EF and behavioral regulation across diverse populations in a larger, more representative sample.

It is possible that inhibitory control could be a necessary skill for more complex EF development, but not sufficient by itself. That is, some level of inhibitory control is necessary to perform more advanced working memory, cognitive flexibility, or integrated EF tasks, but having inhibitory control does not necessitate being able to perform them (Best & Miller, 2010). Furthermore, it could be that inhibitory control is more aligned with the maturational development of children, whereas working memory and cognitive flexibility are more influenced by the environmental contexts of the child (Burrage et al., 2008). This hypothesis is supported by the non-significant difference in mean performance on the Day-Night Stroop between children based on family income. For instance, children in low-income families may be developing some inhibitory control skills at similar rates to their more economically advantaged peers, but struggle when performing EF tasks that draw more heavily on working memory and cognitive flexibility skills, or ones that include gross motor components.

Differences Between EF and Behavioral Regulation Associations with Academic Achievement by Family Income

In general, EF and behavioral regulation measures related to academic achievement similarly for children regardless of family income. However, one exception emerged: the Day-Night Stroop was significantly less related to early mathematics and vocabulary skills for children in Head Start. As discussed above, it is possible that children's development of inhibitory control is more related to maturational processes (e.g., Burrage et al., 2008), which precipitates more complex EF development (Best & Miller, 2010). This is not to suggest that inhibitory control is not important for children's academic achievement. In fact, inhibitory control was strongly related to academic domains for children not in Head Start. Therefore, for children in more economically advantaged home environments, having better inhibitory control skills may contribute to differences because of more exposure to learning opportunities for academic skills (Morrison et al., 2010). For example, children with better inhibitory control may be able to more fully engage in, and learn from, activities that foster academic skills. However, weaker relations between inhibitory control and achievement could exist for economically disadvantaged children who experience fewer learning opportunities. For example, children may have the inhibitory control skills needed to take advantage of learning opportunities, but lack the number of opportunities necessary for growth in academic skills. More research is needed on this topic area in order to better inform theory and intervention efforts targeting school readiness (i.e., executive function, behavioral self-regulation, and academic achievement).

Overall, these findings provide some evidence that demographic factors moderate the relations between basic inhibitory control with early academic achievement, but not other EF skills and classroom behavioral regulation. In other words, it could explain why some work has not found differential relations between EF and academic achievement as a function of risk factors (e.g., ELL status and low-income status; McClelland & Wanless, 2012), while other work has found them (Razza et al., 2010; Rhoades et al., 2011). Although demographic risk may differentially influence aspects of EF and behavioral regulation, more research is needed to understand the implications of this for applied researchers. For instance, children in low-income households may have some EF skills (e.g., inhibitory control) needed to take advantage of learning opportunities for academic skills, but simply need increases in learning opportunities to catch up academically with their more economically advantaged peers. Furthermore, some EF and regulatory skills may be more malleable to contextual inputs, thus suggesting increased likelihood of intervention effects. This information is essential for interventions to target the foundational learning skills necessary for academic success in low-income populations.

Limitations

Although the current study makes a number of contributions in understanding differential associations between EF, behavioral regulation, and academic achievement by family income in early childhood, there are limitations worth noting. First, the analyses only looked at concurrent performance and not growth in these skills. It is unclear if the tasks used in the current study would predict growth of skills differently than concurrent associations, and future research should examine these research questions with longitudinal data. A second limitation is the relatively small sample size of children for comparing group differences and testing moderation.

Both groups were roughly 50 children (based on Head Start status), and more accurate differences would be estimated with a larger sample of each. Thus, caution is warranted in interpreting and generalizing these results given the small and non-random sample. This concern is highlighted by our post-hoc power analyses that showed even if the true interaction effect was as large as we observed, we would have missed statistical significance one-third of the time. However, we consider the relatively large interaction effects for the Day-Night Stroop as substantively meaningful, and this study as evidence that more research is needed in regards to moderation of income status and the associations between EF, behavioral regulation, and academic achievement.

