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# Deprivation and threat as developmental mediators in the relation between early life socioeconomic status and executive functioning outcomes in early childhood

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ABSTRACT

There has been a shift in the study of childhood adversity towards a focus on dimensions of adversity as opposed to a focus on cumulative risk or specific adversities. The Dimensional Model of Adversity and Psychopathology (DMAP) proposes deprivation and threat as core dimensions of childhood adversity. Previous work using DMAP has found links between deprivation and cognitive development and threat and emotional development in adolescence, but few studies have applied this framework to a poverty context, in which children are at heightened risk for adversity experiences, and none have examined outcomes in early childhood. We use data from the Family Life Project (n = 1292) to examine deprivation and threat at child age 24 months as developmental mediators in the association between socioeconomic status (SES) measured at 15 months and executive functions (EF) measured at 48 months. In a multiple mediation model, lower SES was related to higher deprivation and threat. Deprivation was negatively associated with EF, and threat was not associated with EF. Deprivation fully mediated association between SES and EF. These results expand previous work using the DMAP and point to new directions in understanding children's cognitive adaptations to adversity.

## 1. Introduction

The associations between early life adversity (ELA) and a host of adverse outcomes for children are well documented. Specifically, children exposed to ELA are at increased risk of poorer cognitive, socio-emotional, and physical health outcomes (Duncan et al., 1998; Felitti et al., 1998) both in childhood as well as adulthood (Kessler et al., 2010; McLaughlin et al., 2012). Recent models for the study of childhood adversity have focused on how dimensions of adversity experiences influence developmental processes and outcomes. The Dimensional Model of Adversity and Psychopathology (DMAP) is one such model that proposes the study of ELA along core dimensions of deprivation and threat (Sheridan and McLaughlin, 2014; McLaughlin et al., 2014). Grounded in the literature on the effects of experience on neurodevelopment (Changeux and Danchin, 1976; Petanjek et al., 2011; Purves and Lichtman, 1980), the DMAP proposes that deprivation and threat are distinct but related experiences that have unique influences on brain development (McLaughlin et al., 2014; Sheridan and McLaughlin, 2014).

### 1.1. Dimensional model of adversity and psychopathology

Within the DMAP, deprivation is defined as the absence of expected social or cognitive stimulation, and threat is defined as exposure to threatening or harmful experiences or stimulation. The DMAP framework draws on empirical and conceptual models of neurodevelopment, wherein deprivation is thought to influence the development of the association cortex, areas associated with higher order cognitive abilities (McLaughin et al., 2014). Specifically, this conceptualization of deprivation emerges from literature in neuroscience that suggests that levels of social and cognitive stimulation are associated with synaptic pruning in the prefrontal cortex (Hair et al., 2015; Nave and Werner, 2014; Noble et al., 2015). Reduced levels of such stimulation are associated with decreased dendritic arborization and reduced synaptic density on dendritic spines, presumably preparing the brain for less complexity in the environment. This adaptation is thought to impact the development of

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higher order cognitive abilities such as cognitive control and executive functions, among others.

By contrast, threat is thought to more strongly influence the development of the hippocampus, amygdala, and ventromedial prefrontal cortex (vmPFC), areas associated with emotion processing, fear learning, and decision-making (Bechara and Damasio, 2005). In the hippocampus, research from both animal and human models has shown that early threat experiences influence adult functioning through reductions in dendrite length and branching and reduced hippocampal volume (Eiland et al., 2012; Ivy et al., 2010; Teicher et al., 2012). Early threat is thought to lead to over-activation of the amygdala, resulting in elevated amygdala activity in non-threatening situations, disrupted regulation of amygdala activity, and prolonged physiological responses to threat (Eiland and McEwen, 2012; Raineki et al., 2012). The mechanism of this action are threat-related hormones, cortisol and norepinephrine, that flip the brain from a reflective to a reactive mode (Arnsten, 2009). In the vmPFC, threat is associated with reduced synaptic activity and thought to disrupt communication pathways between the vmPFC and the hippocampus, reduce functional connectivity within the vmPFC, and lead to reduced vmPFC volume (De Brito et al., 2013; Hanson et al., 2010). These changes together are hypothesized to disrupt essential fear- and emotion-learning mechanisms, leading to reactive forms of emotion regulation and decision-making.

### 1.2. Deprivation, threat, and poverty

The distinction between deprivation and threat is important for discerning specific mechanisms by which the environment influences neurobehavioral development. However, few studies have considered DMAP (or specific threat vs. deprivation pathways) specifically in contexts of poverty; a context in which children may be more likely to experience moderate forms of such early life adversity (Blair and Raver, 2012, 2016; Nelson, 2017). There is a large body of literature suggesting that children growing up in poverty are at heightened risk for experiencing social and/or cognitive deprivation, but poverty is a process of adaptation as well as risk (Blair and Raver, 2012, 2016; Conger and Donnellan, 2007; Nelson, 2017; Noble et al., 2007; Sohr-Preston et al., 2013). However, emerging research has shown that poverty is not just the absence of expected stimulation, as traditionally framed. There is an emerging body of work suggesting that children growing up in poverty are also more likely to experience heightened levels of threat as well (Conger et al., 2010; Johnson et al., 2016; Vrantsidis et al., 2019), suggesting that early life poverty may be better characterized by not only the absence of expected beneficial input but also the presence of stressful or threatening input (Blair and Raver, 2012). However, few studies have examined dimensions of deprivation and threat specifically in the context of early life poverty, and as such little is known about how deprivation and threat may jointly and independently influence child development within low-SES contexts.

### 1.3. Existing research on poverty and adversity

Traditional frameworks for studying early life adversity have provided a useful foundation for our scientific understanding of the ways in which adversity influences the developing brain. Cumulative risk approaches, which take a count of the number of adversities a child has been exposed to, allow for a broad understanding of how the total number of adversity experiences relate to developmental outcomes, but provide little information about the differential effects of distinct adversity experiences (Felitti et al., 1998). Attempts to remedy these gaps have taken approaches that examine one or two forms of adversity in isolation (Cicchetti and Lynch, 1993; Davies et al., 2002; Manly and Cicchetti, 1994; Sternberg and Others, 1993). This work has created a rich understanding of how individual adversities influence development but failed to account for the similarities across different kinds of adversities, the co-occurrence of adversities, and the underlying mechanisms connecting those experiences to child outcomes.

