PAPER

Predicting individual differences in low-income children's executive control from early to middle childhood

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Abstract

*The present longitudinal study tested the roles of early childhood executive control (EC) as well as exposure to poverty-related adversity at family and school levels as key predictors of low-income children's EC in elementary school (*n = 391*). Findings suggest that children's EC difficulties in preschool and lower family income from early to middle childhood are robust predictors of later EC difficulties as rated by teachers in 2nd and 3rd grades. Findings also suggest enrollment in unsafe elementary schools is significantly predictive of higher levels of teacher-rated EC difficulty, but only for those children who showed initially elevated levels of EC difficulty in early childhood. Implications for scientific models of cognitive development and poverty-related adversity are discussed.*

Research highlights

- Executive control
- Poverty
- School climate
- Early childhood

Introduction

Burgeoning research in the fields of developmental psychology, prevention science, and education has recently highlighted the role of children's executive processes for educational success in early childhood (Blair & Razza, 2007; Hughes, Ensor, Wilson & Graham, 2010; Morrison, Ponitz & McClelland, 2010). Recent investigations that span these fields have referred to children's executive function as 'executive control' (EC), where EC has been defined as children's use of 'higher-order, top-down abilities that enable an action requiring the active maintenance of information in light of competition, delay, distraction, or interference under changing contingencies' (Espy, Sheffield, Wiebe, Clark & Moehr, 2011, p. 33; see also Blaye & Jacques, 2009; Miller & Cohen, 2001). This domain of cognitive functioning (involving children's deployment of attention, planning, and inhibitory control for the purposes of goal-directed behavior) may be particularly important for low-income children: Recent evidence suggests that poverty places children's executive function and, consequently, their chances of academic success in serious jeopardy (Blair, 2010; Bull, Espy, Wiebe, Sheffield & Nelson, 2011; Hackman & Farah, 2009; Sarsour, Sheridan, Jutte, Nuru-Jeter, Hinshaw & Boyce, 2011). Despite this risk, many low-income children develop competent profiles of EC in the face of adversity, with interventions introduced as early as preschool shown to support this important domain of young children's development. These findings offer the promise that the development of executive control in early childhood may confer long-term advantage for children who face educational and socioeconomic risk (Bierman, Nix, Greenberg, Blair & Domitrovitch, 2008; Blair, 2002; Raver, Jones, Li-Grining, Zhai, Bub & Pressler, 2011).

But is it empirically correct to assume that low-income children's individual differences in EC, as captured in the early childhood period, will remain stable through middle childhood? At the neurobiological level, the prefrontal system (i.e. prefrontal cortex, or PFC) underlying children's executive processing undergoes a prolonged period of development from early childhood through adolescence, suggesting that there is a large temporal 'window' during

which children's exposure to enriched versus adverse environments may significantly shape this key set of cognitive functions (Bull *et al.*, 2011, p. 680). This paper examines this pressing empirical question by considering the ways that low-income children's own early profiles of executive control in preschool, as well as exposure to disadvantage in home and school contexts from the transition from preschool through early elementary school, may work independently and additively to predict their executive control in middle childhood.

Definitions and models of executive control across social contexts

In recent work from the field of cognitive developmental neuroscience, examination of young children's executive control is often carried out by measuring children's performance on paradigms such as the Wisconsin Card Sorting Task, Stroop tasks, Digit Span tasks, and the Attention Network Task (or ANT) to tap attention set-shifting, working memory, and inhibitory control (Fan, McCandliss, Sommer, Raz & Posner, 2002; Isquith, Crawford, Espy & Gioia, 2005; Wiebe, Espy & Charak, 2008). This area of research has provided robust evidence of ways that children's performance on these neuropsychological tasks is related to PFC and parietal cortex function and connectivity using a wide array of neuroimaging methods (Jolles, Kleibeuker, Rombouts & Crone, 2011; Zelazo & Müller, 2010). From an alternate empirical perspective, researchers in the fields of clinical psychology and psychiatry have considered the ways that children's executive control relates to their ability to navigate home and school contexts at the behavioral level. That is, teachers and parents can readily identify children's difficulties with modulating their attention, planning, remembering rules and directions, and inhibiting their impulses through empirically validated questionnaires such as the Brief Rating Inventory of Executive Function (BRIEF; Gioia, Isquith, Guy & Kenworthy, 2000; Isquith, Gioia & Armengol, 2000) and the Barratt Impulsivity Scale (BIS-11; Patton, Stanford & Barratt, 1995). In short, EC can be assessed through direct neuropsychological assessments as well as adults' reports, with evidence that the two forms of assessment are robustly correlated (Espy *et al.*, 2011; Sonuga-Barke, Dalen & Remington, 2003). A key strength of the following study is that it relies on (a) a multicomponent measure of executive control (including both direct assessments and more molar ratings by research assistants) in early childhood and (b) teacher reports of executive control in the challenging 'real world' context of the elementary classroom in middle childhood. To help us bridge these different measurement strategies across different research traditions, we use 'executive control' or EC to describe children's higher-order executive processes across both early and later periods of development.

In modeling change in EC over time, our field faces an additional substantial empirical challenge: Children make major transitions across multiple ecological contexts that may shape their trajectories of higher-order cognitive processing from early to middle childhood (see Ursache, Blair & Raver, 2011, for discussion). Transitions across these stage-salient developmental contexts come with additional cognitive demands, where young children face significant increases in class size, higher teacher expectations, and greater workload as they move from preschool through elementary school (Jacobson, Williford & Pianta, 2011; Jones, Brown & Aber, 2008). Children's trajectories of EC might be alternately supported or compromised as they enter more cognitively and emotionally stressful environments; these shifts may be particularly salient for low-income children, who have a substantially higher likelihood of attending lower quality elementary schools than do their more economically advantaged counterparts (Jones, Brown & Aber, 2011; Reardon, 2011). Before turning to questions of EC in the context of both family-level and school-level disadvantage, we first consider children's own characteristics as key predictors of their executive control.