It is also unclear how the small sample of Spanish-speaking children may have influenced the findings, especially considering all Spanish-speaking children were enrolled in Head Start. Future studies should especially consider children developing in dual-language environments with other demographic risks (i.e., low-income or low maternal education) as potential moderators of relations between EF, behavioral regulation, and academic achievement. A related concern is that although Head Start enrollment is a function of family income, it does not rule out the possibility of any number of confounding variables associated with income (e.g., race/ethnicity). There is a great deal of heterogeneity within groups of low-income children so it is unclear how the findings would generalize to the overall population. A third limitation is related to measurement. The current study included three measures of EF, but many more measures of EF exist (e.g., Carlson, 2005; Garon et al., 2008), including more newly developed measures (e.g., Carlson & Harrod, 2013; Zelazo & Bauer, 2013). Furthermore, it is unclear whether the EF and behavioral regulation measures converged on a separate construct that was distinct from the academic achievement measures. More measures of EF (including tasks that tap working memory) and behavioral regulation would allow for more precise measurement models that examine whether indicators are invariant across low-income and non low-income populations. Additionally, studies examining the psychometric properties of different assessments within diverse populations of children are needed to ensure conclusions are not being biased by inadequate reliability and validity. Future work should examine these issues with a variety of assessments, tapping the different components, and with measurement models in order to obtain a deeper understanding of the potential differences associated with demographic factors.

Implications

In spite of these limitations, the present study presents a number of theoretical and applied implications. First, although overall few differences were found by family income, the current study highlights potential differences for inhibitory control associated with family income, including relations to other EF measures, behavioral regulation, and academic achievement. It suggests that interventions and programs designed to boost children's school readiness should consider the different skills children have and what skills are potentially more malleable to intervention effects. Specifically, we found that children in low-income families performed equally well on inhibitory control (as assessed by the Day-Night Stoop) compared to children not in low-income families, but struggled more on the HTKS and Card Sort tasks, with these tasks more closely related to academic achievement. Understanding EF and behavioral regulation development in economically disadvantaged populations is especially relevant because studies find it is an important component of school readiness (Blair & Raver, 2014; Blair & Diamond, 2008; McClelland & Tominey, 2015; Schmitt et al., 2015). Teachers and interventionists can use this information to focus on fostering the areas where children need the most support and the areas that may relate most closely to academic success. Based on the current study findings, curriculum and interventions may be more successful by targeting more complex EF, or behavioral regulation, which may be more related to academic achievement for children facing economic hardships. These skills also may be more context-dependent, suggesting greater malleability to interventions and developmental programs.

Conclusions

Results of this study add to the literature of EF and behavioral regulation in early childhood, supporting similarities across populations but also highlighting a few differences for children from low-income families. Results demonstrated that a measure of inhibitory control was less related to other EF measures and behavioral regulation for children in low-income families. Furthermore, a measure of inhibitory control was less related to mathematics and vocabulary for children in low-income families, whereas the other measures were more consistently related to academic skills regardless of family income status. Results of this study can be used to generate new hypotheses on the ways that components of EF and behavioral regulation develop together and independently, the contributions of maturation and environmental contexts, and ultimately their contributions to early academic success.

References

Acock, A. C. (2005). Working with missing values. *Journal of Marriage and the Family, 67*, 1012 – 1028. doi: 10.1111/j.1741-3737.2005.00191.x

Acock, A. C. (2012). What to do about missing values. In H. Cooper, P. M. Camic, D. L. Long, A. T. Panter, D. Rindskopf & K. J. Sher (Eds.), *Data analysis and research publication. APA handbook of research methods in psychology, Vol. 3.* (Vol. 3, pp. 27-50). Washington, DC: American Psychological Association.

Acock, A. C. (2013). *Discovering structural equation modeling using Stata*. College Station, TX: Stata Press.

Allan, N. P., Hume, L. E., Allan, D. M., Farrington, A. L., & Lonigan, C. J. (2014). Relations between inhibitory control and the development of academic skills in preschool and kindergarten: A meta-analysis. *Developmental Psychology, 50*, 2368 – 2379. doi: 10.1037/a0037493

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. (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.

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

Blackwell, K. A., Cepeda, N. J., & Munakata, Y. (2009). When simple things are meaningful: working memory strength predicts children's cognitive flexibility. *Journal of*

Experimental Child Psychology, *103*(2), 241-249. doi: 10.1016/j.jecp.2009.01.002

Blair, C. (2010). Stress and the development of self-regulation in context. *Child Development Perspectives, 4*, 181 – 188. doi: 10.1111/j.1750-8606.2010.00145.x

Blair, C., & Diamond, A. (2008). Biological processes in prevention and intervention: The promotion of self-regulation as a means of preventing school failure. *Developmental Psychopathology, 20*, 899 – 911. doi: 10.1017/S0954579408000436.

