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Longitudinal associations between self-regulation and the academic and behavioral adjustment of young children born preterm

Janean E. Dilworth-Bart*, Julie A. Poehlmann-Tynan, Amy Taub, Carolyn A. Liesen, Daniel Bolt

University of Wisconsin-Madison, United States

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A B S T R A C T

Much of the research to date about the structure of self-regulation in early childhood has been conducted with low medical risk samples, with the general conclusion that self-regulation can be separated into overlapping executive function and effortful control factors that differentially predict child outcomes. We examined the factor structure of 36-month self-regulation among children born prematurely ($n = 168$) and the extent to which self-regulation predicted maternal ratings of children's socioemotional and academic competence when they were six years of age. Statistical analyses revealed a single self-regulation factor for this high neonatal risk sample, and this self-regulation factor mediated associations between early sociodemographic risk and mothers' ratings of academic competence and externalizing problems. Our findings suggest that early intervention research with children born preterm should focus on promoting supportive early environments, particularly parental sensitivity to infant cues.

Executive function (EF) and effortful control (EC) originate in different scholarly traditions. Nevertheless, they both refer to the volitional control and inhibition of attention (Vohs & Baumeister, 2004) and other innate behaviors, in addition to being measured in similar ways (Zhou, Chen, & Main, 2012). Recent attention to the conceptual and measurement overlap between the two has led some scholars to call for a unified model of self-regulation in early childhood that incorporates research and theory from both literatures (e.g., Bridgett, Oddi, Laake, Murdock, & Bachmann, 2012; Zhou et al., 2012). Research using confirmatory factor analytic approaches counter this call, indicating that despite their similarities, self-regulation can be meaningfully separated into EC and EF latent variables among children born at term (e.g., Brock, Rimm-Kaufman, Nathanson, & Grimm, 2009; Willoughby, Kupersmidt, Voegler-Lee, & Bryant, 2011). However, there is limited knowledge about single- or multifactorial models of self-regulation in children born prematurely (≪37 weeks gestation), including how such models relate to subsequent socioemotional and behavioral outcomes in this high-risk group. Such knowledge can provide critical insight into how and when self-regulation develops as well as inform the content and timing of intervention for both typically developing and high-medical risk children.

We examined the extent to which 36-month self-regulation predicted mothers' ratings of socioemotional and academic competence when children were six years old using one- and two-factor models of self-regulation. We focused on children born prematurely due to the potential brain abnormalities associated with being born prior to term, and the relation between these abnormalities and self-regulation deficits. This topic is particularly relevant for preterm children because of their increased risk for developing less-than-optimal behavioral and socioemotional outcomes in infancy and toddlerhood, as well as poorer academic outcomes as they reach school age (Arpi & Ferrari, 2013; Bhutta, Cleves, Casey, Cradock, & Anand, 2002; Scott et al., 2012).

1. Self-regulation among children born prematurely

Scholars who study emerging self-regulation in young children have often done so from either temperament (EC; Rothbart, Ellis, & Posner, 2004) or cognitive processing/neuropsychological (EF; Welsh & Pennington, 1988; Welsh, Pennington, Ozonoff, Rouse, & McCabe, 1990) perspectives. The empirical literature suggests that EF and EC are related skill sets that develop in a manner corresponding to the maturation of the prefrontal cortex (Bechara, Damasio, Damasio, & Anderson, 1994; Bush, Luu, & Posner, 2000; Happaney, Zelazo, & Stuss, 2004). EC is more often associated with self-regulation in emotionally laden contexts in which children are required to control their responses to cues for immediate reward or punishment (Blair & Razza, 2007; Rothbart et al., 2004). EF is more associated with emotionally neutral contexts requiring cognitive control (Blair & Razza, 2007; Zhou et al., 2012).

The EC and EF distinctions provide a means of specifying the diverse

* Corresponding author at: Department of Human Development and Family Studies, 4198 Nancy Nicholas Hall, 1300 Linden Drive, Madison, WI, United States.
E-mail address: jedilworth@wisc.edu (J.E. Dilworth-Bart).

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subsets of skills that fall under the more general self-regulation term (Willoughby et al., 2011). However, these distinctions are not universally accepted and are replete with conceptual and methodological issues, including the use of identical measures to assess both constructs and specifying the relative heat or coolness of a task and individual differences in experiencing a given task as affect-laden or affect-neutral (Welsh & Peterson, 2014; Zhou et al., 2012). Much of the research in this area has also focused on low medical risk children, with less consideration of the extent to which the structure of self-regulation may be different in high medical risk children.

Identifying potential differences between children who experience high versus low medical risks early in life is important because of the possibility that these early experiences shape how self-regulation develops. For example, two separate studies of self-regulation development of high neonatal risk children observed within-group variation in self-regulation development (e.g., Feldman, 2009; Poehlmann et al., 2010). Feldman's (2009) findings from a longitudinal study of 125 infants born preterm suggest that children's ability to regulate their behaviors develops hierarchically across the first five years of life, beginning with physiological regulation during the neonatal period, emotion regulation in year one, attention regulation in year two, and self-regulation (indexed by a global EF score, a latent self-restraint variable, and a latent behavior problems variable) by year five. Feldman (2009) also observed bidirectional associations between EF and behavior problems and a unidirectional relation between EF and self-restraint at five years old. However, this study did not address the extent to which self-regulation predicted child behavior outcomes across time-points, nor did it examine academic outcomes.

Poehlmann et al. (2010) extended this work by examining changes in the emerging self-regulation of children born prematurely over 24- and 36-month time-points. Although they did not observe predictive associations between 24-month EC and 36-month behavior problems, the authors did find that 24- and 36-month EC composites predicted later cognitive ability. They also observed significant improvement in EC abilities across the two time-points.

Together, Feldman's (2009) and Poehlmann et al.'s (2010) findings point to significant developmental changes in self-regulation across the early life-span among children born preterm.

Yet, neither study addressed whether self-regulation is best represented by a unitary factor or a multi-factorial model composed of specific tasks used to construct EC and EF latent variables. This distinction is particularly important when studying children born prematurely because these children are prone to emotion and behavior regulation problems that can negatively impact the quality of early parent-child interactions (Clark, Woodward, Horwood, & Moor, 2008; Poehlmann et al. 2010) which, in turn, has negative implications for social and academic competence (e.g., Boyce, Cook, Simonsmeier, & Hendershot, 2015; Treyvaud et al., 2016).

The timing of premature birth can have significant impacts on brain development, with children born the most premature experiencing the greatest negative impact (Adams-Chapman, 2009; Kinney, 2006). Instead of experiencing the increase in brain volume and myelination that characterizes the last month of gestation in utero (Ball et al., 2012; Kinney, 2006), children born preterm often experience this critical period in development in high stress neonatal intensive care units (NICUs) (Smith et al., 2011; VandenBerg, 2007). Children born preterm are at significant risk for brain deficits associated with exposure to high stress in the NICU, along with the risk for brain injury associated with prematurity. These events may culminate in a potentially different structure of early self-regulation and developmental timing for this subset of children.