Predicting individual differences in EC in middle childhood

Given its importance for later educational and clinical outcomes, what do we know about the trajectory or course of EC from early to middle childhood? Most recent longitudinal studies have either followed children's EC from preschool through school entry or from early to later adolescence, leaving the period between preschool and elementary school relatively unexplored. Recent longitudinal studies of EC in early childhood suggest improvement from ages 4 to 7 on attention shifting and inhibitory control, with stability and plateaued performance thereafter (Rueda, Fan, McCandliss, Halparin, Gruber, Lercari & Posner, 2004). In the following study, we test whether children's EC in preschool (i.e. their attention and impulse control as measured by neuropsychological tasks and independent observational ratings) is a significant predictor of teachers' reports of EC four years later, when the majority of our longitudinal sample was enrolled in the 2nd or 3rd grades.

Sex differences in children's EC have also been consistently noted in prior research and have been ascribed both to biological differences in brain maturation and also to parental socialization (Bull *et al.*, 2011). Sex hormones (including progesterone and estradiol) appear to be especially important in structural connectivity within and between the cortex and subcortex, with significant implications for PFC functioning and EC (Kolb & Stewart, 1991; Peper, van den Heuvel, Mandl, Pol & van Honk, 2011). Indeed, past research in early and middle childhood samples shows girls to have higher levels of attention and lower levels of attention- and inhibition-related mental health diagnoses compared to boys (Blair, Granger & Razza, 2005; Gaub & Carlson, 1997). To test the potential for sex differences across early to middle childhood, we included gender as a key predictor of EC in our models. Although no

individual differences between African American and Hispanic children were expected on EC in the present study, we also included child's race/ethnicity as a covariate.

Models of the development of EC in the context of family poverty

As outlined earlier, children's socioeconomic status (SES) has been consistently found to predict their performance on both neuropsychological batteries and on adult-reported ratings of higher-order executive control processes (Noble, McCandliss & Farah, 2007). Through what mechanisms might income poverty exert a negative impact on children's development of EC? Emerging evidence suggests support for a model of experiential canalization whereby chronic exposure to poverty-related adversity is likely to significantly alter children's executive abilities and their ability to maintain behavioral self-control (Arnsten & Li, 2005; Blair, Raver, Granger, Mills-Koonce, Hibel & Family Life Project Key Investigators, 2011; Blair & Raver, 2012; Dickerson & Kemeny, 2004; Evans & Schamberg, 2009). For example, children facing greater cumulative poverty-related risks have been found in several studies to demonstrate altered neuroendocrine stress response and compromised self-regulation (Blair, Granger, Kivlighan, Mills-Koonce, Willoughby, Greenberg, Hibel, Fortunato & Family Life Project Investigators, 2008; Evans, 2003; Raver, 2004). The regulation of children's neuroendocrine responses to stress, in turn, has been found to predict effective cognitive and behavioral self-regulation (Blair *et al.*, 2005; Lupien, Fiocco, Wan, Maheu, Lord, Schramek & Tu, 2005; Ramos & Arnsten, 2007). In support of this model, mounting evidence suggests that stressors associated with poverty are clearly linked to higher allostatic load (Evans, 2003) and to compromised executive function for young children (Blair, 2010; Blair & Ursache, in press; Evans & Schamberg, 2009; Raver, Blair, Willoughby & Family Life Project Key Investigators, 2012). In the following analyses, we include family income across three time points to test the role of chronic poverty, as well as caregivers' marital status and educational level as additional predictors in order to avoid overstating the role of family income in our models.

Expanding models of poverty and EC to include school contexts

How can our models of family poverty and EC be expanded to capture children's higher likelihood of chronic exposure to stressful experiences in both home and school contexts? Although the bulk of recent research on the plasticity of children's executive processes has considered caregiving in the home as a key shaping influence (see Bernier, Carlson, Deschênes & Matte-Gagné, 2012; Bernier, Carlson & Whipple, 2010; Hughes & Ensor, 2010), children are exposed to multiple forms of social interaction outside the home that may also shape PFC functioning (Blair, 2002; Ursache *et al.*, 2011). Specifically,

recent research suggests that schools may be powerful ecological contexts where chronic exposure to chaotic and unsafe school settings may be highly stressful and costly to children's trajectories of behavioral regulation (Gottfredson & Gottfredson, 2001; Jones *et al.*, 2011; Roeser, Eccles & Sameroff, 2000). Low-income children face major constraints on the likelihood of attending 'good' schools, and face substantially higher probability of attending schools that are crowded, unsafe, and highly disorganized (Reardon, Yun & Eitle, 2000).

School quality has been characterized along dimensions of school-level poverty (i.e. the proportion of students who are eligible for school lunch subsidy), school-level achievement (i.e. the proportion of students passing standardized achievement tests), and ways that the school may be chaotic, violent or unsafe, offering low levels of adult support (Cook, Gottfredson & Na, 2010; Lippman, Burns & McArthur, 1996). These factors may powerfully shape children's daily experiences in their schools. For example, adults' supportiveness for students has been found to dramatically reduce students' risk of such stressful victimization experiences as being physically attacked, threatened with a weapon, and having their belongings stolen (Gottfredson & DiPietro, 2011). Recent findings suggest that exposure to chronically high levels of negative social interaction (including violence) and lower levels of support are robustly associated with increases in biomarkers of individuals' increased allostatic load (Murali & Chen, 2005; Ross, Martin, Chen & Miller, 2011). Exposure to school as a chronically unsafe and emotionally unsupportive context may be especially stressful to low-income children, at both neuroendocrine as well as psychological levels. Those neuroendocrine responses to the stress of highly unsafe and unsupportive classroom environments might be expected to be associated with additional compromised PFC functioning and correlated cognitive difficulties (Lupien, Gillin & Hauger, 1999; Ursache *et al.*, 2011). In support of this hypothesis, recent findings suggest that student perceptions of more negative school climate were associated with a higher probability of greater behavioral problems over time (Wang, Selman, Dishion & Stormshak, 2010). In light of these prior findings, the present longitudinal study tests the key hypothesis that children's EC is shaped, or canalized, by chronic exposure to stressors associated with highly disadvantaged school as well as family contexts.

