Psychoneuroendocrinology 103 (2019) 96–103

Contents lists available at ScienceDirect

Psychoneuroendocrinology

journal homepage: www.elsevier.com/locate/psyneuen

Socioeconomic status disparities affect children's anxiety and stress-sensitive cortisol awakening response through parental anxiety

Yannan Zhu[a], Xu Chen[b], Hui Zhao[a], Menglu Chen[a], Yanqiu Tian[a], Chao Liu[a], Zhuo Rachel Han[c], Xiuyun Lin[c], Jiang Qiu[b], Gui Xue[a], Hua Shu[a], Shaozheng Qin[a,*]

[a] State Key Laboratory of Cognitive Neuroscience and Learning & McGovern Institute for Brain Research at Beijing Normal University, Beijing, China
[b] Faculty of Psychology at Southwest University, Chongqing, China
[c] Faculty of Psychology at Beijing Normal University, Beijing, China

ARTICLE INFO

Keywords:
Socioeconomic status
Stress
Anxiety
Cortisol awakening response
HPA-axis
Child development

ABSTRACT

Socioeconomic status (SES) disparities have profound impacts on child development and health, which are linked to negative emotions and alterations in the integrity of stress-sensitive hypothalamus-pituitary-adrenal (HPA)-axis system. However, its underlying psychophysiological mechanisms remain poorly understood. Here we investigate how family SES, in concert with parental anxiety, affects children's anxiety and their integrity of HPA-axis system in two studies involving a total of 1318 children and their parents. In Study 1 with a cohort of 1088 children and their parents, we found that low-SES children relative to high-SES ones experienced a higher level of anxiety mediated by increasing parental anxiety. In Study 2 with an independent cohort of 230 children and their parents, we found that low-SES children exhibited an increase in pre-bedtime basal cortisol but a decrease in cortisol awakening response (CAR). Structural equation modeling (SEM) further revealed that the association between low SES and children's reduced CAR was mediated by increased parental and child anxiety. Our findings suggest that low-SES children are more vulnerable to anxiety and altered HPA-axis integrity, most likely mediated through increased parental anxiety.

1. Introduction

Family socioeconomic status (SES) disparities have profound impacts on children's brain development and mental health (Bradley and Corwyn, 2001; Hanson et al., 2013; Kolb and Gibb, 2016). It has become an urgent reality of global society and discourages the thriving and prosperous promises of contemporary society. Children from low-SES families often experience chronic stressful events and long-term allostatic load in their lives (McEwen, 2000), thereby more vulnerable to negative emotions, such as anxiety, and aberrations in the integrity of stress-sensitive hypothalamic-pituitary-adrenal (HPA) axis system (Linda C. Gallo and Matthews, 2003; Lupien et al., 2009). Moreover, family SES is also known to have a profound impact on parental emotional status as well, which in turn affects children's mental and physiological wellbeing (Conger et al., 2010; Hudson and Rapee, 2001). Very little, however, is known about how family SES, in concert with parental anxiety, impacts young children's anxiety and HPA-axis integrity. Understanding this question would provide important implications for psychophysiological factors determining the adverse effects of low-SES on children's emotional development and health more broadly.

Previous psychological studies have demonstrated that individuals with low-SES background are more frequently exposed to negative events and uncertainties (i.e., crowding, noise and less predictable routines) in their daily lives (Evans et al., 2005). Specifically, family studies indicate that parents in low-SES families show not only elevated state anxiety, but also higher trait anxiety, as they experience more stressful events and environmental challenges than parents in high-SES families (Conger et al., 2010, 1994). Moreover, children from low-SES families are also linked to increased risk for anxiety (Bradley and Corwyn, 2001; Chen et al., 2010; Miech et al., 1999). Remarkably, parental emotional status plays a prominent role on children's emotional wellbeing through daily parent-child interactions. The transmission of anxiety from parent to child, for instance, is believed to result from the involvement of anxious parenting and consequent children's excessive response but poor coping skills to stress (Creswell et al., 2010; Hudson and Rapee, 2001). Indeed, evidence from longitudinal and cross-sectional studies suggests that children with anxious

* Corresponding author at: State Key Laboratory of Cognitive Neuroscience and Learning & IDG/McGovern Institute for Brain Research, Beijing Normal University, No. 19, XinJieKouWai St., HaiDian District, Beijing 100875, China.
E-mail address: szqin@bnu.edu.cn (S. Qin).

https://doi.org/10.1016/j.psyneuen.2019.01.008
Received 29 August 2018; Received in revised form 8 December 2018; Accepted 9 January 2019

parents are more likely to develop emotional problems such as anxiety in later adulthood (Beidel and Turner, 1997; Hudson and Rapee, 2001; Pereira et al., 2013; Woodruff-Borden et al., 2002). Both parental trait and state anxiety may play a critical role in affecting children's emotional status, with the former referring as a predisposition of individual's interpretation to various environmental events in a negative way and the latter as a transitory, fluctuating anxious state under some current stimulus (Spielberger, 1983). However, it remains elusive whether and how parental trait or state anxiety mediates the effects of family SES on child anxiety.

A number of neuroendocrine studies have well characterized the diurnal rhythm of HPA-axis system, with a rapid increase of cortisol awakening response (CAR) in the morning followed by a decline throughout the rest of the day, and a relatively stable and basal level at late afternoon and night (Edwards et al., 2001; Gunnar and Cheatham, 2003). Several longitudinal studies have revealed that low SES during early life can lead to dysregulation of cortisol in later adulthood (Gustafsson et al., 2010; Li et al., 2007). However, studies in pediatric population demonstrate that children in low-SES families have already exhibited an increased daily basal cortisol level, due to their prolonged exposure to threat and stress (Chen et al., 2010; McEwen, 2000; Lupien et al., 2000; LUPIEN, 2001). Thus, it is well possible that low SES, considered as a long-term chronic stressor, may have altered the integrity of HPA-axis system since childhood. Maladaptive alternations in HPA-axis system during early childhood have been linked with increased risk of many developmental and health problems in later adolescence and adulthood, including aggression, diabetes and obesity (BjÖrntorp and Rosmond, 1999; Böhnke et al., 2010; Epel et al., 2000). The majority of previous studies about the effects of low SES on HPA-axis activity, however, only focused on either general (unspecified) cortisol or basal cortisol response during the day, but rarely directly investigated its effect on CAR. As a cardinal biomarker of HPA-axis, CAR has been proposed to provide energetic resources necessary to meet the anticipated demands of the upcoming day (Clow et al., 2010). It appears to have an independent regulatory mechanism that differs from general cortisol response during daytime and basal cortisol at night (Schmidt-Reinwald et al., 1999; Wilhelm et al., 2007). Therefore, it remains unknown whether low-SES family environment has a special effect on children's CAR.

Furthermore, increasing evidence from recent studies suggests that negative emotions play a role in understanding how low SES affects the integrity of HPA-axis with cortisol secretion (Chen et al., 2010; Gallo and Matthews, 1999, 2003). Thus, children's negative emotions, especially anxiety as the most commonly adaptive response to stressful events, might represent a key link between SES and their cortisol response (Blomqvist et al., 2007; Ehlert and Straub, 1998). Given the critical role of parental emotional status on children's psychological and physiological reactivity to stress, it is conceivable that parental anxiety would be an important pathway from family SES to individual differences in children's cortisol response. However, it has never been examined how family SES affects children's HPA-axis integrity through the interaction between parental and child anxiety. Evidence of this process is essential because it would integrate family environment, parental emotional status and children health into a comprehensive perspective on children development.