Within the field of research on child development specifically in low-SES contexts, a number of models have been proposed to understand the driving mechanisms linking poverty to variability in children's developmental outcomes (Blair, 2010; Conger and Donnellan, 2007; Conger et al., 2010; Masarik and Conger, 2017; Noble et al., 2005). An increasing body of literature indicates that poverty can impact neurodevelopment by depriving the brain of expected input (e.g., decreased cognitive stimulation, parental neglect, compromised nutrition), while increasing risk for exposure to negative input (e.g., exposure to toxins, elevated stress, parental adversity; reviewed in Blair and Raver, 2016; Johnson et al., 2016). Given that the developmental context of poverty can be characterized by too little that is beneficial for development and too much that is detrimental to development, the DMAP is a more nuanced framework for examining the effects of poverty-related adversity on developmental outcomes. Altogether, the work on early life adversity and early life poverty have not really accounted for the joint experiences of adversity and poverty and the thematic similarities that emerge across adverse experiences.

### 1.4. Deprivation and executive functions

There is a robust body of research linking early life deprivation with an increased risk of reduced executive function (EF) abilities. Much of the work in this area has focused on internationally adopted children who spent differing amounts of time in orphanages in Romania (Fox et al., 2017; Hostinar et al., 2012; McLaughlin et al., 2014; Nelson et al., 2007). Hostinar and colleagues (2007), found significantly reduced EF abilities in a sample of 2.5- to 4-year-old post-institutionalized children compared to their non-institutionalized counterparts. Similarly, work using the Family Stress and Family Investment models has consistently found associations between forms of social and cognitive deprivation and cognitive outcomes (see Conger et al., 2010 for a review). Work using the DMAP has also found these associations. Using the DMAP, Lambert et al. (2017), found that deprivation, but not threat, predicted cognitive control in a sample of adolescents. Similarly, Sheridan et al. (2017) found that experiences of deprivation, but not threat, predicted reduced EF abilities in adolescence. Altogether, there is a clear body of work suggesting that early life social and cognitive deprivation is associated with increased risk for reduced EF abilities as well as related aspects of cognition throughout childhood.

### 1.5. Threat and executive functions

The associations between threat and EF abilities are less clear. Previous work using the DMAP has found no associations between threat and EF in adolescence (Lambert et al., 2017; Sheridan et al., 2017). There is also a substantial body of research that has found negative associations between threat and cognitive development (Beers and De Bellis, 2002; DePrince et al., 2009; Fay-Stammbach et al., 2017). Further contributing to the lack of clarity in this area, there is an emerging body of research that suggests that early life stress, particularly when that stress is moderate, may enhance EF abilities, namely working memory and attention shifting, by requiring children to be more vigilant to their surroundings and detect threats more quickly (Mittal et al., 2015; Young et al., 2018). Additionally, some work has shown that, when tested in stressful circumstances or with threatening stimuli, individuals exposed to high levels of early life threat perform better on EF tasks than in non-stress contexts (Frankenhuis and de Weerth, 2013). This would suggest that, when tested in ecologically valid contexts or with contextually relevant stimuli, children exposed to early life threat may actually perform as well as or better than their non-threat exposed peers due to their cognitive adaptations to those situations. The conflicting findings in this area suggest the need for more precise conceptual and practical definitions of threat, as well as consideration of the effects of deprivation. A model such as DMAP, which provides clear conceptual definitions of deprivation and threat, and accounts for both of these dimensions of experience, may help elucidate the unique contributions of deprivation and threat on developmental outcomes. Altogether, the research on threat and the development of EF would suggest that in ecologically valid contexts, threat may be positively associated with EF, but further research is needed in prospective, longitudinal samples with more consistency in the operational definitions of threat.

There is some theoretical justification for positive associations between threat and EF in childhood. One hypothesis, proposed by Callaghan and Tottenham (2016), is the stress acceleration hypothesis. This hypothesis, based largely in the literature on the development of fear learning systems, suggests that early adversity accelerates the development of the limbic system and primes children to display more adult-like patterns of self-regulation. While not considered adaptive in the long-term, these changes in the trajectory of neural development could potentially lead to enhanced cognitive functioning, particularly executive functions and emotion regulation, in childhood (Callaghan and Tottenham, 2016).

Another model proposed to account for children's adaptations to early life stress is the Adaptive Calibration Model (Del Guidice et al., 2011). This model suggests that environments characterized by low parental investment and high degrees of instability program the stress response system to be more reactive, leading to increased vigilance. This increased vigilance could be reflected in heightened EF abilities, as the child is constantly needing to remain alert to respond to potential threats in their environment and regulate their own behavior. Specifically, this heightened environmental awareness should be reflected in working memory and attention shifting skills, as these are thought to be the most environmentally relevant (Mittal et al., 2015; Young et al., 2018). Importantly, this model proposes two periods of heightened sensitivity to environmental stress with implications for the development of stress response systems: the prenatal and early postnatal period, and puberty. As such, we would expect that children who experience heightened environmental stress beginning in infancy would display more advanced patterns of EF throughout early childhood, as they adapt to the instability of their environments.

### 1.6. Gaps in the DMAP literature

Previous work using the DMAP has provided support for the hypotheses laid out in the theoretical model but has been limited by a number of factors. Empirical studies using this framework have often relied on implicit measures of deprivation (such as maternal education or household income), rather than direct measures of degree of social and cognitive stimulation in the environment (see Sheridan et al., 2017 and Lambert et al., 2017 for examples). As such, deprivation is often conflated with socioeconomic status or poverty rather than accounting for both independently. Similarly, much of the work using this framework has focused on severe forms of threat including abuse or acute trauma (see Sheridan et al., 2017 for an example), successfully capturing the associations between severe threat and development, but potentially missing the subtler, chronic forms of threat that may be common for children growing up in poverty, such as neighborhood violence or conflict between caregivers. Finally, much of the research using this framework has focused on cognitive and emotional outcomes in adolescence (Lambert et al., 2017; Sheridan et al., 2017), and as such little is known about how experiences of deprivation and threat early in life are related to developmental outcomes in early or middle childhood.

