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Executive Control Goes to School: Implications of Preschool Executive Performance for Observed Elementary Classroom Learning Engagement

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Abstract

The transition to elementary school is accompanied by increasing demands for children to regulate their attention and behavior within the classroom setting. Executive control (EC) may be critical for meeting these demands; however, few studies have rigorously examined the association between EC and observed classroom behavior. This study examined EC in preschool (age 5 years, 3 months) as a predictor of classroom learning engagement behaviors in first grade, using a battery of performance-based EC tasks and live classroom observations in a longitudinal sample of 313 children. Multilevel modeling results indicated that stronger EC predicted more focused engagement and fewer task management and competing responses, controlling for socioeconomic status, child sex, and age at observations. Results suggest that early EC may support subsequent classroom engagement behaviors that are critical for successful transition to elementary school and long-term learning trajectories.

Keywords

executive control; classroom behaviors; focused engagement; task management; competing responses; elementary school

The transition to elementary school is characterized by a dramatic change in expectations for children to regulate their attention and behavior to achieve academic success (Li-Grining, Votruba-Drzal, Maldonado-Carreño, & Haas, 2010; Portilla, Ballard, Adler, Boyce, & Obradovic, 2014). Whereas most early child care and preschool settings make minimal demands for sustained focus given young children's limited capacity (Fisher, Hirsh-Pasek, Newcombe, & Golinkoff, 2013), elementary school classrooms typically impose substantially greater expectations for children to direct and sustain their attention toward academic work (Ladd, 1996). Given the importance of this transition, which coincides with the so-called "*5 to 7 year shift*" in cognitive development (Sameroff & Haith, 1996),

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considerable research has focused on understanding the factors that promote success at this critical juncture. Executive control (EC; also known as "executive function") has been proposed as a potentially important set of abilities for navigating the shifting expectations of formal schooling (Bierman, Nix, Greenberg, Blair, & Domitrovich, 2008); however, studies rigorously examining the role of EC in the transition to elementary school are currently limited by their typical use of standardized measures of academic achievement, rather than ecologically valid, "real world" measures of children's behavior in the classroom. The present study aims to address this issue by using structured classroom observations of children's learning engagement behaviors within a longitudinal study of early EC development.

EC can be defined as a set of higher-order brain functions drawn upon to direct goal-oriented thoughts and behaviors, including the abilities to maintain information active in working memory, inhibit inappropriate thoughts and actions, and flexibly shift between different rules or demands (Garon, Bryson, & Smith, 2008). A significant and growing literature has documented the unique relevance of early EC for children's performance on standardized tests of academic skills, such as mathematics and reading (Blair & Razza, 2007; Bull, Espy, Wiebe, Sheffield, & Nelson, 2011; Clark, Sheffield, Wiebe, & Espy, 2013; Espy, McDiarmid, Cwik, Stalets, Hamby, & Senn, 2004). Additionally, EC supports healthy behavior and social skills that also contribute to success in school (Espy, Wiebe, Sheffield, Clark, & Moehr, 2011; Hughes & Ensor, 2011).

Although the correlations between measures of EC and standardized achievement tests are impressive, at least some of their overlap likely reflects the fact that both are administered in formal, one-to-one contexts. Given that EC is conceptualized as a broad-based system that organizes goal-directed behavior, it is critical also to consider the relation of EC assessments to *key behaviors manifested in the everyday classroom environment*. Children's learning-related behaviors – including active engagement with classroom tasks and self-regulated use of learning strategies – have been found to predict school success, above and beyond IQ and instructional environment (Ladd & Dinella, 2009; Muruyama, Pekrun, Lichtenfeld, & vom Hofe, 2013). A small number of recent studies have explored the association between EC and learning-related behaviors, with child EC significantly correlating with concurrent teacher ratings of child learning behaviors (Neuenschwander et al., 2012; Sasser et al., 2015). Further, Nesbitt and colleagues (2015) found that stronger EC was associated with greater levels of observed child engagement in learning activities, as well as less unoccupied and disruptive behavior, in preschool classrooms. These learning behaviors, in turn, mediated the association between EC and academic achievement later in the preschool year. These results are also consistent with findings by Brock and colleagues (2009) linking EC with both teacher-rated classroom behaviors and observed engagement during kindergarten.