Conceptual clarity about the structure of self-regulation is a critical step toward developing effective interventions targeting parent-child interaction quality as a means of enhancing the self-regulation and, thereby, academic and socioemotional outcomes of children born prematurely. Existing research already demonstrates that preterm infants benefit from high quality scaffolding of emerging neurocognitive skills (Landry, Miller-Loncar, Smith, & Swank, 2002). However, the extent to which parent-child interactions are successful in promoting self-regulation depends on the types of behaviors in which parents engage (Dilworth-Bart, Poehlmann, Hilgendorf, Miller, & Lambert, 2010) and child characteristics such as emotionality (Dilworth-Bart, Miller, & Hane, 2012; Poehlmann et al., 2011).

We focus on children born prematurely due to the potential brain abnormalities associated with being born prior to term, and the relation between these abnormalities and self-regulation deficits (Aarnoudse-Moens, Weisglas-Kuperus, van Goudoever, & Oosterlaan, 2009; Baron, Erickson, Ahronovich, Baker, & Litman, 2011; Espy et al., 2002; Orchinik et al., 2011). Our analyses included tasks used by EF and EC researchers to index suppressing or initiating response to signal/inhibitory control, working memory, ability to delay, and effortful attention.

1.1. Suppressing or initiating response to signal/inhibitory control

Suppressing or initiating response to signal, or inhibitory control, refers to the volitional ability to stop an ongoing behavior (Eisenberg, Smith, Sadovsky, & Spinrad, 2004; Garon, Bryson, & Smith, 2008; Miyake et al., 2000). It is associated with both EF and EC (Zhou et al., 2012), further pointing to the conceptual overlap between the two. In this study we include measures of suppressing or initiating response/inhibitory control that were originally conceptualized using EF (i.e., day-night stroop, Gerstadt, Hong, & Diamond, 1994) and EC (i.e., Kochanska & Knaack, 2003; Kochanska, Murray, & Harlan, 2000).

Like other aspects of self-regulation, the skill has developmental precursors in infancy (Garon et al., 2008). Children born prematurely have also been observed to have lower inhibitory control than children born at term (Aarnoudse-Moens, Smidts, Oosterlaan, Duivenvoorden, & Weisglas-Kuperus, 2009; Edgin et al., 2008; Espy et al., 2002). Aarnoudse-Moens, Smidts et al. (2009) and Aarnoudse-Moens, Weisglas-Kuperus et al. (2009) observed that early elementary school students born preterm had lower scores than children born at term on two separate inhibitory control tasks (Go/No Go and Day-Night), even after controlling for processing speed and after excluding preterm children with neurosensory impairments from the sample. However, these effects may be attributable to specific neurological impairments (Edgin et al., 2008). Edgin et al. (2008) found that children born preterm who did not display signs of white matter abnormalities performed similarly to children born full term on inhibitory control tasks, while preterm infants with brain abnormalities had inhibitory control deficits. This suggests that individual differences in inhibitory control impairments among children born preterm may be associated with severity of neonatal risk.

The inhibitory control skills of children born prematurely may reach levels similar to children born at term by elementary school. In a longitudinal study, Aarnoudse-Moens, Duivenvoorden, Weisglas-Kuperus, Van Goudoever, and Oosterlaan (2012) assessed children who were born very preterm and full term controls when they were school aged. They found an interaction effect of age and birth condition on a stop task (which measures inhibitory control), such that the effect of being preterm on inhibitory control declined with time. Four-year-old children born preterm performed 0.70 standard deviations ($p \ll 0.001$) lower than their full-term peers, whereas twelve-year-old children born preterm performed only 0.15 standard deviations ($p \gg > 0.10$) below their full-term peers (Aarnoudse-Moens et al., 2012).

1.2. Executive function

In addition to our measures of inhibitory control, we used a task purported to assess working memory to index EF.

1.2.1. Working memory

Working memory, the short-term storage and manipulation of information, has developmental precursors in infancy and toddlerhood, but undergoes rapid development from three to five years of age (Anderson, 1998; Garon et al., 2008; Miyake et al., 2000), and is typically studied by researchers with a neuropsychological or cognitive processing framework for self-regulation (i.e., EF; Zhou et al., 2012). Differences in working memory between children born prematurely and children born at term have been observed to persist into the preschool age-range, throughout adolescence, and into adulthood (Luciana, Lindeke, Georgieff, Mills, & Nelson, 2011; Luu, Ment, Allan, Schneider, & Vohr, 2011; Nosarti et al., 2007; Sun & Buys, 2011; Vicari, Caravale, Carlesimo, Casadei, & Allemand, 2011). Luu et al. (2011) found differences between 16-year-olds who were born preterm and matched controls even when limiting the preterm sample to those who are relatively low-risk (excluding individuals with neurosensory and cognitive impairments) and after controlling intelligence. Some studies (e.g., Luciana et al., 1999) suggest that spatial working memory specifically may be most impacted for children born preterm due to damage to structures in the basal ganglia and limbic system (Vicari et al., 2004).

1.3. Effortful control

In addition to our tasks assessing suppressing or initiating response to signal we used tasks purported to assess the ability to delay and effortful attention to index EC.

1.3.1. Ability to delay

The ability to delay, as a component of EC, has been measured by using a delay of gratification task requiring children to delay immediate gratification to facilitate attaining a goal (Lynn, Cuskelly, Gray, & O'callaghan, 2012). Lynn et al. (2012) examined ability to delay in children born with extremely low birth weight/extremely preterm at age 2 years in comparison with their full-term peers. They found that children born with extremely low birth weight/extremely preterm performed more poorly on the snack delay task than full-term comparison children. They also found that the performance on the delay task was positively correlated with cognitive ability and language competence.

1.3.2. Effortful attention

Effortful attention, a component of EC, is defined as the ability to intentionally focus on one, typically subordinate, perceptual feature of a stimulus (Kochanska et al., 2000). Significant group differences in children's attention have been observed between children born preterm and children born at term (Bayless & Stevenson, 2007; Shum, Neulinger, O'Callaghan, & Mohay, 2008). Bayless and Stevenson (2007) compared both EF and executive attention between children born very preterm (≪32 weeks gestational age) and children born at term, assessed between the ages of 6 and 12 years of age. They found that children born very preterm performed more poorly in both EF tasks and executive attention tasks, with significant differences in the areas of set-shifting and inhibition. Both groups scored higher on the tasks of executive attention as compared to the other tasks. In addition, Shum et al. (2008) found group differences in attention between seven- to nine-year-old children born preterm and at term in relation to sustained attention and focused attention, but no significant differences were found in selective attention.