Blair, C., & Raver, C. C. (2012). Child development in the context of adversity. *American Psychologist Association*, *67*, 309 – 318. doi: 10.1037/a0027493

Blair, C., & Raver, C. C. (2014). Closing the achievement gap through modification of neurocognitive and neuroendocrine function: Results from a cluster randomized controlled trial of an innovative approach to the education of children in kindergarten. *PloS one*, *9*(11), e112393. doi: 10.1371/journal.pone.0112393

Blair, C., & Raver, C. C. (2015). School readiness and self-regulation: A developmental psychobiological approach. *Annual Review of Psychology*, *66*, 711 – 31. doi: 10.1146/annurev-psych-010814-015221

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., Greenberg, M., Veron-Feagans, L., & The Family Life Project Investigators. (2015). Multiple aspects of self-regulation uniquely predict mathematics but not letter-word knowledge in the early elementary grades. *Developmental Psychology, 51*, 459 – 472. doi: 10.1037/a0038813

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

Bronson, M. B., Tivnan, T., & Seppanen, P. S. (1995). Relationships between teacher and classroom activity variables and the classroom behaviors of prekindergarten children in Chapter 1 funded programs. *Journal of Applied Developmental Psychology, 16*, 253 – 282. doi: 20.1016/0193-3973(95)90035-7.

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

Bull, R., & Scerif, G. (2001). Executive functioning as a predictor of children's mathematics ability: Inhibition, switching, and working memory. *Developmental Neuropsychology, 19,* 273 – 293. doi:10.1207/S15326942DN1903_3

Burrage, M. S., Ponitz, C. C., McCready, E. A., Shah, P., Sims, B. C., Jewkes, A. M., & Morrison, F. J. (2008). Age-and schooling-related effects on executive functions in young children: a natural experiment. *Child Neuropsychology*, *14*(6), 510-524. doi: 10.1080/09297040701756917

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

Cameron 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/a001536.

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., & Harrod, J. (2013). *The executive function scale for preschoolers: Validation phase*. Paper presented at the Society for Research in Child Development Annual Meeting.

Caughy, M. O., Mills, B., Owen, M. T., & Hurst, J. R. (2013). Emergent self-regulation skills among very young ethnic minority children: A confirmatory factor model. *Jouranl of Experimental Child Psychology, 116*, 839 – 855. doi: 10.1016/j.jecp.2013.07017

Cohen, J. 1988. *Statistical Power Analysis for the Behavioral Sciences, Second Edition.* Mahwah, NJ: Lawrence Erlbaum Associates.

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

Evans, G. W., & English, K. (2002). The environment of poverty: Multiple stressor exposure, psychophysiological stress, and socioemotional adjustment. *Child Development*, 1238-1248. doi: http://www.jstor.org/stable/3696282

Fisher, R. A. (1921). On the Probable Error of a Coefficient of Correlation Deduced from a Small Sample. Metron, 1, 3-32.

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. http://dx.doi.org/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

Gathercole, S. E., & Pickering, S. J. (2000). Working memory deficits in children with low achievements in the national curriculum at seven years of age. British *Journal of Educational Psychology, 70*, 177 – 194. doi: 10.1348/000709900158047

Gerstadt, C. L., Hong, Y. J., & Diamond, A. (1994). The relationship between cognition and action: Performance of children 3.5-7 years old on a Stroop-like day-night test. *Cognition, 53*, 129 – 153. doi: 10.1016/0010-0277(94)90068-x

Hindman, A. H., Skibbe, L. E., Miller, A., & Zimmerman, M. (2010). Ecological contexts and early learning: Contributions of child, family, and classroom factors during Head Start, to literacy and mathematics growth through first grade. *Early Childhood Research Quarterly*, *25*(2), 235-250. doi:10.1016/j.ecresq.2009.11.003

Hongwanishkul, D., Happaney, K. R., Lee, W. S. C., & Zelazo, P. D. (2005). Assessment of hot and cool executive function in young children: Age-related changes and individual differences. *Developmental Neuropsychology, 28*, 617 – 644. doi: 10.1207/s15326942dn2802_4

Kishiyama, M. M., Boyce, W. T., Jimenez, A. M., Perry, L. M. & Knight, R. T. (2009). Socioeconomic disparities affect prefrontal function in children. *Journal of Cognitive Neuroscience, 21*, 1106 – 1115. doi:10.1162/jocn.2009.21101

Kline, R. B. (2005). Principles and practice of structural equation modeling (2nd ed.). New York: Guilford.