### 1.7. The current study

We seek to expand upon existing literature by situating the deprivation and threat framework in a developmental context of heightened risk for adversity, namely poverty. We do so by considering dimensions of deprivation and threat as core contributing factors of poverty-related adversity mediating the associations between early life socioeconomic status (SES) and the development of executive functions in early childhood. Both deprivation and threat contain proximal and distal sources of influence on children's development, allowing us to examine these experiences at multiple levels of the child's social ecology. Based on previous research informed by theories of traditional developmental psychology and developmental cognitive neuroscience, we hypothesize that lower family SES at child age of 15 months (as indexed by caregiver education, family income-to-needs ratio, and parental job prestige) will be related to higher instances of both deprivation and threat at 24 months. We hypothesize that deprivation at 24 months of age will be negatively associated with EF at 48 months and mediate the association between 15-month SES and 48-month EF.

By contrast, we draw upon emerging literature examining cognitive adaptations to threat to hypothesize that higher levels of threat in our sample will be related to higher EF scores at 48 months. This hypothesis is informed in large part by the idea that threat in our sample is in the low to moderate range relative to a clinical sample, similar to many of the studies that have found positive effects of threat (Mittal et al., 2015; Young et al., 2018). This hypothesis is also informed by the ecologically valid context of data collection in this study (all data are collected in the child's home), again similar to many of the studies that have found positive associations between threat and EF (Frankenhuis and de Weerth, 2013). Given the high degree of neural plasticity and sensitivity to the environment within the first two years of life (McLaughlin et al., 2015;Nelson, 2017), we focus on SES, deprivation, and threat within the first two years. Our choice of an executive function measure at 48 months comes from the literature suggesting that executive functions at school entry (between 4 and 5 years of age) are an important predictor of school readiness and later academic competence (Fitzpatrick et al., 2014).

## 2. Methods

### 2.1. Participants

Data for these analyses were drawn from the Family Life Project (FLP), a longitudinal investigation of children and families residing in two regions with high rural poverty rates. Families living in target counties in North Carolina (NC) and Pennsylvania (PA) were recruited using a stratified random sampling approach. A representative sample of 1292 families were recruited over a 1-year period spanning September 2003 through September 2004. Low-income families were oversampled in both states, and African American families were oversampled in NC, to ensure adequate power to test study aims. As such, 70 % of the sample is classified as low-income, and 40 % of the sample are classified as living at or below the federal poverty line. The final sample for the FLP is 60 % White, 40 % African American. In this sample, 97.9 % of primary caregivers are the target child's biological mother, another 0.4 % are the child's biological father, 1.1 % are a grandparent, and the remaining 0.5 % are other adults, including foster parents, older siblings, unrelated adult, or other adult relative combined. Additional details about FLP sampling and recruitment can be found elsewhere (Vernon-Feagans et al., 2013).

### 2.2. Procedures

Data collection for this study took place in the participants' homes at the target child ages of 15, 24, and 48 months as part of the ongoing data collection effort for FLP. Participants completed other procedures not included in these analyses. All procedures for the data included in this manuscript were reviewed and approved by the Institutional Review Board of the University of North Carolina at Chapel Hill. Caregivers provided informed consent for their participation and that of their child upon enrollment in the study.

### 2.3. Measures

#### 2.3.1. Family socioeconomic status

Our measure of family SES at 15 months of age was a composite measure of family income-to-needs ratio (INR), caregiver education, and parental job prestige. Family INR was derived from the primary caregiver's report of the family's annual income divided by the federal poverty line standards for a family of that size. An INR value of one or below indicates a family lives in poverty, while a value between one and two would classify a family as low-income. Caregiver education and job prestige were also self-reported from the child's primary and secondary (if present) caregivers. We computed the average education level between the primary caregiver and the secondary caregiver, which is our measure of caregiver education. For children without a secondary caregiver reported, the education of their primary caregiver was used.

#### 2.3.2. Deprivation

Our conceptual definition of deprivation was the one proposed in the original DMAP framework: the absence of expected cognitive and social stimuli (Sheridan and McLaughlin, 2014). We used reverse-scored measures of consistent partnership (does the primary caregiver have a consistent partner?), sensitive parenting, and learning materials in the home as three formative indicators for a latent variable of deprivation at 24 months of age. Consistent partnership was measured using the primary caregiver's report of consistent partnership during an interview with a research assistant.

Sensitive parenting was coded from a semi-structured free play task. Within the sensitive parenting indicator, there were three subscales: sensitivity, responsiveness, and supportive presence. Broadly, coders assessed how the parent observed and responded to the child's social gestures, expressions, and signals including cries, frets, or other expressions of negative affect. Interactions were video recorded and coded for parental sensitivity as defined above. Coders used a scale from 1 (not at all characteristic) to 5 (highly characteristic) to assess the three sensitive parenting behaviors. Thirty percent of interactions were double-coded, and coding pairs maintained an inter-rater reliability of 0.80 or above (Cohen's kappa).

Availability of learning materials in the home was assessed using the learning materials subscale of the Infant/Toddler version of the Home Observation for Measurement of the Environment (HOME) inventory (Caldwell et al., 1984). The inventory was completed by a research assistant following a home visit, and the learning materials subscale asked about toys in the home including those meant to promote learning such as mobiles, hand-eye coordination toys, and toys for literature and music, as well as if the caregiver provided the child with such toys during the visit. Each item asked about a specific behavior, and the rater assigned an item a score of 1 if a behavior was observed, and 0 if it was not. Subscale scores were calculated as the mean of all relevant items after appropriate reverse-scoring, with a range of 0−1.