Finally, emerging work on children's cognitive and behavioral development in the context of high levels of adversity suggests that exposure to the stressors associated with school-level disadvantage may not affect all children equally (Belsky & Pluess, 2009). That is, past research suggests that linkages between environmental adversity and children's cognitive outcomes may be substantially moderated by child characteristics on the one hand, and by social contexts on the other. For example, some children appear to be more biologically sensitive to environmental hazard than others, with more temperamentally reactive children thriving in more supportive

environments while facing greater vulnerability in more adverse environments relative to their less reactive counterparts (Obradović, Bush, Stamperdahl, Adler & Boyce, 2010). Children's early executive control in preschool may therefore serve not only as a key predictor, but also as a key moderator in models linking school quality and the later development of EC in middle childhood. Similarly, the potentially deleterious role of unsafe and unsupportive school climate for EC may be exacerbated for children from households that also struggle with chronic poverty. In short, family poverty may play an additional, key moderating role in testing whether children's EC is significantly predicted by school quality.

The present study

In the following study, we examine these questions by modeling the development of EC among a sample of almost 400 African American and Hispanic children across multiple time points (in preschool and again when most of the students were in 2nd or 3rd grade). We capitalize on this longitudinal dataset to test a model of the shaping or experiential canalization of individual differences in EC across multiple social contexts from early to middle childhood. We first test whether individual, child-level characteristics including early profiles of EC, gender, and racial/ethnic minority status serve as key predictors of EC in elementary school. We also consider whether children's exposure to chronic family-level poverty from preschool to elementary school (as well as caregivers' educational and marital status) is significantly related to changes in EC across time. We then go on to test whether attending unsafe, emotionally unsupportive, and/or inadequately resourced schools is significantly predictive of changes in children's EC above and beyond child characteristics, family-level poverty, and other preschool covariates. Finally, we consider ways that children may be differentially susceptible to exposure to poverty-related adversity at both home and school levels, where the role of school quality may be moderated by children's own early EC on the one hand, and by family level poverty on the other hand (Raver *et al.*, 2012).

Method

Sample

The sample for the present study included 391 former participants from both the treatment and control groups of a classroom-based socioemotional intervention study called the Chicago School Readiness Project[1] (CSRP;

For full inclusion criteria, see Raver Jones, Li-Grining, Metzger, Smallwood & Sardin, 2008).

The average age of children in the current study was 8.20 years (range = 7–9), and 178 (46%) were boys. The majority of children (75%) were identified by their primary caregivers as African American, whereas an additional 20% were identified as Hispanic. Children resided in families with an average income-to-needs ratio in elementary school of 0.83 (SD = 0.76), indicating that the majority of children in this sample came from families whose annual income and family size placed them below the federal poverty line (which is equal to 1.00). Approximately 59% of children came from single-parent households, and 20% of caregivers reported having less than a high school education. At the final timepoint of data collection, children in the present study attended 161 schools within the Chicago Public School (CPS) district. On average, 87% of children in these 161 schools qualified for free lunch and 34% failed to meet state standards on the Illinois Standards Achievement Test for math and reading. See Table 1 for full descriptive information.

Procedure

For the present study, data were collected in the fall of the Head Start year (called 'T'), in the fall of the year following Head Start (called 'T + 1'), and in the winter

Table 1 *Descriptive statistics for variables included in regression analyses*

	M (SD) or%
Dependent variable (n = 391)	
Executive control difficulties (at T + 4)	1.99 (0.65)
Level 1: Child and family characteristics (n = 391)	
Intervention receipt	53%
Cohort (1st)	45%
Age (in months)	8.22 (0.69)
Gender (boy)	45%
Race/Ethnicity	
African American	75%
Hispanic/Latino	20%
White	2%
Caregiver marital status (single)	59%
Caregiver education	
Less than 12th Grade	20%
High School Diploma or GED	38%
Some College	34%
Bachelor's Degree or Higher	8%
Average early executive control difficulties (at time T)	0.01 (0.75)
Average income-to-needs across all time points	0.71 (0.49)
Income-to-needs at T	0.62 (0.47)
Income-to-needs at T + 1	0.74 (0.57)
Income-to-needs at T + 4	0.83 (0.77)
Level 2: School characteristics (n = 161)	
School poverty	87%
Meet/Exceed ISAT standards in reading/math	66%
Low adult support	0.00 (4.67)
Unsafe school climate	0.00 (11.27)

Note: T refers to children's Head Start year, T + 1 to one year after Head Start, and T + 4 to four years after Head Start, when children were in elementary school

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4 years after children's Head Start year (called 'T + 4'). The 391 children in our analyses represent 65% of the original 602 CSRP participants. Of the 211 children who were not included in the analyses, 36 were excluded because they were not attending a CPS school at the time of T + 4 data collection, and the remaining 175 either did not consent to participate in the follow-up portion of CSRP or were not able to be contacted.

As part of the data collection process, trained and reliable data collectors conducted in-person interviews with the children's primary caregivers in either English or Spanish at each time point (T to T + 4). During the interviews, a variety of data were collected, including demographic information about the caregiver, household, and child (e.g. marital status, household income, child race/ethnicity). At T, children's early EC was assessed by independent observers using a standard battery of self-regulatory tasks that was conducted in children's schools. At T + 4, teachers reported on children's EC using a paper-and-pencil survey as part of a larger interview. School quality and poverty data at T + 4 were obtained through publically available measures published by CPS. Caregivers and teachers were provided modest monetary compensation for their time.

