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Poverty as a Predictor of 4-Year-Olds' Executive Function: New Perspectives on Models of Differential Susceptibility

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In a predominantly low-income, population-based longitudinal sample of 1,259 children followed from birth, results suggest that chronic exposure to poverty and the strains of financial hardship were each uniquely predictive of young children's performance on measures of executive functioning. Results suggest that temperament-based vulnerability serves as a statistical moderator of the link between poverty-related risk and children's executive functioning. Implications for models of ecology and biology in shaping the development of children's self-regulation are discussed.

Keywords: poverty, executive function, self-regulation

Burgeoning evidence from intersecting fields of developmental neuroscience and education suggests that children's executive functioning plays a key role in supporting early learning and positive behavioral outcomes in school (Blair, 2002; Blair & Razza, 2007; Blair et al., 2011; Raver et al., 2011). Put simply, children who can remember information, who can regulate their attention, and who can maintain inhibitory control are in better position to take advantage of opportunities for learning than children who struggle with problems of memory, inattention, and impulsivity. How do these important individual differences in executive functioning (EF) arise among young children?

Recently, a number of investigators have offered a set of interactionist models as a key theoretical lens through which to map the ontogeny of individual differences in the development of self-regulation, including EF (Blair & Urshache, 2010; Boyce & Ellis, 2005). Developmental theory (Cairns, Elder, & Costello, 1996; Gottlieb, 1983, 2007) posits that environmental and genetic sources of influence work mutually and interactively to produce children's differing behavioral profiles and that these profiles are adaptive within specific socially defined contexts. For example, theories of differential susceptibility or sensitivity to context have been immensely helpful in highlighting ways that children who are more temperamentally reactive are not only more likely to exhibit poor outcomes when reared in conditions of psychosocial adversity but are also more likely to exhibit advantageous outcomes when reared in highly supportive environments (Belsky & Pluess, 2009; Boyce & Ellis, 2005).

Yet this new area of research has primarily focused on the role of children's temperamental predispositions in magnifying or attenuating the effects of exposure to adversity (see, e.g., Pennington et al., 2009; Wiebe et al., 2009) and has focused less attention on ways that children's environments themselves may change over time. For example, the differential susceptibility model poses a partitioned G $\times$ E (i.e., Gene $\times$ Environment) framework, where children's temperamental reactivity is understood to represent the potential maximizing of reproductive fitness under conditions where environments can be alternately supportive or harsh from one generation to the next (Belsky & Pluess, 2009). But how can these models be applied to predict individual differences in EF when children move into and out of materially harsh and ecologically hazardous environments within a generation, or even within a given epoch of childhood?

In this paper, we explore ways that models of differential susceptibility can be expanded in light of recent advances in the study of human development in social context. Parallel to the emergence of more complex models in the field of behavioral genetics, new research on the roles of poverty and poverty-related risk has led to clearer recognition of the extant complexity of socioeconomic forces in shaping development. For example, a number of recent studies have reported robust evidence that children's EF is clearly associated with families' socioeconomic status (SES), but those findings have not yet been extensively "unpacked" to detect whether those results are driven primarily by more stable components of SES, such as parental education, or by

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more rapidly changing family economic status characteristics, such as parental income or financial strain (Hughes, Ensor, Wilson, & Graham, 2010; Kishiyama, Boyce, Jimenez, Perry, & Knight, 2009; Mezzacappa, 2004; Noble, McCandliss, & Farah, 2007). Recently, several innovative theoretical and analytic approaches have been taken to model the role of multiple dimensions of family economic disadvantage over time in predicting young children's outcomes (Blair, 2010; Hutto, Waldfogel, Kaushal, & Garfinkel, 2011; Magnuson & Votruba-Drzal, 2009).

As these new approaches suggest, families' experience of economic disadvantage can be more complexly characterized as a dynamic process: Both the chronicity and the depth of poverty exposure matter for children's development, with chronicity of exposure to poverty found to be more deleterious to children's outcomes than is family poverty status at a single point in time (Brooks-Gunn & Duncan, 1997; Magnuson & Duncan, 2006; Wagmiller, Lennon, Kuang, Alberti, & Aber, 2006). Adversity associated with poverty can also be more complexly modeled across multiple dimensions as well as across time, as we describe in greater detail, below. Using these more complex models, we examine whether chronic exposure to poverty and poverty-related risk are significantly predictive of EF among children enrolled in the Family Life Project (FLP), a population-based sample of African American and White families living in nonurban and low-wealth counties in North Carolina and Pennsylvania (see Burchinal, Vernon-Feagans, Cox, & Family Life Project Key Investigators, 2008). The FLP was designed to study young children and their families who live in two of the four major geographical areas of the United States with high poverty rates (Dill & Williams, 1992), with three counties in eastern North Carolina and three counties in central Pennsylvania selected to be indicative of the Black South and Appalachia, respectively.

Using longitudinal data drawn from this sample, we consider the role of poverty-related risk for children's EF through an alternative theoretical lens known as experiential canalization (Gottlieb, 1983, 2007). Rather than viewing individual and environmental influences as essentially fixed and at best statistically interactive, experiential canalization describes the process whereby environments and individual characteristics are mutually influential over time (Gottlieb, 2007; see Blair & Raver, 2012, for more extensive discussion of Gottlieb's theory of canalization as it relates to the development of EF). From the perspective of experiential canalization, individual differences in EF can be understood as arising from the complex interplay between children's temperamentally based reactivity and their exposure to a wide range of time-varying environmental supports and hazards through the earliest years of life.

In this paper, we specifically test an experiential canalization model of EF, testing whether chronic exposure to time-varying hazards (or risks) posed by income poverty are predictive of children's performance on a set of EF tasks at 48 months of age. We test the role of chronic poverty and poverty-related risk, even after taking into account the depth of poverty and hardship experienced by families when they are first assessed in their child's early infancy. We then ask whether children's biologically based temperamental characteristic of high reactivity (assessed in early infancy) and children's membership in one of three racial/region categories serve as key moderators of those time-varying risks posed by poverty. In these ways, we expand current models of differential susceptibility and environmental influence to allow for the ways that those environmental conditions (a) are multidimensional, (b) may remain stable or may change over time, and (c) may be moderated by children's temperamental and demographic characteristics.

Linking Poverty and Children's Development of EF

What evidence is there to suggest that children's EF is negatively affected by cumulative exposure to environmental adversity? Recent research suggests that environmental adversity places children under greater allostatic burden, altering human stress response physiology in ways that are likely to directly influence executive function abilities (Arnsten & Li, 2005; Blair et al., 2011; 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 et al., 2008; Evans, 2003; Raver, 2004). The regulation of the stress response, in turn, is a central influence on the prefrontal executive system (Blair, Granger, & Razza, 2005; Lupien et al., 2005; Ramos & Arnsten, 2007).