#### 2.3.3. Threat

We again followed the definition of threat proposed in the DMAP framework: the presence of unexpected harmful or threatening stimuli (Sheridan and McLaughlin, 2014.). The indicators of threat we used were measures of verbal and physical aggression between the primary caregivers, and neighborhood noise and safety at child age 24 months, for a total of three formative indicators of a latent variable of threat. Physical aggression between the caregivers was assessed using the physical violence subscales of the Conflict Tactics Scale (CTS; Straus, 1979) administered to the primary caregiver. We created a composite measure of physical aggression by summing two subscales from the CTS: (1) the primary caregiver's report of their use of physical violence towards the secondary caregiver in the last 12 months, and (2) the secondary caregiver's use of physical violence toward the primary caregiver during that same 12 month period. We also assessed verbal aggression between the caregivers using primary caregiver report from the CTS. We created a composite measure of verbal aggression by summing two subscales from the CTS: (1) the primary caregiver's report of their use of verbal aggression towards the secondary caregiver in the last 12 months, and (2) the secondary caregiver's use of verbal aggression towards them during that same 12 month period.

For the measurement of threat, we also used a subscale from an observational report by an RA at 24 months to assess neighborhood noise and safety. After visiting the participant in their home, the RA rated the participant's home and neighborhood based on a set of pre-selected criteria pertaining to the noise, safety, and cleanliness of the dwelling and neighborhood. The measures included in this subscale are: safety outside the child's dwelling, noise level in the neighborhood, and safety of the neighborhood around the child's dwelling assessed using Likert scales. Scores from these three measures were used to create a composite mean score of neighborhood safety. Higher scores on this scale are indicative of less noise and more safety. As such, we reverse scored this measure for inclusion in our threat measure such that higher scores were indicative of *more* noise and *less* safety.

#### 2.3.4. Executive functions

EF outcomes were assessed at 48 months of age using a battery consisting of two working memory tasks, three inhibitory control tasks, and one attention shifting task. RAs administered up to three practice trials preceding test trials for each task and discontinued the task for children who did not demonstrate task comprehension. Each task was presented in a spiral flipbook with $8 \times 14$ inch pages. Further details about task administration and procedures are available in Willoughby et al., 2011 and Willoughby et al., 2012. Each task is described briefly below.

*2.3.4.1. Operation span (working memory).* In this task, children are shown a drawing of an animal and a colored dot within the outline of a house. Children are then shown an empty outline of a house and asked to recall either the animal they saw or the color of the dot. Children must hold two pieces of information in mind (the color of the dot and the animal) but recall only the prompted piece (similar to Engle, 2002). Difficulty increases as the number of items per trial increases.

*2.3.4.2. Pick the picture game (working memory).* Children are presented with a set of pictures that are thematically similar (i.e. fruits, animals, etc.). For every set, the same items appear on subsequent pages in different orders, and on each page children are instructed to pick an item that they have not yet picked so that each item "gets a turn." Children are required to remember which items they have already picked, and difficulty increases as sets increase from 2 to 6 pictures.

*2.3.4.3. Silly sounds stroop (inhibitory control).* Children are presented with line drawings of cats and dogs and asked to make the sound of the animal not pictured (i.e. when shown a cat, the correct response would be to make a dog sound).

*2.3.4.4. Spatial conflict arrows (inhibitory control).* Children are presented with cards with two black circles, one on either side of the page, and one arrow on either the right or the left side of the page. They are instructed to touch the circle corresponding to the side where the arrow is pointing. Congruent trials occur when the arrow is pointing in the same direction as the side of the page it's on (i.e. left-pointing arrows are on the left side of the page), and incongruent trials occur when the arrow is pointing in the opposite direction of the side it's found on (left-pointing arrows on the right side of the page).

*2.3.4.5. Animal go/no-go (inhibitory control).* This is a standard go/no-go task presented in a flipbook format. Children are instructed to click a button (which produces a sound) every time they see an animal (go trials), unless the animal is a pig (no-go trials). Varying numbers of go trials are presented prior to each no-go trial, including, in standard order, 1-go, 3-go, 3-go, 5-go, 1-go, 1-go, and 3-go trials.

*2.3.4.6. Item selection task (attention shifting).* Children are presented with a pair of items matching in terms of color, shape, or size. The examiner draws the child's attention to the similar dimension between the items, and then the child is presented with a third item that is similar to one of the first two. The child is asked to identify which of the two original pictures is similar to the third picture. This task requires children to shift their attention from the original similar dimension to a new one (for example, from shape to color).

*2.3.4.7. EF task scoring and composite formation.* For performance on any task to be scored, children needed to complete at least 75 % of trials. Scores for tasks were calculated using item response theory, which is a more precise way to estimate children's executive function abilities than percentage correct scores (Willoughby et al., 2011). Expected a posteriori scores (EAP) were derived for each task and averaged to create an EF composite score. The reliability coefficient for this composite was $\alpha = .50$, which is typical of most EF measures.

### 2.4. Analyses

#### 2.4.1. Variable creation

We created a composite measure of early life SES by creating z-scores for our three indicators of SES and taking the mean. We performed structural equation modeling to create latent variables for deprivation and threat. Our deprivation measure consisted of the three indicator variables described above: learning materials in the home, consistent partnership (an index of single parent status), and sensitive parenting. We first reverse scored all three variables such that higher scores meant greater deprivation. Our measure of threat consisted of three indicator variables described above: physical and verbal aggression between caregivers, and neighborhood noise and safety. We reverse scored the neighborhood noise and safety score such that higher scores meant higher levels of noise and lower levels of safety. Our measure of physical aggression between caregivers had a high positive skew, so we log transformed this variable to normalize the distribution.