Here we set up two independent studies to investigate how family SES, in concert with parental anxiety, impacts children's anxiety and their HPA-axis activity. In Study 1, we investigated how family SES affected child anxiety through parental anxiety from a large sample of 1088 children and their parents (Cohort 1). In Study 2, we further investigated how family SES, along with parental and child anxiety, affected children's HPA-axis activity from an independent sample of 230 children and their parents (Cohort 2). Children's HPA-axis activities were measured by their pre-bedtime basal cortisol at night and CAR in the followed morning. Based on empirical observations in previous studies, we hypothesized that the relation between family SES and child anxiety would be mediated by parental anxiety. We further hypothesized that parental anxiety, along with child anxiety, would mediate the relation between family SES and children's HPA-axis activity.

2. Methods

2.1. Participants

A total of 1088 typically developing children (Cohort 1: 565 boys and 523 girls; aged 6–15 years old; mean age ± SD: 10.36 ± 2.26 years old) and their parents (Cohort 1: 372 fathers and 716 mothers) in Study 1 were recruited through advertising campaign at primary and secondary schools in Beijing urban area. Another independent 230 children (Cohort 2: 122 boys and 108 girls; aged 6–15 years old; mean age ± SD: 9.46 ± 2.05 years) and their parents (Cohort 2: 71 fathers, 159 mothers) in Study 2 were recruited through the same way in urban areas of Beijing and Chongqing. Both children and parents from two studies were given written informed consent before their participation. All protocols were approved by the institutional review board at Beijing Normal University, and participants were treated in accordance with the American Psychological Association Code of Conduct. Neither children nor their parents had any history of neurological or psychiatric disorders.

2.2. Socioeconomic status (SES) assessment

Parents (either mother or father) were asked to complete a self-administered family background questionnaire on their income and education levels for both parents to develop a SES indicator based on a combination of these factors (Noble et al., 2006; Zhang et al., 2013). Parents' income was measured with a 6-point scale (i.e., 1, < 499; 2, between 500 and 1999; 3, between 2000 and 4999; 4, between 5000 and 9999; 5, between 10,000 and 20,000; 6, more than 20,000 Chinese Yuan CNY per month). Parents' education levels were measured with a 10-point scale (i.e., 1, none; 2 = primary grade 3 or below, 3 = primary grade 4–6, 4 = middle school, 5 = Secondary Specialized School, 6 = high school, 7 = junior college, 8 = college, 9 = master graduate, 10 = doctoral graduate). These measures were then transformed into z-scores separately, averaged across parents and across income and education measurements to form a composite SES score. A total of 1088 families in Cohort 1 and 196 families in Cohort 2 completed the family background questionnaire (no missing item), with an effective rate of 100% and 85.22% respectively.

2.3. Anxiety assessments

Parental anxiety was measured using a self-reported State-Trait Anxiety Inventory (STAI) (Spielberger, 1983). The STAI consists of 40 items in total, with 20 items for each subscale of state and trait anxiety. Participants were asked to rate how frequently each item occurred in their own lives on a 4-point Likert scale (i.e., from 1 "not at all" to 4 "very much") with the possible score ranging from 20 to 80. Child anxiety was obtained by a parent-rated anxiety questionnaire (i.e., parent/guardian version for children aged 6–17). This scale consisting of 10 items is adapted from PROMIS Emotional Distress—Anxiety—Parent Item Bank and widely used to assess the pure domain of anxiety in children and adolescents (Irwin et al., 2010). Parents were instructed to report how often their children had been bothered by a list of symptoms within the past 7 days on a 5-point scale (i.e., from 1 "almost never" to 5 "almost always") with the total score varying from 10 to 50. The raw score was then transformed into T-score ranging from 34.4 to 88.8, according to the standardized norm in the general population. The T-scores were included in the further analyses.

Both parental and child anxiety were reported by one parent consistent with the one who completed SES assessment. According to scoring rules (Irwin et al., 2010; Spielberger, 1983), the questionnaire

with more than 75% of items answered was considered as valid. Thus, there were 1027 parents in Cohort 1 and 196 parents in Cohort 2 completing the assessment of STAI, with an effective rate of 94.39% and 85.22% respectively. In addition, there were 1042 parents in Cohort 1 and 190 parents in Cohort 2 completing the assessment of their children's anxiety, with an effective rate of 95.77% and 82.61% respectively.

2.4. Salivary cortisol collection and analysis

Children and their parents were both instructed on how to collect saliva samples in oral form. They were also provided with a pack containing a written version of instructions for saliva collection, Salivette collection devices (Sarstedt, Nümbrecht, Germany) and a health status questionnaire. Especially, we called and also sent a instruction message to each child's parent in the evening before experiment to make sure that they could correctly instruct their children to take salivary samples. Five saliva samples were collected on one of the weekdays from each child in Cohort 2 with their parents' assistance: one at pre-bedtime during night (i.e., S0), remaining four ones at immediately upon awakening (i.e., S1) in the following morning, then 15 min (i.e., S2), 30 min (i.e., S3), and 60 min (i.e., S4) later respectively. To avoid contamination of saliva, participants were asked not to brush teeth, drink, or eat at least 60 min before sampling. To confirm adherence, we undertook several steps including comprehensive instructions, time recordings and screenings in order to obtain reliable salivary data as outlined by previous studies (Stalder et al., 2016; Wu et al., 2015). Each participant's sleeping and awakening time as well as the exact time of taking each salivary sample were recorded not only by writing on the collection devices but also by taking photos with an automatically time-logged function. These samples were then brought back to the laboratory where kept frozen (-20°C) until assay. Cortisol samples from participants who reported any sickness (i.e., periodontitis, fever or endocrine diseases), related medication regimen (especially hormone medicines) within the last two weeks, close menstrual cycle (for girls), or failure in obeying sampling time, would not be further analyzed.

Salivary samples were thawed and centrifuged at 3200 rpm for 10 min. Cortisol concentration was analyzed by use of electrochemiluminescence immunoassay (Cobas e 601, Roche Diagnostics, Numbrecht, Germany) with sensitivity of 0.500 nmol/L (lower limit) and a standard range in assay of 0.5–1750 nmol/L. Intra and inter-assay variations were below 10%.

A natural log transformation was applied to cortisol data of five samples to ensure normal distribution. Two measurements were used to quantify HPA-axis activity after the log transformation: (1) pre-bedtime basal cortisol level (i.e., S0), (2) area under the curve of four points in the morning with respect to the pre-bedtime sample at last night - $AUCi_{(night)}$ = (S1 + S2)*0.25/2 + (S2 + S3)*0.25/2 + (S3 + S4)*0.5/2 - S0 * (0.25 + 0.25 + 0.5). The AUCi is used to capture the relative increase in cortisol level over certain time points of interest, as a reliable index reflecting the integrity of HPA-axis (Pruessner et al., 2003).

