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Association of social-environmental factors with cognitive function in children with sickle cell disease

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Abstract

The aim of this study was to examine the relationship between cognitive function in pediatric sickle cell disease (SCD) patients and mothers' reports of social-environmental stress, depressive symptoms, and parenting. A total of 65 children with SCD completed comprehensive neuropsychological testing to assess several domains of cognitive functioning, including general intellectual ability, academic achievement, and executive function. Mothers reported on demographics, social-environmental stress, depressive symptoms, and parenting. As predicted, children with SCD significantly underperformed relative to normative data on measures of cognitive function. Associations between maternal social-environmental stress, maternal depressive symptoms, and parenting were mixed. The results show partial support for the hypothesis that greater stress and depressive symptoms and less positive parenting are associated with poorer cognitive function in children with SCD. Linear regression analyses showed that maternal financial stress was the strongest predictor across all domains of cognitive function. The findings replicate and extend past research, reaffirming that children with SCD are at risk for cognitive impairment across multiple domains. Additionally, social-environmental stress, particularly financial strain, is linked to mothers' depressive symptoms and parenting behaviors as well as children's cognitive function. Future studies using direct observations of parenting behaviors are needed. These findings, along with recent research on parenting interventions, may inform the development of concrete, teachable parenting and coping skills to improve cognitive functioning in children with SCD.

Keywords

Sickle cell disease; stress; cognitive function; poverty; parenting

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Sickle cell disease (SCD) refers to a group of inherited blood disorders that are among the most common monogenic disorders worldwide (Weatherall, Hofman, Rodgers, Ruffin, & Hrynkow, 2005). This chronic disease is characterized by recurrent pain crises, chronic anemia, and other debilitating complications. SCD most commonly affects those of African descent (Driscoll, 2007). In the United States (US), approximately 100,000 people live with SCD (Hassell, 2010).

Impaired cognitive function is one of the most significant adverse outcomes faced by individuals with SCD. Children with SCD experience cognitive deficits across several domains when compared to healthy peers and normative samples (e.g., Hijmans, Fijnvandraat, et al., 2011; Steen et al., 2005). In a comprehensive meta-analysis, Schatz, Finke, Kellett, and Kramer (2002) found that the mean IQ of children with SCD was 4.3 standard score points lower ($d = -.31$) than that of healthy comparison groups. More specifically, children with SCD underperform relative to controls on measures of verbal, performance, and general intelligence, as well as domain-specific areas of cognitive function such as memory, language, and executive function (e.g., Hijmans, Fijnvandraat, et al., 2011; Schatz, Puffer, Sanchez, Stancil, & Roberts, 2009). Further, school-aged children with SCD tend to score lower than their peers on tests of academic achievement, including reading, writing, and math (Schatz, 2004; Schatz et al., 2002). As an example of the magnitude of this difference in performance, Schatz (2004) found medium to large effects on tests of reading decoding ($d = -.65$) and math calculations ($d = -.80$).

To date, most research has focused on disease-related factors as predictors of cognitive dysfunction. In particular, patients are at increased risk of experiencing cerebrovascular disease, including both overt and silent strokes. Such injuries to the brain are associated with greater deficits in cognitive function when compared to both SCD patients with no neurological abnormalities and healthy controls (e.g., King et al., 2014; Schatz & McClellan, 2006). Given that children with SCD *without* a history of cerebrovascular disease also experience notable cognitive impairment (e.g., Brown et al., 2000; Hogan, Pit-ten Cate, Vargha-Khadem, Prengler, & Kirkham, 2006), it is important to consider the impact of other biomedical factors on patients' cognition. For example, cerebral blood flow, sleep-disordered breathing, and anemia severity have also been associated with deficits across a number of domains (e.g., Hijmans, Grootenhuis, et al., 2011; Hollocks et al., 2012). In the current study, hemoglobin levels were selected as an important biomarker of the oxygen-carrying capacity of red blood cells. Previously, low levels of hemoglobin have been found to be associated with lower IQ scores among children with SCD (Steen et al., 2003).

Nevertheless, biomedical characteristics of the disease only explain a portion of the variance in children's cognitive function, suggesting that there may be other important, but not yet explored, factors contributing to the observed effects. In a recent study, King et al. (2014) found that while biological factors play a significant role in the cognitive function of children with SCD, a considerable amount of the additional variance is associated with social-environmental factors, including parental education and income. While the 2012 US poverty rate (US$23,283 annual income for households with two adults and two children) was 15%, more than one quarter (27.2%) of all African-American families live in poverty (DeNavas-Walt, Proctor, & Smith, 2013).

This statistic has troubling implications for the predominantly African-American population of SCD patients. Indeed, a recent multi-site study showed that over 50% of individuals with SCD enrolled at sites in the US lived at or below poverty, and nearly 70% received Medicaid health coverage (King et al., 2014). Additionally, children with SCD are exposed to family conflict and family stress, which are related to greater functional impairment and poorer psychosocial adjustment (Treadwell, Alkon, Quirolo, & Boyce, 2010).