In support of this model, a recent set of findings suggests that poverty and poverty-related stressors are generally associated with higher allostatic load, lower executive function ability, and compromised self-regulation for young children (Blair et al., 2011; Evans, 2003; Evans, Gonnella, Marcynyszyn, Gentile, & Salpekar, 2005; Hackman & Farah, 2009; Noble et al., 2007). To more fully understand ways that poverty may affect children's EF, however, our empirical attention must be widened to consider a set of poverty-related cofactors that families face when trying to make ends meet with low incomes (Evans & English, 2002; Gershoff, Aber, Raver, & Lennon, 2007; Magnuson & Duncan, 2006). Drawing evidence from neuroscience, prevention science, and applied developmental psychology, we detail preliminary evidence for these multiple poverty-related cofactors as likely predictors of children's EF skills, below.

Expanding Models of Poverty

The field's approach to the study of poverty and children's EF can be broadened in several key ways. First, extant models may be improved by the inclusion of families' income-to-needs ratio as a key indicator of poverty. The income-to-needs ratio represents a given family's reported pretax cash income relative to an absolute estimate of family "emergency needs", and it has significant material consequences in the lives of families trying to make ends meet (see Hutto et al., 2011). In particular, a family's status as being at or just below the U.S. federal poverty threshold (or an income-to-needs ratio at or just below 1.0) renders that family eligible for a host of material supports including child care assistance, food assistance, and health care access from local, state, and federal sources (Gershoff, Aber, & Raver, 2003; Meyer & Sullivan, 2003).

Second, given the stress mechanisms that are hypothesized to underlie the linkage between SES and EF (Blair, 2010; Evans & Schamberg, 2009), it is important to test whether the psychological strains that low-income families often face can be empirically distinguished from material measures such as income in predicting children's EF. In much recent research, family financial strain is operationalized in terms of parents' subjective experience of not being able to keep up with the challenges of meeting basic necessities such as food, clothing, and shelter with the limited income that is available (Burchinal et al., 2008; Edin & Lein, 1997; McLoyd, 1998). Recent analyses of poverty and family functioning in this sample suggest that low income powerfully shapes families' experiences of psychological strain: Families that reported the lowest incomes when their infants were approximately 7 months of age also struggled with higher levels of financial strain and lower levels of psychological well-being in the two and a half years that followed (Newland, Crnic, Cox, & Mills-Koonce, 2012). A pressing next empirical question is whether parents' perception of financial strain (or their report of struggling to make ends meet) is uniquely associated with children's executive function, even after family income and maternal education have been statistically accounted for. In the following analyses, we include families' reports of financial strain in addition to family income from infancy through the preschool period as predictors of children's EF at 48 months as one way to answer that question.

Third, income also clearly determines the places where young children can live, with poverty seriously constraining families' housing and neighborhood choices. Housing costs make up the largest share of poor families' budgets, with lower income families inhabiting homes in more dangerous neighborhoods with fewer rooms, less privacy, and more noise (Iceland & Bauman, 2007). Household characteristics such as lack of safety, noise, and crowding are associated with greater cognitive and neuroendocrine indicators of stress and lower levels of child adjustment (Dahl, Ceballo, & Huerta, 2010; Evans, Rhee, Forbes, Allen, & Lepore, 2000; Evans & Wener, 2007; Kujala & Brattico, 2009; Schapkin, Falkenstein, Marks, & Griefahn, 2006). Recent quasi-experimental and experimental studies of low-income families' housing mobility and symptoms of anxiety and stress suggest that low housing quality may be an additional dimension of poverty-related risk to consider, even after taking income and psychological dimensions of poverty into account (Halpern, 1995; Ludwig et al., 2008). We therefore test whether exposure to unsafe, crowded, and noisy environments may be uniquely associated with preschoolers' difficulties with EF even after controlling for maternal education, income, and financial strain.

Finally, consistent with the canalization approach, recent research suggests that an important next step in expanding models of poverty is to consider the chronicity of families' exposure to low income and hardship rather than whether they are poor at a given point in time (Bane & Ellwood, 1986; Huston & Bentley, 2009). For example, persistent poverty over the first 5 years of life has approximately twice the explanatory power in predicting children's intellectual development as does transient poverty (Bane & Ellwood, 1986; Duncan & Brooks-Gunn, 1997). Magnuson and Votruba-Drzal (2009) highlighted ways that families' experiences of poverty and hardship may be marked by volatility, where "events like unemployment and divorce lead families into poverty and reemployment, marriage, and career gains pull them out" (Magnuson & Votruba-Drzal, 2009, p. 155). To capture children's episodic versus chronic exposure to poverty-related adversity, a number of investigators in the field of child development and social policy consider the total number of years that children spend at or below the federal poverty threshold as a key predictor of their chances of later behavioral and academic success (Foster, 2002; Magnuson & Votruba-Drzal. 2009; also see Analytic Strategy, below, for a hypothetical example illustrating the utility of this approach). Thus, in this paper, we consider the role of chronicity of poverty as well as the role of chronic exposure to poverty-related risks over time as key predictors of children's EF at 48 months of age.

Although we focus on the effects of poverty in the child's early years, considerable research indicates the importance of considering pre- and perinatal exposure to risks associated with economic disadvantage as additional aspects of the link between SES and EF. Accordingly, we also take into account the depth of families' experiences of poverty and poverty-related hazards in early infancy (as reported during parents' first home visit when infants are age 7 months). We consider the extent to which chronic exposure to poverty, chronic exposure to family financial strain, and chronic exposure to substandard housing quality, as reported by parents from their 15 through their 48 month assessments, are strong or weak predictors of children's executive function at 48 months after controlling for the same poverty-related risks at baseline (see Nepomnyaschy & Garfinkel, 2011, for additional discussion of this approach).

To help distinguish the roles of these different types of poverty-related hazard in models of early cognitive development, we also include mother's level of education as an independent predictor of children's EF at 48 months. For example, poor parents with higher levels of education may be able to make key nonmonetary investments by structuring linguistically and cognitively enriching activities to support their infant's cognitive development (Landry, Miller-Loncar, Smith, & Swank, 2002; Magnuson & Duncan, 2006). Recent work points to the value of disaggregating maternal education from SES: Parental education has recently been found to correlate with corticostriatal functioning and connectivity among adults in response to reward, net of financial disadvantage (Gianaros et al., 2011). To check the robustness of our findings, we also consider whether these multidimensional models of poverty-related risk hold, even when we include (a) changes in maternal education, (b) changes in family status as "low-income" rather than "poor" (i.e., by setting the threshold for economic disadvantage somewhat higher at 1.85 times the poverty threshold), and (c) family income-to-needs ratio averaged across 15 to 48 months in place of chronic exposure to poverty (Gershoff et al., 2003). These robustness checks help us avoid the risk of potentially overstating the role of chronic exposure to poverty in predicting children's EF.