2.5. Statistical analysis

Partial correlation analyses were conducted using SPSS 22.0 to investigate relationships among family SES, parental anxiety, child anxiety and children's cortisol responses by controlling children's gender and age, and gender of the parent (who filled questionnaire). We also used a machine-learning approach with balanced 4-fold cross-validation to confirm the robustness of these established relationships (J. R. Cohen, 2010; Liu et al., 2016; Qin et al., 2014; Supekar et al., 2013), because conventional regression models assess correlations which are sensitive to outliers and have no predictive value (Geisser, 2017).

For machine learning approach, children's CAR was treated as a dependent variable, and SES as an independent variable. Data for these two variables were divided into four folds. A linear regression model was built using data from three out of the four folds and used to predict the remaining data in the left-out fold. This procedure was repeated four times to compute a final $r_{(predicted,\ observed)}$. Such $r_{(predicted,\ observed)}$, representing the correlation between the observed value of the dependent variable and the predicted value generated by the linear regression model, was estimated as a measure of how well SES predicted children's CAR. Finally, we used a nonparametric testing approach to test for the statistical significance of the model by generating 1000 surrogate data sets under the null hypothesis of $r_{(predicted,\ observed)}$ (see Qin et al., 2014 for more details). The statistical significance (p value) of the model was determined by measuring the percentage of generated surrogate data. Parallel analyses were also conducted to compute other predictive relations, with SES (parental state/trait anxiety or child anxiety) as an independent variable and children's pre-bedtime basal cortisol (or CAR) as a dependent variable.

To further characterize differences of parental anxiety, child anxiety and children's cortisol responses, the sample was divided into three groups of low-, medium- and high-SES families based on their SES scores with 0-25th, 25-75th and 75-100th percentiles respectively. The valid sample size in each group was shown in Table S1, which varied slightly due to missing values for each variable. Separate one-way analyses of variance (ANOVAs) with SES group (low vs. medium vs. high) as a between-subject factor were conducted to analyze group differences in parental and child anxiety, as well as children's cortisol responses. Children's gender and age, and gender of the parent (who filled questionnaire) were included as covariates of no interest in statistical tests. Corresponding *post-hoc* analyses were conducted using Least Square Difference (LSD) or Tamhane's T2 when test of homogeneity of variances was larger or smaller than 0.05 respectively. The effect sizes were reported using partial eta square ($partial\eta^2$).

Structural equation models (SEMs) were constructed to examine the hypothesized mediating effects of parental anxiety on the associations of family SES with children's anxiety and cortisol responses using Mplus 7.0 (Hayes et al., 2011). Several indices evaluating the fitness of the proposed model were provided. A Chi-squared test is used to examine the significance of good fitness for the predicted model congruent with the observed data. The Root Mean Square Error of Approximation (RMSEA) is considered adequate below 0.08. The Standardized Root Mean Square Residual (SRMR) refers to the standardized difference between the observed correlation and the predicted correlation, which is considered acceptable with values at 0.05 or less. The Comparative Fit Index (CFI) indicates the number of parameters or paths in the model, and is considered as good at 0.90 or above. Moreover, bias-corrected bootstrap was conducted (1000 samples) to test the mediating effect (Shrout and Bolger, 2002). Both direct and indirect effects of SES on children's cortisol responses were estimated, which generated percentile based on confidence intervals (CI). All reported p values are two-tailed.

3. Results

3.1. Participant demographics, psychological and endocrinal measures

Participant demographics, family SES, parental anxiety and child anxiety are summarized in Table 1. Independent-sample t-tests were conducted to examine potential differences in these measurements between Cohort 1 and Cohort 2. These analyses revealed no any significant difference between two cohorts in their family SES (z-score) ($t_{(1282)}$ = 0.65, p = 0.52), parental anxiety (trait: $t_{(1221)}$=-1.01, p = 0.31; state: $t_{(1221)}$ = 0.79, p = 0.43) and child anxiety ($t_{(1230)}$ = -1.27, p = 0.20), indicating high homogeneity between Cohort 1 and Cohort 2. These measurements also have similar frequency distributions between the two cohorts (Fig. S1).

Cortisol levels as a function of sampling time points (i.e., S0, S1, S2, S3, S4) in Cohort 2 are shown in Fig. 1 and Table S2. All children went

Table 1
Participant Demographic and Psychological Characteristics.

Characteristics	Cohort 1 in Study 1 (N = 1088) Mean ± SD (range)	Cohort 2 in Study 2 (N = 230) Mean ± SD (range)
Demographics		
Age (year)	10.36 ± 2.26 (6-15)	9.46 ± 2.05 (6-15)
Gender (%, female)	48.07	46.96
Parent (%, mother)	65.81	69.13
SES		
Parental Education	5.73 ± 1.65 (1-10)	5.51 ± 1.55 (2-8.5)
Parental Income	3.41 ± 0.88 (1-6)	3.23 ± 0.78 (1-6)
Parental Anxiety		
State Anxiety	35.79 ± 9.17 (20-73)	35.29 ± 9.04 (20-63)
Trait Anxiety	37.56 ± 8.19 (20-66)	38.28 ± 8.34 (20-61)
Child Anxiety	43.53 ± 9.71 (34.4-88.8)	44.44 ± 9.54 (34.4-65.8)

Notes: SES (socioeconomic status of family) was a composite measure of parental education and income. Parental anxiety was obtained from State-Trait Anxiety Inventory (STAI). Child anxiety was obtained from a standardized parent-rated anxiety questionnaire.

to bed before 11:00 pm and waked up after 5:00 am in the next morning with 8-hour sleep duration on average. Children's cortisol responses prominently increased from pre-bedtime (i.e., S0, mean ± SEM: 3.93 ± 0.14) to immediate awakening (i.e., S1, mean ± SEM: 14.18 ± 0.33) in the morning, and peaked around 15-30-min later (i.e., S2, mean ± SEM: 16.02 ± 0.35; S3, mean ± SEM: 16.05 ± 0.37) followed by a rapid decline at 60-min after awakening (i.e., S4, mean ± SEM: 11.19 ± 0.31). $AUCi_{(night)}$ (mean ± SEM: 10.69 ± 0.28), representing the relative increase of cortisol in the morning with pre-bedtime cortisol at last night as the baseline, was calculated with all five cortisol samples (Fig. 1B). We did not observe any reliable relationship of age, gender, sleep duration or wake time with cortisol levels (*all $p > 0.10$*). Repeated-measures ANOVAs with sampling Time as a within-subject factor for cortisol data, by controlling potential confounds of age and gender, demonstrated a significant main effect of Time ($F_{(}4,860_{)} = 15.68$, $p < 0.001$, *partial* $\eta^2 = 0.07$). Further post-hoc analyses revealed that pre-bedtime cortisol level was significantly lower than cortisol levels at all other four points in the followed morning (*$p < 0.001$ for all other four points*). These results indicate the prominent diurnal dynamics of HPA-axis system in young children, with lower basal cortisol level before sleep (i.e., S0) and elevated CAR (i.e., $AUCi_{(night)}$) in the morning.