Although research on the impact of poverty on pediatric SCD patients is limited, recent work with healthy children does provide evidence of its damaging effects on early cognitive development. In a review of the relationship between socioeconomic status (SES) and brain development, Hackman and Farah (2009) described pronounced economic disparities in several areas of cognitive ability, including language, executive function, and memory. The impact of growing up in persistent poverty is also apparent on broader measures of cognitive functioning, such as IQ and academic achievement (e.g., Bradley & Corwyn, 2002; Sirin, 2005). Given that children with SCD experience disease-related effects on cognitive ability and many grow up in economically disadvantaged homes, a significant portion of these children may be facing a double burden of both biological risks and adverse environmental conditions.

In an effort to better understand the pathway through which social-environmental factors, including economic hardship, impact cognitive development in children, researchers have examined parents' functioning and parenting behaviors as possible mechanisms. Parents with low income are often faced with the challenges of unemployment, health problems, and a lack of vital resources (Guo & Harris, 2000) and report low levels of familial and community support (Middlemiss, 2003). Further, those who identify as African American often cite exposure to racial discrimination as a significant stressor (Sellers, Caldwell, Schmeelk-Cone, & Zimmerman, 2003), which research shows is related to a number of adverse outcomes, including poor physical and mental health (e.g., Gallo & Matthews, 2003). Further, the physical home environment of low-income families is often marked by high levels of crowding, noise, and chaos (Evans, Gonnella, Marcynyszyn, Gentile, & Salpekar, 2005). Persistent exposure to such conditions is associated with chronic psychological distress in parents, including elevated rates of depressive symptoms and difficulties with adjustment (Kaiser & Delaney, 1996). The stress and negative emotionality associated with poverty compromises parents' abilities to engage in responsive interactions with their children (Bradley & Corwyn, 2002). Indeed, socioeconomically disadvantaged adults often exhibit parenting behaviors that lack consistency, support, and sensitivity to children's needs (e.g., Hackman, Farah, & Meaney, 2010; Kaiser & Delaney, 1996).

Evans and colleagues have examined this concept of parental responsiveness extensively, demonstrating that psychological stress, limited social support and chaotic home environments partially account for the relationship between poverty and parental responsiveness (e.g., Evans, Boxhill, & Pinkava, 2008; Evans et al., 2010). Conversely, the resilience of some children raised in chronic high-stress environments may be attributed to parenting that is responsive and attuned to the child's needs. For example, Doan and Evans (2011) found that mothers who are highly responsive are more likely to exhibit child-centered teaching skills that stimulate cognitive development, thus indirectly compensating for the direct effects of long-standing poverty and stress. Given the evidence that parenting behaviors are implicated in the cognitive development of offspring, these findings are relevant to the SCD population (e.g., Lugo-Gil & Tamis-LeMonda, 2008; Tamis-LeMonda, Shannon, Cabrera, & Lamb, 2004).

Based on the theoretical framework of parent-mediated cognitive development in the face of poverty of Evans and colleagues (e.g., Evans et al., 2008), the purpose of the present research is to extend the existing literature on social-environmental stress, parenting, and cognitive function in the context of pediatric SCD. The following hypotheses were tested: (1) children with SCD will score lower than normative samples on measures of cognitive function, including the domains of intelligence, academic achievement, and executive functioning; (2) higher levels of social-environmental stress will be associated with higher levels of maternal depressive symptoms and lower levels of positive parenting behaviors; and (3) higher levels of maternal stress and depressive symptoms and lower levels of positive parenting will be associated with lower levels of cognitive functioning in children with SCD. Finally, exploratory analyses were used to examine stress, depressive symptoms, and parenting as unique predictors of children's performance on measures of cognitive function, after controlling for disease-related biomedical risk.

Method

Participants

A total of 65 children and their mothers were recruited to participate as part of a study of cognitive function and school achievement in children with SCD. The inclusion criteria for participants in the present study were: (a) a diagnosis of SCD confirmed by hemoglobin analysis; (b) current enrollment in a school; (c) documented brain magnetic resonance imaging (MRI) at 5 years of age or older; and (d) completion of the neuropsychological battery. Children with a prior history of known cerebrovascular disease were excluded from the study.

The children ranged from 6 to 16 years of age ($M = 11.2$, $SD = 3.2$). A total of 54% of children were diagnosed with hemoglobin SS, 25.4% with hemoglobin SC, and 20.7% with variations of hemoglobin S-beta thalassemia. Evaluation of patient MRI studies by a trained neuroradiologist confirmed that the majority of children (95.2%) displayed no evidence of stroke. The remaining 4.8% displayed evidence of past silent stroke. The scans were obtained within 24 months of study entry as part of standard clinical care. Examination of participants' school records from the academic year prior to evaluation showed that 25.9% of the sample had repeated a grade, 26.3% had an Individualized Education Program in place, and 14% had an established 504 Plan. Participants had missed an average of 24.4 school days ($SD = 22.1$) in the year prior to enrolling in the study.

At the time of enrollment, the mothers had a mean age of 37.7 years ($SD = 6.5$) and all self-identified as Black or African American. Just over half (56%) of the mothers reported attending some college or trade school. The majority of participants (82.4%) were employed outside of the home and earned an average monthly income of US$2,051, while 11.5% were unemployed. On average, parents had two children and reported living in households of approximately four people. Based on the reported monthly income and household size, 43% of participating families were living at or below the federal poverty threshold at the time of enrollment (DeNavas-Walt et al., 2013).