Lee, K., Bull, R. and Ho, R. M. H. (2013), Developmental Changes in Executive Functioning. *Child Development, 84*, 1933–1953. doi: 10.1111/cdev.12096

Lim, S. M., Rodger, S., & Brown, T. (2010). Validation of the Child Behavioral Rating Scale in Singapore (part 1): Rasch analysis. *Hong Kong Journal of Occupational Therapy, 20*, 52 – 62. doi: 10.1016/S1569-1861(11)70004-3

Mather, N., & Woodcock, R. W. (2001). *Examiner's manual: Woodcock-Johnson III Tests of Achievement*. Itasca, IL: Riverside.

McClelland, M. M., Acock, A. C., & Morrison, F. J. (2006). The impact of kindergarten learning-related skills on academic trajectories at the end of elementary school. *Early Childhood Research Quarterly, 21*, 471 – 490. doi/10.1016/j.ecresq.2006.09.003

McClelland, M.M., Acock, A. C., Piccinin A., Rhea, S. A., & Stalling, M. C. (2013). Relations between preschool attention and sociability and later achievement outcomes. *Early Childhood Research Quarterly, 28*, 314 – 324. doi:10.1016/j.ecreq.2012.07.008

McClelland, M. M., & Cameron Ponitz, C. (2012). Self-regulation in early childhood: Improving conceptual clarity and developing ecologically-valid measures. *Child Development Perspectives*. 6, 136 – 142. doi: 10.1111/j.1750-8606.2011.00191.x

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., Cameron, C. E., Duncan, R., Bowles, R. P., Acock, A. C., Miao, A., & Pratt,

M. E. (2014). Predictors of early growth in academic achievement: The head-toes-knees-shoulders task. *Frontiers in psychology*, *5*. doi: 10.3389/fpsyg.2014.00599

McClelland, M. M., Cameron Ponitz, C., Messersmith, E. E., & Tominey, S. (2010). Self-regulation: The integration of cognition and emotion. In. R. Lerner (Series Ed.) & W. Overton (Vol. Ed.), Handbook of life-span development. Hoboken, NJ: Wiley and Sons.

McClelland, M. M., & Tominey, S. L. (2015). *Stop, Think, Act: Integrating Self-Regulation in the Early Childhood Classroom*. Routledge: New York, NY.

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

McGrew, K. S. & Woodcock, R. W. (2001). Technical Manual. *Woodcock-Johnson III*. Itasca, IL: Riverside Publishing.

McLoyd, V. C. (1998). Socioeconomic disadvantage and child development. *American psychologist*, *53*(2), 185. doi: 10.1037/0003-066X.53.2.185

Morrison, F. J., Cameron Ponitz, C., & McClelland, M. M. (2010). Self-regulation and academic achievement in the transition to school. In S. D. Calkins & M. Bell (Eds)., *Child development at the intersection of emotion and cognition* (pp. 203 – 224): Washington, DC: American Psychological Association.

Muñoz-Sandoval, A. F., Woodcock, R. W., McGrew, K. S., & Mather, N. (2005). *Bateria III Woodcock- Muñoz: Pruebas de aprovechamiento*. Itasca, IL: Riverside Publishing.

Razza, R. A., Martin, A., & Brooks-Gunn, J. (2010). Associations among family environment, sustained attention, and school readiness for low-income children. *Developmental Psychology, 46*, 1528 – 1542. doi: 10.1037/a0020389

Reardon, S. F. (2011). The widening academic achievement gap between the rich and the poor: New evidence and possible explanations. *Whither Opportunity*, 91-116.