3.2. Low-SES children experienced higher anxiety mediated by increasing parental anxiety

In Study 1, we investigated the relation between family SES and child anxiety, and the mediating effect of parental anxiety on such relation with the large sample of 1088 families from Cohort 1. Partial correlation analyses were first conducted to examine the relations among family SES, parental anxiety and children anxiety with age and gender as covariates of no interest (Table S3). These analyses revealed that child anxiety had significantly positive correlations with parental state ($r_{(1022)} = 0.26$, $p < 0.001$, *95% confidence interval (CI) = [0.21, 0.32]*) and trait ($r_{(1022)} = 0.25$, $p < 0.001$, *95% CI = [0.19, 0.31]*) anxiety. Family SES was negatively correlated with parental state ($r_{(1022)} = -0.15$, $p < 0.001$, *95% CI = [-0.21, -0.09]*) and trait ($r_{(1022)} = -0.17$, $p < 0.001$, *95% CI = [-0.23, -0.11]*) anxiety. In addition, SES showed relatively weaker yet significant negative correlation with child anxiety ($r_{(1037)} = -0.08$, $p = 0.016$, *95% CI = [-0.13, -0.01]*). Parallel analyses in Study 2 with independent Cohort 2 reproduced very similar results (Table S4).

Next, we conducted separate ANOVAs with SES Group as the between-subject factor to characterize differences of parental and children anxiety in low (0-25th percentile), medium (25-75th percentile) and high (75-100th percentile) SES groups (Fig. 2) for complementary purposes. These analyses revealed significant main effects of Group on parental state ($F_{(}2,1021_{)} = 14.59$, $p < 0.001$, *partial* $\eta^2 = 0.03$) and trait ($F_{(}2,1021_{)} = 17.95$, $p < 0.001$, *partial* $\eta^2 = 0.03$) anxiety as well as child anxiety ($F_{(}2,1036_{)} = 4.29$, $p = 0.014$, *partial* $\eta^2 = 0.01$). Further post-hoc analyses revealed that parental anxiety in low-SES group was significantly higher than it in medium-SES (*state: $p = 0.004$; trait: $p < 0.001$*) and high-SES group (*state: $p < 0.001$; trait: $p < 0.001$*). Child anxiety in low-SES group was marginally significantly higher than it in high-SES group (*$p = 0.083$*). These results indicate that both children and their parents in low-SES families experienced significantly higher anxiety than those in high-SES families.

To further determine the hypothesized mediating effects of parental anxiety on the negative association between SES and child anxiety, we conducted two full SEMs including parental trait and state anxiety separately (Fig. 3). The path coefficients for SES to child anxiety dropped to non-significance when the mediating paths were added. The mediating effects of parental trait (*Indirect Est = -0.06, $p < 0.001$, 95% CI = [-0.09, -0.04]*) and state (*Indirect Est = -0.06, $p < 0.001$, 95% CI = [-0.08, -0.04]*) anxiety were both significant. These results indicate a complete mediating pathway of parental anxiety on the negative association between family SES and child anxiety.

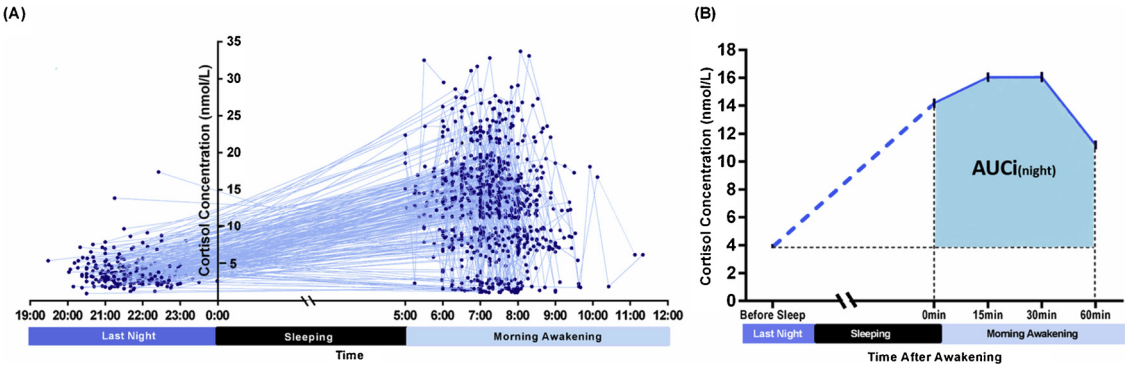

Fig. 1. Salivary cortisol levels at pre-bedtime during night and within the first hour immediately after awakening in the followed morning. (A) Cortisol levels as a function of Time for children in Cohort 2 (valid sample N = 230). The x-axis represents absolute time in 24-hour format. (B) Averaged cortisol levels as a function of sampling time points across participants. The x-axis represents five time points of saliva sampling at pre-bedtime during night and within the first hour in the followed morning immediately after awakening (0-min), 15-min, 30-min, 60-min. The y-axis represents salivary cortisol concentration (nmol/L). The dashed area represents $AUCi_{(night)}$, area under the curve of four points in the morning with respect to the pre-bedtime sample at last night. Notes: Error bars represent standard error of the mean (S.E.M.).

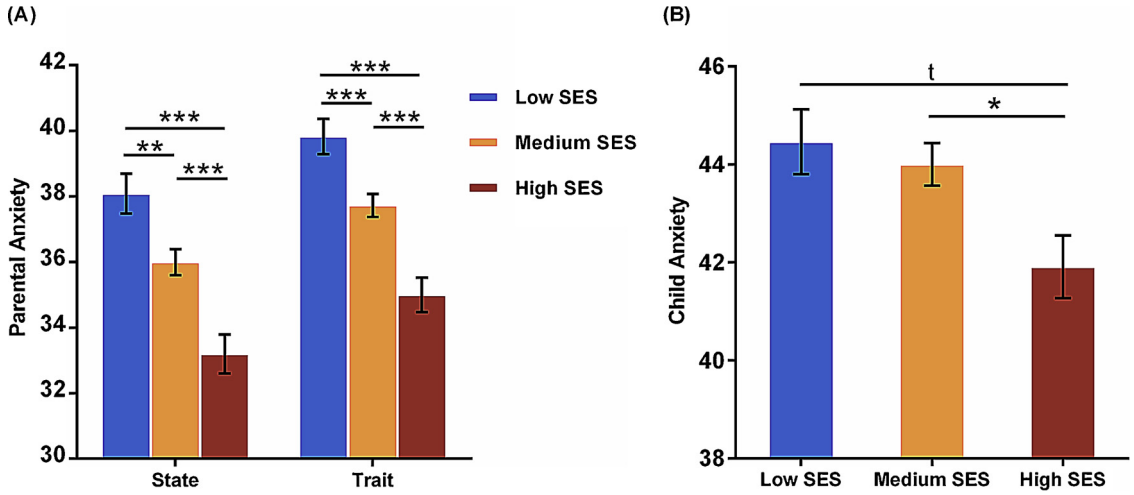

Fig. 2. Mean parental and child anxiety levels as a function of three SES groups. **(A)** Parental state and trait anxiety (valid sample N = 1027) in low, medium and high SES groups respectively. **(B)** Child anxiety (valid sample N = 1042) in low, medium and high SES groups respectively. The error bars represent standard error of the mean (S.E.M.). Children's age and gender, and gender of the parent (who filled questionnaires) were included as covariates of no interest. Notes: ^{t} $p < 0.100$; * $p < 0.050$; ** $p < 0.010$; *** $p < 0.001$.