Despite emerging evidence that EC is related to child learning behaviors, additional studies are needed to more fully explicate the relation of early EC to critical classroom behaviors. In particular, studies employing rigorous observational methods to assess child learning behaviors in the classroom remain limited (see Brock et al., 2009; Diaz et al., in press; and Nesbitt et al., 2015, for rare examples of observational studies). Systematic classroom observations are critical for capturing specific learning-related behaviors and overcoming the limitations of teacher-reported ratings, which may miss more subtle non-disruptive behaviors or reflect more global impressions of the child rather than specific behaviors. Extensive educational literature has shown that in-vivo observation of discrete classroom engagement behaviors is a better predictor of skill development than more global composite ratings (Chafouleas, 2011; Wakschlag et al., 2005). Further, although studies have examined the association between EC and classroom behaviors in preschool (e.g., Nesbitt et al., 2015) and elementary school (e.g., Neuenschwander et al., 2012), specifically, studies spanning the *transition* from preschool to elementary school are quite limited. In fact, we are not aware of any published studies that include measurement of EC in preschool – which is a critical period for EC development (Clark et al., in press; Garon et al., 2008) – predicting observed classroom behaviors in elementary school. Such an investigation is needed to determine *whether early EC predicts subsequent adaptation to the demands of the elementary school classroom environment*.

Engagement can be defined as a child's active attempts to interact with the classroom environment in a way that best promotes learning (Cadima, Doumen, Verschueren, & Buyse, 2015). Children's graded and variable levels of classroom engagement have been quantified based on observed behaviors (Greenwood, Terry, Marquis, & Walker, 1994). First, *focused engagement* refers to optimal, positive engagement behaviors and includes direct involvement in academic tasks, such as writing, reading aloud, and asking or answering questions (Greenwood et al., 1984; Greenwood, Horton, & Utley, 2002). These behaviors reflect the highest levels of behavioral engagement and relate positively to standardized academic test performance (Wanzek, Roberts, & Otaiba, 2014). Second, *task management* encompasses behaviors that prepare a child to engage in an academic response if given the opportunity (Greenwood et al., 2002), including looking at the teacher, hand-raising, and locating materials (Greenwood et al., 1984). Third, *competing*, or inappropriate, behaviors include non-engaged behaviors that detract from meeting classroom expectations, such as non-compliance with teacher requests, looking around, and disruption of peers. In general, these behaviors encompass anything disruptive to the educational directives in the classroom and the child's personal learning, and they negatively correlate with academic achievement (Greenwood et al., 1984). Competing behaviors typically co-exist with problems with mastery, persistence, motivation, and externalizing behavior (Dominguez, Vitiello, Maier, & Greenfield, 2010).

EC may be particularly relevant to active, engaged classroom learning. Strong EC is expected to support focused engagement by providing the core regulatory capacity needed to direct attention and behavior toward a specific academic task. The ability to sustain attention, remember task instructions, and enact an appropriate response, all while refraining from potentially distracting behaviors, is essential for the consistent engagement that supports learning and future academic success (Ladd & Dinella, 2009). Relatedly, strong EC likely limits competing or inappropriate behaviors that interfere with adaptive engagement. Given the association between poor EC and externalizing problems (Espy, et al., 2011), lower EC can be expected to contribute to competing behaviors during structured classroom time upon entering school. Work considering EC in relation to task management is too limited to inform specific hypotheses at this time. On one hand, time spent engaging in these "pre-academic" responses may reflect strong regulatory ability to engage in behaviors that may ultimately support actual academic responses. On the other hand, children who engage in these behaviors at the expense of academic productivity may display an inefficiency in transitioning from task management to focused engagement, reflecting sub-optimal regulatory abilities that ultimately undermine classroom engagement.