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

Schmitt, S. A., McClelland, M. M., Tominey, S. L., & Acock, A. C. (2015). Strengthening school readiness for Head Start children: Evaluation of a self-regulation intervention. *Early Childhood Research Quarterly*, *30*, 20-31. doi:10.1016/j.ecresq.2014.08.001

Schmitt, S. A., Pratt, M. E., & McClelland, M. M. (2014). Examining the validity of behavioral self-regulation tools in predicting preschoolers' academic achievement. *Early Education and Development*, *25*(5), 641-660. doi: 10.1080/10409289.2014.850397

Sektnan, M., McClelland, M. M., Acock, A., & Morrison, F. J. (2010). Relations between early family risk, children's behavioral regulation, and academic achievement. *Early Childhood Research Quarterly, 25*, 464 – 479. doi:10.1016/j.ecresq.2010.02.005

Soper, D.S. (2016). Significance of the Difference between Two Correlations Calculator [Software]. Available from http://www.danielsoper.com/statcalc

StataCorp. 2011. *Stata Statistical Software: Release 12*. College Station, TX: StataCorp LP.

von Suchodoletz, A., Gestsdottir, S., Wanless, S. B., McClelland, M. M., Birgisdottir, F., Gunzenhauser, C., & Ragnarsdottir, H. (2013). Behavioral self-regulation and relations to emergent academic skills among children in Germany and Iceland. *Early Childhood Research Quarterly, 28*, 62 – 73. doi: 10.1016/j.ecresq.2012.05.003

Tucker-Drob, E. M. (2009). Differentiation of cognitive abilities across the life span.

Developmental psychology, *45*(4), 1097. doi: 10.1037/a0015864

U.S. Department of Health and Human Services (2010). *Head Start Impact Study: Final Report, Janurary 2010.* Washington, DC: Administration for Children and Families, Office of Planning, Research and Evaluation. Retrieved from http://www.acf.hhs.gov/programs/opre/research/project/head-start-impact-study-and-follow-up

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*(2), 122-128. doi: 10.1111/j.1750-8606.2011.00209.x

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

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 & Development, 22, 1 – 28.* DOI:10.1080/10409280903493306

Wanless, S. B., McClelland, M. M., Lan, X., Son, S. H., Cameron, C. E., Morrison, F. J. et al. (2013). Gender differences in behavioral regulation in four societies: The United States, Taiwan, South Korea, and China. *Early Childhood Research Quarterly, 28*(3), 621-633. doi: http://dx.doi.org/10.1016/j.ecresq.2013.04.002

Wasserstein, R. L. & Lazar, N. A. (2016): The ASA's statement on p-values: context, process, and purpose, *The American Statistician*, doi: 10.1080/00031305.2016.1154108

Waterman, C., McDermott, P. A., Fantuzzo, J. W., Gadsden, V. L. (2011). The matter of assessor variance in early childhood education – Or whose score is it anyway? *Early Childhood*

Research Quarterly, 27, 46 – 54. doi: 10.1016/j.ecresq.2011.06.003

Weiland, C. & Yoshikawa, H. (2014). Does higher peer socio-economic status predict children's language and executive function skills gains in prekindergarten? *Journal of Applied Developmental Psychology, 35*, 422 – 432. doi: 10.1016/j.appdev.2014.07.001

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

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

Woodcock, R. W., & Muņoz-Sandoval, A. F. (1993). An IRT approach to cross-language test equating and interpretation. *European Journal of Psychological Assessment, 9*, 233 – 241.

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

Zelazo, P. D., & Bauer, P. J. (2013). *National Institutes of Health Toolbox—Cognition Battery (NIH Toolbox CB): Validation for children between 3 and 15 years*. Ann Arbor, MI: Society for Research in Child Development.

Table 1

Descriptive Statistics for Demographic Variables, EF, Behavioral Regulation, and Academic Achievement

	Full Sample			Head Start			Not Head Start			Group Comparison	
Demographics	*N*	*M*	*SD*	*N*	*M*	*SD*	*N*	*M*	*SD*	*T-test*	*Cohen's D*
Age (in months)	100	58.81	4.23	51	59.61	3.86	49	57.98	4.48	*t*(98) = 1.95	0.38
Gender (% Male)	100	51%		51	49%		49	53%		*t*(98) = 0.40	
Maternal Ed.	76	14.32	4.06	33	11.83	3.05	43	16.23	3.70	*t*(74) = 5.54***	1.08
EF											
HTKS (range 0 – 40)	92	15.32	14.14	47	11.04	13.03	45	19.78	14.00	*t*(90) = 3.10**	0.62
Card Sort (range 0 – 18)	90	13.91	3.57	43	12.30	3.43	47	15.38	3.04	*t*(88) = 4.52***	0.87
Day-N (range 0 – 32)	93	24.24	8.83	47	23.13	9.28	46	25.37	8.31	*t*(91) = 1.23	0.26
Behavioral Regulation											
CBRS (range 0 – 5)	100	3.89	0.83	51	3.73	0.86	49	4.06	0.78	*t*(98) = 2.01*	0.40
Achievement											
Applied Problems	87	413.52	23.30	42	403.57	22.52	45	422.80	20.14	*t*(85) = 4.20***	0.82

