

## RESEARCH ARTICLE

# Socioeconomic status in early adolescence predicts blunted stress responses in adulthood

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## Abstract

Individuals who grow up in families with lower socioeconomic status (SES) tend to experience disproportionate rates of chronic stress. The “freeze” response, characterized by blunted cardiovascular reactivity and reduced engagement with the environment, is associated with chronic stress and may be utilized when an individual is unable to escape or overcome environmental stressors. Using a diverse community sample of 184 adolescents followed from the age of 13 to 29 years, along with their friends and romantic partners, this study examined links between family SES and stress responses in adulthood. Low family SES at the age of 13 years directly predicted blunted heart rate responding and fewer attempts to answer math problems during a modified version of the Trier Social Stress Task at the age of 29 years. Indirect effects were found from low family SES to blunted respiratory sinus arrhythmia responding and the number of words spoken during a speech task. SES at the age of 29 years mediated many of these relations. Findings held after accounting for a number of potential confounds, including adolescent academic and attachment functioning and body mass index. We interpret these findings as evidence that low familial SES may predict freezing-type responses in adulthood.

## KEYWORDS

blunted cardiovascular reactivity, freezing, SES, social support, stress

## 1 | INTRODUCTION

Low familial socioeconomic status (SES) is associated with a host of stressors, including poorer access to education, poorer health care, greater incidence of maltreatment, greater exposure to violence, and more taxed caregivers (Adler & Ostrove, 1999; Garmezy et al., 1984). Adolescents growing up in lower SES households continually encounter the threats of structural disadvantages and accompanying problems that are not readily solved by attempts to engage or escape the stress. Although acute stress is often associated with sympathetic

activation and parasympathetic withdrawal in order to prepare the body for action (the autonomic responses of fight-or-flight), chronic, inescapable stress may be associated with a third autonomic response: freezing (Niermann et al., 2015). The current paper examines whether adolescents who grow up in lower SES homes might later display more freezing-type responses during a laboratory stressor task in adulthood.

The freeze response is often associated with blunted cardiovascular responding, reduced vocalizations, and reduced movement (Azevedo et al., 2005; Jelen et al., 2003; Roelofs et al., 2010). Responses on the freeze continuum are thought to reduce the individual's salience as

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a target and may be employed when fight-or-flight strategies are not possible or not effective (Hagenaars et al., 2014; McLaughlin et al., 2014; Volchan et al., 2011). Other related constructs include tonic immobility (“playing dead”) and demobilizing (“involuntary defeat strategy”; Davies et al., 2016; Volchan et al., 2011). Increasingly, evidence supports the idea that chronic stress predicts blunted physiological responding (whereas acute stress often predicts heightened reactivity (Lovallo, 2013)). For example, retrospective reports of childhood adversity have been found to predict blunted cardiovascular and cortisol responding to stress (Bloomfield et al., 2019; Heleniak et al., 2016; Lovallo et al., 2012). In addition to blunted physiological responding, individuals who exhibit freezing-type responses may also show reduced engagement with the environment and slower responding in some types of tasks (Estes & Verges, 2008). For example, one study found that individuals who had more blunted cardiovascular responding also displayed (but did not self-report) lower persistence during a stressor task (Chantry et al., 2019). Physiologically, tempering the fight-or-flight response through blunted cardiovascular responding can be considered adaptive at least in the short term by allowing for the conservation of crucial resources (Sandner et al., 2020). On the other hand, some studies have found blunted cardiovascular responding to be predictive of cardiac events and even death in the long term (Eguchi et al., 2009; Phillips, 2011). Similarly, chronically stressed individuals who show reduced persistence may be displaying an effective short-term strategy to preserve energy—though reduced persistence may carry long-term consequences for academic, vocational, and social domains (Del Giudice et al., 2011; Liu et al., 2020).

Two types of cardiovascular reactivity are particularly useful indicators of freezing-type responses: Heart rate and respiratory sinus arrhythmia (RSA). Heart rate normatively and adaptively increases during acute stress and this process is influenced by both sympathetic and parasympathetic processes. RSA is a measure of heart rate variability that covaries with breathing and reflects parasympathetic activation. Greater resting RSA is associated with positive outcomes not just in cardiovascular disease, but also in mental health (Demaree et al., 2004). However, RSA normatively and adaptively decreases under stress, representing parasympathetic withdrawal and readying of the body to face a threat (Cribbet et al., 2020). Human studies suggest that blunted heart rate or bradycardia can be indicative of a freeze-type response (Lojowska et al., 2018; Löw et al., 2015; Roelofs, 2017). Similarly, human studies have found that the freeze response is associated with attenuated RSA withdrawal (i.e., keeping on the parasympathetic “brake” in the face of a stressor) (Buss et al., 2018; Liu et al., 2020). Blunted heart rate acceleration and attenuated or absent RSA withdrawal under stress suggests a lack of mobilization (and potentially a degree of burnout) in the body’s “fight-or-flight” responses (Brotman et al., 2007; McLaughlin et al., 2014). Both types of blunted reactivity are associated with poor health outcomes (Bylsma et al., 2014; Cavanagh & Obasi, 2021; Liu et al., 2020; Phillips et al., 2013).