The goal of the current study was to examine the role of EC in the critical period of preschool for learning engagement behaviors in the transition to elementary school, using rigorous classroom observations. To our knowledge, this is the first study to investigate this issue across the so-called “5 to 7 year shift” using performance-based measures of preschool EC and classroom-based observations of child learning engagement behaviors in elementary school. We hypothesized that higher preschool EC would predict more focused engagement and fewer competing behaviors in elementary school. We also examined the association between EC and task management, although the literature in this area was insufficient to make a directional a priori hypothesis. Overall, this study makes a unique contribution in elucidating the importance of early EC for learning behaviors at a critical and challenging transition. Given evidence for the modifiability of EC, particularly in preschool (Diamond & Lee, 2011), the findings have the potential to inform interventions to promote healthy academic trajectories.

Method

Participants

The participants were 313 children (51.12% female) recruited through flyer distribution for a longitudinal study spanning preschool and elementary school in a small Midwestern city. Because the overarching study was focused on describing typical EC development, children were excluded if they had a *diagnosed* developmental, language or behavioral disorder at the time of initial enrollment. Families for whom the primary language spoken at home was not English were also excluded. Children with diagnosed developmental or language delays that were reported by the parent after enrollment were excluded, as well. Importantly, children who were diagnosed with a behavioral disorder subsequent to enrollment were *not* excluded. Only 7 children in the sample of 313 were diagnosed with a behavioral disorder after enrollment, including 5 children who were diagnosed with attention-deficit/hyperactivity disorder (ADHD) only and 2 children who were diagnosed with both ADHD and conduct disorder. The sample was stratified by sociodemographic risk, with an oversampling for children with higher risk status (56.23% receiving public medical assistance at the time of enrollment, by parent report). The sample was regionally representative in terms of race and ethnicity with 63.58% Caucasian, 13.42% Hispanic, 3.83% African American, 0.32% Asian, and 18.85% multiracial.

Procedures

All participants completed laboratory sessions at age 5 years, 3 months as a part of the preschool phase of the larger study. During this visit, each child completed a battery of individually-administered developmentally-appropriate tasks assessing key aspects of EC. Families were later invited to participate in the elementary school follow-up phase beginning in first grade. In the Fall of first grade, parents provided consent for this phase of the study, including school observations. At this point, the research team contacted school principals and then teachers to obtain permission to conduct classroom observations. Two one-hour observations per child, within 2 weeks of each other in the Fall semester (but not within the first month of the school year), were scheduled for times that the teacher identified as periods of academic instruction (regardless of the specific subject covered). Trained coders who had not had previous contact with the target child then conducted observations at the scheduled time. If the child was absent on the day of the scheduled observation, the observation was rescheduled for another day. Children were observed in the classrooms of 126 different teachers across 51 different schools. Child age at the first classroom observation ranged from 6.03 to 7.59 years (mean age = 6.72, SD = .34), with a mean time lag of 1.48 years between the EC assessment and classroom observation.

A total of 313 children completed the EC tasks at age 5 years, 3 months. Of these children, 109 did not participate in classroom observations for the following reasons: child was already past the fall semester of first grade when enrolled in the elementary school project phase (due to a gap in research funding; n=70); parents did not consent for elementary school phase (n=13); parents did not consent for observations, specifically (n=2); child was homeschooled (n=5); child's school was located outside of study area (n=9); child's teacher/school did not grant permission for observation (n=10). Attrition was not related to child sex, income-to-needs ratio, or performance on any of the EC tasks (ps>.05). However, given the relative advantages of including all participants with data from at least one wave of a longitudinal study instead of using listwise deletion (see Enders & Bandalos, 2001; Widaman, 2006), all 313 participants with data from age 5 years, 3 months were included in the analyses using maximum likelihood estimation.