Measures

Executive control

Children's difficulty with EC was assessed at two time points: during fall of their Head Start year (T) and 4 years later (T + 4). Children's difficulty maintaining EC at Head Start (T) was rated in two ways. First, children's EC was captured using two direct assessments of executive function from the Preschool Self-Regulation Assessment (PSRA), a comprehensive 30-minute assessment of children's self-regulation and cognitive skills (Smith-Donald, Raver, Hayes & Richardson, 2007; see Raver et al., 2011). Specifically, children completed the Balance Beam (Murray & Kochanska, 2002) and Pencil Tap (Blair, 2002; Diamond & Taylor, 1996) tasks. These tasks were designed to test children's ability to attend to assessor instructions, maintain the rules of the task in working memory, and inhibit prepotent responses. During the Balance Beam task, children were asked to walk as slowly as possible along a piece of masking tape on the floor after waiting for the assessor's instruction to begin. In the Pencil Tap task, children were asked to tap a pencil against a desk once whenever the assessor tapped twice, and two times whenever the assessor tapped once. Assessors scored the tasks based on children's performance (e.g. ability to follow instructions) and latency to completion. These scores were reverse coded to represent difficulties with EC (see Raver et al., 2011, for additional details).

Following completion of the tasks, independent assessors completed the 28-item paper-and-pencil PSRA Assessor Report for each child. Items were coded using a Likert scale ranging from 0 to 3, with some items reversed-coded to minimize automatic responding. Factor analyses based on the full dataset yielded robust evidence for two factors: Inattention/Impulsivity (with 16 items loading > .4) and Positive Emotion (with seven items loading > .4; Smith-Donald et al., 2007; Raver et al., 2011). The final aggregate for the Inattention/Impulsivity subscale is used here as a global assessment of children's observed difficulties with EC at T, and includes items targeting children's concentration, distractibility, impulsivity, and regulation of arousal (e.g. '[child is] distracted by sights and sounds'). The overall internal consistency for the measure of observed EC at time T was high at α = .92. Table 2 shows the bivariate correlations between the PSRA tasks and assessor report. To reduce collinearity in study analyses, scores on the Pencil Tap task, the Balance Beam task, and the PSRA Assessor Report were standardized (i.e. z-scored) and averaged to create an overall composite of early EC difficulty. This composite was used as the final representation of EC problems at T. Children's difficulty with EC at T + 4 represents the dependent variable in this study's analyses, and was assessed using teacher-reported items from the Barratt Impulsiveness Scale (version 11; BIS-11; Patton et al., 1995) and the Behavior Rating Inventory of Executive Function (BRIEF; Gioia et al., 2000). Specifically, nine of the original 30 items of the BIS-11 were included to capture aspects of attentional impulsiveness (lack of focus or attention), motor impulsiveness (acting on the spur of the moment), and non-planning impulsiveness (lack of a future orientation; Moeller, Barratt, Dougherty, Schmitz & Swann, 2001). Items for the BIS-11 (e.g. 'child can only think about one thing at a time') were rated by teachers on a scale of 1 to 4 to indicate frequency of problems with EC (1 = rarely/never, 2 = occasionally, 3 = often, 4 = almost always/always). [2] In addition, 10 items were included from the working memory and inhibit subscales of the BRIEF, a measure of executive function for children aged 5 to 18 that has been used in clinical contexts to aid in the diagnosis of attention deficit hyperactivity disorder (Gioia et al., 2000; Isquith, Gioia & Espy, 2004; Mahone, Cirino, Cutting, Cerrone, Hagelthorn, Hiemenz, Singer & Denckla, 2002). Items on the BRIEF (e.g. 'has a short attention span') were rated by teachers on a scale of 1 to 3 (1 = never, 2 = sometimes, 3 = often), where higher scores indicate greater dysfunction. Items from the BIS-11 and BRIEF were combined for use in the present study to represent the overall dimension of EC, based on recent factor analytic work demonstrating robust internal and criterion validity among these items for low-income children across race, gender, and income status (McCoy, Raver, Lowenstein & Tirado-Strayer, 2011). The overall internal consistency for the final composite measure of 19 items was high at α = .97.

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[2] Due to an administrative error, the questionnaire used in this study provided five options, where 1 = rarely/never, 2 = occasionally, 3 = often, 4 = almost, 5 = almost always/always. To correct the inclusion of the erroneous option 4, scores for option 4 and option 5 were collapsed into a single response category during data cleaning.