#### 2.4.2. Analysis plan

We first examined correlations between our SES composite, our indicators of deprivation and threat, and our EF score. We used structural equation modeling (SEM) to create latent variables for deprivation and threat. We then examined whether the SES composite was negatively related to deprivation and threat. Next, we tested a single mediation model with deprivation as a mediator between SES and EF to test our hypothesis that deprivation would be negatively associated with EF. We then tested another single mediation model with threat as the mediator linking SES and EF to test our hypothesis that threat would be positively associated with EF. Finally, we tested a multiple mediation model with both deprivation and threat mediating the association between SES and EF. We used maximum likelihood estimation and performed 5000 bootstrap estimates to calculate standard errors.

#### 2.4.3. Covariates

All regression and mediation analyses control for the participant's race (African American or White), state (PA vs. NC), and sex.

#### 2.4.4. Missing data

The total FLP sample consisted of 1292 participants recruited at the birth of the target child. 1169 families were visited at 15 months, 1044 families were seen at 24 months, and 1056 families were seen at 48 months, with complete, usable EF task data for 1000 participants. We tested for selective attrition over time on the basis of SES, participant race, and state of residence. We found no evidence of selective attrition over time on the basis of SES (ts between -1.47 and -0.45, $p > 0.15$) or race (ts between -0.03 and 0.42, $p > 0.6$). However, participants in North Carolina were more likely to be missing EF data at 48 months than those in Pennsylvania ($t = 3.137$, $p = 0.002$). Missing data were handled using Maximum Likelihood estimation in all models, which uses a case's existing data to compute estimates for missing parameters in that case.

## 3. Results

### 3.1. Descriptive statistics

Descriptive statistics for all study variables can be found in Table 1.

**Table 1**
Descriptive statistics for all demographic, SES, deprivation, threat, and EF variables.

| Demographics and SES variables | | EF and Study Variables | Scale | Mean (sd) |
|---|---|---|---|---|
| Child sex | | Deprivation measures | | |
| Male | 50.46 % | HOME: Learning materials | 0–1 (continuous) | 0.9 (0.18) |
| Female | 48.76 % | Sensitive parenting | 1–5 (categorical) | 2.76 (1) |
| Child race | | Consistent partner | 0–1 (dichotomous) | 53 % partnered, 47 % unpartnered |
| Black | 41.95 % | | | |
| White | 57.28 % | Threat measures | | |
| Primary caregiver identity | | CTS: Verbal aggression | 0–12 (continuous) | 2.74 (1.14) |
| Biological mother | 97.9 % | CTS: Physical aggression | 0–12 (continuous) | 0.24 (0.69) |
| Biological father | 0.4 % | Windshield: Neighborhood noise/safety | 1–4 (continuous) | 2.98 (0.49) |
| Grandparent | 1.1 % | | | |
| Other adult | 0.5 % | EF EAP Score | | −0.12 (0.51) |
| Primary caregiver education (n = 1169) | | Secondary caregiver education (n = 907) | | |
| Less than high school | 18.14 % | | 15.99 % | |
| High school diploma/GED | 31.22 % | | 37.38 % | |
| H.S./GED and additional training | 8.55 % | | 9.38 % | |
| Some college | 21.73 % | | 13.45 % | |
| Associates degree | 5.73 % | | 7.39 % | |
| Four year college degree | 9.62 % | | 11.47 % | |
| More than a four-year college degree | 4.79 % | | 5.29 % | |
| | Mean (sd) | Min | Max | |
| Income-to-needs ratio | 1.76 (1.67) | 0 | 16.76 | |
| Parental job prestige | 40.09 (11.56) | 16.78 | 86.05 | |

### 3.2. Correlations

We examined correlations between indicator variables for deprivation and threat, all measured at the 24-month time point, the SES composite at 15 months, and child EF at 48 months. A full correlation matrix can be found in Table 2 below. To facilitate initial interpretation, we used the raw scores (rather than reverse scores) for learning materials, sensitive parenting, and neighborhood noise and safety in correlation analyses. Overall, we found that SES was correlated with every indicator of both deprivation and threat in the expected direction. Similarly, we found that every indicator of deprivation was correlated with EF in the expected direction, and that two of our threat indicators were correlated with EF. While small to moderate in magnitude, these correlations provide initial support for our hypotheses that, in low-SES contexts, children are more likely to experience heightened deprivation and threat, and that higher deprivation may be associated with lower EF scores in early childhood. The correlations between threat and EF would suggest a negative or null association, but we follow up with structural equation modeling with latent variables of deprivation and threat to examine how these constructs as a whole may predict early childhood EF (Table 2).

### 3.3. Measurement of deprivation and threat

The measurement model for deprivation and threat had excellent model fit (RMSEA = 0.041, 90 %CI [0.021, 0.062], $p = 0.733$; CFI = 0.983; TLI = 0.964; $X^2 = 20.477$, $p = 0.0046$). To test our hypothesis that deprivation and threat would mediate the association between early life SES and EF, we ran single and multiple mediation models using SES as the main predictor, deprivation and/or threat as mediators, and EF as the outcome.

### 3.4. Single mediation models

#### 3.4.1. Deprivation

In a single mediation model with 24-month deprivation as a mediator between 15-month SES and 48-month EF, SES and deprivation were significantly negatively related ($\beta = -0.586$, 95 % CI [−0.647, −0.527], $p < 0.001$), such that lower levels of SES were related to higher levels of deprivation. The relation between deprivation and EF was also negative ($\beta = -0.591$, 95 % CI [−1.002, −0.343], $p < 0.001$), such that higher levels of deprivation were related to lower EF scores. The indirect effect of SES on EF through deprivation was significant ($\beta = 0.347$, 95 %CI [0.195, 0.617]), as was the total effect of this model ($\beta = 0.223$, 95 % CI [0.167, 0.279]). Deprivation fully mediated the association between SES and EF, such that the direct effect of SES on EF was no longer significant ($\beta = -0.123$, 95 % CI [−0.390, 0.034]). This model had acceptable fit (RMSEA = 0.049, 90 % CI [0.031, 0.069], $p = 0.486$; CFI = 0.980; TLI = 0.954; $X^2 = 29.952$, $p < 0.001$).