The Moderating Roles of Child Reactivity and Race/Region

A key lesson drawn from recent research on SES and child outcomes is that exposure to poverty and other poverty-related hazards may not affect all children equally. Past research suggests that linkages between poverty and children's cognitive outcomes may be substantially moderated by both child characteristics on the one hand and demographic and community contexts in which children reside on the other. For example, recent work on differential susceptibility supports the hypothesis that some children are more temperamentally sensitive to environmental hazard than others: Highly reactive children have been found to thrive in more supportive environments while facing greater vulnerability in more adverse environments, relative to their less reactive counterparts (Belsky & Pluess, 2009; Obradović, Bush, Stamperdahl, Adler, &

Boyce, 2010). In short, children's temperamental reactivity may confer advantage in some conditions and greater vulnerability in other conditions, serving as a key moderator in models of the link between poverty and the development of executive function. To test this hypothesis, the following analyses consider the moderating role of children's temperamental proneness to high levels of negative emotional reactivity assessed through laboratory-based paradigms administered in infancy. Because we are interested in the role of chronic poverty on potentially canalizing young children's EF in different ways for children with early profiles of high versus low reactivity, we restrict our analyses to tests of negative emotional reactivity at 7 months of age as a moderator. We pursue this restricted set of analyses recognizing that emotional, physiological, and behavioral patterns of reactivity and regulation within the context of poverty represent complex modeling challenges in their own right and are also likely to demonstrate dynamic change over time (see Blair et al., 2011; Towe-Goodman, Stifter, Mills-Koonce, Granger, & Family Life Project Key Investigators, 2011).

Families' experiences of poverty and children's subsequent attainment of key cognitive competencies may also be substantially conditioned by demographic characteristics (Elder, Eccles, Ardelt, & Lord, 1995; Raver, Gershoff, & Aber, 2007). For example, some studies (but not others) have found that poverty-related risks appear to operate in relatively equivalent ways across multiple racial/ethnic and regional groups (Burchinal et al., 2008; Raver et al., 2007). Given these equivocal findings, the following study takes careful steps to detect whether models of poverty, poverty-related risk, and the development of children's EF fit similarly or differently for children with substantially different demographic characteristics, given that the FLP sample includes both African American and White families within North Carolina as well as White families within Pennsylvania.

In sum, models of poverty and child executive function can be expanded to establish not simply *whether* poverty is associated with child executive function but *how* poverty may be associated with child executive function and *for whom* poverty may be most deleterious. To examine these questions, we consider whether chronic exposure to poverty, including multiple spells of low income as well as multiple spells of financial strain and inadequate housing during early childhood, are associated with lower executive function ability, even after taking into account children's exposure to poverty-related risk at baseline (or 7 months of age). Second, we test whether models of poverty and children's EF are moderated by child temperamental reactivity at age 7 months, on one hand, and by a demographic profile that includes race/ethnicity and region, on the other. Our goal in considering the role of these two potential moderators is to test ways that EF can be understood as arising from the complex interplay between children's temperamentally based sensitivity and their exposure to a wide range of time-varying environmental supports and hazards, reflecting the process of experiential canalization.

Method

Participants

The FLP adopted a developmental epidemiological design in which sampling procedures were employed to recruit a representative sample of 1,292 children whose families resided in one of the six counties at the time of the child's birth. The sample was drawn using an epidemiological frame, with low-income families in both states and with African American families in North Carolina being oversampled. (African American families were not oversampled in Pennsylvania, as the target communities were > 95% White.) At both sites, recruitment occurred 7 days per week over the 12-month recruitment period spanning September 15, 2003, through September 14, 2004, using a standardized script and screening protocol. The coverage rate was over 90% for all births that occurred to women in these counties in that 1-year period. In Pennsylvania, families were recruited in person from three hospitals. These three hospitals represented a weighted probability sample (hospitals were sampled proportional to size within county) of seven total hospitals that delivered babies in the three target Pennsylvania counties. Pennsylvania hospitals were sampled because the number of babies born in all seven target hospitals far exceeded the number needed for purposes of the design. In North Carolina, families were recruited in person and by phone. In-person recruitment occurred in all three of the hospitals that delivered babies in the target counties. Phone recruitment occurred for families who resided in target counties but delivered in non-target county hospitals. These families were located through systematic searches of the birth records located in the county courthouses of nearby counties.

FLP recruiters identified 5,471 (59% North Carolina, 41% Pennsylvania) women who gave birth to a child in the 12-month period. A total of 1,515 (28%) of all identified families were determined to be ineligible for participation for three primary reasons: not speaking English as the primary language in the home, residence in a nontarget county, and intent to move within 3 years. Of the 2,691 eligible families who agreed to the randomization process, 1,571 (58%) families were selected to participate using the sampling fractions that were continually updated from our data center. Of those families selected to participate in the study, 1,292 (82%) families completed a home visit at 2 months of child age, at which point they were formally enrolled in the study. Based on the mothers' ethnic status, the sample was 58% White and 42% African American, and 66.6% of the sample had an income-to-need ratio less than 200% of poverty. A little over half (51.9%) of the mothers were not married at the time the study began, and the majority (88.8%) of single mothers had never been married.

Procedures

Families were seen in home visits at child ages of approximately 7, 15, 24, 36, and 48 months. At all time points except 15 months, families were seen in two separate visits. All home visits for data collection were two or more hours in duration. During visits for data collection conducted at 7, 15, and 24 months, mothers completed questionnaires concerning family demographics, estimated earned income for all members of the household for the prior year, and completed a set of parent–child interaction tasks (Cox, Paley, Burchinal, & Payne, 1999; National Institute of Child Health and Human Development Early Child Care Research Network [NICHD ECCRN], 1999). Near the conclusion of the home visit for data collection at 7 months, children were presented with emotion challenge tasks designed to elicit emotional responding, including a mask presentation, barrier task, and arm restraint. All procedures have been previously validated (Stifter & Braungart, 1995). As an assessment of infant reactivity, child peak distress was coded and temperamental proneness to distress was reported by data collectors on survey reports.

At the home visit at child age 48 months, children were administered tasks to assess executive function. Children were seated across from the experimenter at a convenient location in the home. All tasks were administered in a standard order. The executive function tasks were administered at the conclusion of an assessment session in which children also completed a series of tasks with the mother that included a picture book reading task, an empathy task, and a puzzle task. Cumulatively, these tasks took about one hour to complete.