Table 2 *Bivariate correlations of study variables*

	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	14.	15.	16.	17.	18.
1. EC difficulty (T + 4)	1																	
2. Intervention receipt	0.01	1																
3. Cohort	−0.05	−0.04	1															
4. Age	−0.06	0.01	−0.01	1														
5. Gender (boy)	0.24**	0.09+	−0.02	−0.03	1													
6. Race (African American)	0.10*	0.05	−0.54**	0.00	0.07	1												
7. Race (Hispanic)	−0.13**	−0.01	0.48**	−0.02	−0.09+	−0.86**	1											
8. Race (White)	−0.02	−0.11*	0.14**	0.09+	0.00	−0.28**	−0.11*	1										
9. Single mother	0.00	0.07	−0.14**	−0.02	0.06	0.24**	−0.21**	−0.06	1									
10. Mother <HS education	0.03	−0.11*	0.11*	0.00	−0.04	−0.21**	0.23**	0.01	0.01	1								
11. Balance Beam Task	0.09+	−0.06	−0.10*	−0.26**	0.02	−0.02	0.04	−0.17**	−0.08	−0.01	1							
12. Pencil Tap Task	0.20**	−0.11*	0.03	−0.34**	0.05	0.03	0.01	−0.12*	−0.09+	−0.06	0.32**	1						
13. PSRA Assessor Report	0.18**	−0.11*	0.08	−0.32**	0.16**	0.09+	−0.09+	−0.04	−0.02	−0.01	0.30**	0.44**	1					
14. Average EC difficulty (T)	0.21**	−0.12*	0.01	−0.41**	0.10*	0.04	−0.01	−0.14**	−0.08	−0.03	0.72**	0.78**	0.77**	1				
15. Average income-to-needs	−0.13**	0.04	0.20**	0.06	0.05	−0.7**	0.14**	0.06	−0.28**	−0.26**	0.00	0.00	0.01	0.01	1			
16. School poverty	0.03	−0.16**	−0.06	−0.02	−0.01	0.05	−0.01	−0.12*	0.03	0.10*	0.11*	0.08	0.03	0.10*	−0.24**	1		
17. Meet/exceed ISAT standards	−0.01	0.11*	0.25**	−0.05	0.01	−0.42**	0.35**	0.16**	−0.17**	0.05	−0.06	−0.03	−0.08	−0.07	0.30**	−0.52**	1	
18. Low adult support	−0.01	−0.11*	0.40**	0.04	0.06	−0.28**	0.22**	0.10*	−0.14**	0.03	−0.04	−0.04	0.03	−0.02	0.12*	−0.05	0.02	1
19. Unsafe school climate	0.03	0.01	−0.22**	0.08	0.02	0.40**	−0.42**	−0.01	0.15**	−0.06	0.03	−0.00	0.05	0.03	−0.29**	0.41**	−0.72**	0.00

Note: ** $p < .01$; * $p < .05$; + $p < .10$.

Income and poverty

Children's experiences of family income and poverty were reported by caregivers for the past year at each of the three time points (in Head Start at time T, a year later at T + 1, and 4 years after preschool when children were in 2nd or 3rd grade, at T + 4). First, income-to-needs ratios for each time point were calculated as the family's reported total household income for a given year divided by the federal poverty threshold for that year, adjusted for the number of persons in the home. To reduce the potential influence of positive outliers on study analyses, income-to-needs ratios were top-coded at +2 SDs from the mean within each time point. Income-to-needs ratios across all three time points were then averaged to create an estimate of family income-to-needs across the preschool to early elementary school period.

School quality

School quality was measured using (a) school-level poverty, estimated as the proportion of students in the child's school who were eligible for free or reduced price lunch, and (b) school-level achievement, estimated as the proportion of students in the child's school who had passed basic proficiency standards in reading and math on the Illinois Standards Achievement Test (ISAT; Illinois State Board of Education, 2009). Values for each elementary school in which study children were enrolled were extracted from the CPS CEO Report, a database listing the percentages of students who met or exceeded the ISAT standards by grade and subject area.

In addition, two additional measures of school quality were included: (c) unsafe school climate and (d) low adult support. These two aggregates were based on 22 school-level variables collected in 2008 from administrative and publicly available data from CPS. These data came from the Student Connection Survey (SCS), which provides information on school climate as rated by middle-school students and is reported at the school level for each CPS school. The SCS is administered to all 6th-, 7th-, and 8th-grade students in the CPS system. It records students' perceptions of several aspects of the school environment, including the degree to which students feel safe, challenged, supported, and socially and emotionally skilled (Osher, Kendziora & Chinen, 2008). Because 80% of all elementary schools in the CPS system serve either kindergarten through 8th grade or pre-kindergarten through 8th grade, the SCS data are considered to be reflective of both middle- and elementary-school climate. Past factor analytic work conducted with the 22 school-level variables revealed good fit for the two aggregates included in the present analyses (Lowenstein, Raver, Jones & Pess, 2011). Cronbach's alphas for survey items loading onto the school quality dimensions of unsafe school and low adult support were .95 and .79, respectively.

Child- and family-level covariates

Demographic information was collected using a questionnaire completed by the primary caregiver at each time point, and included the following: child's gender, age, grade, and race/ethnicity; and caregiver's marital status and highest level of education completed. In addition, a set of preschool-level covariates were included to take into account children's enrollment in treatment versus control-assigned Head Start programs during the first year of their involvement in the study, as well as their membership in the first versus second cohort of the two-cohort design to account for potential unmeasured historical factors.

Missing data

Complete data were available for all 391 children in the present sample for the dependent variable of EC at T + 4, as well as for basic demographic information (i.e. race, gender, maternal education, maternal marital status), and for school-level data at T + 4. However, a moderate proportion of children were missing data on either income or EC at earlier time points. Specifically, although 54.48% had complete income data across all time points, 38.36% were missing income data at one time point and 7.16% were missing income data at two time points. No children were missing income data at all time points. For children who were missing income data, average income-to-needs ratios were calculated using data from any available time point, ignoring the missing time points. Such a strategy allowed for inclusion of all participants in the dataset and was preferable to less precise missing data estimation methods or listwise deletion.

In addition, 16.11% of the sample was missing data on EC from Head Start. Rather than excluding these children from analyses, full information maximum likelihood (FIML) was used to estimate model parameters in Mplus (version 6; Muthén & Muthén, 1998–2010). FIML makes use of all available data to estimate coefficients within the full set of participants, including those with missing data on early EC. This approach is considered superior to alternative methods of addressing missing data, including listwise deletion or mean imputation, as it retains use of the full sample and provides less biased, more efficient estimates (Enders & Bandalos, 2001). To guard against the small likelihood of biased estimates from the use of FIML to handle missingness, all analyses were re-run and checked with a restricted sample of those cases with no missing data for early EC at T; results of this sensitivity check are reported below.