#### 3.4.2. Threat

In a model with threat as the sole mediator in the association between SES and EF, there was a significant negative association between threat and SES ($\beta = -0.615$, 95 % CI [−0.764, −0.504], $p < 0.001$), such that lower SES was related to higher threat. There was no association between threat and EF ($\beta = -0.005$, 95 % CI [−0.144, 0.147], $p = 0.953$). The direct effect of SES on EF was significant ($\beta = 0.220$, 95 % CI [0.111, 0.335], $p < 0.001$), while the indirect effect through threat was not ($\beta = 0.003$, 95 % CI [-0.096, 0.094]). The total effect of this model was significant ($\beta = 0.223$, 95 %CI [0.164, 0.279]). This model had suboptimal fit (RMSEA = 0.078, 90 % CI [0.060, 0.098], $p = 0.007$; CFI = 0.944; TLI = 0.855; $X^2 = 55.196$, $p < 0.001$), indicating that threat is not adequate on its own to mediate the association between SES and EF.

### 3.5. Multiple mediation model

To account for possible suppression effects due to high correlations between deprivation and threat, in a multiple mediation model with both deprivation and threat as mediators, we constrained the raw value of the covariance between deprivation and threat to 0.01 to allow for some correlation between the two, but maintain a high degree of distinction. There is precedent for this technique using Bayesian estimators (see Tzala and Best, 2008). We ran this model using both Bayesian and maximum likelihood estimators, and results remain consistent across both. We provide the MPlus output for both estimation techniques in the supplementary materials and present the results of maximum likelihood estimation in this section, to facilitate interpretation by a wider audience.

In the multiple mediation model with SES as the main predictor, 48-month EF as the outcome, and deprivation and threat as mediators, SES was negatively related to both mediators, such that lower levels of SES were related to higher levels of both deprivation ($\beta = -0.589$, 95 % CI [−0.650, −0.530], $p < 0.001$) and threat ($\beta = -0.606$, 95 % CI [−0.769, −0.324], $p < 0.001$). Deprivation and EF were again negatively related in this model ($\beta = -0.625$, 95 % CI [−1.111, −0.362], $p = 0.001$), such that higher levels of deprivation were related to lower EF scores. Threat and EF were not significantly related ($\beta = 0.071$, 95 % CI [−0.052, 0.255], $p = 0.440$).

There was a significant indirect effect of 15-month SES on 48-month EF through deprivation ($\beta = 0.368$, 95 % CI [0.207, 0.682]). The indirect effect for threat on EF at 48 months was not significant ($\beta = -0.043$, 95 % CI [−0.180, 0.032]). The total effect was also significant ($\beta = 0.223$, 95 % CI [0.167, 0.279]). Finally, the direct effect of SES on EF was not significant in this model ($\beta = -0.102$, 95 % CI [−0.384, 0.087], $p = 0.417$), suggesting that deprivation and threat fully mediated the association between SES and EF. However, it is worth noting that deprivation drove this full mediation, as threat was not significant mediator either on its own or with deprivation. This model had acceptable fit (RMSEA = 0.060, 90 % CI[0.049, 0.063], $p = 0.063$; CFI = 0.945; TLI = 0.904; $X^2 = 120.105$, $p < 0.001$). These results are

**Table 2**
Correlation matrix of SES, indicator variables, and EF.

| | SES | HOME Learning Materials | Sensitive parenting | Consistent partner | Physical Aggression | Verbal aggression | Neighborhood noise and safety |
|---|---|---|---|---|---|---|---|
| SES | – | | | | | | |
| HOME Learning Materials | 0.236*** | – | | | | | |
| Sensitive parenting | 0.445*** | 0.197*** | – | | | | |
| Consistent partner | 0.473*** | 0.140*** | 0.384*** | – | | | |
| Physical Aggression | −0.188*** | −0.053 | −0.166*** | −0.189*** | – | | |
| Verbal Aggression | −0.140*** | −0.055 | −0.097** | −0.073* | 0.538*** | – | |
| Neighborhood safety | 0.348*** | 0.177*** | 0.207*** | 0.224*** | −0.167*** | −0.171*** | – |
| EF | 0.315*** | 0.173*** | 0.382*** | 0.259*** | −0.081* | 0.009 | 0.107*** |

Note: ***p < 0.001, **p < 0.01, *p < 0.05.

illustrated in Fig. 1 below. Table 3 provides a summary of all mediation analysis results.

## 4. Discussion

In this study, we sought to extend previous work using the DMAP framework of childhood adversity by applying it in a low-SES context, using dimensions of deprivation and threat as mediators in the association between early life SES and early childhood EF. Specifically, we examined how distinct but related dimensions of deprivation and threat, derived using data from a predominantly low-income and nonurban sample, are associated with EF at age 48 months. To that end, we examined dimensions of deprivation and threat at 24 months of age as mediators between SES at 15 months and executive function at 48 months. Results from our multiple mediation analysis partially supported our hypotheses. Specifically, we found that lower SES was related to greater exposure to both deprivation and threat, and that deprivation was negatively related to EF. We did not find support for our hypothesis that threat would be positively associated with EF. These results align with and extend previous work using the DMAP to predict EF in adolescents (Lambert et al., 2017; Sheridan et al., 2017). It extends prior work by demonstrating the association between deprivation and EF in early childhood in a low-income sample and, most prominently, by demonstrating that this association emerges in early childhood.