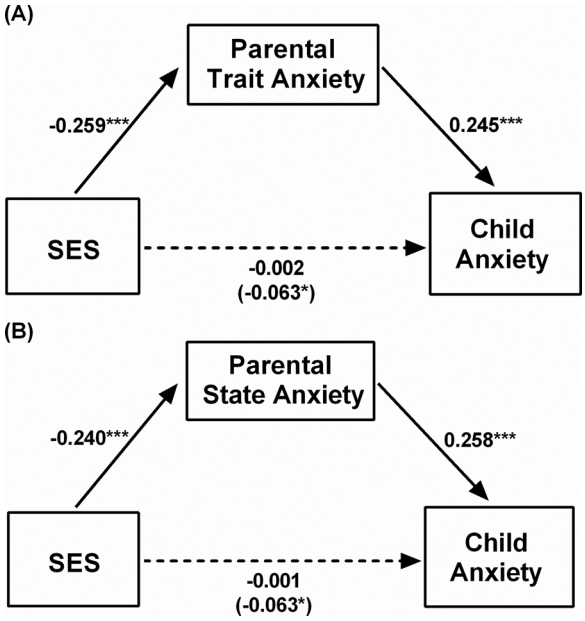

Fig. 3. The mediating effects of parental anxiety on the negative association between SES and child anxiety (valid sample N = 1027). (A) Model 1 with parental trait anxiety as mediator. The mediating effect of parental anxiety was significant (*Indirect Est.* $= -0.06$, $p < 0.001$, *95%CI = [-0.09, -0.04]*). (B) Model 2 with parental state anxiety as mediator. The mediating effect of parental anxiety was significant (*Indirect Est.* $= -0.06$, $p < 0.001$, *95%CI = [-0.08, -0.04]*). Paths are marked with standardized coefficients. Significant paths in the model are shown as solid lines, whereas non-significant paths are shown as dashed lines. The coefficients in brackets show the associations before parental anxiety was included into the models. Notes: * $p < 0.050$; *** $p < 0.001$.

3.3. Low-SES children exhibited increased basal cortisol but reduced CAR

In Study 2, we investigated how family SES related to children's HPA-axis activity with the independent sample of 230 families from Cohort 2. Partial correlation analyses firstly revealed a significantly negative correlation between SES and pre-bedtime basal cortisol (i.e., S0) ($r_{(191)} = -0.20$, $p = 0.006$, *95%CI = [-0.34,* -0.07]; $r_{(predicted,\ observed)} = 0.17$, $p = 0.004$), but a significantly positive correlation between SES and CAR (i.e., $AUCi_{(night)}$) ($r_{(191)} = 0.19$, $p = 0.010$, *95%CI = [0.01, 0.30]*; $r_{(predicted,\ observed)} = 0.16$, $p = 0.004$). Results from prediction analysis based on a machine learning algorithm were consistent with these correlation results (Table S5).

Then, separate ANOVAs revealed significant main effects of SES Group on pre-bedtime basal cortisol ($F_{(}2,191_{)} = 4.74$, $p = 0.010$, $partial\eta^2 = 0.05$) and CAR ($F_{(}2,191_{)} = 3.47$, $p = 0.033$, $partial\eta^2 = 0.04$) (Fig. 4). Post-hoc tests revealed that pre-bedtime basal cortisol (i.e., S0) in low-SES group was significantly higher than it in high-SES group ($p = 0.002$), but CAR (i.e., $AUCi_{(night)}$) in low-SES group was significantly lower than high-SES group ($p = 0.011$). These results indicate that low-SES children relative to those in affluent families showed a significant elevation of pre-bedtime basal cortisol before sleep, but a reduction of CAR in the followed morning.

3.4. The relationship between low SES and children's reduced CAR was mediated by increased parental and child anxiety

We further conducted two SEMs to investigate the hypothesized mediating effects of parental and child anxiety on the positive association between SES and children's CAR as indicated by $AUCi_{(night)}$. The

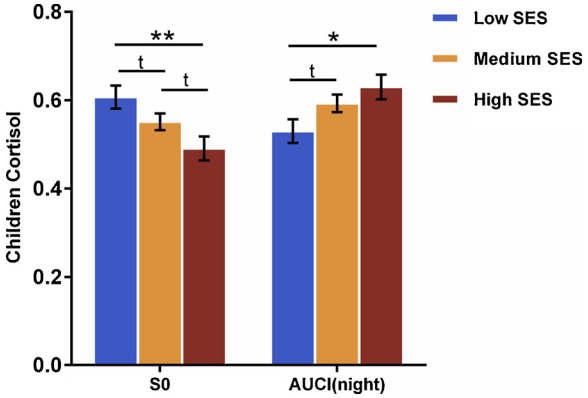

Fig. 4. Children's pre-bedtime basal cortisol at night and CAR in the followed morning as a function of three SES groups (valid sample N = 196). Mean pre-bedtime basal cortisol levels (i.e., S0) at night, and CAR (i.e., $AUCi_{(night)}$) in the followed morning in low, medium and high SES groups respectively. The error bars represent standard error of the mean (S.E.M.). Children's age and gender, and gender of the parent (who filled questionnaires) were included as covariates of no interest. Notes: ^{t} $p < 0.100$; * $p < 0.050$; ** $p < 0.010$.

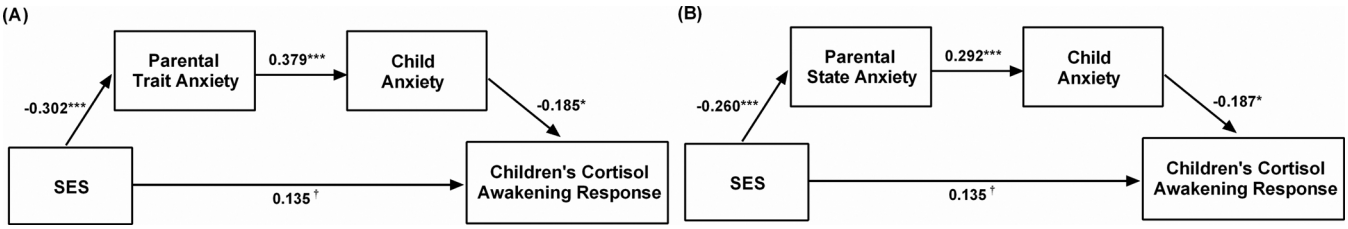

Fig. 5. The mediating effects of parental and child anxiety on the positive association between SES and children's CAR (valid sample N = 190). (A) Model 1 with parental trait anxiety and child anxiety as mediators. The mediating effect was significant (Indirect Est = 0.02, p < 0.05, 95% CI = [0.00, 0.04]). (B) Model 2 with parental state anxiety and child anxiety as mediators. The mediating effect was marginally significant (Indirect Est = 0.01, p = 0.08, 95% CI = [-0.00, 0.03]). Paths are marked with standardized coefficients. Demographic variables including children's age and gender, and gender of the parent (who filled questionnaires) were included as covariates of no interest in the models (not shown). Notes: † p < 0.10; * p < 0.05; *** p < 0.001.

model 1 with parental trait anxiety and child anxiety as mediators (Fig. 5A) resulted in good model fit (*Chi^2 = 4.93, p > 0.05; RMSEA = 0.00; SRMR = 0.03; CFI = 1.00*). There was a marginally significant direct effect of SES on children's CAR (*direct Est = 0.14, p = 0.077*), and a significant mediating effect of parental trait anxiety and child anxiety (*Indirect Est = 0.02, p = 0.049, 95% CI = [0.00, 0.04]*). The model 2 with parental state anxiety and child anxiety as mediators (Fig. 5B) also resulted in good model fit (*Chi^2 = 4.40, p > 0.05; RMSEA = 0.00; SRMR = 0.02; CFI = 1.00*). There was again a marginally significant direct effect of SES on children's CAR (*direct Est = 0.14, p = 0.078*), and a marginally significant mediating effect of parental state anxiety and child anxiety (*Indirect Est = 0.01, p = 0.081, 95% CI = [-0.00, 0.03]*).