Measures

Executive function was assessed with three newly developed tasks designed to primarily assess the working memory, attentional set shifting, and inhibitory control dimensions of the construct. The EF tasks were modeled on tasks previously used successfully with young children and included a span-type working memory task, a spatial conflict inhibitory control task, and an item selection attentional flexibility task. In the working memory span task, children must hold in mind two pieces of information simultaneously and activate one while overcoming interference from the other. In the task, children are presented with a line drawing of an animal figure above which is a color dot. Both the animal and the color dot are located within the outline of a house. After establishing that the child knows both colors and animals in a pretest phase, the examiner asks the child to name the animal and then to name the color. The examiner then flips a page containing only the outline of the house to cover the page with the animal and the color dot. The examiner then asks the child which animal was/is/lives in the house. The task requires children to perform the operation of naming and holding in mind two pieces of information simultaneously and to activate the animal name while overcoming interference occurring from naming the color.

The item selection task is modeled on the flexible item selection task developed by Jacques and Zelazo (2001). In the version of the task developed for flipbook administration, children are first presented with a page on which there are two line-drawn items that are identical in terms of shape, size, or color. The examiner draws the child's attention to the dimension along which the items are identical, stating, "See, here are two pictures. These pictures are the same, they are both [cats, blue, big, etc.]." The examiner then flips a page that presents the same two items again, to the right of which is a dashed vertical line and a picture of a third item. The new third item is similar to one of the first two items along a second dimension that is different from the similarity of the first two items (e.g., if the first two items were identical in shape, the third item would be identical to one of the first two items in either size or color). When presenting the new, third item to the child, the examiner states to the child, "See, here is a new picture. The new picture is the same as one of these two pictures. Show me which of these two pictures is the same as this new picture." Percent correct responding on 14 trials was used for analysis. This task is preceded by a pretest in which children demonstrate knowledge of color, shape, and size.

The spatial conflict arrows task is a Simon task similar to that used by Gerardi-Caulton (2000) to assess inhibitory control. A response card, which has two side-by-side black circles that are referred to as "buttons," is placed in front of the child. The research assistant turns pages that depict either a left-pointing or a right-pointing arrow. The child is instructed to touch the button on the left with the left hand when the arrow points to the left and to touch the button on the right with the right hand when the arrow points to the right. Across the first eight trials, arrows are depicted centrally (in the center of the page). These items provide an opportunity to teach the child the task (touch the left button when you see left-pointing arrows and the right button when you see right-pointing arrows). For Items 9–22, left- and right-pointing arrows are depicted laterally, with left-pointing arrows always appearing on the left side of the flipbook page (left arrows appear "above" the left button) and right-pointing arrows always appearing on the right side of the flipbook page (right arrows appear "above" the right button). These items build a prepotency to touch the response card based on the location of the stimuli. For Items 23–35, left- and right-pointing arrows begin to be depicted contralaterally, with left-pointing arrows usually (though not exclusively) appearing on the right side of the flipbook page ("above" the right button of the response card) and right-pointing appearing on the left side of the flipbook page ("above" the left button of the response card). Items presented contralaterally require inhibitory control from the previously established prepotent response in order to be answered correctly (spatial location is no longer informative). Responses (correct, incorrect) to contralaterally presented items were used for purposes of scoring.

As is standard for executive function measures with children (Zelazo, 2006), for all tasks children were required to successfully complete pretest trials in which they clearly demonstrated knowledge of the rules for the task and the ability to successfully complete the pretest trials as instructed. Children were also required to complete 75% of test trials in a given task in order to receive a score for that task. Of 1,049 children administered the executive function tasks, 927 successfully completed the working memory span task, 954 successfully completed the attention flexibility task, and 971 successfully completed the spatial conflict inhibitory control task. All tasks were scored as percent correct responding: working memory span, $M = .56$, $SD = .27$; attention flexibility, $M = .72$, $SD = .18$; inhibitory control, $M = .52$, $SD = .28$. Scores were moderately correlated (rs $= .19$–$.27$, $p < .0001$).

Income-to-need ratio was calculated as the family's reported total household income for a given year divided by the federal poverty threshold for that year, adjusted for number of persons in the home. Income-to-needs ratios were then used in three different ways in our analyses. First, based on work by our collaborators suggesting the relatively minimal slope of increase in income-to-needs from infancy through early childhood, *depth of poverty* at baseline was defined as family income-to-needs ratio at 7 months of age (Newland et al., 2012). Family transitions into and out of poverty were calculated as 1 versus 0 for each assessment period. (In accordance with federally recommended thresholds of income-to-needs ratio, families whose income was less than or equal to 1.0 were coded as "poor" and given a score of 1, and families whose income fell above 1.0 were coded as "nonpoor" and were given a score of 0.) Second, *chronicity of time spent in poverty* from 15 to 48 months was calculated by summing the number of times families were categorized as poor over those four assessment periods (see Table 1). Third, *chronicity of time spent in low-income status* was calculated by summing the number of times families had income-to-needs ratios that fell at or below an income-to-needs ratio value of 1.85, for use in follow-up analyses serving as a robustness check (see below).

Financial strain. Families' report of financial strain was indexed by four items drawn from the Economic Strain Questionnaire, an index of the degree to which families had enough money in the household to cover the costs of housing, food, clothing, and medical care (Conger & Elder, 1994). Items were reversed and averaged for an aggregate score of financial strain for the 7, 15, 24, and 35 month assessments; they demonstrated moderate associations with family income-to-needs ratios across all time points, the expected direction ($r = -.22$ to $r = -.33$, $p < .001$). For each time point, families were coded as coping with significant financial strain (a score of 1) at a given time point if their aggregate reversed score was 3.0 or higher (i.e., they disagreed or strongly disagreed with the statement that they had enough money to afford basic needs); otherwise, they were scored 0 for that time point (see Nepomnyaschy & Garfinkel, 2011). *Chronicity of financial strain* was calculated by summing the number of times the family was categorized as experiencing categorically high levels of strain across 15, 24, and 35 month assessments.

Housing quality. Families' exposure to substandard housing quality was assessed via observer reports on four items tapping the cleanliness of the home, the number of rooms in the home, the safety of the building's interior, and safety of the area outside the building on a 0–4 Likert-type scale, with higher scores indicating higher housing quality. Average scores across all four items (reversed) were calculated to indicate low housing quality at each time point (6 months, 24 months, 35 months, and 48 months). Aggregate scores were then dichotomized (i.e., assigned a value of 0 when the score was equal to or above 3.0, representing a rating of "adequate," or of 1 if the score fell below 3.0 within time points) and summed across time points for scores of *chronic exposure to substandard housing quality*.