1.4. Neonatal and sociodemographic risks and child outcomes

Self-regulation underlies important learning-related skills associated with academic and social competence (McClelland & Morrison, 2003; Montroy, Bowles, Skibbe, & Foster, 2014). Children born preterm, particularly those living in homes characterized by lower sociodemographic status, are at greater risk for lower academic and social skills (Dieterich, Hebert, Landry, Swank, & Smith, 2004; McGrath & Sullivan, 2003). Similar to observations of self-regulation deficits between children born preterm and term, the impacts of neonatal and sociodemographic risk on children's academic and behavioral outcomes are independent of child intelligence (e.g., Downie, Frisk, & Jakobson, 2005). However, the pathways from early risks to later academic and behavioral outcomes are less clear for children born preterm.

The complex relation between preterm birth, self-regulation, and child outcomes continues into the academic setting. Williams and colleagues observed that preterm birth and lower maternal education were associated with significantly increased likelihood of low math, reading, and language arts achievement among first graders (Williams et al., 2013). Yet, Frye and colleagues concluded that preterm birth, itself, did not predict lower achievement (Frye, Landry, Swank, & Smith, 2009). Their study included 253 children born term (n = 97), preterm with low neonatal risks (n = 94), and preterm with high neonatal risks (n = 62) whose reading (Word Attack; Woodcock, Kevin, & Fredrick, 2007) was assessed at third, fifth, and seventh grade. Two indicators of EF were also obtained at these time-points: the Continuous Performance Task (Halperin, Wolf, Greenblatt, & Young, 1991), a measure of sustained attention, and a modified Tower of London (Shallice, 1982), a measure of cognitive flexibility and planning. The authors observed average Word Attack scores within the normal range for all three groups. However, they further observed that children born preterm with high neonatal risks, who also had difficulties with reading, were more likely to also have significantly lower performances on the Continuous Performance Task (sustained attention) and Tower of London (cognitive flexibility and planning).

1.5. The current study

In all, the reviewed research suggests that children born prematurely have a higher likelihood of deficits on indices used in both EF and EC studies, and that these deficits can be related to poorer behavioral and academic outcomes. However, the extent to which the EC and EF distinctions are meaningful in this high-medical-risk population is less clear.

We focus on tasks used in EC and EF studies as indicators of working memory, suppressing or initiating response to signal/inhibitory control, ability to delay, and effortful attention to address two research questions. First, we sought to determine the factor structure of self-regulation at 36 months for children born preterm or with low birth weights. Contrary to previous research with low medical-risk samples (Brock et al., 2009; Willoughby et al., 2011), but consistent with emerging theory about the structure of self-regulation in early childhood (i.e., Blair & Ursache, 2011; Welsh & Peterson, 2014; Zhou et al., 2012), we hypothesized that self-regulation for this sample of children born prematurely would be most parsimoniously represented by a single self-regulation latent variable composed of indicators used in studies of EF and EC. Second, we consider the factor structure of self-regulation again with additional variables using structural equation modeling (SEM). We tested the extent to which self-regulation mediated associations of neonatal and early sociodemographic risks with internalizing problems, externalizing problems, and academic competence when children were 6 years old.

2. Material and method

2.1. Participants and sampling

Data for the current study were derived from a larger longitudinal investigation of social and physiological processes related to the emerging self-regulation of children who experienced significant neonatal risks (Poehlmann et al., 2010; n = 181). Participants in the larger study were recruited from three neonatal intensive care units in southeastern Wisconsin between 2002 and 2005. Eligibility criteria were: (a) born at or before 35 weeks gestation or having a birthweight of 2500 g or less, (b) infants had no known congenital malformations, major neurological problems (e.g., Down Syndrome, periventricular leukomalacia), or prenatal drug exposures, (c) mothers were at least 17 years old, (d) mothers could read English, (e) mothers self-identified as the infant's primary caregiver. One infant was randomly selected to participate in cases of multiple births. Participation rates could not be calculated because study personnel were unable to be first contact with potential participants. One hundred eight-one (97%) of the 186 mothers who signed study consent forms chose to participate in the study. Data were collected at seven time points: prior to hospital discharge; at 4-, 9-, 16-, 24-, and 36-months; and when children were six years old. The data collected prior to the six-year-old assessment were corrected for prematurity based on mothers' due dates (DiPietro & Allen, 1991).

The study initially enrolled 181 participants, but 7 were excluded from participation after the initial screening determined they did not meet the inclusion criteria reducing the overall sample size to 174. An additional three participants were removed because it was later discovered they experienced grade IV intraventricular hemorrhage before hospital discharge, and one was removed due to a later diagnosis of cerebral palsy. Five additional participants were excluded from the current study because they experienced low birthweight but were born at or after 36 weeks, and our focus is on EF and EC as indices of emerging self-regulation in children born premature.

The analyses included data from assessments when children were discharged from the hospital after birth, when children were 16- and 36-months-old (age-corrected for prematurity), and when children were six years old. Mean gestational age was 31.27 weeks (SD = 3.058; range = 23.71–35.86). Mean birthweight was 1707.57 g (SD = 587.09; range = 490-3328.00 g). The subsample was 53.3% male (n = 89). Mean annual household income for the subsample was US$89,462.81 ($SD$ = US$75,739.23; range = US$0–500,000), and mean maternal education at the 6-year-old follow-up visit was 15.65 years (SD = 2.35; range = 11–21 years). This was a relatively low-risk sample, with 44 (26.2%) of the participants experiencing 2 or more sociodemographic risks based on a sociodemographic risk index developed by Burchinal, Roberts, Hooper, and Zeisel, (2000) and 124 (73.8%) of participants experiencing 1 or fewer sociodemographic risks.

Sixty percent of the original families participated at the six-year-old assessment. Families who participated in the six-year-old follow-up visit did not differ in sociodemographic risks from those who did not participate, $F(1, 166) = 1.18$, $p = 0.477$. There were also no significant differences between children who participated in the six-year-old follow-up in neonatal risk ($F(1, 166) = 0.00$, $p = 0.99$), birthweight ($F(1, 166) = 1.06$, $p = 0.305$), gestational age ($F(1, 166) = 1.03$, $p = 0.31$), or days in the NICU ($F(1, 166) = 1.25$, $p = 0.25$; Wilk's $\lambda = 0.99$, $p = 0.867$). Participants in the six-year-old follow-up study also did not differ in terms of gender, $\chi^2(1) = 1.34$, $p = 0.247$. Table 1 presents an overview of the study design and attrition rates at hospital discharge, 16 months and 36 months postterm, and at 6 years old.

2.2. Procedure

A research nurse at each NICU informed eligible families about the study. Interested families signed an IRB-approved consent form and were contacted by study personnel to schedule a visit prior to NICU discharge. During this visit, a researcher collected demographic data from the mother and infant health risk information from the infant's medical chart. At 36-months postterm, families visited the laboratory playroom, and trained researchers (supervised by a licensed psychologist) assessed the child's EC, EF, and cognitive skills. Tasks were administered to all of the participants in a standardized order, and breaks were offered if the children became fatigued during assessments. All sessions were video-taped during the visit to facilitate later scoring. Families were paid $85 for the 36-month visit, and children were given an age-appropriate book or toy. When children were six years of age, mothers were contacted by phone or mail and signed new IRB-approved consent forms. Mothers participated in a telephone interview and completed questionnaires, including the Child Behavior Checklist. Families were given a $15 gift card for their participation (Table 1). Video-taped self-regulation tasks (Magic Mountain, the Shapes task, the modified Towers task, and Day-Night) were coded by a team of undergraduate and graduate students.