Measures

Executive control in preschool—The EC battery consisted of nine tasks administered to children during laboratory visits at age 5 years, 3 months. Table 1 provides a brief description of each task. Tasks varied in terms of format and response demands, and each was selected to assess a core aspect of EC in a developmentally-appropriate manner. Measures of the child's ability to maintain and manipulate information in mind (working memory) included *Nine Boxes* (adapted from Diamond et al., 1997), *Delayed Alternation* (Espy et al., 1999), and *Nebraska Barnyard* (adapted from Noisy Book task; Hughes, Dunn, & White, 1998). Tasks assessing the ability to inhibit mental associations or behavioral responses (inhibitory control) included *Big-Little Stroop* (adapted from Kochanska, Murray, & Harlan, 2000), the *Go/No-Go* task (adapted from Simpson & Riggs, 2006), *Shape School - Inhibit Condition* (Espy, 1997; Espy, Bull, Martin, & Stroup, 2006), and a modified version of the *Snack Delay* task (adapted from Kochanska, Murray, Jacques, Koenig, & Vandegeest, 1996; Korkman, Kirk, & Kemp, 1998). Measures of the ability to shift between changing task demands (flexible shifting) consisted of *Shape School – Switching Condition* (Espy, 1997; Espy et al., 2006) and the *Trails* task – Switching Condition (modified from Espy & Cwik, 2004). A detailed description of each task, along with extensive psychometric information, is provided in James et al. (in press). Outlier scores on tasks were trimmed to 3 standard deviations from the mean to reduce skewness. Previous work using these tasks with preschool children has found that the factor structure is parsimoniously represented by a unitary EC construct with all 9 tasks loading directly onto a latent EC factor (Nelson et al., in press). This unitary factor structure was tested in the current sample to ensure its appropriateness at age 5 years, 3 months as a precursor to predictive models.

Classroom learning engagement in first grade—Learning engagement behaviors were assessed via live classroom observations by a trained coder using the Mainstream Version-Code for Instructional Structure and Student Academic Response (MS-CISSAR) protocol (Greenwood et al., 1994). The MS-CISSAR is a system for sampling and coding behavioral observations of elementary school children in a classroom setting and provides for the collection of detailed information regarding the student and teacher behavior, as well as the broader classroom setting. Coders used the Ecobehavioral Assessment Systems Software (EBASS; Greenwood, Carta, & Dawson, 2000), which is a computer-based program designed to support data collection with the MS-CISSAR. Although the MS-CISSAR has often been used as a measure of student engagement in the context of special education and intervention, it was originally used in classrooms with typically-developing students (Greenwood, 1991) and was chosen for this study based on its well-established reputation, measurement properties, and validity studies showing that observations across 1–2 days are positively correlated with academic achievement scores (Greenwood et al., 1994; Greenwood et al., 2002).

In the current study, 120 minutes of total observation time with the MS-CISSAR was planned across two days for each participant in his or her regular classroom setting. The actual observation time for each participant ranged from 96 to 120 minutes (mean = 118.49 minutes). Each observation session was divided into 1-minute observation cycles, during which student, teacher and classroom data were collected. Student data, which were the focus of the current study, were collected based on observation for 20 seconds in each 1-minute interval. (Note: Teacher and classroom data were collected for the remaining 40 seconds of each minute, but those data were not used in the current study.) Therefore, within the 120 minute observation time, the *child's* behavior was observed for up to 120 observations of 20 seconds each, resulting in a maximum of 40 minutes of total observation time for each child, which is consistent with recommendations and previous studies (e.g., Greenwood et al., 1994; Greenwood et al., 2002). Three categories of student data were available for coding during each student observation interval: *focused engagement*, *task management*, and *competing response*. These categories corresponded to definitions of each provided in the Introduction, and the presence of a coded behavior was recorded by observers. Although most intervals are coded as only one of these categories (and at least one code is given for each interval), it is possible to have multiple codes for a given interval if multiple behaviors are observed at the time of coding.

Twelve coders were trained to reliability on the MS-CISSAR before completing classroom observations. Approximately 21% of the observation sessions were independently coded by two raters to facilitate an examination of reliability. Inter-rater reliability was excellent (97.3% agreement for student codes).