(range 350 – 467)											
Letter-Word (range 276 – 467)	95	346.08	35.06	48	335.58	32.89	47	356.81	34.26	*t*(93) = 3.08**	0.60
Picture Vocabulary (range 423 – 498)	93	467.08	15.24	48	461.83	14.06	45	472.67	14.57	*t*(91) = 3.65***	0.72

Note. Maternal Ed. is the mother's self-reported years of education completed. HTKS is the Head-Toes-Knees Shoulders. Day-N is the Day-Night Stroop. CBRS is the Child Behavioral Rating Scale. All t-tests are comparing mean performance between children enrolled in Head Start versus those who were not.

*$p < .05$. **$p < .01$. ***$p < .001$.

Table 2

Bivariate Associations Between EF, Behavioral Regulation, and Academic Achievement (N = 88-93)

Variables	1	2	3	4	5	6	7	8	9	10	11
1. Age	–										
2. Male	-.10	–									
3. Maternal Ed.	-.15	-.00	–								
4. Head Start	.19†	-.04	-.54***	–							
5. HTKS	.24*	-.05	.21†	-.31**	–						
6. Card Sort	.17	-.01	.37**	-.43***	.61***	–					
7. Day-N	.27**	-.15	.13	-.13	.33**	.30**	–				
8. CBRS	.30**	-.36***	.26*	-.20*	.40***	.44***	.36***	–			
9. Mathematics	.15	-.14	.39***	-.41***	.51***	.55***	.42***	.56***	–		
10. Literacy	.19†	-.19†	.46***	-.30**	.40***	.38***	.38***	.47***	.51***	–	
11. Vocabulary	.13	-.08	.47***	-.36***	.50***	.56***	.33**	.41***	.64***	.48***	–

Note. Maternal Ed. is the mother's self-reported years of education completed. Head Start is coded 1 = Head Start and 0 = not in Head Start. Male is coded 1 = male and 0 = female. HTKS is the Head-Toes-Knees Shoulders. Day-N is the Day-Night Stroop. CBRS is the Child Behavioral Rating Scale.

$^{\dagger}p < .10$. $^{*}p < .05$. $^{**}p < .01$. $^{***}p < .001$.

Table 3

Bivariate Associations Between EF, Behavioral Regulation, and Academic Achievement by Head Start Status (Not in Head Start, n = 44 – 47; Head Start, n = 39 – 48)

Variables	1	2	3	4	5	6	7
1. HTKS	–	.47**	.14	.26†	.43**	.37*	.35*
2. Card Sort	.66***	–	.17	.39**	.40*	.36*	.49***
3. Day-N	.47**	.36*	–	.18	.20	.30*	.11
4. CBRS	.49***	.47***	.56***	–	.61***	.42**	.39**
5. Mathematics	.47**	.51***	.62***	.47**	–	.46**	.67***
6. Literacy	.31*	.20	.42**	.46**	.43**	–	.41**
7. Vocabulary	.52***	.46**	.51***	.36*	.51***	.44**	–

Note. HTKS is the Head-Toes-Knees Shoulders. Day-N is the Day-Night Stroop. CBRS is the Child Behavioral Rating Scale. Children in Head Start are across the top diagonal and children not in Head Start are across the bottom diagonal.

†$p < .10$. *$p < .05$. **$p < .01$. ***$p < .001$.

Table 4

EF and Classroom Behavioral Regulation Associations with Mathematics, Emergent Literacy, and Vocabulary

	Mathematics (N = 87)			*Literacy (N = 95)*			*Vocabulary (N = 93)*		
	B (SE)	β	R^2	*B (SE)*	β	R^2	*B (SE)*	β	R^2
Controls Only			.27			.32			.27
Head Start (HS)	-16.49** (5.52)	-.36		-8.94 (7.40)	-.13		-6.46† (3.33)	-.21	
Age	1.13* (0.52)	.21		2.14** (0.76)	.26		0.76* (0.34)	.21	
Maternal Ed.	1.16† (0.69)	.20		3.71*** (0.93)	.43		1.34** (0.43)	.35	
Male	-7.09† (4.24)	-.15		-14.03* (6.06)	-.20		-3.16 (2.76)	-.10	
HTKS Model[a]			.40			.38			.42
HTKS	0.71*** (0.20)	.43		0.77* (0.31)	.31		0.58*** (0.13)	.54	
HTKS*HS	-0.20 (0.31)	-.08		-0.31 (0.45)	-.10		-0.35† (0.19)	-.24	
Card Sort Model[a]			.42			.34			.41
Card Sort	3.29*** (0.93)	.50		1.40 (1.48)	.14		2.03*** (0.62)	.47	
Card Sort*HS	-0.74 (1.31)	-.21		0.46 (2.00)	.09		-0.38	-.16	