Results

Table 1 presents descriptive statistics and Table 2 presents bivariate correlations for the key independent and dependent variables included in the present analyses. For regression analyses, a series of three models was run in

which children's difficulty with EC at T + 4 was predicted from child-, family-, and school-level variables, as well as a series of interactions. All models utilized a residualized change approach, where children's levels of teacher-rated EC problems 4 years after Head Start were predicted controlling for their earlier problems with EC in preschool. Specifically, Model 1 included individual-level variables only, including child characteristics, family characteristics (including families' average income-to-needs ratios across all three time points), and a set of covariates (including early levels of EC difficulty). In Model 2, level-2 variables for school-level poverty, school-level academic achievement, and school climate indicators (unsafe school climate and low adult support) were included as predictors of children's EC problems at T + 4. Finally, Models 3a and 3b incorporated interactions between child/family characteristics and school characteristics to test the role of children's EC problems in preschool and exposure to family poverty as moderators. That is, Model 3a tested interactions between children's EC at T and each of the school-level variables, and Model 3b tested cross-level interactions between families' average income-to-needs across time and each of the school-level variables.

For analyses, all variables were grand mean-centered to aid in interpretation of interaction coefficients. There was a negligible level of nestedness within classrooms for most of our sample, with most T + 4 schools containing multiple classrooms per grade, and approximately 80%

of the schools in our sample containing three or fewer participant children (mean number of participants per school = 2.43, SD = 2.70, range = 1–22). As an additional robustness check, intra-class correlations for EC at T + 4 were calculated and indicated that only approximately 5% of the variance in children's EC difficulties 4 years after their Head Start year was attributable to the school level, rather than the individual level. To account for this small degree of non-independence, standard errors for all analyses were adjusted for students' clustering in T + 4 schools using the CLUSTER command in Mplus.

Table 3 presents coefficients and standard errors for all models predicting children's EC difficulties at T + 4. As is shown in Table 3, Model 1 demonstrates that boys were rated by elementary school teachers as displaying significantly higher levels of difficulty with EC than girls (B = 0.29, SE = 0.06, p < .01), and Hispanic children were rated by teachers as having significantly lower levels of difficulty with EC relative to their African American counterparts (B = −0.19, SE = 0.09, p < .05). Results from Model 1 also indicate that children who had higher levels of difficulty with EC in fall of their Head Start year were rated by elementary-school teachers as having higher levels of difficulty with EC 4 years later (B = 0.16, SE = 0.05, p < .01). Supplementary analyses were conducted to examine the predictive utility of each of the early EC measures: When each early measure was entered separately at Level 1, children's early performance on the pencil tap task was the

Table 3   *Results of linear regression predicting children's executive control difficulties four years after Head Start from early profiles of executive control, child demographics, family income-to-needs, and school-level poverty, quality, and climate*

	Model 1		Model 2		Model 3a		Model 3b	
	B	(SE)	B	(SE)	B	(SE)	B	(SE)
Level 1 Estimates								
Intercept	2.001**	(0.095)	2.048**	(0.098)	2.025**	(0.096)	2.052**	(0.097)
Intervention receipt	0.032	(0.060)	0.026	(0.060)	0.022	(0.060)	0.030	(0.060)
Cohort	0.048	(0.066)	0.035	(0.067)	0.042	(0.068)	0.038	(0.067)
Child age (in months)	0.009	(0.052)	0.020	(0.051)	0.017	(0.051)	0.022	(0.050)
Child gender (1 = boy)	0.288**	(0.060)	0.282**	(0.061)	0.277**	(0.061)	0.280**	(0.062)
Child Race: White	−0.045	(0.112)	−0.103	(0.118)	−0.053	(0.132)	−0.084	(0.118)
Child Race: Hispanic	−0.191*	(0.090)	−0.253**	(0.091)	−0.256**	(0.091)	−0.251**	(0.090)
Caregiver marital status (1 = single)	−0.082	(0.071)	−0.072	(0.070)	−0.048	(0.069)	−0.071	(0.070)
Caregiver education risk (1 = <HS education)	0.057	(0.088)	0.045	(0.086)	0.052	(0.084)	0.039	(0.087)
Child early executive control difficulties (time T)	0.160**	(0.048)	0.168**	(0.049)	0.169**	(0.046)	0.165**	(0.049)
Average family income-to-needs ratio	−0.180**	(0.069)	−0.210**	(0.070)	−0.195**	(0.071)	−0.205*	(0.071)
Level 2 Estimates								
School poverty			0.002	(0.003)	0.003	(0.003)	0.002	(0.003)
% Meet/Exceed ISAT standards			0.005	(0.004)	0.005	(0.004)	0.004	(0.004)
Low adult support			0.003	(0.004)	0.003	(0.004)	0.002	(0.005)
Unsafe school climate			−0.001	(0.004)	−0.001	(0.004)	−0.001	(0.004)
Cross-Level Interactions								
Early EC difficulty * School poverty					0.001	(0.004)		
Early EC difficulty * ISAT					0.008+	(0.005)		
Early EC difficulty * Low adult support					0.004	(0.004)		
Early EC difficulty * Unsafe school climate					0.011**	(0.004)		
Average family income * School poverty							−0.001	(0.007)
Average family income * ISAT							−0.010	(0.008)
Average family income * Low adult support							−0.006	(0.007)
Average family income * Unsafe school climate							−0.008	(0.007)

Note: ** p < .01; * p < .05; + p < .10. Table includes unstandardized coefficients and adjusted SE. All variables grand mean-centered.

strongest of the three early measures of executive control when predicting later EC at T + 4 ($B_{penciltap}$ = 0.11, SE = 0.04, p < .01, $B_{balance}$ = 0.02, SE = 0.03, p = ns, and B_{PSRA} = 0.03, SE = 0.04, p = ns). Additional supplementary analyses suggest that the PSRA Assessor Report of early EC was a statistically significant predictor of later EC when entered alone (and direct assessments were not included) (B = 0.12, SE = 0.05, p < .05). Regarding family level predictors, higher average family income-to-needs ratio from T to T + 4 was significantly predictive of lower levels of EC difficulty in elementary school (B = −0.18, SE = 0.07, p < .01), even after controlling for other family characteristics such as caregiver education and single head of household status (neither of which was a significant predictor of children's EC difficulty).