### 4.1. Interpretative frameworks

There are a number of frameworks that have been proposed to explain the specific associations between SES and family-level adversities. We focus on two that facilitate an interpretation of our findings. The Family Stress and Family Investment Models (Conger et al., 2010; Conger and Donnellan, 2007; Masarik and Conger, 2017) describe pathways through which socioeconomic status and financial hardship influence relationships within families and child development. The Family Stress Model proposes that economic stressors (low income, financial hardships, etc.) increase stress in the family, thus influencing the quality of familial relationships and interactions between family members (Conger et al., 2010), which in turn can influence child outcomes. The Family Investment Model suggests that families in low-SES contexts may have fewer material and interpersonal resources to invest in their children (including time to spend with children, availability of caregivers, toys, etc.; Conger and Donnellan, 2007). By no means mutually exclusive, these two frameworks provide potential explanations for why lower SES is related to increased threat and deprivation. There is substantial literature in which associations of both of these frameworks to child social-emotional and cognitive outcomes are well established (Hackman et al., 2015; Noble et al., 2007; Sohr-Preston et al., 2013; Vrantsidis et al., 2019). The insight gained in this analysis is that the bulk of variance in child cognitive outcomes in early childhood in the context of poverty is accounted for by the Family Investment Model, operationalized here as deprivation.

### 4.2. Deficit

The expected association between deprivation at 24 months and EF at 48 months aligns with much of the previous work using the DMAP framework (Lambert et al., 2017; Sheridan et al., 2017), as well as previous work examining parenting and family-level influences on cognitive development (Blair et al., 2011; Suor et al., 2015). Deprivation measures the extent of a child's cognitive and social stimulation. The magnitude of this effect ($\beta = -0.625$), when considered in a model including threat, suggests that each standard deviation increase in deprivation is associated with roughly two thirds of a standard deviation decrease in EF performance at 48 months in this sample. The negative associations between deprivation and EF in these analyses are supported by neuroscience research suggesting that decreased social and cognitive stimulation leads to reduced synaptic density in the prefrontal cortex as the brain adapts to the reduced environmental stimulation that supports and promotes higher order thinking skills (Hair et al., 2015; Noble et al., 2015). This process is hypothesized to lead to reduced EF under traditional testing conditions (McLaughlin et al., 2014).

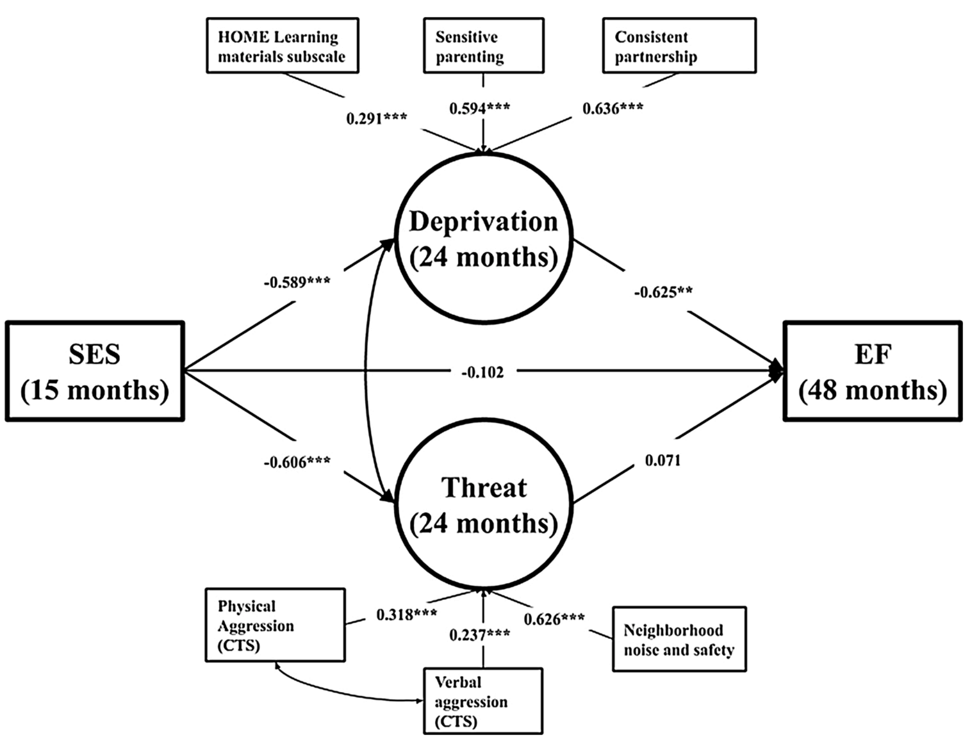


**Fig. 1.** Multiple mediation model showing associations between socioeconomic status (SES), deprivation, threat, and executive functions (EF). Betas are presented as well as factor loadings. *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

**Table 3**
Summary of results from all mediation analyses.

| Model | Predictor | Outcome | Effect (Beta) | Standard Error | p-value |
|---|---|---|---|---|---|
| Single mediation: SES > Deprivation > EF | | | | | |
| | SES | Deprivation | β=-0.586 | 0.030 | p < 0.001 |
| | Deprivation | EF | β=-0.591 | 0.166 | p < 0.001 |
| | | | Indirect effect: β = 0.347 | 0.106 | p = 0.001 |
| | | | Total effect: β = 0.223 | 0.029 | p < 0.001 |
| Single mediation: SES > Threat > EF | | | | | |
| | SES | Threat | β=-0.615 | 0.067 | p < 0.001 |
| | Threat | EF | β=-0.005 | 0.078 | p = 0.953 |
| | | | Indirect effect: β = 0.003 | 0.054 | p = 0.958 |
| | | | Total effect: β = 0.223 | 0.030 | p < 0.001 |
| Multiple mediation: SES > Deprivation & Threat > EF | | | | | |
| | SES | Deprivation | β=-0.589 | 0.031 | p < 0.001 |
| | SES | Threat | β=-0.606 | 0.102 | p < 0.001 |
| | Deprivation | EF | β=-0.625 | 0.187 | p = 0.001 |
| | Threat | EF | β = 0.071 | 0.092 | p = 0.440 |
| | | | Indirect effect – deprivation: β = 0.368 | 0.121 | p = 0.002 |
| | | | Indirect effect – threat: β=-0.043 | 0.070 | p = 0.541 |
| | | | Total effect: β = 0.223 | 0.029 | p < 0.001 |

### 4.3. Adaptation

The lack of support for a positive association between threat and EF in this analysis, although not as we hypothesized, is supported by much of the prior literature using DMAP (Lambert et al., 2017; Sheridan et al., 2017). However, as noted in the introduction, there is some disagreement in the literature as to the nature of associations between threat and EF. Studies using the DMAP have consistently found no associations between threat and cognitive outcomes (Lambert et al., 2017; Sheridan et al., 2017), however a number of other studies have found both positive (Mittal et al., 2015; Young et al., 2018), and negative (Beers and De Bellis, 2002; DePrince et al., 2009; Fay-Stammbach et al., 2017) associations between threat and measures of EF. Given the relatively low to moderate levels of threat present in our sample, we hypothesized that threat might be positively associated with EF, as prior research has found that mild to moderate stressors can promote certain domains of cognitive development for children (Mittal et al., 2015; Young et al., 2018). However, we did not find support for that hypothesis in this analysis.