Temperamental proneness to high negative emotional reactivity was captured by (a) peak emotional arousal during three emotional challenge tasks and (b) observer reports on the irritability subscale of the Infant Behavior Record (IBR; Bayley, 1969) as adapted for use by Stifter and Corey (2001). Assessments of peak emotional arousal were completed via independent coders' ratings of low, moderate, and high negative reactivity using Better Coding Approach software (Danville, Pennsylvania), with coders trained to achieve at least .75 (Cohen's k) reliability on the reactivity coding. A composite score for negative reactivity for each task was created by summing the seconds of low, moderate, and high negative reactivity and then calculating the proportion by dividing the sum of all negative reactivity scores by the total time of the task. Subsequent interrater reliability was calculated on 15% of cases using kappa coefficients, resulting in a kappa of .94 for the masks task, .89 for the barrier task, and .86 for the arm restraint task at the infancy assessment. After the 7 month home visit, an adaptation of the IBR was completed independently by both home visitors. The IBR was applied to behavior observed globally across the entire home visit (Stifter & Corey, 2001). The IBR scales included Sociability, Positive Affect, Attention, Activity Level, Reactivity, and Irritability, with alphas ranging from .70 (Irritability) to .88 (Attention). The mean of the Irritability subscale from home visitors' ratings was combined with peak arousal during the direct assessment to provide a single aggregate that has been shown in recent latent class analyses to reliably distinguish highly reactive from less reactive temperamental profiles across early infancy for the children in this sample (Towe-Goodman et al., 2011).

Demographic category membership in race/region. On the basis of parental report of child race as either Black or White and on residence in either North Carolina or Pennsylvania, children

Table 1
Descriptive Statistics for FLP Sample

Variable (n)	Full sample *M*	Full sample *SD*
Concurrent/recent		
Maternal age	30.44	6.98
Maternal education	12.82	1.74
% mothers reporting increase in education, 6 to 48 months	20%	
Marital status = married	50%	
Income-to-needs ratio (n = 1,044)	1.63	1.37
Financial strain (n = 1,092)	2.00	0.65
Housing quality (n = 1,008)	3.02	0.58
EF at 48 months	0.60	0.18
At 6 months		
Income-to-needs ratio (n = 1,173)	1.84	1.69
Financial strain (n = 1,163)	2.12	0.69
Housing quality (n = 1,151)	2.99	0.57
Infant reactivity	0.03	0.89
From 15 months to 48 months		
No. spells ≤ poverty threshold	1.35	0.30
No. spells ≤ low income threshold	2.55	1.59
No. spells high financial strain	0.30	0.67
No. spells low housing quality	0.96	1.11

Note. FLP = Family Life Project; EF = executive functioning.

were categorized as members of one of the following racial/region categories: North Carolina Black, North Carolina White, Pennsylvania White, or Pennsylvania Black. Because so few Pennsylvania-residing children were identified as Black or African American (n = 33), this small subgroup of children was excluded from the following analyses. Children's membership in the remaining three racial/region groups was subsequently dummy coded (0, 1) to allow separate estimation of the role of racial group membership for children living in North Carolina (with North Carolina Black scored as 1 and North Carolina White scored as 0) and to estimate the role of state residence for children identified as White (with Pennsylvania White scored as 1 and North Carolina White scored as 0). As indicated by this coding procedure, children categorized as North Carolina White represent the reference group against which the other two groups are compared in all analyses presented below.

Additional demographic covariates. Several additional key family demographic covariates (assessed at 48 months) were included in the following analyses, including mother's level of education, mother's age, and mother's marital status as single (with marital status as never married, divorced, or separated coded as 1 and as married coded as 0). Mother's level of education was coded to indicate years of education from elementary to high school completion (scored as 1–12). Post-high school education status was aggregated to yield categories indicating some college (but no degree), associate's degree, 4-year college degree, some post-college (but no degree), master's degree, professional degree (including MD and JD), and Ph.D., at each wave of data collection (13–19). Of the sample, 20% of mothers reported an increase in education level from 7 to 48 months (M = .36, SD = .76). Education level data at 48 months were used in all ordinary least squares (OLS) regressions in order to credit families with highest level of educational attainment completed.

Analytic Strategy

Issues of missing data were first addressed with the following approach. Total sample size recruited at study entry was 1,292 children, with 1,204 seen at age 7 months, 1,169 at 15 months, 1,144 at 24 months, 1,123 at 36 months, and 1,066 at 48 months. To assess possible differential attrition in the sample at each time point, we examined a number of variables for which we had complete information collected at child age of approximately 2 months. The variables included state of residence, race, sex, child age at the 2 month follow-up, an income screen, total number of household members, number of children in the household, and primary caregiver age, education, marital status, and employment. Few variables indicated differences between families who were present and those who were missing at each time point. For example, at 15 months, no variables differentiated participants who were missing from those who were present. At 24 months, missing participants were more likely have been older at the 2 month follow-up, to have resided in North Carolina, and to have a primary caregiver who was employed. To avoid bias in estimates associated with missing data, we imputed data using the MI procedure in SAS. We imputed 20 analysis data sets and recombined regression estimates using the MIANALYZE procedure in SAS, yielding efficiency in the estimates of greater than 98%.

Descriptive data are briefly examined to provide a broad overview of families' experiences of poverty and poverty-related risks at 7 months of age and of chronicity of exposure to poverty and poverty-related risks across the child's first through fourth year. Following descriptive analyses, a series of OLS regression analyses are conducted to detect the role of chronic poverty and chronic exposure to poverty-related risks for children's EF at 48 months.

Consideration of a hypothetical family's experiences illustrates the utility of including chronicity of children's exposure to poverty and poverty-related risk over time as predictors in our analyses. Imagine that a parent earns $18,000 a year in 2006 (putting the family just above the U.S. poverty line) when her child is age 1 but then loses her job and falls below the poverty line for Years 2 and 3 (earning approximately $12,000 per year in 2007 and in 2008). By Year 4, the parent gets a job that pays $22,000 a year in 2009, lifting her small family substantially above the poverty line for that year. If averaged across all 4 years, the family's income might hover just above the poverty line, obscuring the ways that the family struggled below the U.S. poverty threshold for 2 of the child's first 4 years. We therefore include chronicity of exposure to poverty and poverty-related risk, rather than averaged values for these risks, as key predictors in our central analyses.

As is mentioned in the Method section, chronicity of exposure to poverty is operationalized as the sum of the number of years that a given family spent at or below the poverty line, as reported by families during yearly assessments from 15 to 48 months. To streamline our model of children's chronic versus limited exposure to multiple forms of disadvantage, we use the same approach of dichotomizing risk for a given year (e.g., experiencing higher versus lower financial strain, or being rated as in housing that is either at or above standards of basic adequacy or below that standard) and then summing those exposures across 15, 24, 36, and 48 month assessments for a given poverty-related risk. In this way, we are then able to test a comprehensive model where the chronicity of exposure to multiple forms of adversity can be tested and interpreted across multiple analyses.