Table 1
Schedule of data collection across four time points.

Time point	N	Measures
NICU Discharge	174(96% of enrolled/ screened)[a]	NICU medical records Sociodemographic Risk index
16-Months Postterm Laboratory Visit	148 (85% of enrolled/ screened)	Bayley Scales of Infant Development
36-Months Postterm	132 (76% of enrolled/ screened)	Self-Regulation Tasks: Magic Mountain, Shapes Task; Modified Towers Task; Day/Night Task; Working Memory
6-Year-Old Mailed Surveys	141 (78% of enrolled/ screened)	Child Behavior Checklist

[a] 186 Mothers recruited for the study, 181 enrolled mother-child dyads, 174 dyads following screening.

2.3. Measures

2.3.1. Self-regulation

In this analysis, we included five tasks used to assess child self-regulation at 36 months. Tasks were administered by trained graduate research assistants. Mothers remained in the room behind a screen for all tasks except the one assessing delay.

2.3.2. Magic mountain

The Magic Mountain task has previously been used to assess children's ability to delay (e.g., Poehlmann et al., 2010), and it is based on delay of gratification tasks used with low medical risk samples (Kochanska et al., 2000). Children were presented with an interesting toy and asked to refrain from touching it until the adults returned to the room. The mother and researcher then left the child in the room alone with the toy for 3 min. There were no other toys in the room at the time. Children were coded on seconds until touch and seconds until manipulation of the toy. 10% of the sample was coded for interrater reliability purposes. Interrater reliability, established across 8 coders using a fully-crossed design and intraclass correlation coefficients (ICC), ranged from 0.90 to 1.0 (considered correct if agreement was within 2 s; a 2-s standard was used because of the relatively long length of this observation). The number of seconds until the child touched the toy was used in this analysis.

2.3.3. Shapes task

The Shapes task has been used in studies of EC to index effortful attention (e.g., Kochanska et al., 2000; Poehlmann et al., 2010). In the current study, the researcher presented the child with animal cards and asked him or her to point to the less salient animal. For example, the card may contain a large dog with a picture of a small bird in the middle, and the child would be asked to point to the bird. Children first participated in training to ensure they knew animal names and the words "big" and "little." They were shown two sets of three cards, one with large pictures of animals and another with the same animals in smaller sizes. For the testing phase, the cards were comprised of two, 3-card decks with smaller pictures of the animals embedded in larger pictures of different animals. Children were asked to point to the smaller animal. Answers were coded: 0, refusal or pointing to the wrong animal; 1, pointing to the large rather than the small animal; 2, self-correction; or 3, correctly pointing to the small animal. Higher scores indicated more effortful attention. Cronbach's alpha for the task was 0.83, and the average kappa reliability coefficient (κ), calculated for the nominal codes across 4 coder pairs and 10% of the sample's videos, was 0.86 (ranging from 0.74 to 1.0).

2.3.4. Modified towers task

The Towers task has been used previously to assess suppressing/initiating response to signal, or inhibitory control, in studies of both EC and EF (Kochanska & Knaack, 2003; Kochanska et al., 2000). A modified version of the Towers task was used in this study. Instead of using blocks to build a tower, as in the original task, we used cards with brightly colored characters. Children were instructed to play a game in which they took turns with the researcher when matching the cards on a board. The modified Towers task was coded as the number of turns the child allowed the experimenter to take. Higher scores indicated more turn-taking and, therefore, better suppressing-initiating activity to signal, ICC = 0.94 (calculated across 8 coders and 10% of the sample). On average, experimenters took three turns in the modified Tower game (range of 0–14 turns).

2.3.5. Day/night task

Performance on the Day/Night task is an indicator of inhibitory control for children aged 3 ½ to 4 ½ years old and has been previously used in studies of EF (Diamond, Kirkham, & Amso, 2002; Gerstadt et al., 1994). Children were administered the day/night task at the 36-month assessment. Children were presented a deck of 16 cards (14 cm × 10 cm). The front of eight of the cards featured a white background with a yellow sun. The front of the remaining eight cards was black with a yellow moon and silver stars. During the training phase, the experimenter presented children with a black card with moon and stars and instructed children to say, "day" when they saw that card. The experimenter then showed children a yellow sun card, and instructed child to say, "night," when shown that card. Children were queried to determine whether they understood the directions, and were considered to have passed the training if they correctly responded two consecutive times during the six trial training phase.

Testing with the full 16-card deck began immediately after children passed two consecutive training trials without repetition of the instructions (Diamond et al., 2002; Gerstadt et al., 1994). The experimenter repeated the rules if either of the first two test trials were incorrect. However, no feedback was provided after the first two testing trials. For cases in which the child did not pass the training phase after six trials, the experimenter explained both rules again and began the testing phase. The child was considered to have not understood the instructions if he or she did not pass any of the six training trials and after two testing phase trials, and testing was discontinued. The eight sun (S) and eight moon (M) cards were presented in a standard order (S, M, M, S, M, S, S, M, M, S, M, S, S, M, S, M). Inter-rater reliability for day/night scoring calculated across 3 coders was ICC = 0.97 for 10% of videos.

2.3.6. Working memory

Children's working memory, a component of EF, was assessed using the verbal and nonverbal working memory subtests of the Stanford-Binet 5th edition (Roid, 2003). The verbal subtests include increasingly difficult sentence repetition and last word items. The nonverbal subtest includes increasingly difficult form-board and pattern activities ranging from finding hidden objects to repeating block-tapping sequences. The current analysis used the working memory index score, a composite of nonverbal and verbal working memory standard scores. The working memory index score correlates 0.61 with the working memory scale of the Woodcock-Johnson III Test of Cognitive Abilities (Woodcock & Mather, 2001).

2.3.7. Behavioral problems and school competence

Behavioral problems and academic competence at six years old was indexed using mother ratings of internalizing and externalizing behaviors and competence in the academic realm from the Child Behavior Checklist (CBCL, Achenbach & Dumenci, 2001). This 99-item parent-report lists problem-behaviors that are rated 0 (not true), 1 (somewhat true), or 2 (very true or often true) about the target child in the past two months. The parent is also asked to list any problems not yet mentioned as the 100th item. Subscales for internalizing behavior problems, externalizing problems, and school competence were calculated by summing the items associated with those subscales. Raw scores were used in this analysis, with higher scores indicating more internalizing or externalizing behaviors or greater academic competence.