Measures

Hemoglobin levels—At study entry, a comprehensive review of medical records was completed, including extraction of hemoglobin concentration levels from the most recent laboratory data available within 30 days of the neuropsychological evaluation. Laboratory data was collected as part of standard clinical care visits. For the general population, normal hemoglobin levels are approximately 12–14 g/dL in clinical laboratories.

Intellectual functioning—The children completed the Wechsler Abbreviated Scale of Intelligence (WASI; Wechsler, 1999). The total combined performance on the tests' four subtests was used to generate the full-scale intelligence quotient (FSIQ), a broad estimate of general intellectual ability. The verbal intelligence quotient (VIQ) is designed to measure verbal comprehension and the performance intelligence quotient (PIQ) is designed to measure non-verbal intellectual abilities, specifically perceptual organization of visual stimuli.

Academic achievement—The children completed five tests from the Woodcock-Johnson-III Tests of Achievement (WJ-III; Mather & Woodcock, 2001): Math Fluency, Reading Fluency, Letter-Word Identification, Calculations, and Spelling. Reading Fluency and Letter-Word Identification are designed to assess a variety of reading skills including decoding, speed, and semantic processing. The Math Fluency and Calculations tests are an assessment of number facility, automaticity, and overall achievement in mathematics. Finally, performance in Spelling demonstrates achievement in basic writing skills.

Executive function—The children completed several performance-based tests from the Delis-Kaplan Executive Function System (D-KEFS; Delis, Kaplan, & Kramer, 2001). The D-KEFS consists of nine tests designed to measure verbal and spatial (non-verbal) components of executive function in children and adults. The current study included conditions from the Trail Making, Verbal Fluency, Color-Word Interference and Sorting tests. Collectively, these tests assess a variety of executive function domains such as flexibility, sequencing, shifting, and inhibition.

Mothers also completed the Behavior Rating Inventory of Executive Function (BRIEF; Gioia, 2000) with regard to their children's current functioning. The BRIEF is a paper-and-pencil questionnaire administered to caregivers to assess a variety of perceived behavioral concerns in children with regard to executive function. The BRIEF generates eight clinical scales that form the Global Executive Composite (GEC), an overall index of problems related to executive function. Two index scores are also generated: the Behavioral Regulation Index (BRI; the child's ability to utilize inhibitory control to regulate emotions and behaviors) and the Metacognition Index (MI; the child's ability to monitor and manage his or her own performance). Higher scores reflect more symptoms of executive dysfunction. Reliability and validity are well established for the BRIEF. Normative standard scores and

T-scores were derived from nationally representative samples of children for each of the cognitive function measures mentioned above.

Maternal social-environmental stress—Mothers' responses were solicited by a trained research assistant in an orally-presented, computer-assisted parent interview. Items were pre-programmed and read aloud from the computer screen. Participants were then able to enter responses with a keystroke. Mothers reported the frequency and/or magnitude of several potentially stressful social-environmental factors in the following four areas.

Financial stress: The strain associated with income and the mother's ability to provide essential resources for her family was measured as a composite of reported monthly income and scales derived from a measure created by Murry et al. (2008). Participants were asked a series of questions regarding their present financial situation to determine their ability to make ends meet (e.g., "how much difficulty have you had paying your bills during the past 12 months?") as well as the extent of any unmet material need (e.g., "we have enough money to afford the kind of food we need"; "we have enough money to afford the kind of medical care we need"). A previous study conducted with rural African-American women demonstrated acceptable reliability for both scales (α = .70 and α = .80, respectively; Murry et al., 2008).

Racial discrimination stress: Mothers also completed nine items derived from a revised version of the Schedule of Racist Events (SRE; Landrine & Klonoff, 1996). These items determine the frequency with which participants encounter a number of racially-biased situations (e.g., "how often have you been treated rudely or disrespectfully because of your race?"). The revised version of the SRE has been used in previous studies of sociodemographically disadvantaged youth and caregivers with internal consistency ranging from α = .87 to α = .89 (e.g., Brody et al., 2014).

Household constellation: Participants were asked to report the number of children currently living in the home. This information was used as a proxy to determine the size and general arrangement of the household. The number of people in the home is related to other markers of environmental stress, including noise and crowding in the home (Evans, 2006).

Home routine and chaos: The interview included a series of items related to routine and chaos based on a home environment scale constructed by Evans et al. (2005). This instrument is designed to measure the degree of planning (e.g., "we have an evening bed time routine with [child]") and order (e.g., "there is very little commotion in our home, we can talk to each other without being interrupted") present in the household. This scale has been used in previous work with low-income families with acceptable reliability (α = .77; Evans et al., 2005).

Maternal depressive symptoms—Within the parent interview, mothers completed the Center for Epidemiologic Studies Depression Scale (CES-D; Radloff, 1977). The CES-D is a widely used 20-item self-report measure designed to assess depressive symptoms in adults. For each item, participants report how often they have experienced a number of emotions and behaviors over the last week on a scale ranging from 0 (*rarely or none of the time*) to 3 (*most or almost all of the time*). The CES-D covers a range of depressive symptoms, including sadness, hopelessness, loneliness, altered appetite, and abnormal sleep. Reliability is well established for the CES-D, with internal consistency averaging $\alpha = .85$ among community samples.