Socioeconomic status—As a part of the larger study, parents reported on family income and size, which were used to derive the family's income-to-needs ratio by dividing the total household income by the federal poverty threshold for a family of that size. Family income-to-needs ratio (mean = 2.53; SD = 2.99) was used as a proxy variable for socioeconomic status.

Statistical Methods

Prior to modeling EC and its relation to specific classroom behavior codes, we conducted a descriptive analysis of the distributions of each behavior code within the sample using SAS 9.4 (SAS Institute, Cary, NC). Subsequent latent modeling analyses were conducted in Mplus 7.4 (Muthén & Muthén, Los Angeles, CA), with a critical α of .05 for all tests. Analyses were conducted including all participants with EC data from preschool (N=313) using maximum likelihood estimation. To evaluate latent EC structure, a unitary model was tested, where all tasks loaded on a single common factor, as well as a two-factor model that included both working memory and inhibition constructs and a three-factor model that included working memory, inhibition and flexible shifting constructs. The indicators used to specify latent constructs were the same as those used in previous analyses of preschool EC (see Espy et al., in press), with one exception. For the Big-Little Stroop, mean response time for correct conflict trials was selected as the dependent variable, rather than the percent correct for conflict trials variable used previously, due to better distribution for response time in this sample at this age. Because lower times reflect better performance on this task, Big-Little Stroop was reverse coded in creating the latent EC factor so that all loadings were positive. Model fit was assessed using the Root Mean Square Error of Approximation (RMSEA; Browne & Cudeck, 1993) and the Comparative Fit Index (CFI). RMSEA values less than 0.06 and CFI indexes between .95 and 1.00 indicate good fit (Hu & Bentler, 1999). All models were nested, so the χ^2 difference test was used to compare model fit. Where models did not differ significantly, the simpler model was preferred on the basis of parsimony (Bollen, 1989). Classroom observation data are nested; therefore, the model examining the impact of early EC on engagement behaviors used a multilevel model composed of children nested within classrooms.

Results

Description of Child Learning Engagement

There was considerable variability in the relative frequency of child learning engagement behaviors observed. Across all observations, 28.8% of intervals were coded as focused engagement, 57% were coded as task management, and 25.7% were coded as competing responses. (Note: Total sums to more than 100% because more than one category may be coded during a single observation interval.) The range of intervals coded in the different categories for individual children was 11%–67% for focused engagement, 26%–85% for task management, and 1%–73% for competing responses.

EC Factor Structure

As a precursor to predictive models, the factor structure of EC in the current sample was examined using confirmatory factor analysis. Specifically one- (unitary EC), two- (working memory and inhibition), and three-factor (working memory, inhibition, and flexible shifting) models were compared to determine the most appropriate factor structure. Model comparison results found the unitary EC structure to be preferred because the psi matrix was not positive definite for the 2- and 3-Factor EC models. The latent correlation between working memory and inhibition in the 2-factor model was estimated to be over 1, further suggesting a unitary model for EC best represents the data. All EC tasks loaded significantly on the unitary EC factor and the model fit was good (χ^2=34.68, *p*=.119; RMSEA=.033; CFI=.96).

EC and Classroom Behaviors

To examine EC as a predictor of classroom learning engagement behaviors, a multilevel model with latent EC in preschool predicting the three student-level behavior categories in first grade was specified. MLR estimation was used and missing data were handled using maximum likelihood under the MAR assumption. The model accounted for nesting of children within classrooms and controlled for income-to-needs ratio, child sex, and child age at observation. The interclass correlation was .013 for focused engagement, .162 for task management, and .000 for competing response. The variability in competing response between classrooms was negligible (<1%); therefore, competing response was included only as a within-level variable.