2.3.8. Neonatal health risk

Neonatal health risks were obtained from a medical record review prior to the hospital discharge assessment. The composite score was created by first standardizing and summing children's birthweights and gestational ages to create a prematurity index. These scores were reversed so that higher scores were indicative of greater risk. Second, to create a medical risk score, we summed the presence (1) or absence (0) of 10 neonatal medical risks: apnea, respiratory distress, chronic lung disease, gastroesophageal reflux, supplemental oxygen at NICU discharge, apnea monitor at NICU discharge, 5-min Apgar score less than 6, ventilation during NICU stay, and a NICU stay of more than 30 days. Third, the prematurity index and medical risk scores were summed to create an overall neonatal health risk index (α = 0.70). Higher scores on this index reflected greater prematurity and medical risk.

2.3.9. Sociodemographic risk

A family sociodemographic risk index was created based on previous research (Burchinal et al., 2000). Families received one point for the presence of each of the following risks: (1) household income below the federal poverty level (adjusted for family size), (2) both parents unemployed, (3) single mother, (4) the target child was born when the mother was a teen, (5) four or more dependent children living in the home, (6) mother had less than a high school education at the hospital discharge assessment, (7) father had less than a high school education at the hospital discharge assessment. Possible index scores range from zero to seven, with higher scores being indicative of greater risk (α = 0.75).

2.3.10. General cognitive development

Children's cognitive development was assessed at 16-months post-term using the Bayley Scales of Infant Development (Bayley, 1993). This standardized assessment is appropriate for ages 1–42 months to measure cognitive and motor development. Standard scores for the battery have a mean of 100 (*SD* = 15), with higher scores being indicative of greater cognitive development.

2.3.11. Child gender

Child gender was dummy coded (0 = boys; 1 = girls).

3. Analysis plan

The research questions were addressed in three steps. First, we calculated descriptive means and scale intercorrelations using SPSS version 20 (IBM Corp, 2011; Table 2). Second, using M-plus version 7.1 (Muthen & Muthen, 1998–2012), we ran confirmatory factor analyses (CFA) for the full sample and for gender groups based on Zhou et al.'s (2012) premise that self-regulation may be better conceptualized as one factor rather than separate EC and EF factors in studies of early childhood. Third, we used structural equation modeling (SEM) in Mplus to determine the extent to which self-regulation at 36-months predicted maternal ratings of internalizing, externalizing, and academic competence when children were six years old. SEM was chosen over other

Table 2
Scale intercorrelationsand descriptive statistics.

		1	2	3	4	5	6	7	8	9	10	11	*Mean(sd)*
1	Mental Development[a]	–											87.93(11.85)
2	Neonatal Risk[b]	−0.03	–										3.12(2.24)
3	Sociodemographic Risk[c]	0.10	0.08	–									1.04(1.54)
4	Magic Mountain Task[d]	0.02	0.05	−0.26**	–								82.08(75.29)
5	Shapes Task[e]	0.03	0.04	−0.23**	0.31**	–							10.82(4.43)
6	Tower Task[f]	0.27*	0.02	−0.14	0.33*	0.14	–						2.74(3.39)
7	Day/Night Task[g]	0.05	0.13	−0.10	0.21*	0.16	0.16	–					4.03(4.92)
8	Working Memory[h]	−0.05	0.07	−0.09	0.20	0.27*	0.10	0.22*	–				87.80(15.46)
9	School Competence[i]	0.20	−0.01	−0.23*	0.24*	0.17	0.15	0.10	0.22	–			4.75(.99)
10	Internalizing Problems[i]	0.16	0.00	0.13	−0.04	0.02	0.13	0.09	−0.10	−0.15	–		5.06(4.83)
11	Externalizing Problems[i]	0.16	−0.06	0.18	−0.21*	−0.12	0.06	0.01	−0.02	−0.32*	0.41*	–	6.45(5.79)

* $p \ll 0.05$.
[a] Bayley Scales of Infant Development (Bayley, 1993).
[b] Composite of standardized, summed and reversed birthweight and gestational age plus presence or absences of 10 neonatal medical risks.
[c] Family sociodemographic risk index based on Burchinal et al. (2000).
[d] Ability to delay.
[e] Effortful attention.
[f] Suppressing/initiating response to signal, or inhibitory control.
[g] Inhibitory control.
[h] Stanford-Binet 5th edition.
[i] Child Behavior Checklist – parent report.

analytic approaches because it affords the simultaneous testing of multiple pathways, latent constructs, and hypothesized associations among variables. Additionally, a full information maximum likelihood (FIML) procedure was used to address missing data.

The fit of the CFA and SEM models were assessed using χ^2, the Standardized Root-Mean-square Residual (SRMR), the comparative fit index (CFI), and Akaike's Information Criteria (AIC). The χ^2 index is a model of misspecification; therefore, a significant χ^2 means that the model does not fit the sample data. We supplemented our analysis of model fit using SRMR and CFI because it is generally claimed that the exact fit tested in χ^2 is an unrealistic standard due to its high sensitivity to sample size (Hooper, Coughlan, & Mullen, 2008). SRMR is an absolute fit index for which a zero indicates perfect fit. Values less than 0.08 are considered to have acceptable model fit (Hooper et al., 2008). The CFI compares the specified model to a null model. The null model posits that there are no associations among the variables. CFI ranges from 0 to 1, with higher values indicating better fit. CFI values $\gg >$ .90 are generally interpreted as acceptable model fit (Hu & Bentler, 1998). Models were only interpreted if they had acceptable fit across all 3 indices. We used AIC indices to compare one- and two-factor models, with lower values being indicative of better fit. Because the AIC is not normed, there are no cutoffs for determining the best fitting model. However, a difference (Δ_{AIC}) of 10 or more indicates that the model with the higher AIC has essentially no empirical support, and a difference between 4 and 7 indicates that the model with the higher AIC has considerably less empirical support. If the Δ_{AIC} is less than 2, there is equivalent support for both models (Burnham & Anderson, 2003). Tables 4 and 5 present path coefficients, standard errors, and p-values for all the models.

4. Results

4.1. Self-regulation factor structure

One- and two-factor models were fit to the five self-regulation tasks. We observed good fit for both models (one factor: $\chi^2(5) = 4.37$, $p = 0.497$; CFI = 1.00; SRMR = 0.04) and two-factor models ($\chi^2(4) = 2.49$, $p = 0.646$; CFI = 1.00; SRMR = 0.03), and the standardized parameter estimates for both models were significant and in the expected direction (Table 3). The EC and EF factors in the two-factor model were moderately correlated 0.65 ($p \ll 0.010$). Comparison of the AICs revealed equivalent support for both models (one factor AIC = 4429.14; two factor AIC = 4429.26; $\Delta_{AIC} = 0.12$).

Table 3
One-factorand two-factor models of self-regulation.