Maternal positive parenting—Positive parenting behaviors were also assessed as part of the parent interview. Mothers were asked to use a 4-point scale to indicate how often they engaged in two specific components of positive parenting: consistent discipline and child monitoring. Consistent discipline refers to the mother's ability to maintain and adhere to previously established rules regarding the child's behavior (e.g., "how often do you discipline [child] for something at one time, and then at other times, not discipline him/her for the same thing?"). Items in this domain were based on questions constructed by Brody et al. (2001). Child monitoring refers to the mother's knowledge regarding events and activities in the child's daily life (e.g., "how often do you know when [child] does something really well at school or someplace else away from home?"). The items in this domain were derived from a revised version of the Monitoring Questionnaire (Brody, Dorsey, Forehand, & Armistead, 2002). Mothers reported the frequency of these behaviors on a scale ranging from 1 (*never*) to 4 (*always*). Responses from each of the two scales were scored and aggregated to create a combined index of positive parenting. In earlier work with African-American youth and caregivers, reliability for consistent disciple and child monitoring has ranged from $\alpha = .56$ to $\alpha = .91$ (Brody et al., 2001, 2002).

Procedure—The university Institutional Review Board approved the study protocol. Mothers of eligible children with SCD were identified and approached in an outpatient pediatric hematology clinic by a trained member of the research team. Mothers and children provided informed consent and assent, respectively. Children completed the neuropsychological testing battery while mothers completed the BRIEF and the additional questionnaires included in the parent interview. The study visit typically lasted 3 to 4 hours. For their efforts, participants received gift cards for local retail stores.

Data reduction—In order to reduce the number of analyses conducted, variables that measured similar constructs and were sufficiently inter-correlated were combined to create composite variables. All five tests of the WJ-III were significantly correlated ($p < .001$, $r = .52$ to .82). Therefore, the children's scores on these tests were averaged to create a composite academic achievement variable. The home routine and home chaos variables, which were not significantly correlated with other home environment variables, were examined independently in the analyses. Finally, monthly income, ability to make ends meet, and extent of unmet material need were significantly correlated ($p < .001$, $r = -.44$ to .80). Thus, mothers' scores on these variables were averaged to create a composite financial stress variable.

Statistical analyses—Statistical Analyses were conducted using the Statistical Package for Social Sciences, 19th Edition (SPSS). To test Hypothesis 1, means and standard deviations (*SD*s) of the WASI, WJ-III, D-KEFS, and BRIEF were calculated and one-sample *t*-tests (two-tailed) were used to compare pediatric SCD patients' performance on these measures to that of the normative samples. Effect sizes were determined using Cohen's *d* calculations with pooled SDs. Our interpretations of effect sizes are based on Cohen's definitions of small ($d = .20$), medium ($d = .50$), and large ($d = .80$) effects (Cohen, 1977). For Hypotheses 2 and 3, Pearson correlations were calculated to determine associations between measures of children's cognitive function, maternal social-environmental stressors, maternal depressive symptoms, and positive parenting. Finally, the impact of maternal social-environmental stress, depressive symptoms, and positive parenting on children's cognitive function was evaluated using multiple linear regression analyses. To account and control for disease-related risk, hemoglobin concentration was entered in Step 1 along with maternal financial stress, household constellation, and racial discrimination stress. Maternal depressive symptoms were entered in Step 2 and positive parenting was entered in Step 3. This ordering of independent variables represents a progression from predictors that are physically and psychologically distal to the dependent variable to those that are more proximal.

Results

Descriptive analyses

The mean hemoglobin concentration for the current sample was 8.8 g/dL ($SD = 1.6$), which is in the expected range for patients with SCD. When compared to the normative sample of same-age peers on measures of cognitive function, children with SCD significantly under-performed on a variety of domains related to intelligence, achievement, and executive functioning (Table 1). Participants scored significantly lower on all indices of the WASI, including VIQ, PIQ, and FSIQ (all *p*s < .05). Subscales with significant differences on the WASI ranged from small to medium effect sizes. Children with SCD also scored significantly below average on the Letter-Word Identification, Reading Fluency, Calculations, and Math Fluency tests of the WJ-III (all *p*s < .05) with effect sizes ranging from medium to large. There was no significant difference on the Spelling test of the WJ-III.

Results were mixed for both mother-reported and observed measures of executive function. On the BRIEF, mothers reported that their children with SCD experienced significantly more problems with tasks related to initiating, planning and organizing, and working memory. These problems were reflected in the MI and GEC scores, which were both significantly above average, with effect sizes ranging from small to medium. On the D-KEFS, pediatric SCD patients scored significantly lower than the normative sample on the Number/Letter Switching condition of the Trail Making task and the Inhibition Switching condition of the Color/Word Interference task, indicating deficits in functioning; Cohen's *d* effect sizes for both tests were in the medium range. There were no significant differences between children with SCD and the normative sample on any of the conditions of the Verbal Fluency or Card Sorts tasks. Because scores on the Trail Making and Color/Word Interference tasks differed significantly from the normative sample, they were included in the following correlational analyses.