We also conducted two SEMs to investigate the mediating effects of parental and child anxiety on the negative association between SES and children's pre-bedtime basal cortisol (i.e., S0). We observed no reliable mediating effect for either parental trait *(Indirect Est = -0.02, p = 0.144, 95% CI = [-0.03, 0.01];* Fig. S3A*)* or state anxiety *(Indirect Est = -0.01, p = 0.180, 95% CI = [-0.02, 0.01];* Fig. S3B*)*.

Next, we conducted a set of paralleled analyses to examine alternative mediation models. These analyses revealed no significant mediating effects in the four alternative mediation models, with SES as the independent variable, parental anxiety and children's cortisol response as the mediators, and child anxiety as the outcome variable (Fig. S6). We also conducted additional analyses to examine the moderating effects of parental anxiety on the association of SES with children's anxiety and cortisol responses (Figs. S7–S8). Again, no reliable moderating effect of parental anxiety was observed. These results indicate that our data did not support these alternative models noted above. Altogether, our results demonstrate that the positive relationship between family SES and children's CAR was mediated by parental and child anxiety.

4. Discussion

Our study investigated how family SES, in concert with parental anxiety, affected children's psychological and endocrinal measures of stress. We found that low-SES children relative to those in affluent families experienced higher anxiety, which was mediated by increasing parental anxiety. Moreover, low-SES children showed a significant elevation of pre-bedtime basal cortisol at night, but a reduction of CAR in the followed morning. Critically, SEMs revealed that the relationship between low SES and children's reduced CAR was mediated by increased parental and child anxiety. Our findings suggest a psychoendocrinological mechanism that the adverse effects of low family SES on children's anxiety and their integrity of stress-sensitive HPA-axis system could be mediated by increased parental anxiety.

Our observed relations of low-SES with increased parental and child anxiety from Study 1 and Study 2 are in line with findings from previous studies (McLoyd, 1998; Merikangas et al., 2010; Starfield et al., 2002). These studies have suggested that negative emotions, such as anxiety, are often aroused disproportionately in parents and children from low-SES families, due to the lack of living resources and high stress load. Building on these previous findings, results from our present study further reveal a prominent mediating pathway of parental anxiety on the negative relation between family SES and child anxiety. Given the evidence from previous longitudinal and cross-sectional studies on the transmission of anxiety from parent to child (Creswell et al., 2010; Hudson and Rapee, 2001), it is thus conceivable that high anxiety in parents from low-SES families comes into anxious rearing and disrupted parenting practices, thereby contributing to high anxiety in young children through parent-child interactions. The complete mediating effect of parental anxiety also suggests that low family SES may not directly result in high anxiety of young children, but only through the pathway of increased parental anxiety. This finding highlights the crucial role of parental emotional status in mediating the negative effects of low-SES family environment on children's emotional wellbeing.

Beyond high anxiety in low-SES children, we observed the elevation of pre-bedtime basal cortisol in these children. Elevated cortisol levels have been linked to hyper-activation of HPA-axis system in response to acute or chronic stressor in both healthy adults and children (Chen et al., 2010; Cohen et al., 2006; LUPIEN et al., 2001). Thus, it is possible that elevated pre-bedtime basal cortisol reflecting hyper-activation of HPA-axis system was resulted from the prolonged exposure to stressful events in low-SES environment. Indeed, this finding in our present study, along with findings from many previous studies, corroborates that low-SES family environment, analogous to chronic stress, can lead to hyper-activation of HPA-axis accompanying with excessive basal cortisol secretion in pediatric population.

In contrary to elevated pre-bedtime basal cortisol, we observed a significant reduction in CAR of low-SES children. Recent studies have demonstrated that low SES background predicts high bedtime cortisol levels but low CAR in adults, indicating an unhealthy profile overall (Desantis et al., 2015; Hajat et al., 2010). Consistent with these studies, our findings provide the first evidence that young children exposed to low-SES family exhibit not only excessive basal cortisol response at night, but also blunted CAR in the followed morning. Several previous studies suggest that long-term excessive secretion of cortisol in low-SES background may exhaust the self-regulating ability of HPA-axis system, including the negative feedback mechanism (Holsboer, 2001; Schatzberg and Lindley, 2008). The exhausted HPA-axis fails in response to subsequent stimulus effectively, thereby leading to a blunted CAR which is unable to normally arouse and provide sufficient energy to deal with the upcoming day (Clow et al., 2010; Duan et al., 2013). Thus, both elevated pre-bedtime basal cortisol and reduced CAR reflect alternations in the integrity of HPA-axis system under low-SES environment. Given the modulatory roles of cortisol in brain systems including the hippocampus, amygdala and frontal cortex that are critical for stress response and cognitive development (Dedovic et al., 2010; Qin et al., 2014; Wu et al., 2015), our findings implicate that the increased risk of brain developmental and health problems in children from low-SES families may largely result from their maladaptive

alterations in HPA-axis integrity under long-term stress.

Critically, we further found that increased parental and child anxiety appeared to play a crucial role in mediating the association between low family SES and children's reduced CAR. By extending previous findings on cortisol responses in both healthy and clinical pediatric populations (Cullen et al., 2014; Walker et al., 2001), our findings provide novel evidence to suggest that parental trait anxiety, together with child anxiety, mediates the positive association between family SES and children's CAR. Our results also show a marginally significant mediating effect of parental state anxiety on this association. As we know, trait anxiety reflects a predisposition of individual's interpretation to potentially threatening events in a negative way, whereas state anxiety is a temporal and fluctuating state reflecting a combination of both trait anxiety and current environmental influences on emotional status (Endler and Kocovski, 2001; Spielberger, 1983). Low family SES, analogous to a chronic stressor, could affect children's cortisol responses through both parental trait and state anxiety. However, parental trait anxiety might be a more stable and reliable indicator reflecting the long-term effects of low-SES. Fluctuating state anxiety is more likely to respond to other acute stressors. Further studies are required to delineate the neurobiological mechanisms underlying this difference between mediating effects of parental trait and state anxiety. Taken together, these results highlight a special psychoendocrinological pathway of parental and child anxiety from low SES family environment to children's HPA-axis integrity. Our findings also provide implications for interventions to reduce the high risk for HPA-axis maladaptation in low-SES children, for instance, through positive parent-child interactions and secure parenting to mitigate the transmission of anxiety from parents to their children.