	One-Factor Model		Two-Factor Model	
	B(*SE*)	*p*	*B*(*SE*)	*p*
			Effortful Control	
Magic Mountain[a]	0.68(.11)	≪0.01	0.71(.12)	≪0.01
Shapes Task[b]	0.46(.10)	≪0.01	0.44(.10)	≪0.01
Tower Task[c]	0.45(.10)	≪0.01	0.45(.10)	≪0.01
			Executive Function	
Day/Night Task[d]	0.35(.11)	≪0.01	0.45(.15)	≪0.01
Working Memory	0.39(.14)	≪0.01	0.48(.16)	≪0.01
EC with EF			0.71(.23)	≪0.01
Model Fit				
χ^2	3.18	0.67	2.13	0.71
CFI	1.00		1.00	
SRMR	0.03		0.03	
AIC	4570.98		4571.93	

[a] Ability to delay.
[b] Effortful attention.
[c] Suppressing/initiating response to signal, or inhibitory control.
[d] Inhibitory control.

4.2. Associations of one- and two-factor self-regulation models with six-year-old outcomes

We addressed our second research question with a series of models in which six-year-old, mother-rated school competence, internalizing behavior problems, and externalizing behavior problems were regressed onto both one- and two-factor models because both CFA models fit the data well. We also anticipated that studying self-regulation in the presence of other variables may yield further distinctions between factors. Separate models were run for school competence and both internalizing and externalizing behavior problems. As with the factor structure of self-regulation, we evaluated the fit of the SEM models using χ^2, CFI, and SRMR, and we compared AIC indices to identify the best-fitting models. We estimated indirect effects using the product of significant direct effects. Overall, we observed that the models testing the unitary self-regulation factor provided a better fit to the data.

4.3. School competence

We observed partial support for the hypothesis that self-regulation mediates associations between demographic and neonatal risk and six-year-old school competence. We observed good fit for the one-factor self-regulation model ($\chi^2(29) = 21.48$, $p = 0.840$; CFI = 1.00; SRMR = 0.05). The paths from demographic risk to the self-regulation factor ($B = -0.45$, $SE = 0.10$) and from the self-regulation factor to school competence ($B = 0.43$, $SE = 0.12$) were both significant (p's $\ll 0.010$), and there was a significant specific indirect effect of demographic risk on school competence (indirect effect = −0.19, $SE = 0.07$, $p = 0.010$). The mediation hypothesis was not supported for the paths from neonatal risk to school competence (specific indirect effect = 0.04, $SE = 0.04$, $p = 0.360$; Table 4). The two-factor model also fit the data well ($\chi^2(25) = 18.043$, $p = 0.841$; CFI = 1.00; SRMR = 0.05). However, the mediation hypothesis was not supported for the paths that included either the EC or the EF factors. Consistent with these findings, comparison of AIC indices revealed a better fit for the one-factor model (AIC = 7424.49) than for the two-factor model (AIC = 7429.044; $\Delta_{AIC} = 4.65$).

4.4. Externalizing behavior problems

The one-factor self-regulation model predicting mother-rated externalizing behavior problems at six years old provided good fit to the data ($\chi^2(29) = 24.99$, $p = 0.68$; CFI = 1.00; SRMR = 0.06). The individual paths from demographic risk to self-regulation ($B = -0.47$, $SE = 0.10$, $p \ll 0.010$) and from self-regulation to externalizing behavior ($B = -0.32$, $SE = 0.12$, $p = 0.007$) were significant, and the indirect effect of demographic risk on externalizing problems was also significant (indirect effect = 0.14; $SE = 0.07$; $p = 0.032$). The self-regulation factor did not mediate the association between neonatal risk and externalizing behavior problems (indirect effect = −0.04, $SE = 0.04$, $p = 0.31$; Table 4).

The two-factor EF/EC model also fit the data ($\chi^2(25) = 19.36$, $p = 0.780$; CFI = 1.00; SRMR = 0.05). Although the individual path from demographic risk to EC was significant ($B = -0.45$, $SE = 0.10$, $p \ll 0.001$), the path from EC to mother-rated externalizing behavior was not ($B = -0.68$, $SE = 0.37$, $p = 0.064$), nor did the indirect effect from of EC on the demographic risk/externalizing behavior association meet the conventional cutoff for statistical significance (indirect effect = 0.30, $SE = 0.18$, $p = 0.093$). Similarly, EC did not mediate an association between neonatal risk and externalizing behavior (indirect effect = −0.07, SE = 0.09, $p = 0.422$).

The mediation hypothesis was not supported for both sociodemographic risk/externalizing behavior (indirect effect = −0.09, SE = 0.11, $p = 0.425$) or neonatal risk/externalizing behavior (indirect effect = −0.08, SE = 0.08, $p = 0.340$) (Table 5). Comparison of the AIC indices of the unitary self-regulation model and the EF/EC model

Table 4
Mediation analysis of neonatal and demographic risk on school competence with one-factor self-regulation.

	School Competence[h]		Externalizing[h]		Internalizing[h]	
	B(SE)	*p*	*B(SE)*	*p*	*B(SE)*	*p*
EC and EF indices on Self-Regulation						
Magic Mountain[a]	0.66(.10)	≪0.01	0.69(.10)	≪0.01	0.67(.10)	≪0.01
Shapes Task[b]	0.48(.10)	≪0.01	0.49(.10)	≪0.01	0.48(.10)	≪0.01
Tower Task[c]	0.43(.10)	≪0.01	0.41(.10)	≪0.01	0.43(.10)	≪0.01
Day/Night Task[d]	0.37(.10)	≪0.01	0.34(.10)	≪0.01	0.36(.10)	≪0.01
Working Memory	0.43(.13)	≪0.01	0.39(.13)	≪0.01	0.41(.13)	≪0.01
Self-Regulation on						
Demographic Risk[e]	−0.45(.10)	≪0.01	−0.44(.10)	≪0.01	−0.42(.10)	≪0.01
Neonatal Risk[f]	0.10(.10)	0.35	0.11(.10)	0.27	0.12(.10)	0.28
Outcome on						
Self-Regulation	0.43(.12)	≪0.01	−0.32(.12)	0.01	−0.05(.13)	0.73
Cognitive Ability[g]	0.14(.10)	0.15	0.20(.10)	0.03	0.17(.10)	0.07
Gender	0.03(.10)	0.79	−0.10(.09)	0.04	−0.17(.10)	0.09
Demographic Risk With						
Gender	0.06(.08)	0.43	0.06(.08)	0.43	0.06(.08)	0.43
Neonatal Risk With						
Gender	−0.20(.07)	0.01	−0.20(.07)	0.01	−0.20(.07)	0.01
Demographic Risk	0.09(.08)	0.25	0.09(.08)	0.25	0.09(.08)	0.25
Cognitive Ability With						
Gender	0.19(.08)	0.02	0.20(.08)	0.01	0.20(.08)	0.02
Demographic Risk	0.10(.08)	0.21	0.10(.08)	0.20	0.10(.08)	0.20
Neonatal Risk	−0.04(.08)	0.66	−0.04(.08)	0.68	−0.04(.09)	0.66
Indirect Effects						
Demographic Risk	−0.19(.08)	0.01	0.14(.07)	0.03	0.02(.06)	0.73
Neonatal Risk	0.04(.05)	0.36	−0.04(.04)	0.31	−0.01(.02)	0.74
Model Fit						
χ^2	21.48	0.84	24.99	0.68	24.163	0.72
CFI	1.00		1.00		1.00	
SRMR	0.06		0.06		0.06	
AIC	7424.49		7789.16		7758.93	
N	168		168		168	

[a] Ability to delay.
[b] Effortful attention.
[c] Suppressing/initiating response to signal, or inhibitory control.
[d] Inhibitory control.
[e] Family sociodemographic risk index based on Burchinal et al. (2000).
[f] Composite of standardized, summed and reversed birthweight and gestational age plus presence or absences of 10 neonatal medical risks.
[g] Bayley Scales of Infant Development (Bayley, 1993).
[h] Child Behavior Checklist parent-report.

were 7789.15 and 7791.52 (Δ_{AIC} = 2.37), respectively, suggesting empirical support for both models. Nevertheless, within the context of our research question, whether the one- or two-factor models mediates associations with 6-year-old externalizing behavior, the model using the single self-regulation factor is best supported by the data.