Correlational analyses

Correlations among the measures of child cognitive function, maternal social-environmental stress, maternal depressive symptoms, positive parenting, and disease-related risk are presented in Table 2. Maternal depressive symptoms, as measured by the CES-D, were significantly positively correlated with both financial stress and racial discrimination stress. Positive parenting was significantly positively related to home routine, such that more positive parenting was associated with more home routine and structure. Positive parenting was also negatively correlated with financial stress, but was not related to household constellation, home chaos, or racial discrimination stress.

Results of the correlational analyses between child cognitive function and maternal stress and depressive symptoms were mixed. Maternal financial stress was significantly negatively correlated with children's VIQ, FSIQ, academic achievement, and D-KEFS scores. Financial stress was also positively related to executive function as measured by the BRIEF, implying greater concern for executive dysfunction with increasing financial stress. There was no significant association between maternal financial stress and children's PIQ scores. Home routine was significantly negatively associated with the BRIEF, such that more routine and structure in the home environment was related to fewer perceived problems in children. Household constellation, home chaos, and racial discrimination stress were not significantly related to intelligence, academic achievement, or executive function problems in children with SCD. It should be noted, however, that the negative relationship between maternal racial discrimination stress and child academic achievement approached significance. Maternal depressive symptoms were significantly correlated with reported executive function problems and academic achievement, but not associated with PIQ or FSIQ; the correlation with VIQ approached significance.

Finally, positive parenting was significantly negatively correlated with the BRIEF (i.e., positive parenting was associated with fewer concerns about children's executive functions). Positive parenting was not related to intelligence or academic achievement in children with SCD. Disease-related risk, as determined by children's hemoglobin levels, was not significantly related to any domains of cognitive function.

Linear regression analyses

A series of linear multiple regression analyses were conducted to further explore how maternal social-environmental stress, depressive symptoms, and positive parenting account for variability in cognitive functioning in children with SCD. The preliminary analyses of the regression models indicated no concerns for collinearity among the independent variables. Tolerance values ranged from 0.31 to 0.96, which are all above the threshold value of 0.20. Conversely, variation inflation factor (VIF) values ranged from 1.05 to 3.19, which are all below the threshold value of 5.00. In each regression analysis, we first controlled for a salient disease characteristic (hemoglobin levels) and broad indicators of maternal stress (i.e., financial, household constellation, and racial discrimination). In Step 2, we added the more proximal effects of mothers' depressive symptoms, and in Step 3 we added positive parenting to complete the final model. The results of the regression analyses are shown in Table 3.

Financial stress was a significant predictor of FSIQ in Step 1 ($\beta = -.30$, $p = .05$), but was no longer significant when maternal depression, and positive parenting were added to the model. No other variables accounted for FSIQ. However, given that global IQ is comprised of a heterogeneous set of skills represented by distinct subscales (i.e., performance intelligence and verbal intelligence), exploratory analyses were conducted to determine if maternal stress, depressive symptoms, and positive parenting were associated with each of these skillsets differently. Therefore, PIQ and VIQ were entered as separate dependent variables in the following analyses. In the model predicting PIQ scores, none of the entered variables significantly accounted for differences in children's performance intelligence. However, in the model predicting VIQ scores, financial stress was a significant predictor in Step 1 ($\beta = -.34$, $p = .03$) but no longer remained significant when depressive symptoms and positive parenting were added to the model.

A similar pattern occurred in the regression model predicting academic achievement. Financial stress was a significant predictor in Step 1 ($\beta = -.31$, $p = .04$), but no longer remained significant when depressive symptoms and positive parenting were added in Steps 2 and 3, respectively. No other variables accounted for academic achievement in this model.

Parents' concern about problems in their children's executive function on the BRIEF was entered as a dependent variable in the following regression. As with the previous analyses, financial stress was a significant predictor in Step 1 ($\beta = .41$, $p = .007$) but no longer remained significant in Step 2, whereas maternal depression was a significant predictor ($\beta = .67$, $p = .001$). In Step 3, positive parenting partially accounted for scores on the BRIEF ($\beta = -.36$, $p = .04$), while maternal depression also remained significant ($\beta = .48$, $p = .02$). Household constellation and racial discrimination stress did not account for parents' concern for children's executive function during any step in this model.

The performance-based test of executive function, as measured by the Trail Making task of the D-KEFS, was also examined. The results show that financial stress was a significant predictor in Step 1 ($\beta = -.47$, $p = .02$), and approached significance when maternal depressive symptoms and positive parenting were added in Steps 2 ($\beta = -.58$, $p = .06$) and 3 ($\beta = -.58$, $p = .07$), respectively. No other variables accounted for observed executive function in this model.