There are some limitations in our study that should be mentioned. First, participants in our study were recruited from urban areas with relatively better economic development in China. This may limit the generalizability of our current findings to other underdeveloped (especially rural) areas. Second, child anxiety reported by their parent might be affected by their parent's own emotional status, which may complicate the reliable assessment of child anxiety. Third, the mediating pathways from SES to children's cortisol responses are derived from cross-sectional data in our present study, which provides limited information to infer any developmental causality. Future studies with longitudinal designs and cutting-edge brain imaging techniques are required to determine the developmental causality pathways and their underlying neurobiological mechanisms.

In conclusion, our study provides prominent evidence demonstrating that children exposed to low-SES environment are more vulnerable to anxiety and altered HPA-axis integrity, as reflecting by elevated basal cortisol and blunted CAR. Notably, parental anxiety appears to play a critical role in mediating the association of family SES with children's anxiety and their integrity of HPA-axis system. Our findings also provide important implications for psychological and endocrinological factors determining the adverse effects of SES on children's emotional development and health, which has the potential to develop effective interventions toward ameliorating high risk for developmental and mental problems in low-SES children.

Author contributions

Y. Zhu and S. Qin designed the research; X. Chen, H. Zhao, M. Chen, Y. Tian, C. Liu, Z. Han, X. Lin, J. Qiu, G. Xue, H. Shu and S. Qin performed the research; Y. Zhu analyzed the data; Y. Zhu and S. Qin wrote the manuscript; H. Zhao and Y. Tian contributed to editing it.

Declaration of conflicting interests

The author(s) declared that there were no conflicts of interest with respect to the authorship or the publication of this article.

Funding

This work was supported by the National Natural Science Foundation of China (31522028, 81571056), the National Key Basic Research Program of China (973 Program, 2014CB744600), the Thousand (Young) Talents Program of China, the Beijing Municipal Science & Technology Commission (Z151100003915122), the Open Research Fund of the State Key Laboratory of Cognitive Neuroscience and Learning (CNLZD1503), and the Fundamental Research Funds for the Central Universities.

Acknowledgments

We are grateful to the families who took part in this study.

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.psyneuen.2019.01.008.

References

Beidel, D.C., Turner, S.M., 1997. At risk for anxiety: I. Psychopathology in the offspring of anxious parents. J. Am. Acad. Child Adolesc. Psychiatry 36 (7), 918–924.
BjÖrntorp, P., Rosmond, R., 1999. Hypothalamic origin of the metabolic syndrome X. Ann. N. Y. Acad. Sci. 892 (1), 297–307.
Blomqvist, M., Holmberg, K., Lindblad, F., et al., 2007. Salivary cortisol levels and dental anxiety in children with attention deficit hyperactivity disorder. Eur. J. Oral Sci. 115 (1), 1–6.
Böhnke, R., Bertsch, K., Kruk, M.R., Naumann, E., 2010. The relationship between basal and acute HPA axis activity and aggressive behavior in adults. J. Neural Transm. 117 (5), 629–637.
Bradley, R.H., Corwyn, R.F., 2001. Socioeconomic status and child development. Annu. Rev. Psychol. 53 (1), 371–399.
Chen, E., Cohen, S., Miller, G.E., 2010. How low socioeconomic status affects 2-year hormonal trajectories in children. Psychol. Sci. 21 (1), 31–37. https://doi.org/10.1177/0956797609355566.
Clow, A., Hucklebridge, F., Stalder, T., Evans, P., Thorn, L., 2010. The cortisol awakening response: more than a measure of HPA axis function. Neurosci. Biobehav. Rev. 35 (1), 97–103. https://doi.org/10.1016/j.neubiorev.2009.12.011.
Cohen, J.R., 2010. Decoding developmental differences and individual variability in response inhibition through predictive analyses across individuals. Front. Hum. Neurosci. 4, 47.
Cohen, S., Doyle, W.J., Baum, A., 2006. Socioeconomic status is associated with stress hormones. Psychosom. Med. 68 (3), 414–420.
Conger, R.D., Ge, X., Elder Jr, G.H., Lorenz, F.O., Simons, R.L., 1994. Economic stress, coercive family process, and developmental problems of adolescents. Child Dev. 65 (2), 541–561.
Conger, R.D., Conger, K.J., Martin, M.J., 2010. Socioeconomic status, family processes, and individual development. J. Marriage Fam. 72 (3), 685–704.
Creswell, C., Cooper, P., Murray, L., 2010. Intergenerational transmission of anxious information processing biases. Information Processing Biases and Anxiety: a Developmental Perspective. pp. 279–295.
Cullen, A.E., Zunszain, P.A., Dickson, H., et al., 2014. Cortisol awakening response and diurnal cortisol among children at elevated risk for schizophrenia: relationship to psychosocial stress and cognition. Psychoneuroendocrinology 46, 1–13. https://doi.org/10.1016/j.psyneuen.2014.03.010.
Dedovic, K., Engert, V., Duchesne, A., et al., 2010. Cortisol awakening response and hippocampal volume: vulnerability for major depressive disorder? Biol. Psychiatry 68 (9), 847–853. https://doi.org/10.1016/j.biopsych.2010.07.025.
Desantis, A.S., Kuzawa, C.W., Adam, E.K., 2015. Developmental origins of flatter cortisol rhythms: socioeconomic status and adult cortisol activity. Am. J. Hum. Biol. 27 (4), 458–467. https://doi.org/10.1002/ajhb.226682015.
Duan, H., Yuan, Y., Zhang, L., et al., 2013. Chronic stress exposure decreases the cortisol awakening response in healthy young men. Stress 16 (6), 630–637. https://doi.org/10.3109/10253890.2013.840579.
Edwards, S., Evans, P., Hucklebridge, F., Clow, A., 2001. Association between time of awakening and diurnal cortisol secretory activity. Psychoneuroendocrinology 26 (6), 613–622. https://doi.org/10.1016/s0306-4530(01)00015-4.
Ehlert, U., Straub, R., 1998. Physiological and emotional response to psychological stressors in psychiatric and psychosomatic disorders. Ann. N. Y. Acad. Sci. 851 (1), 477–486.
Endler, N.S., Kocovski, N.L., 2001. State and trait anxiety revisited. J. Anxiety Disord. 15 (3), 231–245.
Epel, E.S., McEwen, B., Seeman, T., et al., 2000. Stress and body shape: stress-induced cortisol secretion is consistently greater among women with central fat. Psychosom. Med. 62 (5), 623–632.
Evans, G.W., Gonnella, C., Marcynyszyn, L.A., Gentile, L., Salpekar, N., 2005. The role of