Results from Model 2 suggest that school-level variables were not statistically significant predictors of children's difficulties with EC at T + 4 after controlling for family income-to-needs ratio, child characteristics, and baseline levels of EC problems. However, Model 3a revealed that the interaction between schools' lack of safety and children's difficulties with EC in preschool was statistically significant at p < .01. Specifically, as is shown in Figure 1, children with differing early profiles of EC did not differ in their risk of later problems with EC when they were enrolled in schools that were independently rated as relatively safe (i.e. 'low' on ratings of unsafe climate). However, early preschool profiles of EC appear to be clearly related to differential outcomes among children who attend more unsafe schools. Specifically, children with high levels of early EC problems showed even greater levels of EC difficulty relative to their peers when they attended unsafe elementary schools. In contrast, children with low early EC problems showed the lowest amount of later EC difficulty
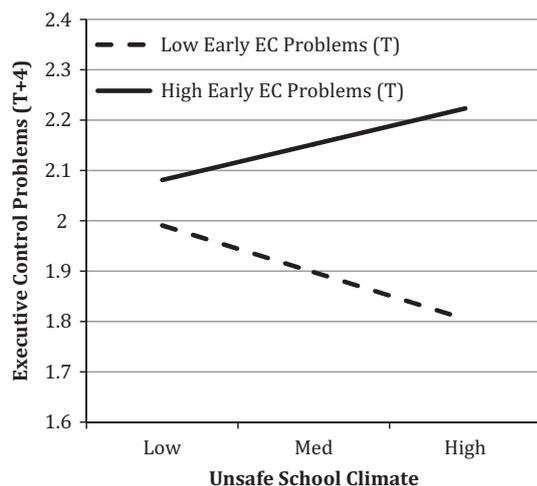

Figure 1 *Visual representation of the relationship between unsafe school climate and children's executive control problems in elementary school, as moderated by children's early levels of executive control difficulty in Head Start. Notes: EC = Executive Control; For unsafe school climate, Low = 1 SD below mean, Med = mean, High = 1 SD above mean; For early EC difficulty, Low = 1 SD below mean, High = 1 SD above mean.*

when enrolled in unsafe schools. Additional analyses revealed that the simple slopes of the relationship between school safety and children's later EC difficulty were significantly different from zero for both low levels (i.e. 1 SD below the mean) of early EC difficulty (t(271) = −2.51, p < .01) and high levels (i.e. 1 SD above the mean) of early EC difficulty (t(271) = 2.47, p < .01). No significant interactions were seen in Model 3b between early EC difficulty and family poverty. Finally, results of an additional set of identical 'sensitivity check' models using listwise deletion to restrict the sample to cases that were not missing early EC data suggest that the sign and statistical significance of all coefficients reported above were robust to the FIML approach taken to handle missing data. An additional table of results of these post-hoc sensitivity analyses is available from the authors upon request.

Discussion

In light of recent, positive news of the role of early executive control for supporting academic outcomes, a key question in developmental science is whether individual differences in young children's EC are stable versus relatively malleable over time. In particular, is there evidence to suggest that disadvantaged environmental contexts of home and school may shape children's trajectories of executive control over time? If so, what additional role does children's early EC play in predicting later individual differences in this key cognitive domain? It is these questions that this study aimed to address.

First, our findings clearly suggest that children's EC in early childhood is a robust predictor of their later ability to manage their attention, impulses, and working memory as rated by teachers in early elementary school. Most past longitudinal research on children's executive processes has spanned several years *within* developmental periods such as early childhood or adolescence: This study offers new empirical insight into the development of EC by bridging *across* key developmental periods of early and middle childhood. We were able to capitalize on our early, multi-component measure of children's executive function in preschool (which included both direct assessment and observer report) as a composite indicator of EC in early childhood. With this composite measure, we found that, for every one standard deviation increase in early EC problems in preschool, children showed a 0.12 standard deviation increase in later EC difficulty in early elementary school. Although the effect size (or magnitude) of children's early inattention and impulsivity in predicting children's EC difficulty in elementary school is relatively small, it is important to recognize that these associations hold true even when including multiple covariates in the model and relying on two different composite measures across the time points spaced 4 years apart. In broader terms, this highlights the ways that children maintain some stability in their profiles of higher-order executive processing skill, even when taking into account exposure

to a wide range of ecological supports and threats, over time. Additional research by other research teams (including longitudinal studies currently underway and led by colleagues such as Diamond, Fox, Carlson, Blair and Moffitt) will help us to determine the extent to which our findings are generalizable across different samples, different settings, and across different measurement approaches.

Second, in keeping with past research, our analyses also revealed that EC in elementary school was associated with several key child characteristics. For example, teachers reported boys as having greater problems with EC in elementary school relative to girls, even when accounting for baseline rates of inattention and impulsivity. Results also indicated that teachers rated African American children as having more difficulty with EC than Hispanic students. Although these differences may be attributable to true differences in the ways in which EC problems develop across time for children with different demographic profiles (e.g. through the influence of sex hormones on neurological maturation, differential socialization processes, or exposure to additional risk across gender/culture), they may also be reflective of biases in teachers' ratings of child behavior. Past research has shown that teachers may rate behavior or academic performance differently when children's race or ethnicity does not match their own (Zimmerman, Khoury, Vega, Gil & Warheit, 1995). Future research is needed to better understand the ways in which the school environment may frame the expectations for different children's attentiveness, planfulness, and inhibitory control based on 'social address' characteristics, as well as ways in which these expectations might affect teachers' ratings of child behavior.