Discussion

The purpose of the present study was to build upon and extend findings from current research on social-environmental stress, parenting, and cognitive function in children with SCD. It has been well established that children with SCD are at risk for significant impairments in intelligence, executive function, academic achievement, and other domains of cognitive function (Schatz et al., 2002). Research with non-SCD populations has shown that social-environmental factors related to low SES are associated with cognitive development in children, a relationship that appears to be accounted for, in part, by parenting behaviors (e.g., Evans et al., 2010). This is a particularly salient concern for children with SCD and their families given their distinct demographic characteristics (i.e., largely African American, low income). Thus, we examined social-environmental factors and parenting and tested these factors as possible predictors of various domains of cognitive function in children with SCD.

As predicted by the first hypothesis, children with SCD significantly underperformed relative to normative data on measures assessing intelligence, academic achievement, and executive function. On the WASI, children scored significantly lower than national norms on FSIQ, VIQ, and PIQ. Children's mean scores on several tests of academic achievement were also significantly lower than the normative sample means. These findings are consistent with previous findings demonstrating significant impairment in pediatric SCD patients across multiple indices of intelligence and tasks related to scholastic achievement (e.g., Hijmans, Fijnvandraat, et al., 2011; Schatz, 2004). Problems in executive function were assessed using standardized tests and maternal reports. Mothers reported that their children with SCD experienced greater difficulty monitoring and managing their own performance, contributing to significantly higher levels of perceived problems in executive function. Deficits were also observed on D-KEFS tasks related to sequencing, shifting, and inhibition. These results provide evidence for observed and reported deficits across a range of domains related to executive functioning.

With regard to the second hypothesis, maternal depressive symptoms were significantly correlated with racial discrimination stress and financial stress, but not stressors related to home environment. This finding adds to prior research showing that racism and financial hardship are considerable stressors for many African Americans and that exposure to such conditions is related to poor mental health (e.g., Lorant, 2003; Paradies, 2006), extending this to the mothers of children with SCD. There was partial support for the hypothesis that higher levels of social-environmental stress are associated with lower levels of positive parenting. Positive maternal parenting was significantly positively correlated with home routine, but was not related to home chaos or household constellation. Furthermore, positive parenting was negatively related to financial stress, such that mothers with more financial strain reported fewer positive parenting behaviors. This is consistent with findings that parents with lower incomes are more likely to exhibit maladaptive parenting behaviors that are generally less responsive, particularly in parent-child interactions (Guo & Harris, 2000; Hart & Risley, 1995).

With regard to the third hypothesis, examination of the independent associations of maternal variables with cognitive functioning in children with SCD revealed that home environment stress and maternal racial discrimination stress are generally unrelated to cognitive function in children. However, higher levels of maternal financial stress were linked to poorer cognitive function in children across the domains of intelligence, academic achievement, and executive function. Additionally, maternal depression was linked to both lower academic achievement and more executive function problems, but not IQ. Finally, mothers' positive parenting behaviors were not related to their children's IQ or school achievement but were related to lower executive dysfunction.

The final question of the current study aimed to explore the relative influence of each of the previously discussed maternal factors in predicting cognitive function in children with SCD. These analyses generated several important findings. First, the results showed that social-environmental factors are related to children's cognitive function after controlling for hemoglobin level, indicating that these stressors add to children's risk beyond the risk attributable to characteristics of the disease itself.

Second, there were differences in the degree to which maternal factors accounted for variance in PIQ and VIQ. Maternal financial stress accounted for a significant degree of variance when predicting *VIQ*, while none of the maternal factors served as significant predictors of children's *PIQ*. This suggests that mothers' financial stress may be distinctly related to their children's verbal comprehension within the larger sphere of intellectual ability. Research shows that family income (and other indicators of SES) is linked to language development in children (e.g., Huttenlocher, Vasilyeva, Cymerman, & Levine, 2002). These findings suggest that financial hardship has important implications for a family's social environment and that the effect of this environment is greater on verbal skills than non-verbal skills.

Third, maternal depressive symptoms and positive parenting were significant predictors of children's executive function, but not intelligence or academic achievement. This may be due, in part, to a methodological issue. Given that behavioral aspects of executive function as measured by the BRIEF, maternal depression, and maternal positive parenting behavior were all assessed based on mothers' self-reports and are all significantly correlated, it is possible that shared method variance among maternal depression and positive parenting amplified each variable's ability to independently predict problems related to executive function in pediatric SCD patients. This highlights the importance of adopting a multi-method approach in assessing this particular group of constructs.

Finally, financial stress appears to be the strongest predictor across all domains of cognitive function in the present sample, above and beyond positive parenting behaviors. This was unexpected given previous findings demonstrating that parenting partially accounts for the relationship between low income and cognitive function in children (e.g., Evans et al., 2008). Prior studies have used income and related indicators to assess economic hardship. The present study, however, considered the mothers' ability to provide essential resources for their families in combination with income to measure financial stress. This is an important distinction, as it captures greater detail about mothers' financial situations than income alone. It is also possible that mothers of children with SCD have particularly complex financial challenges that have not been captured in prior research with non-SCD samples. Parents of ill children are chronically faced with the economic costs of their child's illness, including medications, hospital stays, and lost wages (Brown et al., 2008). This creates an overwhelming load for mothers of children with SCD who are already significantly more likely to experience financial hardship independent of their child's disease (Barbarin, Whitten, Bond, & Conner-Warren, 1999). Although the current findings are suggestive of a meditational model, a true test of such a relationship would require longitudinal data, which is a suggested direction for future work.