chaos in poverty and children's socioemotional adjustment. Psychol. Sci. 16 (7), 560–565.
Gallo, L.C., Matthews, K.A., 1999. Do negative emotions mediate the association between socioeconomic status and health? Ann. N. Y. Acad. Sci. 896 (1), 226–245.
Gallo, L.C., Matthews, K.A., 2003. Understanding the association between socioeconomic status and physical health: Do negative emotions play a role? Psychol. Bull. 129 (1), 10–51. https://doi.org/10.1037/0033-2909.129.1.10.
Geisser, S., 2017. Predictive Inference. Routledge.
Gunnar, M.R., Cheatham, C.L., 2003. Brain and behavior interface: stress and the developing brain. Infant Ment. Health J. 24 (3), 195–211.
Gustafsson, P.E., Janlert, U., Theorell, T., Hammarstrom, A., 2010. Life-course socioeconomic trajectories and diurnal cortisol regulation in adulthood. Psychoneuroendocrinology 35 (4), 613–623.
Hajat, A., Diez-Roux, A., Franklin, T.G., Seeman, T., Shrager, S., Ranjit, N., et al., 2010. Socioeconomic and race/ethnic differences in daily salivary cortisol profiles: The Multi-Ethnic Study of Atherosclerosis. Psychoneuroendocrinology 35 (6), 932–943.
Hanson, J.L., Hair, N., Shen, D.G., et al., 2013. Family poverty affects the rate of human infant brain growth. PLoS One 8 (12), e80954.
Hayes, A.F., Preacher, K.J., Myers, T.A., 2011. Mediation and the estimation of indirect effects in political communication research. Sourcebook for Political Communication Research: Methods, Measures, and Analytical Techniques 23. pp. 434–465.
Holsboer, F., 2001. Stress, hypercortisolism and corticosteroid receptors in depression: implicatons for therapy. J. Affect. Disord. 62 (1), 77–91.
Hudson, J.L., Rapee, R.M., 2001. Parent–child interactions and anxiety disorders: an observational study. Behav. Res. Ther. 39 (12), 1411–1427.
Irwin, D.E., Stucky, B., Langer, M.M., et al., 2010. An item response analysis of the pediatric PROMIS anxiety and depressive symptoms scales. Qual. Life Res. 19 (4), 595–607.
Kolb, B., Gibb, R., 2016. Childhood poverty and brain development. Hum. Dev. 58 (4-5), 215–217.
Li, L., Power, C., Kelly, S., Kirschbaum, C., Hertzman, C., 2007. Life-time socio-economic position and cortisol patterns in mid-life. Psychoneuroendocrinology 32 (7), 824–833.
Liu, Y., Lin, W., Liu, C., et al., 2016. Memory consolidation reconfigures neural pathways involved in the suppression of emotional memories. Nat. Commun. 7, 13375. https://doi.org/10.1038/ncomms13375.
Lupien, S.J., King, S., Meaney, M.J., McEwen, B.S., 2000. Child's stress hormone levels correlate with mother's socioeconomic status and depressive state. Biol. Psychiatry 48 (10), 976–980.
Lupien, S.J., King, S., Meaney, M.J., Mcewen, B.S., 2001. Can poverty get under your skin? Basal cortisol levels and cognitive function in children from low and high socioeconomic status. Dev. Psychopathol. 13 (2001), 653–676.
Lupien, S.J., McEwen, B.S., Gunnar, M.R., Heim, C., 2009. Effects of stress throughout the lifespan on the brain, behaviour and cognition. Nat. Rev. Neurosci. 10 (6), 434–445. https://doi.org/10.1038/nrn2639.
McEwen, B.S., 2000. Allostasis and allostatic load: implications for neuropsychopharmacology. Neuropsychopharmacology 22 (2), 108–124.
McLoyd, V.C., 1998. Socioeconomic disadvantage and child development. Am. Psychol. 53 (2), 185.
Merikangas, K.R., He, J.-P., Brody, D., et al., 2010. Prevalence and treatment of mental disorders among US children in the 2001–2004 NHANES. Pediatrics 125 (1), 75–81.
Miech, R.A., Caspi, A., Moffitt, T.E., Wright, B.R.E., Silva, P.A., 1999. Low socioeconomic status and mental disorders: a longitudinal study of selection and causation during young adulthood. Am. J. Sociol. 104 (4), 1096–1131.
Noble, K.G., Wolmetz, M.E., Ochs, L.G., Farah, M.J., McCandliss, B.D., 2006. Brain–behavior relationships in reading acquisition are modulated by socioeconomic factors. Dev. Sci. 9 (6), 642–654.
Pereira, A.I., Barros, L., Mendonça, D., Muris, P., 2013. The relationships among parental anxiety, parenting, and children's anxiety: the mediating effects of children's cognitive vulnerabilities. J. Child Fam. Stud. 23 (2), 399–409. https://doi.org/10.1007/s10826-013-9767-5.
Pruessner, J.C., Kirschbaum, C., Meinlschmid, G., Hellhammer, D.H., 2003. Two formulas for computation of the area under the curve represent measures of total hormone concentration versus time-dependent change. Psychoneuroendocrinology 28 (7), 916–931. https://doi.org/10.1016/s0306-4530(02)00108-7.
Qin, S., Young, C.B., Duan, X., et al., 2014. Amygdala subregional structure and intrinsic functional connectivity predicts individual differences in anxiety during early childhood. Biol. Psychiatry 75 (11), 892–900.
Schatzberg, A.F., Lindley, S., 2008. Glucocorticoid antagonists in neuropsychotic disorders. Eur. J. Pharmacol. 583 (2), 358–364.
Schmidt-Reinwald, A., Pruessner, J., Hellhammer, D., et al., 1999. The cortisol response to awakening in relation to different challenge tests and a 12-hour cortisol rhythm. Life Sci. 64 (18), 1653–1660.
Shrout, P.E., Bolger, N., 2002. Mediation in experimental and nonexperimental studies: new procedures and recommendations. Psychol. Methods 7 (4), 422–445. https://doi.org/10.1037/1082-989x.7.4.422.
Spielberger, C.D., 1983. Manual for the State-trait Anxiety Inventory STAI (form Y)(" Self-evaluation Questionnaire").
Stalder, T., Kirschbaum, C., Kudielka, B.M., et al., 2016. Assessment of the cortisol awakening response: expert consensus guidelines. Psychoneuroendocrinology 63, 414–432.
Starfield, B., Riley, A.W., Witt, W.P., Robertson, J., 2002. Social class gradients in health during adolescence. J. Epidemiol. Community Health 56 (5), 354–361.
Supekar, K., Swigart, A.G., Tenison, C., et al., 2013. Neural predictors of individual differences in response to math tutoring in primary-grade school children. Proc. Natl. Acad. Sci. 110 (20), 8230–8235.
Walker, E.F., Walder, D.J., Reynolds, F., 2001. Developmental changes in cortisol secretion in normal and at-risk youth. Dev. Psychopathol. 13 (3), 721–732.
Wilhelm, I., Born, J., Kudielka, B.M., Schlotz, W., Wüst, S., 2007. Is the cortisol awakening rise a response to awakening? Psychoneuroendocrinology 32 (4), 358–366.
Woodruff-Borden, J., Morrow, C., Bourland, S., Cambron, S., 2002. The behavior of anxious parents: examining mechanisms of transmission of anxiety from parent to child. J. Clin. Child Adolesc. Psychol. 31 (3), 364–374. https://doi.org/10.1207/S15374424JCCP3103_08.
Wu, J., Zhang, S., Li, W., et al., 2015. Cortisol awakening response predicts intrinsic functional connectivity of the medial prefrontal cortex in the afternoon of the same day. Neuroimage 122, 158–165. https://doi.org/10.1016/j.neuroimage.2015.08.016.
Zhang, Y., Tardif, T., Shu, H., et al., 2013. Phonological skills and vocabulary knowledge mediate socioeconomic status effects in predicting reading outcomes for Chinese children. Dev. Psychol. 49 (4), 665–671. https://doi.org/10.1037/a0028612.