4.5. Internalizing behavior problems

The one-factor self-regulation models predicting mother-rated internalizing behavior problems fit the data well ($\chi^2(29) = 25.30$, $p = 0.710$; CFI = 1.00; SRMR = 0.06). However, the mediation hypothesis was not supported by the analyses (Table 4). The two-factor model also fit the data ($\chi^2(25) = 20.15$, $p = 0.740$; CFI = 1.00; SRMR = 0.05). Similar to the one-factor self-regulation model, the mediation hypothesis was not supported (Table 5).

5. Discussion

We addressed the question of whether self-regulation among children born prematurely is best represented by one or multiple factors of EF and EC indices assessed at 36 months. Instead of focusing on the broader EF and EC rubrics, we focused on five tasks that have been used in studies examining both constructs. Our analysis of the data using CFA indicated that the one-factor model provided the most parsimonious fit to the data from this high neonatal risk sample. Our subsequent mediation analyses suggested the self-regulation factor mediated associations between sociodemographic risk and mother-rated school competence and externalizing behavior when children were six-years-old. We observed that higher sociodemographic risks were associated with lower self-regulation and, subsequently, higher externalizing behavior and lower school competence. We did not observe significant indirect effects of the individual EF or EC factors on child outcomes.

These findings are consistent with previous research pointing to associations between self-regulation and behavioral problems (e.g., Feldman, 2009; Poehlmann et al., 2010), including our finding that the mediation effects were independent of general cognitive abilities (e.g., Blair & Razza, 2007). We extended this previous research by addressing the extent to which self-regulation reflects a unitary factor among children born preterm and if the unitary self-regulation factor mediated associations between early risk and child outcomes across time-points.

5.1. Implications for early childhood research and intervention

Our findings that the one-factor models provided the most

Table 5
Mediation analysisof neonatal and demographic risk on 6-year-old outcomes with two-factor self-regulation.

	School Competence[h]		Externalizing[h]		Internalizing[h]	
	B(SE)	*p*	*B(SE)*	*p*	*B(SE)*	*p*
EC by						
Magic Mountain[a]	0.65(.10)	≪0.01	0.68(.09)	≪0.01	0.67(.11)	≪0.01
Shapes Task[b]	0.48(.10)	≪0.01	0.49(.10)	≪0.01	0.47(.10)	≪0.01
Tower Task[c]	0.43(.10)	≪0.01	0.41(.10)	≪0.01	0.43(.10)	≪0.01
EF by						
Day/Night Task[d]	0.46(.20)	0.02	0.51(.14)	≪0.01	0.49(.17)	≪0.01
Working Memory	0.50(.19)	0.01	0.51(.15)	≪0.01	0.48(.15)	≪0.01
EC on						
Demographic Risk[e]	−0.47(.10)	≪0.01	−0.45(.10)	≪0.01	−0.45(.11)	≪0.01
Neonatal Risk[f]	0.07(.11)	0.55	0.10(.10)	0.33	0.09(.11)	0.43
EF on						
Demographic Risk	−0.24(.17)	0.15	−0.21(.15)	0.18	−0.20(.16)	0.20
Neonatal Risk	0.24(.16)	0.15	0.18(.14)	0.21	0.22(.15)	0.14
Outcome on						
EC	0.61(.81)	0.45	−0.68(.37)	0.06	−0.33(.52)	0.53
EF	−0.19(.85)	0.83	0.44(.39)	0.27	0.33(.54)	0.55
Cognitive Ability[g]	0.13(.10)	0.19	0.21(.09)	0.02	0.19(.10)	0.05
Gender	0.03(.10)	0.77	−0.21(.09)	0.02	−0.18(.10)	0.08
EC With EF	0.82(.53)	0.12	0.68(.22)	≪0.01	0.74(.33)	0.03
Demographic Risk With						
Gender	0.06(.08)	0.43	0.06(.08)	0.43	0.06(.08)	0.43
Neonatal Risk With						
Gender	−0.20(.07)	0.01	−0.20(.07)	0.01	−0.20(.07)	0.01
Demographic Risk	0.09(.08)	0.25	0.09(.08)	0.25	0.09(.08)	0.25
Cognitive Ability With						
Gender	0.19(.08)	0.02	0.20(.08)	0.01	0.20(.08)	0.02
Demographic Risk	0.10(.08)	0.21	0.10(.08)	0.21	0.10(.08)	0.19
Neonatal Risk	−0.04(.08)	0.67	−0.04(.08)	0.66	−0.04(.08)	0.65
Indirect Effects						
EC Demographic Risk	−0.29(.39)	0.46	0.31(.18)	0.09	0.15(.25)	0.55
EF Demographic Risk	0.05(.21)	0.83	−0.09(.11)	0.43	−0.07(.12)	0.58
EC Neonatal Risk	0.04(.10)	0.69	−0.07(.09)	0.42	−0.03(.06)	0.65
EF Neonatal Risk	−0.04(.21)	0.84	0.08(.08)	0.34	0.07(.12)	0.55
Model Fit						
χ2	18.04	0.84	19.36	0.78	20.15	0.74
SRMR	0.05		0.05		0.06	
CFI	1.00		1.00		1.00	
AIC	7429.04		7791.53		7762.92	
N	168		168		168	

[a] Ability to delay.
[b] Effortful attention.
[c] Suppressing/initiating response to signal, or inhibitory control.
[d] Inhibitory control.
[e] Family sociodemographic risk index based on Burchinal et al. (2000).
[f] Composite of standardized, summed and reversed birthweight and gestational age plus presence or absences of 10 neonatal medical risks.
[g] Bayley Scales of Infant Development (Bayley, 1993).
[h] Child Behavior Checklist parent-report.

parsimonious fit to our data and that the single self-regulation factor mediated associations between early demographic risk and mother-ratings of academic competence and externalizing behavior counters previous confirmatory factor analytic research with low medical risk samples. These researchers observed distinct EC and EF self-regulation factors in older children (e.g., Brock et al., 2009; Willoughby et al., 2011) or a unified EF factor (Wiebe, Espy, & Charak, 2008; Wiebe et al., 2011) among 36-month olds. It is important to note, however, that in addition to possessing higher neonatal risks than this previous research, self-regulation skills for the current sample were assessed when children were much younger − 36-months in the current sample compared to a mean of 4.6 years (Willoughby et al., 2011) and approximately five years (Brock et al., 2009). Consequently, we are unable to determine whether the differences in findings across these studies reflects potential differentiation of self-regulation skills over the course of development rather than differences based on level of medical risk.