Parenting behaviors did not emerge as a significant predictor of most domains of cognitive function in the present study; however, parenting in families of children with SCD warrants further research. Future work may benefit from a more direct and comprehensive assessment of parenting behaviors that captures a level of detail not typically obtained from parents' self-reports. One approach would be to code specific parenting behaviors during observed parent-child interactions. Aspland and Gardner (2003) encourage the use of observational measures in assessing parenting behavior, as these methods may be more closely aligned with real-world processes and are less vulnerable to participant biases.

There are several limitations to the present study that may guide developments in future research. First, the sample is restricted in variance in SCD characteristics, as less than 5% of the participants in the present study had experienced a silent stroke and no participants had a history of overt stroke. Pediatric SCD patients with a history of stroke, particularly overt stroke, are at the greatest risk for cognitive impairment (Schatz & McClellan, 2006). As these cases were underrepresented in the present study, the results likely reflect higher-functioning patients. However, the original study was designed to capture children with no cerebrovascular disease in an effort to remove the traditional "high-risk" patients with the most cognitive damage in order to study the impact of environmental factors. To generalize these findings to the broader SCD population, future studies should, when possible, recruit a larger sample with a wider range of disease severity. Finally, the present study did not include a comparison group and instead compared sample means to normative data obtained from large, representative samples from a wider population. However, the demographic characteristics of these samples may not sufficiently match those of children with SCD who are disproportionately poor and of minority status. While the primary aim of the present study was to examine factors that account for variability among children with SCD, an alternative approach would be to include a control group of demographically-matched, healthy children.

In summary, the results of the present study partially replicate findings from past research, reaffirming that children with SCD are at risk for significant cognitive impairment across multiple domains when compared to their same-age peers. Additionally, this work builds upon previous findings with non-SCD children and families to show that mothers of pediatric SCD patients experience a number of social-environmental stressors, many of which are linked not only to their own depressive symptoms and parenting behaviors, but also to their children's cognitive functioning. When considered collectively, mothers' financial stress emerges as the strongest and most consistent predictor of cognitive function, which may reflect the overwhelming difficulty of raising a chronically ill child in a low-income home environment. The next steps in this research are informed by recent findings which show that (a) teaching adaptive coping strategies has beneficial effects on managing caregiver financial stress and (b) building responsive parenting skills has beneficial effects on improving cognitive function in children from low-income families, albeit in children without SCD (Neville et al., 2013; Raviv & Wadsworth, 2010). These findings emphasize the importance of exploring potential interventions that combine stress management with parenting skills training. Thus, future work is necessary to better understand the complex dynamic of social-environmental stress, parenting, and cognitive function, specifically in children with SCD and their families, with the long-term goal of identifying concrete, teachable parenting and coping skills that may improve functioning in this population.

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Table 1

Means, SDs and One-Sample T-Tests Comparing Children's Performance on Cognitive Function Measures to Normative Samples.

Measure	*M*	*SD*	*t*	*d*
WASI				
Verbal IQ	94.97	15.63	–2.47***	–.33
Performance IQ	90.73	14.29	–4.98*	–.63
Full Scale IQ	*92.31*	*14.73*	*–4.01****	*–.52*
WJ-III				
Letter-Word Identification	47.28	10.46	–1.98*	–.27
Reading Fluency	43.58	8.13	–5.74***	–.70
Calculations	46.05	10.15	–2.91**	–.39
Math Fluency	40.81	8.96	–7.53***	–.97
Spelling	48.74	10.95	–0.88	–.12
BRIEF				
Behavioral Regulation Index (BRI)	51.78	10.83	1.26	.17
Metacognition Index (MI)	55.56	10.49	4.07***	.54
Global Executive Composite (GEC)	*53.88*	*10.46*	*2.85***	*.38*
D-KEFS				
Verbal Fluency: Category Switching	49.79	10.59	–0.12	–.02
Trail Making: Number/Letter Switching	41.24	13.76	–3.93***	–.73
Color/Word: Inhibition Switching	43.82	10.46	–3.65***	–.60
Confirmed Correct Card Sorts	47.89	9.05	–1.44	–.22

Note.

BRIEF = Behavior Rating Inventory of Executive Function; D-KEFS = Delis-Kaplan Executive Function System; WASI = Wechsler Abbreviated Scale of Intelligence; WJ-III = Woodcock-Johnson-III Tests of Achievement.