As shown in Figure 1, after controlling for covariates, preschool EC significantly predicted focused engagement (*unstandardized b* = .020, *p*=.014) and competing response (*unstandardized b* = −.036, *p*=.004), as hypothesized, with stronger EC associated with more focused engagement and fewer competing responses. Preschool EC also significantly predicted task management (*unstandardized b* = −.026, *p*=.023), with stronger EC predicting less task management. EC accounted for 25% of the total variance across the three classroom engagement variables after controlling for covariates (pseudo-R^2 = .25).

To ensure that the results were not driven primarily by a small number of children with behavioral disorders, the analyses were re-run excluding the 7 children with behavioral disorders diagnosed after study enrollment. The results were essentially unchanged with stronger EC significantly predicting more focused engagement (*unstandardized b* = .024), fewer competing responses (*unstandardized b* = −.037), and less task management (*unstandardized b* = −.026).

Discussion

Although previous studies have linked EC and learning behaviors, the current study makes novel contributions both in its unique longitudinal timing and rigorous assessment strategy. By spanning preschool and elementary school, this study provides insight into how early EC “sets the stage” for a successful transition to elementary school when increasing classroom demands press children to deploy these abilities. Our use of a structured classroom observation and coding system enabled us to examine relations between early EC and subsequent engagement behaviors that are critical for academic success. Further, the current study employed an extensive and well-validated EC task battery in preschool, expanding on previous studies that have used more limited batteries. Taken together, the rich measurement of key constructs at theoretically important junctures in development makes the current study a unique and powerful investigation of the role of early EC in later classroom success.

The findings of the current study are consistent with a priori hypotheses and literature on EC and learning behaviors, with preschool EC significantly predicting all three types of engagement behaviors in elementary school. The finding that stronger EC predicted more focused engagement is consistent with expectations and studies finding EC predicts on-task classroom behavior (Brock et al., 2009) and level of instructional involvement (Nesbitt et al., 2015). Focused engagement, although sometimes only a single observable behavior, requires children to draw on the core elements that comprise EC to enact the desired behavior. Such responses typically require children to direct attention to teacher instructions and hold the information in mind (working memory), inhibit potential distracting competing responses (inhibitory control), and flexibly adjust to different instructions for different tasks (flexible shifting). EC in preschool is best modeled as a unitary factor, suggesting that the variance shared by the EC measures reflects a single, overarching regulatory process that correlates with active regulation in the classroom. Accordingly, neuroimaging studies have shown that EC tasks generally involve both common activation of a diffuse fronto-parietal network, as well as more localized activation according to specific task requirements (Niendam et al., 2012). More complex tasks, including those with multiple-step instructions and requiring sustained attention, may particularly tax this superordinate coordinating control system, demanding stronger EC to support adaptive responding. This coordinated effort drawing on the full dimensionality of effortful EC may go awry for children with poor EC. The more complex demands of the elementary school classroom, therefore, “press” EC to a level not experienced in earlier settings, exposing immature EC and making strong EC a prerequisite for consistent engagement.

The finding of a negative relation between EC and competing responses was consistent with expectations and previous literature linking poor EC with externalizing behavior (Espy et al., 2011) and disruptive classroom behaviors in preschool (Nesbitt et al., 2015). Competing behaviors detract from appropriate engagement and may be disruptive to learning for both the target child and other children. Refraining from such inappropriate behavior actually requires two types of inhibition: *response inhibition*, which involves inhibiting overt behavior, and *interference suppression inhibition*, which involves inhibiting attention to distracting stimuli (Nigg, 2000). While children may be expected to exercise some response inhibition prior to elementary school (e.g., refraining from hitting peers), the demand for consistent interference suppression may be relatively new in elementary school. EC appears to be critical in navigating these escalating expectations.

EC also relates to task management, with better preschool EC significantly predicting *less* task management behavior in elementary school. This finding may at first seem counter-intuitive because task management can be viewed as preparation for academic responding. The broader pattern of results, however, suggests that children with poorer EC spend more time engaging in task management *at the expense* of actual academic responding, as evidenced by the negative correlation between task management and focused engagement. Perhaps these children struggle to organize their attention and behavior toward focused engagement and instead spend a disproportionate amount of time and energy “getting ready” to respond, resulting in a perpetually-preparing-but-rarely-responding pattern of classroom behavior. Strong EC, on the other hand, may facilitate more efficient transitions from preparation to enactment of desired behaviors.