When we estimate the role of exposure to chronic poverty and poverty-related risks in predicting children's executive function using OLS regression analysis, we also include (a) baseline levels of the depth of poverty and baseline levels of poverty-related risks when children were 7 months of age. As articulated earlier, this helps distinguish children's exposure to poverty-related risk in the perinatal period from (b) chronicity of exposure to poverty and of exposure to poverty-related risks from 15 to 48 months. We also include (c) infant reactivity and racial/region group membership as predictors. We then conduct additional regression analysis with (d) changes in mother's education included as an additional predictor, with (e) chronicity of exposure to low-income status (as calculated by families falling at or below 185% of the U.S. poverty threshold) and (f) a continuous value of income-to-needs ratio averaged across 15 to 48 months, replacing the chronicity of exposure to poverty term (Item b above) as robustness checks to our main analyses. Within each set of models, additional analyses were completed with racial/region category membership and infant reactivity as statistical moderators to test whether associations differed for children with different early profiles of reactivity and for children with differing demographic profiles. All analyses were conducted with all continuous variables centered.

Results

Descriptive Analyses

Calculation of means and standard deviations suggest that, on average, families were poor to low income both at 48 months (with average income-to-needs ratio equal to 1.65, $SD = 1.137$) and at baseline ($M = 1.84$, $SD = 1.69$). Families experienced an average of 1.35 years of poverty over the subsequent 4 years (calculated across 15, 24, 36, and 48 month assessments). Patterns of financial strain and exposure to substandard housing quality demonstrated similar heterogeneity across the sample.

Testing the role of early and chronic poverty-related factors in predicting children's EF at 48 months. To test the roles of the depth and chronicity of exposure to poverty and to poverty-related hazards from infancy to early childhood, we next completed a set of OLS regression analyses where we regressed executive function performance at 48 months on four groups of variables, including (a) family demographic characteristics at 48 months, (b) baseline levels of the depth of poverty and poverty-related hazards when children were 7 months of age, (c) chronicity of exposure to poverty and of exposure to poverty-related hazards from 15 to 48 months, and (d) infant reactivity and racial/region group membership. In the first of this set of analyses (Model 1), we regressed EF performance at 48 months on these four groups of variables without including any interaction terms. Additional analyses were then run with children's EF performance at 48 months regressed on all four sets of predictors, plus an additional set of interaction terms for (e) child's profile of reactivity at 7 months and (f) child's membership in one of three racial/region categories included as moderators.

Results from this set of models provide clear evidence that children's performance at 48 months on the aggregate battery of EF tasks is robustly predicted by chronic exposure to poverty and to chronic exposure to environmental hazards associated with poverty, $R^2 = .22$, $F(12, 1246) = 22.39$, $p < .001$. Results suggest that children exposed to a greater number of years in poverty and to a higher number of spells of financial strain performed significantly worse on the battery of EF tasks relative to children who had experienced fewer years in poverty and fewer years of financial strain (see Table 2 for standardized and unstandardized regression coefficients and see Figure 1 for graphic representation of residualized means in EF performance across groups of children experiencing 0, 1, 2, or 3 spells of poverty).

Additional analyses testing for the moderating role of child reactivity at 7 months explained a small amount of additional variance in EF at 48 months, $R^2 = .23$, $F(15, 1243) = 18.71$, $p < .001$. Results suggested that child reactivity at 7 months serves as a moderator of the association between chronic exposure to income poverty and EF at 48 months ($B = .01$, $\beta = .07$, $p < .05$). Examination of graphed estimated values of EF suggest that, although slopes for both groups of children with differing temperamental profiles were negative (i.e., that children demonstrated higher EF scores when exposed to fewer number of years of poverty), this association was stronger (i.e., had a more steeply

Table 2
Predicting EF at 48 Months From Early and Chronic Exposure to Poverty and Poverty-Related Hazard

	EF_{mn}					
	Model 1		Model 2		Model 3	
Parameter	*B*	β	*B*	β	*B*	β
Intercept	.31***	.00***	.33***	.00***	.31***	.00***
Maternal education	.02***	.20***	.02***	.19***	.02***	.19***
Maternal age	.00	.00	.00	.00	.00	.00
Maternal marital status	.01	.03	.01	.03	.01	.03
NC Black	−.04**	−.12**	−.05**	−.12**	−.05**	−.13**
PA White	.07***	.20***	.07***	.19***	.08***	.21***
Reactivity at 7 months	.01†	.05†	.01	.04	.01*	.06*
Income at 7 months	.00	.01	.00	.02	.00	.00
Financial strain at 7 months	.01	.04	.01	.03	.01	.04
Housing quality at 7 months	.00	.01	.00	.01	−.00	−.01
Chronicity of income risk (15 to 48 months)	−.01**	−.10*	−.01**	−.11**	−.02†	−.16†
Chronicity of financial strain (15 to 35 months)	−.02*	−.07*	−.02*	−.07*	−.06*	−.20*
Chronicity of housing risk (15 to 48 months)	−.01	−.03	−.01	−.04	−.00	−.02
Chronicity of Income Risk × Reactivity			.01*	.07*		
Chronicity of Financial Strain × Reactivity			−.02*	−.06*		
Chronicity of Housing Risk × Reactivity			.00	.03		
Chronicity of Income Risk × PA White					.01	.04
Chronicity of Income Risk × NC Black					.01	.04
Chronicity of Financial Strain × PA White					.02	.07
Chronicity of Financial Strain × NC Black					.04	.12
Chronicity of Housing Risk × PA White					−.01	−.05
Chronicity of Housing Risk × NC Black					.01	.03
Total R^2	.22***		.23***		.23***	

Note. EF = executive functioning; NC = North Carolina; PA = Pennsylvania.
† $p < .10$. * $p < .05$. ** $p < .01$. *** $p < .001$.

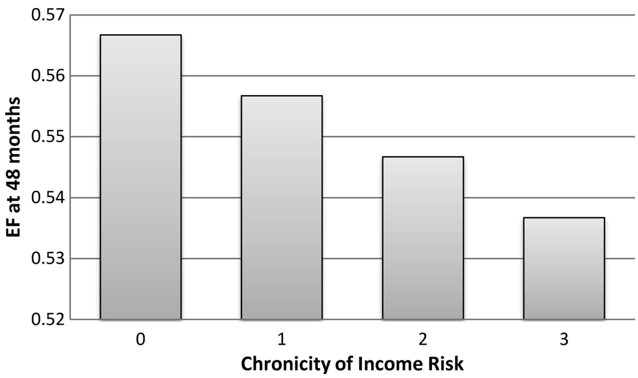

Figure 1. Executive functioning (EF) at 48 months predicted by chronicity of income risk, where chronicity (i.e., a value of 0, 1, 2, or 3) is defined as the number of 12-month time periods in which family income falls at or below the U.S. poverty threshold.

negative slope) for those children who were temperamentally less reactive in infancy. Results also indicated that reactivity serves as a moderator of the association between chronic financial strain and EF skills at 48 months ($B = -.02$, $\beta = -.06$, $p < .05$). Notably, the interaction of chronic financial strain with reactivity in the prediction of executive function at child age 4 years showed a different pattern suggesting a crossover interaction. In keeping with models of differential susceptibility (and as illustrated in Figure 2), lower exposure to financial strain is associated with higher performance on EF tasks at 48 months for children with temperamental profiles of high reactivity, and chronic exposure to high financial strain is associated with lower EF performance at 48 months for the same group of children. In contrast, exposure to chronic financial strain across infancy and early childhood is not associated with EF performance for children who had temperamental profiles of low reactivity in infancy (see Figure 2). Additional tests of interactions of racial/region group membership × poverty and × financial strain were not statistically significant, and they did not yield evidence for the role of race/region category as a moderator of the associations between poverty-related risk and executive function ability.