Further research is needed to rectify the inconsistencies in the results of low medical risk samples to determine if these differences are due to developmental age or other extraneous factors. Nevertheless, our findings are consistent with previous conclusions that EF may emerge from the emotionality and attention processes associated with the effortful aspects of child temperament (Blair & Ursache, 2011; Feldman, 2009). Additional longitudinal research across the early life spans of children born prematurely is needed to specify the processes by which self-regulation emerges in high medical and sociodemographic risk groups.

Despite finding that the single self-regulation factor overall provided the most parsimonious fit to the data in this analysis with a sample of children born prematurely, we were surprised to observe that self-regulation did not mediate neonatal risk/six-year-old outcome associations. This lack of relationship would suggest that sociodemographic and neonatal risk do not interact to produce poorer developmental outcomes, a finding that is somewhat at odds with other research with high-medical risk samples (Patra, Greene, Patel, & Meier, 2016). While we examined sociodemographic risks in our analyses, we did not examine use of intervention and other services that could have buffered the impact of preterm birth within both high and low sociodemographic risk contexts. Moreover, the children with the greatest medical risks resulting from preterm or low birthweight birth (i.e., intraventricular hemorrhage, cerebral palsy) were eliminated from the sample, and our sample is relatively affluent, meaning that our sample does not represent the full range of neonatal and sociodemographic risk.

Nevertheless, our findings suggest that the associations between early self-regulatory skills and developmental competencies may be stronger and more difficult to tease apart among children born preterm than among children born with low medical risks (e.g., Blair & Razza, 2007), and raise the question of whether self-regulation develops in the same way among children born preterm as it does among children born term. Children born preterm are at significant risk for brain deficits associated with exposure to high stress in the NICU, along with the risk for brain injury associated with prematurity (Adams-Chapman, 2009; Kinney, 2006; Smith et al., 2011; VandenBerg, 2007). If it is the case that preterm birth and subsequent NICU stays impact the structure and timing of self-regulation development of children born preterm, the models of self-regulation development among low medical risk samples may not adequately reflect the developmental trajectories and areas for potential intervention research with children who experienced higher medical risks at birth. This premise is supported by multiple studies demonstrating that children born preterm and NICU graduates have deficits in self-regulation compared to their same-aged peers that, in some instances, have been observed to attenuate over time (Aarnoudse-Moens et al., 2012; Aarnoudse-Moens, Smidts et al., 2009).

There are significant implications for early intervention research if this premise holds. Early intervention focusing on parental sensitivity and scaffolding behaviors is needed to prevent long term disruptions in the parent-child relationship that can exacerbate existing self-regulation deficits (e.g., Cuevas et al., 2014; Mathis & Bierman, 2015) and contribute to significant psychopathology in later life (e.g., Feldman, 2015; Kochanska & Kim, 2012). Interventions that focus on parental sensitivity to infant cues are important given recent evidence that children born preterm who interact with sensitive mothers as toddlers experience self-regulation gains that approach the skills of their term peers (Camerota, Willoughby, Cox, & Greenberg, 2015) and that maternal sensitivity can buffer the effects of preterm birth on academic outcomes (Jaekel, Pluess, Belsky, & Wolke, 2015). Furthermore, while research with low-medical-risk samples points to the importance of scaffolding behaviors in the emergence of self-regulation skills (e.g., Devine, Bignardi & Hughes, 2016; Hammond, Mueller, Carpendale, Bibok, & Liebermann-Finestone, 2012), previous analyses with this preterm sample (e.g., Dilworth-Bart et al., 2011) suggest that the type of scaffolding parents provide should be driven by parents' sensitivity to their preterm child's specific needs and cues.

5.2. Limitations

There are several study limitations that prevent us from being able to speak more definitively about the structure of self-regulation in early childhood among children born prematurely and the relation between self-regulation and behavioral and academic outcomes. First, although examining the structure of self-regulation within a high medical risk sample is one of the strengths of this longitudinal study, not having a sample with a fuller range of high to low medical risks precluded our ability to directly investigate potential medical risk/self-regulation associations. Similarly, the lack of association between neonatal risk and self-regulation could be related to the lack of variability in prematurity within the sample. Although all the participants in this sample were born prior to 36 weeks gestation, the distribution of gestational ages was negatively skewed such that much of the sample was moderate- to late-preterm (i.e., after 32 weeks). We are also unable to speak fully to whether degree of preterm birth and subsequent neurological risk pose unique additive or multiplicative risks above those presented by sociodemographic factors such as family- and neighborhood-level poverty. Furthermore, the significant neurological risks for children born very preterm (28–≪32 weeks gestation) and extremely preterm (≪28 weeks gestation) raises the possibility that self-regulation development in this subgroup is distinct from children born moderate- to late-preterm. Future research to confirm the unitary self-regulation factor structure in samples with a wider range of gestational ages is needed. Studies that include children with a wider range of gestational ages will help further distinguish potential differences in the structure of self-regulation between children born very preterm, moderate- to late-preterm, or at term.

Second, we had limited access to key contextual data for this sample. Our sample was relatively affluent and low sociodemographic risk at the first time point, and we were unable to determine whether changes in family income and education occurred by age six. Change in sociodemographic risks like income and education have been demonstrated to have a critical influence on early childhood outcomes (Duncan, Magnuson, & Votruba-Drzal, 2014). Similarly, it is also notable that we used only mother reports of child behavior problems and academic competence. Future studies in this area should also include multiple sources of outcome data including parent and teacher report and direct assessments of academic and behavioral competence.

Third, these findings may not generalize across the population of high medical risk infants because, although overall sample attrition was low, participants living in higher sociodemographic risk families were more likely to be lost to attrition over the course of this longitudinal study. As a result, we were unable to more fully evaluate the potential interactive role of contextual risk on child outcomes. Fourth, study measures were not administered in counterbalanced order, as is often the case in developmental studies (e.g., Cuevas et al., 2014; Miller et al., 2016), raising the risk of order effects, especially due to participant fatigue. However, the research protocol was administered in the same order for all participants, and breaks were given as needed. Fifth, although SEM models can be run with samples as small as 50–100 (Fabrigar, Porter, & Norris, 2010; Iacobucci, 2010) our sample size was still relatively small, and we are unable to make inferences as to the explanatory power of specific indicator variables nor were we able to conduct subgroup analyses. Future research should include larger-scale, longitudinal samples of high-medical risk children to further clarify the structure of self-regulation and its relation to child outcomes across early and middle childhood.

Authors note

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