Some limitations of this study should be noted. First, children's classroom behaviors were observed for a relatively short period of time. Such brief observations provide only a sampling of child behavior, and it is possible that some error was introduced when children were observed on days that may not be fully representative of their usual behavior. However, the duration and rigor of the observations used in this study compare favorably to previous studies in this area, and the relatively large sample helps to strengthen confidence in the findings. Second, although this study links early EC and later academic engagement behaviors, the ultimate effects on academic *outcomes* were not examined. While the literature linking EC with academic outcomes – as well as research demonstrating an association between classroom engagement behavior and academic trajectories – points to a possible path from preschool EC to elementary classroom behavior to long-term academic success, a longitudinal study including academic outcomes later in development is needed. Finally, it is worth noting that although the measurement model showed good fit, the fit of the predictive model was only adequate.

Despite these limitations, the current study builds on the existing literature by rigorously measuring EC and specific learning-related behaviors in a longitudinal study across a key developmental transition. The results have potentially important implications for intervention and research. In terms of intervention, this study highlights the role of early EC as a potential target in promoting healthy transitions to formal schooling. Given the observed associations between EC and key learning behaviors, it is possible that efforts to promote early EC development, particularly during the critical period of preschool, may pay academic dividends later by equipping children with the abilities needed to successfully meet the expectations of elementary school. This is especially important given the well-documented "Matthew effect," in which children who enter the classroom environment ill-equipped to manage its demands fall increasingly behind over the course of their schooling careers (Bakermans-Kranenburg, van IJzendoorn, & Bradley, 2005). The growing evidence for a variety of EC interventions (Diamond & Lee, 2011) suggests the potential impact of targeted intervention to remediate critical deficits prior to the start of formal schooling. Efforts to promote stronger EC among preschoolers are underway (e.g., Traverso, Viterbori, & Usai, 2015) and show considerable promise; however, research to test the "downstream" effects of early EC interventions on critical classroom behaviors and, ultimately, key academic and social outcomes is needed.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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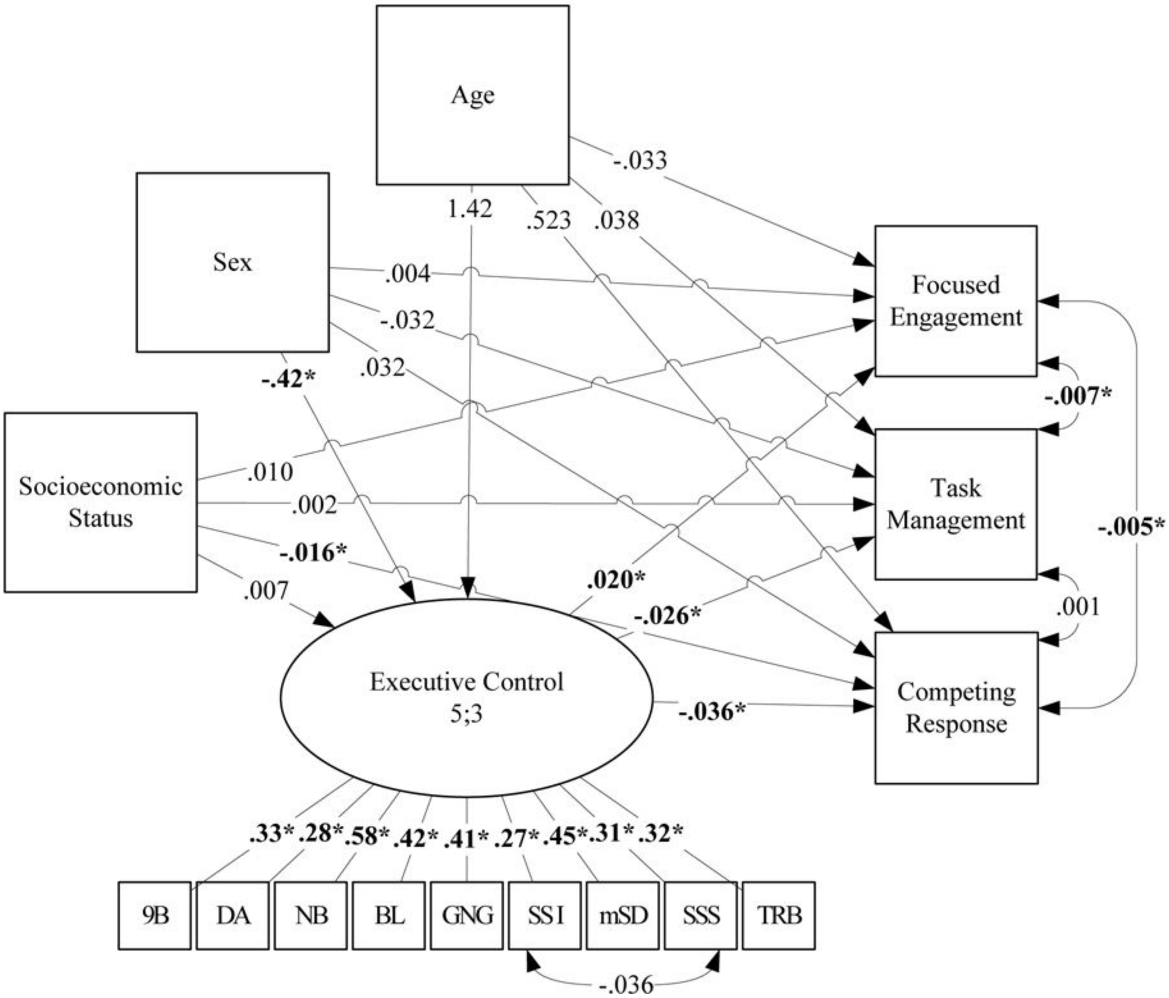