Third, our findings expand recent theoretical and empirical discussion of the role of multiple forms of adversity in shaping children's EC over time. Specifically, our results suggest clear evidence for the role of lower family income over a 4-year period in predicting children's increasing difficulties in EC in early elementary school. This work also supports prior research with a rural, low-income sample of younger children indicating that exposure to economic forms of environmental adversity is associated with substantial cost to low-income children's cognitive functioning (Blair *et al.*, 2011; Raver *et al.*, 2012). This set of findings extends prior work on SES and children's executive function to consider the role of family-level adversity as children make the transition from early to middle childhood. In addition, by controlling for children's preschool levels of EC difficulty when predicting EC in elementary school, this study takes on a statistically conservative approach to estimating the specific role that individual-, family-, and school-level factors may play in shaping changes in EC across this critical period of development. Taken together, these findings support the hypothesis that prefrontal cortical development continues to demonstrate malleability or plasticity in the period between early and middle childhood, with family-level poverty playing an important role in shaping these trajectories across time.

Fourth, our findings are the first, to our knowledge, to provide evidence of the role of school-level adversity in predicting children's EC in middle childhood. Specifically, we found that children were at greater risk of continuing to demonstrate elevated levels of problems with EC if they were enrolled in schools that were violent or unsafe. However, these relationships only held true for those children who showed initially elevated levels of difficulty with executive control when they were preschoolers, 4 years earlier. These findings align with recent models of differential susceptibility, where some children appear to be particularly vulnerable to long-term negative sequelae of environmental adversity (see Obradović *et al.*, 2010, for extended discussion). Teachers in very unsafe schools viewed these children at greatest risk of having difficulty with higher-order, top-down abilities that would help them focus their attention and inhibit their impulses in real-world classroom situations filled with delay, distraction, and cognitive interference. Our findings for this group suggest that early EC difficulty, when paired with unsupportive educational settings, may not bode well for low-income children's opportunities for learning. In contrast, the role of school safety was not as clear for those children demonstrating higher EC in early childhood, with 'high early EC' children in very unsafe schools reported by teachers to manifest lower levels of later EC problems than other similar children who were attending safer schools. We suspect that this may have been at least partly a result of the ways that children with early profiles of cognitive competence may be viewed by teachers relative to their other students in unsafe, violent, or chaotic schools.

Our findings are a helpful reminder that our later measure of EC depends at least partially on the 'eye of the beholder', and may not only capture individual differences among the children in our sample, but also differences between teachers in their perception of CSRP children relative to other children in their schools. These findings highlight the need for direct assessments as well as adults' reports of EC in middle childhood in future longitudinal studies of this kind. In addition, although our findings suggest that some aspects of school context were found to matter for children's EC, others such as school-level poverty and school-level achievement were not. Future research will aid in clarifying the specific components of school contexts that may increase children's risk of difficulty in EC and whether such difficulties are mediated through increased allostatic load and compromised neuroendocrine functioning, as some colleagues have suggested (Chen, Cohen & Miller, 2010).

Limitations

One significant limitation to this study is the restricted range of incomes represented by families enrolled in the CSRP sample. Although we had the remarkable opportunity to capitalize on long-term follow-up of this preschool intervention sample, the initial recruitment of families through the federally funded and means-tested

Head Start program (for which families are eligible only if they are poor, with income-to-needs ratios generally no greater than 1.0) meant that the sample is limited in the range of family incomes it represents. The restricted range of income, in turn, makes it more difficult to detect the role of financial disadvantage in predicting individual differences in children's cognitive function. Given that caveat, we speculate that our estimate of the role of income poverty for children's difficulty with EC represents a lower bound, or an underestimate, rather than an upper bounded or inflated estimate. Future research with a more economically diverse sample may better answer questions of the magnitude of association between this form of adversity and children's EC.

A second limitation is that we are seriously limited in our ability to draw causal inferences from our study. For example, children's elementary-school-aged EC difficulties and peers' perceptions of school safety may be bi-directional. Similarly, we cannot rule out the role of unobserved or omitted variables from our models linking adversity and child EC. Other investigators have made the case for the high heritability of EC, for example; the implication is that we cannot rule out the role that parental self-regulation may play as a predictor of income poverty, families' schooling choices, and child EC in our analyses. Despite this limitation, we have taken care to include early measurement of child EC in the preschool period in our models, with the expectation that time-invariant (i.e. potentially genetically transmitted) characteristics that might emerge early in childhood are essentially controlled in our analyses. In short, we have tested the role of family income from early to middle childhood as a predictor of increases versus decreases in difficulty with EC over time in our analyses. In light of this limitation, experimental interventions using randomized design, whereby families and children are randomly assigned to higher quality schools or to income support such as the earned income tax credit (EITC) through lotteries are the next right empirical step to be taken in order to draw causal inferences regarding the roles of poverty and school quality for children's development of EC.

Third, although the inclusion of early EC difficulties represents a considerable strength of our study, the use of different measures and reporters for EC across time may have led to increased 'noise' in our analyses that resulted from measurement error. It is important to note, however, that the use of different measurement techniques likely led to an underestimate rather than overestimate of the relationship between EC in early and middle childhood.

Conclusions

Findings from this study address recent calls for multidisciplinary approaches to developmental cognitive neuroscience, shedding light on ways that children's early profiles of executive control work dynamically with their exposure to adversity in home and school contexts to

shape their later profiles of executive control (see, for example, Scerif, 2010; Society for Neuroscience, 2009). These findings 'set the stage' for additional inquiry into ways in which environmental adversity in children's home and school contexts may have short- and long-term influences for children's neurocognitive outcomes. In turn, integrated models of ways that neurocognitive processes such as executive control are affected both by individual and environmental factors may be particularly important for the fields of developmental psychopathology and prevention science, particularly given that difficulty with EC serves as a robust predictor of adolescents' later risk-taking behavior (Pharo, Sim, Graham, Gross & Hayne, 2011). In our view, this area of inquiry has much to offer both developmental science and related fields of translational research in the years ahead.

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