Additional analyses suggest that although mothers' educational level at baseline is statistically significant and a strong predictor of children's EF at 48 months of age ($B = .02$, $\beta = .19$, $p < .05$), mothers' increase in their educational attainment from 15 to 48 months was not a statistically significant predictor of their children's EF at 48 months ($p = .27$). In that model, results suggest substantially similar and statistically significant estimates for the role of chronic poverty ($B = -.01$, $p = .01$) and chronic exposure to financial hardship ($B = -.02$, $p < .05$) in predictions of EF, $R^2 = .22$, $F(13, 1245) = 20.68$, $p < .001$.

Finally, robustness checks were completed, where additional analyses with chronicity of time spent with family income-to-needs ratio falling in versus above the "low income" category of 185% of the U.S. poverty threshold were similar to findings yielded by our earlier analyses, $R^2 = .22$, $F(12, 1246) = 22.10$, $p < .001$. Regression coefficients for all predictors were in the same direction and of the same magnitude (or slightly smaller) in these latter analyses. Results suggested that children who had spent more years in low-income status performed significantly worse on the battery of three EF tasks relative to children who had experienced fewer years in low-income status ($B = -.01$, $p < .05$). Given their similarity to the findings reported earlier, these results are not graphed, but they provide assurance that chronic exposure to economic disadvantage (operationalized by summing the number of years that the family was below the low-income threshold) remains a robust predictor of children's EF across a range of model specifications. An additional, final model yielded nonsignificant findings for the role of a continuous measure of income-to-needs ratio averaged across 15 through 48 month assessments as a predictor of 48 month EF (table of unstandardized and standardized regression coefficients available from authors upon request).

Discussion

Rural families were initially recruited into the Family Life Project in 2003–2004, a time of relative economic prosperity in the United States as a whole but of general decline for nonmetropolitan areas in the United States. Consistent with this overall economic picture, our analyses suggest that many of the families in this study faced stark economic and material difficulties during the first 4 years of their children's lives. As with previous studies, our descriptive analyses suggest families' experiences with poverty and covarying risks or hazards are complex. For example, some children lived in households that were characterized as poor and chronically stressed across multiple years from 12 through 48 months, and other children were in families where poverty was temporary and where parents reported little financial strain.

Given this stark set of socioeconomic conditions, what were our findings regarding the roles of poverty and poverty-related hazards for children's EF? Our findings provide clear evidence for the role of chronic exposure to poverty and chronic exposure to key psychological stressors associated with poverty in predicting children's EF at 48 months. Taken together, these findings suggest that children whose lives were marked by multiple years of income

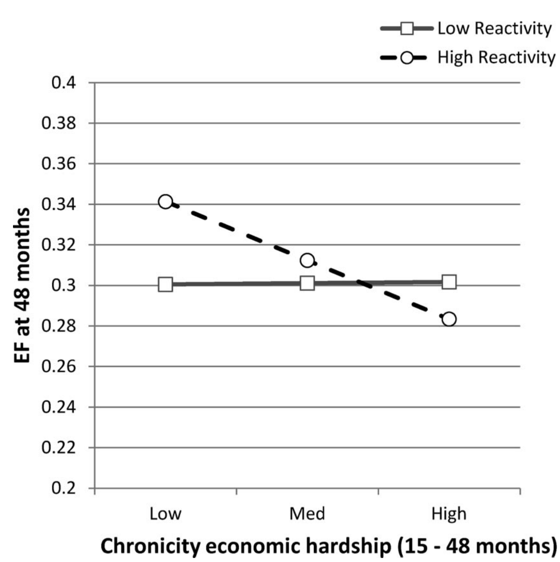

Figure 2. Executive functioning (EF) at 48 months predicted by chronic exposure to family financial strain, moderated by infant reactivity (and after adjusting for all covariates).

poverty from 15 to 48 months had lower EF at 48 months than did children who spent fewer years in poverty, even after taking into account the depth of poverty experienced by families during the crucial developmental period of early infancy. Effect size estimates from our analyses suggest reason for grave concern: Even after maternal demographic characteristics and exposure to a range of poverty-related hazards in early infancy were taken into account, each additional year that a given family lived at or below the poverty line was associated with .10 *SD* lower score on that child's performance on a battery of three EF tasks.

Families' experiences of a higher number of episodes of financial strain were also uniquely predictive of lower executive function at 48 months, signaling support for models whereby parental psychosocial stress and allostatic load serve as possible mechanisms through which poverty may have a deleterious impact on children's cognitive development (see Blair & Raver, 2012). Although tests of mediation through parental reports of psychological distress and parenting are beyond the scope of this paper, results from other recent analyses with the FLP data set suggest that these may be promising pathways to consider when testing models of experiential canalization of children's EF over time (see, e.g., Blair et al., 2011; Newland et al., 2012; Towe-Goodman et al., 2011).

Findings from our analyses also suggest that not all children are equally affected by conditions of income poverty and financial hardship. In our longitudinal analyses, chronic poverty was found to be more strongly negatively associated with lower EF scores for children with less temperamentally reactive profiles in infancy than for their more temperamentally reactive counterparts. In contrast, when we examined the joint roles of infant temperament and families' exposure to chronic financial strain, we found clear support for previously hypothesized models of differential susceptibility (Belsky & Pluess, 2009). That is, temperamentally more reactive children appeared more "responsive" to the presence versus absence of adversity when it was characterized in terms of parents' report of the psychological strains associated with material hardship. Our results indicated that temperamentally more reactive children exhibited lower EF in households that struggled with high levels of chronic financial hardship and exhibited higher EF in households that were less economically strapped, over time. In contrast, children with less reactive temperamental profiles showed similar levels of EF regardless of families' exposure to chronic financial strain. These latter findings are in keeping with theoretically similar ideas that temperamentally reactive children may demonstrate greater "biological sensitivity to context" than do children with less reactive profiles (Boyce & Ellis, 2005). It is surprising that this pattern was statistically detected with one but not both measures of poverty-related risk: The reasons for this discrepancy remain unclear and will be explored in future analyses. With that caveat in mind, our findings regarding the role of financial hardship for children's EF are in keeping with other models of "for better and for worse" differential susceptibility, obtained with measures of children's behavior problems, including their externalizing behavior problems and conduct disorder (Obradović et al., 2010). One of the innovative aspects of our analysis is the testing of differential susceptibility theory with a related but distinct aspect of self-regulation in childhood, namely, executive function.