Figure 1. Predictive model results

9B = 9 Boxes; DA = Delayed Alternation; NB = Nebraska Barnyard; BL = Big Little Stroop; GNG = Go-No-Go; SSI = Shape School Inhibit; mSD = modified Snack Delay; SSS = Shape School Switch; TRB = Trail Making Test

Predictive Model Fit: $\chi^2 = 114.5$, $p < .05$, RMSEA = .051; CFI = .90

Note: All estimates are unstandardized.

Table 1

Brief descriptions of executive control tasks

Task	Description
Working Memory	
Nine Boxes	Child chooses one of nine boxes of varying color and shape in each trial to search for reward. Child must keep color and shape of previously searched boxes in mind to find rewards in fewest possible trials. Boxes are scrambled for each trial.
Delayed Alternation	Child chooses between two locations on a testing board to find a reward. Location of reward alternates, so child has to keep the last location in mind over a delay to find the reward.
Nebraska Barnyard	Child is shown a 3×3 arrangement of squares with animal figures on a touchscreen. Pictures are removed and child touches squares corresponding to locations of sequences of animal names. Sequence length increases across trials.
Inhibition	
Big-Little Stroop	Child is asked to name smaller drawings embedded within a larger drawing. On “conflict trials” the child must suppress the name of the larger object and instead name only the smaller drawings.
Go/No-Go	Child is told to press a button in response to fish stimuli on screen but to inhibit response to shark stimuli.
Shape School – Inhibit Condition	Child is asked to say the color of cartoon stimuli with happy faces but to inhibit naming for stimuli with sad faces.
modified Snack Delay	Child is told to stand still when presented with distraction and tempting candy reward until a bell rings.
Flexible Shifting	
Shape School – Switching Condition	Child is asked to say the color of cartoon stimuli without hats and say the shape of stimuli with hats.
Trails – Switching Condition	Child is ask to alternate between stamping dog and bone stimuli of increasing size.

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