The findings presented in this paper indicate that for children exposed to higher levels of deprivation and/or threat, self-regulation will develop in ways that are appropriate for the context in which development is occurring. Previous studies have suggested that children growing up in environments of poverty or heightened stress develop hidden talents, or experience-based adaptations that serve important functions in their environments (see Ellis et al., 2020 for a review). Within the hidden talents framework for considering the effects of adversity on development, much of the research that has found positive associations between threat and EF have focused on components of EF, rather than global EF scores (Mittal et al., 2015; Young et al., 2018). In this analysis, we focus on a global EF score that comprises working memory, attention shifting, and inhibitory control. It is generally thought that these positive associations may emerge more readily for working memory and attention shifting, and not for inhibitory control. In early childhood, the age range of the sample analyzed here, EF is often considered to be unitary (Garon, Bryson, & Smith, 2008), however there is some disagreement as to the best practices for measuring early childhood EF (Bernier et al., 2012; Garon et al., 2014; Mulder et al., 2014; Skogan et al., 2016). The construct is often found to differentiate in adulthood (Miyake et al., 2000), as such it is possible that a positive association between threat and EF only emerges in adulthood (Mittal et al., 2015). Future research could perhaps consider the extent to which global EF scores are useful in considerations of threat and EF, given these findings. Altogether, this paper in conjunction with the rest of the literature in this area would suggest that more research is needed on the neurodevelopmental mechanisms that underlie the development of executive functions in the context of early life threat, in order to inform a more nuanced understanding of adaptation to environmental disadvantage that goes beyond traditional deficit-based approaches (Frankenhuis and Nettle, 2020).

### 4.4. Strengths and limitations

There are a number of strengths to this analysis that substantiate and extend previous literature. By using a mediation analysis, we are able to demonstrate that (1) SES may increase risk for or give rise to experiences of deprivation and threat in childhood, (2) SES and deprivation are highly related but distinct experiences, and (3) our analysis indicates that experiences of deprivation and threat differentially account for the SES-related differences in higher order cognitive abilities. Our multiple measures of both deprivation and threat allowed us to capture information about the child's environment at multiple levels of the child's social ecology (parent-child interaction, parent-parent interaction, neighborhood factors, etc.). Home-based data collection and the population-based nature of our sample allows us to examine experiences of deprivation and threat common in low-SES contexts in a more ecologically valid way than possible in much neuroscience and neurodevelopment research, giving a potentially more generalizable understanding of poverty-related adversities than previous work in this area. However, because of the nature of our sample we are also open to the possibility of our findings being sample specific, and our operationalizations of deprivation and threat may not be appropriate for other samples.

Despite the many strengths of our approach, there are also a number of limitations that merit addressing. To begin with, our use of consistent partnership in our measure of deprivation is used as a proxy to estimate the number of adults available to provide the child with social or cognitive stimulation. This measure would perhaps be better replaced with a more explicit parent-report measure of number of adults and siblings in the child's environment who provide the child with that sort of stimulation. Similarly, our measure of deprivation more broadly does not capture the full extent of social and cognitive stimulation and may neglect the other forms of social and cognitive stimulation that children living in poverty receive from their environments (for example from siblings, daycare providers, etc.). Finally, our measure of sensitive caregiving may be biased towards white, middle class ideals of what sensitive and responsive caregiving entails, as is common in much psychological research (Baugh, 2017), and as such these results may not capture the full range of what sensitive caregiving looks like in low-SES contexts. As well, to the extent to which our sample overrepresents children and families in poverty in nonurban contexts, our effect estimates may be over- or underestimates of effects in the general population of families in the US. Despite these limitations, these analyses provide an important first step towards bridging the gaps between childhood adversity research and child poverty research and provide useful insight into processes of deficit and adaptation in children growing up in poverty.

An additional limitation comes from our measurement model for deprivation and threat. While all indicators for both deprivation and threat loaded significantly and in the expected direction, some factor loadings are smaller than the typical $\beta = 0.4$ threshold. We attribute this to the high degree of variability within this sample for what characterizes deprivation and threat. Of particular note is that our sample is 40 % single parents, or primary caregivers that report that they do not have a consistent partner. This high degree of single parenthood leads to increased weight on this variable in the deprivation measure. Likewise, we suspect this high degree of single parenthood leads to decreased weight of our verbal and physical aggression measures in the threat measure, as there is less consistency in these measures throughout the sample. Future studies should perhaps consider examining these dimensions in samples with exclusively 2-parent (or 2-caregiver) families to avoid such degrees of variability.

## 5. Conclusions

In this study, we have applied the Dimensional Model of Adversity and Psychopathology to a low-SES context and demonstrated that deprivation and threat may be core experiences of poverty-related adversity influencing child outcomes. Specifically, we found that deprivation and threat together fully mediate the associations between early life SES and EF abilities, such that higher deprivation was related to poorer EF outcomes, but that higher threat was unrelated to EF scores. Future work in this area could profitably examine how these associations manifest longitudinally, and in different developmental contexts (i.e. rural vs. urban samples, in non-US samples, etc.). This study provides an important step forward in understanding the experiences of children growing up in poverty and introduces important areas for future research to inform interventions for children and families in poverty.

## Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

## Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.dcn.2020.100907.

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