* $p < .05$

** $p < .01$

*** $p < .001$.

Table 2

Bivariate Correlations of Children's Cognitive Function Measures, Maternal Stress, and Parenting.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14
Child Cognitive Function														
1. Verbal IQ	–													
2. Performance IQ	$.57^{***}$	–												
3. Full Scale IQ	$.91^{***}$	$.87^{***}$	–											
4. Academic Achievement	$.73^{***}$	$.60^{***}$	$.75^{***}$	–										
5. BRIEF Global Composite	–.18	–.18	$-.19^{\dagger}$	$-.31^{*}$	–									
6. D-KEFS Trail Making	$.64^{***}$	$.39^{*}$	$.60^{***}$	$.70^{***}$	$-.46^{**}$	–								
7. D-KEFS Color/Word	.13	$.39^{*}$	$.29^{\dagger}$	$.29^{\dagger}$	–.20	.13	–							
Maternal Stress Factors														
8. Household Constellation	–.05	.07	.01	–.06	–.03	–.07	–.13	–						
9. Home Chaos	.04	–.01	.03	–.08	–.01	–.09	–.03	–.04	–					
10. Home Routine	–.01	.06	.02	.20	$-.28^{*}$	.20	.03	–.03	–.17	–				
11. Financial Stress	$-.35^{**}$	–.16	$-.29^{*}$	$-.36^{**}$	$.34^{*}$	$-.49^{**}$	–.12	$.30^{*}$	$.27^{\dagger}$	$-.24^{\dagger}$	–			
12. Racial Discrimination	–.05	.16	.05	$-.22^{\dagger}$	.03	.06	.13	$.23^{\dagger}$	–.06	–.08	.19	–		
13 Depressive Symptoms	$-.24^{\dagger}$	–.09	–.18	$-.28^{*}$	$.56^{***}$	–.25	–.07	$.27^{\dagger}$	.16	–.19	$.68^{***}$	$.38^{**}$	–	
Maternal Parenting														
14. Positive Parenting	.07	.12	.10	.10	$-.54^{***}$	.24	.07	–.14	–.20	$.36^{**}$	$-.32^{*}$	.09	$-.46^{***}$	–
Disease-Related Risk Factor														
15. Hemoglobin	.11	–.01	.08	$.21^{\dagger}$	–.13	$.31^{\dagger}$	$.28^{\dagger}$	–.08	–.07	–.13	–.17	.15	.11	–.20

Note.

BRIEF = Behavior Rating Inventory of Executive Function; D-KEFS = Delis-Kaplan Executive Function System.

$^{\dagger}p < .10$

$^{*}p < .05$

$^{**}p < .01$

*** $p < .001$.

Table 3

Summary of Linear Regression Analyses for Variables Predicting Cognitive Function Domains.

	FSIQ		PIQ		VIQ		Achievement		BRIEF		D-KEFS Trails	
Variable	***β***	***t***	***β***	***t***	***β***	***t***	***β***	***t***	***β***	***t***	***β***	***t***
Step 1	R^2 = .084		R^2 = .067		R^2 = .107		R^2 = .159		R^2 = .153		R^2 = .084	
Hemoglobin	–.03	–0.17	–.09	–0.62	.01	0.04	.08	0.56	.03	0.20	.08	0.41
Financial Stress	–.30	–1.98*	–.22	–1.41	–.34	–2.21*	–.29	–1.96*	.41	2.77**	–.47	–2.44*
Household Constellation	.10	0.62	.08	0.53	.09	0.60	.11	0.71	–.07	–0.49	.09	0.50
Racial Discrimination Stress	.08	0.50	.18	1.16	–.02	–0.13	–.22	–1.49	.02	0.12	.10	0.49
Step 2	R^2 = .086		R^2 = .068		R^2 = .109		R^2 = .161		R^2 = .361		R^2 = .084	
Hemoglobin	–.01	–0.09	–.08	–0.54	.02	0.11	.09	0.60	–.09	–0.66	.07	0.35
Financial Stress	–.26	–1.27	–.19	–0.89	–.29	–1.43	–.26	–1.30	–.02	–0.12	–.58	–1.98†
Household Constellation	.10	0.64	.08	0.54	.09	0.62	.11	0.72	–.11	–0.86	.09	0.49
Racial Discrimination Stress	.09	0.55	.19	1.17	–.01	–0.04	–.21	–1.34	–.15	–1.13	.06	0.30
Depressive Symptoms	–.07	–0.30	–.05	–0.23	–.07	–.31	–.06	–0.27	.67	3.75***	.15	0.50
Step 3	R^2 = .093		R^2 = .069		R^2 = .122		R^2 = .162		R^2 = .444		R^2 = .084	
Hemoglobin	–.04	–0.27	–.10	–0.57	–.02	–0.14	.08	0.51	–.19	–1.48	.11	0.52
Financial Stress	–.26	–1.25	–.19	–0.88	–.29	–1.42	–.26	–1.28	–.02	–0.10	–.58	–1.93†
Household Constellation	.10	0.61	.08	0.53	.09	0.59	.11	0.70	–.12	–0.98	.11	0.57
Racial Discrimination Stress	.12	0.70	.20	1.17	.04	0.21	–.21	–1.21	–.05	–0.35	.01	0.05
Depressive Symptoms	–.12	–0.51	–.07	–0.30	–.14	–0.60	–.07	–0.29	.48	2.58**	.20	0.64
Positive Parenting	–.11	–0.58	–.04	–0.21	–.14	–0.77	–.02	–0.11	–.36	–2.51*	.11	0.52

Note.

BRIEF = Behavior Rating Inventory of Executive Function; D-KEFS = Delis-Kaplan Executive Function System; FSIQ = full-scale intelligence quotient; PIQ = performance IQ; VIQ = verbal IQ.

† $p < .10$

* $p < .05$

** $p < .01$

*** $p < .001$.