Day-N Model[a]			.41			.39			.37
Day-N	1.48*** (0.34)	.57		1.55** (0.51)	.39		0.88*** (0.24)	.51	
Day-N*HS	-1.08* (0.45)	-.62		-0.82 (0.67)	-.31		-0.79** (0.30)	-.69	
CBRS Model[a]			.46			.39			.34
CBRS	11.35** (3.87)	.40		15.55* (6.08)	.37		5.31† (2.78)	.29	
CBRS*HS	4.61 (4.87)	.38		-4.88 (7.58)	-.27		0.31 (3.48)	.04	

Note. Maternal Ed. is the mother's self-reported years of education completed. Head Start is coded 1 = Head Start and 0 = not in Head Start. Male is coded 1 = male and 0 = female. HTKS is the Head-Toes-Knees Shoulders. Day-N is the Day-Night Stroop. CBRS is the Child Behavioral Rating Scale. R^2 is the explained variance for the outcome variable in the structural equation model using a maximum likelihood estimator.

[a] Models included Head Start, age, gender, and maternal education as controls (i.e., coefficients not shown to reduce clutter and repetitiveness across models).

†*p* < .10. **p* < .05. ***p* < .01. ****p* < .001.

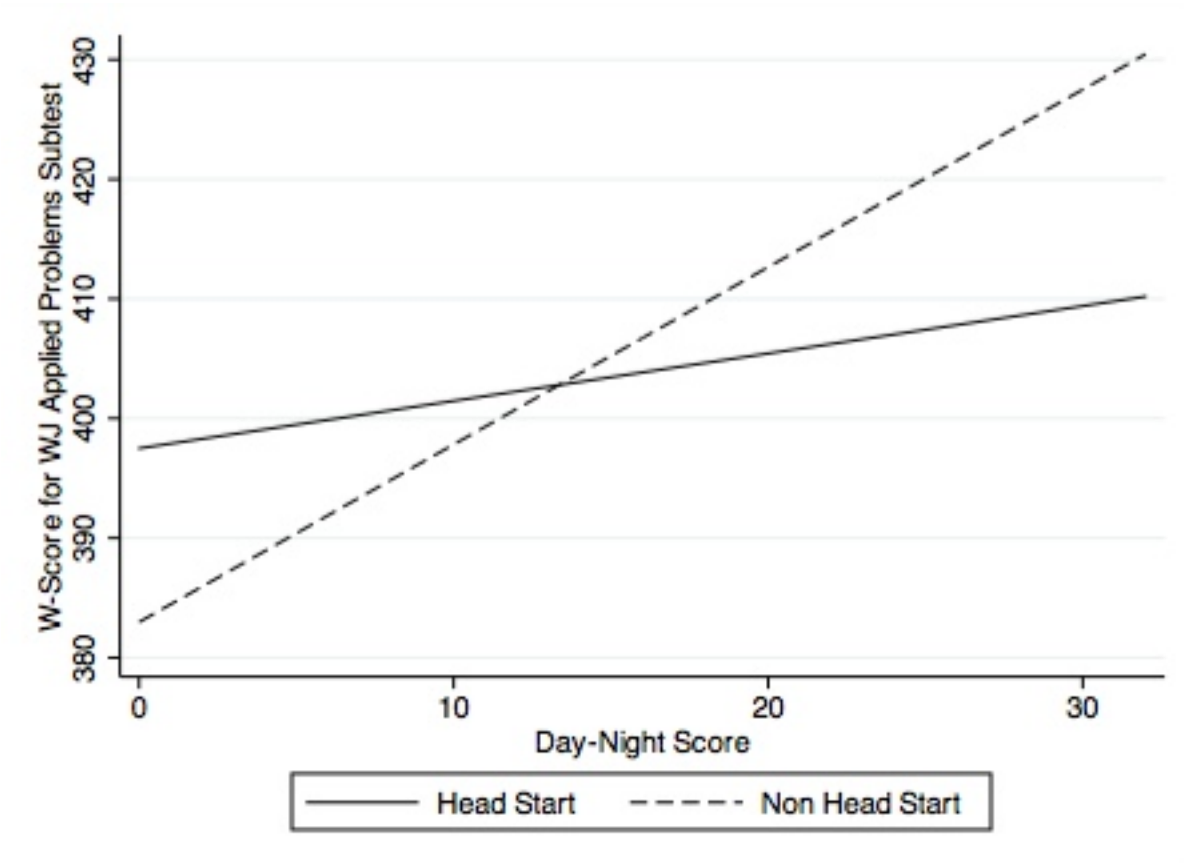

Figure 1. Interaction between Head Start Status and Day-Night Stroop for Predicting Mathematics Performance

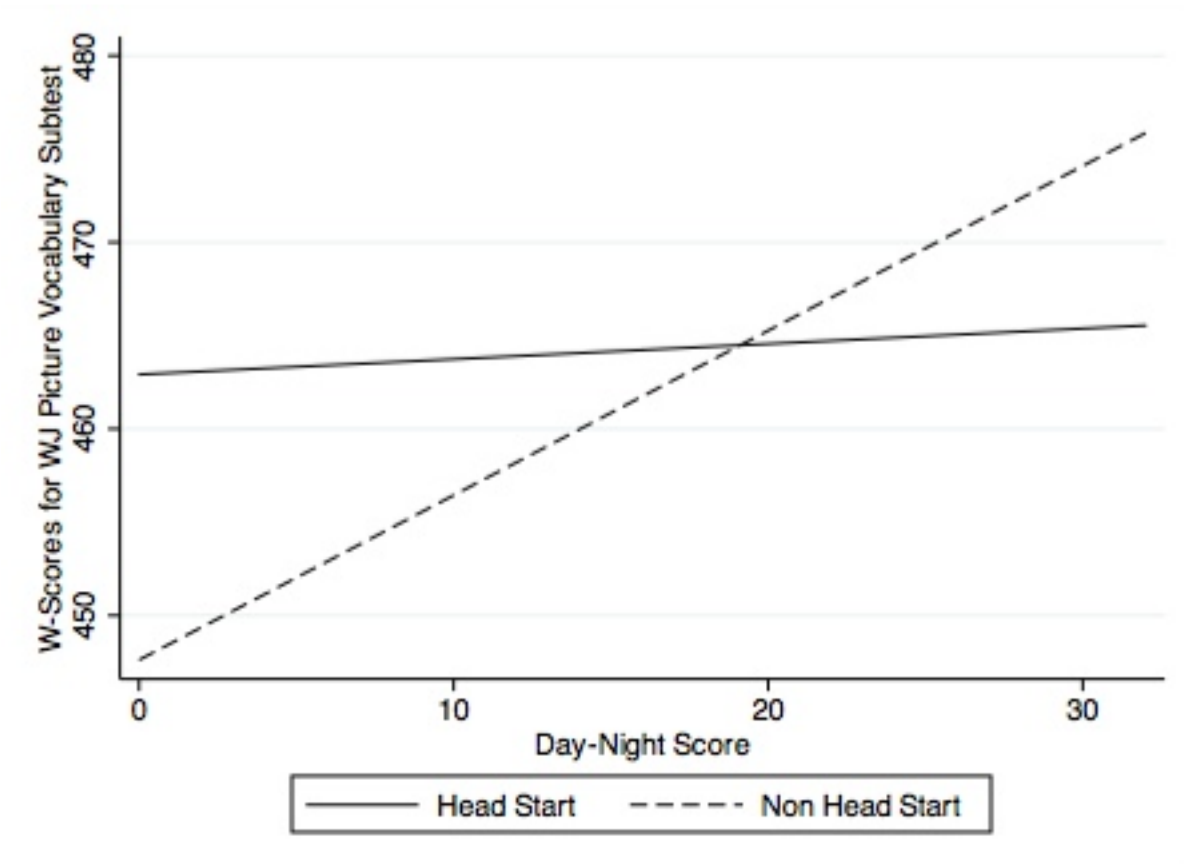

Figure 2. Interaction between Head Start Status and Day-Night Stroop for Predicting Vocabulary