In addition, this study extends earlier findings by our research team and others, suggesting ways that temperamentally based child characteristics and time-varying exposure to environmental hazards and environmental supports work in complex ways to canalize self-regulation development in young children (Bernier, Carlson, & Whipple, 2010; Blair et al., 2008; Li-Grining, 2007). In our view, these findings suggest that such a process of canalization (or the channeling of development) is complex and dynamic, as has perhaps been implied but not tested in previous models examining Child × Environment, or G × E interaction (Belsky & Pluess, 2009; Caspi et al., 2003; Keltikangas-Järvinen et al., 2009). As well, we did not find any evidence that children's demographic characteristics (as reflected by membership in racial and regional categories) served as a statistical moderator, suggesting that our models were equivalent across three different ecological settings when predicting children's performance on this EF task battery.

These findings contribute to two emerging areas in developmental science that consider the roles of economic hardship and poverty on one hand and biobehaviorally based vulnerability to environmental adversity on the other as important contributors to individual differences in children's behavioral outcomes. Building on and integrating those two strands of research, we found clear evidence for the ways that EF in early childhood may be jeopardized by experiences of poverty and poverty-related hazard. In our analyses, we considered ecological conditions of poverty as dynamically changing versus stable over time and as complexly characterized along psychological and spatial dimensions. Evidence from most prior research has been confined to concurrent (Hackman & Farah, 2009) or short-term longitudinal relations between broader social address markers of SES at a single time point and children's EF (Hughes & Ensor, 2007). This analysis has expanded that literature by demonstrating relations prospectively between specific aspects of the context of poverty over the child's first 4 years and this central aspect of emerging cognitive ability. In so doing, this study's findings are aligned with those of other recent studies with older children in which cumulative poverty was found to be predictive of difficulties with working memory and self-regulation (Evans et al., 2005; Evans & Schamberg, 2009). Our analyses demonstrate that this relation between length of time in poverty and executive functioning is detectable with a comprehensive direct assessment of EF designed to assess the tripartite division of the construct in its working memory, inhibitory control, and attention shifting components. As well, we demonstrate that this association is present not only for cumulative time in poverty but for children's cumulative exposure to families' experiences of financial strain, even after other poverty-related factors have been accounted for.

Limitations

Although these findings help to illuminate the process of experiential canalization of executive function in early childhood, they are limited in a number of respects. First, we acknowledge that this study is based on observational, longitudinal data collected over time and that we are not able to draw causal inferences from analytic methods that are essentially correlational in nature. One option to handle the threats posed by omitted variable bias might be to use fixed effects estimation when considering the role of chronic poverty in shaping children's cognitive outcomes more generally (NICHD ECCRN & Duncan, 2003, for example). However, in our case, we are constrained by the developmental reality that executive function is a late-emerging prefrontal neurocognitive capacity that emerges only in early childhood (Diamond, 2002). Thus, for conceptual as well as measurement reasons, we could not test the role of changes in poverty in predicting changes in EF from infancy to early childhood. That said, we have taken care to specify our models of the role of poverty and poverty-related cofactors in empirically conservative ways that (a) capture observable selection characteristics such as maternal age, maternal education, and maternal marital status and (b) distinguish the psychological and spatial characteristics of poverty-related hazard over and above family poverty status, itself. We also empirically distinguish the role of chronicity of poverty and poverty-related hazards in predicting children's EF from families' initial levels of poverty and poverty-related hazard during the perinatal period (i.e., before 7 months of age, at baseline). As children grow older and both the interpretability and the measurement of their executive function are increasingly robust (from early to middle childhood), we plan to take advantage of fixed effects estimation with additional waves of data in future papers, to continue to address this limitation.

Second, although our findings lead us to make inferences as to the role of the environment for progressive canalization of development by experience, our outcome and our moderators are measured at only one time point. Ongoing work by other members of our research team (as well as by other investigators) has highlighted the complex and dynamic nature of physiological, emotional, and behavioral dimensions of infant reactivity, over time (see Blair et al., 2008; Calkins, Graziano, & Keane, 2007; Towe-Goodman et al., 2011). Accordingly, the next right empirical step will be to model both intercepts and slopes of growth in EF as a function of stable versus changing temperamental profiles and of stable versus changing environmental conditions of poverty, as a more fine-grained test of experiential canalization.

Third, despite some intriguing prior findings of the link between noisy, crowded, and unsafe housing conditions and children's EF, we found no evidence to support this hypothesis in our analyses. Our ability to detect this association may have been hampered by less precise measures of housing quality in this study, as well as by relatively low rates of mobility among the families enrolled in our sample, where the majority of families may have found resourceful means of coping with income volatility without having to resort to moving out of their homes during the early years of their children's lives. Similarly, although other studies have found that children ages 6–12 years with younger mothers with lower levels of education do better on cognitively oriented assessments over time when their mothers go back and complete more years of schooling, this study did not find any evidence to support higher EF among children with mothers who attained more education, over time (Magnuson, 2007). Importantly, mothers' educational levels at baseline (i.e., when infants were age 7 months) was a significant predictor of EF at 48 months, suggesting that a second pathway involving more cognitively stimulating caregiving may also clearly support young children's attention, working memory, and inhibitory control (Gianaros et al., 2011; Landry et al., 2002). Recent work on maternal scaffolding and child development of EF from age 2 to age 4 supports this second pathway and suggests this may serve as an important protective factor for low-income children's development of EF (Bernier et al., 2009; Hammond, Müller, Carpendale, Bibok, & Liebermann-Finestone, 2012; Hughes & Ensor, 2009).

A fourth, important limitation is that the generalizability of our findings is expressly limited to a specific sample of African American and White children living in specific, well-defined rural regions of the United States. With the recent recession of 2008 and other major economic and policy changes, findings may not hold across time or across place. That said, these findings offer an important complementary set of empirical insights to the development of young children who are commonly underrepresented in most research on self-regulation.

Summary and Implications

Most previous studies that found evidence for the hypothesis of children's differential susceptibility to environmental adversity have focused on more broad domains of development, including children's behavior problems. In this study, we capitalized on a remarkable data set with extensive poverty-related survey measures and developmentally rich, direct assessments of infant temperamental reactivity and EF in early childhood to suggest specific ways in which models of susceptibility to environmental adversity can be extended to children's self-regulation. Our findings highlight possible mechanisms by which environmental adversity and temperamental reactivity may work together in multiple processes of complex co-action that shape children's skills in self-regulation. This study represents an important empirical step in testing the multiple environmentally and biologically mediating and moderating pathways through which time-varying environmental hazards may canalize EF development over time.

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