If there is a link from low SES in adolescence to freezing-type responses in adulthood, one key question is what might mediate such a long-term link? First, the presence of high versus low quality

social relationships appears as a likely critical mediator. Social withdrawal behavior, for example, has been found to mediate effects of adolescent-era relational stressors to blunted cardiovascular responding in adulthood (Loeb et al., 2021). In contrast, social support has been shown to protect against some negative effects of socioeconomic disadvantage (Gorman & Sivaganesan, 2007), including cardiovascular mortality (Stringhini et al., 2012). The biopsychosocial model of challenge and threat suggests that the body responds differentially when the individual has the needed resources to meet a demand (challenge) than when adequate resources are not available (threat) (Hase et al., 2020). It may be that the presence of warm, supportive relationships function as a psychological resource to mobilize the individual in response to the environment rather than freezing. This is consistent with both social baseline theory and attachment theory, which suggest that people need and expect social support to be available in order to regulate physically and emotionally (Beckes & Coan, 2011; Bowlby, 1980).

However, quality social support may be more difficult to obtain for individuals from lower SES backgrounds (Conger et al., 2010). Those from underprivileged backgrounds are generally exposed to more interpersonal stress and trauma (Gallo et al., 2006). In addition, the strain of socioeconomic disadvantage and marginalization for caregivers negatively impacts the quality of social support available to children (Matthews et al., 2010). In response, individuals from lower SES backgrounds are likely to develop ways of interacting that are more guarded and less vulnerable even in intimate relationships (Consedine et al., 2007), which can be considered adaptive and even necessary in the short term in order to protect against harm from others. However, without adequate social resources to help regulate autonomic responses to threat, individuals may implement more freezing-type responses as the body copes with chronically elevated stress (Hughes et al., 2018; McMahon et al., 2020). In line with this idea, one study found that men from lower SES backgrounds reported more use of emotional suppression, less social support, and showed more evidence of cardiovascular blunting during an anger recall task (Cundiff et al., 2019).

In addition to the adequacy of social support, *ongoing* socioeconomic stressors are likely to play a major role in the path from SES in adolescence to adults’ response strategies (Luo & Waite, 2005). Adult experiences of poverty generally succeed childhood experiences of poverty, resulting in greater overall magnitude of cumulative stress and subsequently greater autonomic wear and tear (Bartley & Plewis, 2007). Questions remain about the timing of socioeconomic stressors and health outcomes: Some theories posit adolescence as a sensitive period, such that low SES in adolescence will affect physiological functioning over and above concurrent SES (Cohen et al., 2010; Fuhrmann et al., 2015). Others describe “chains of risk” whereby socioeconomic disadvantage in adolescence is likely to predict ongoing socioeconomic disadvantage, which in turn will predict physiological outcomes (Chapman et al., 2009). In the current study, we examined potential evidence for both the sensitive period and chains of risk perspectives. To attempt to account for other known sequelae of family SES in adolescence that are predictive of adult social and emotional functioning

(i.e., attachment security and academic achievement), we included adolescent attachment security and grade point average (GPA) in analyses predicting adult outcomes (Conger et al., 2010; Hasl et al., 2019). Body weight is closely tied to cardiovascular functioning (Phillips, 2011), so we included BMI as a control variable. In addition, because racial/ethnic minority status and gender have both been implicated in differences in cardiovascular reactivity (e.g., Hoggard et al., 2015; Hughes, 2007), we examined possible interactions with minority status and gender.

A diverse community sample followed from the ages of 13 to 29 years was used to assess the following specific predictions regarding links between SES, observable social support in romantic relationships, and freezing-type responses during a standardized social-evaluative stressor task in adulthood:

It was specifically hypothesized that:

1. Lower SES at the age of 13 years would predict higher propensity to freezing-type responses during stressor tasks at the age of 29 years, reflected in blunted heart rate reactivity, blunted RSA reactivity, and less behavioral persistence.
2. Lower SES at the age of 13 years would predict both lower observed social support from romantic partners from the ages of 18–24 years and lower SES at the age of 29 years.
3. Lower social support from romantic partners from the ages of 18–24 years and lower SES at the age of 29 years would both predict a greater propensity to freezing-type responses during stressor tasks at the age of 29 years.
4. Lower social support from partners from the ages of 18–24 years and concurrent SES would mediate some relations between SES at the age of 13 years and propensity to freezing-type responses during stressor tasks at the age of 29 years.

## 2 | METHODS

Interview and observational data were obtained longitudinally from a community sample of 184 adolescents (86 boys, 98 girls) along with parents, friends, and romantic partners, first assessed in seventh and eighth grade (mean age = 13.3 years), and reinterviewed annually up through the age of 29 years. Adolescents were originally recruited from the seventh and eighth grades at a public middle school drawing from suburban and urban populations in the Southeastern United States. The sample was demographically diverse and representative of the population from which it was drawn (age of 13 years median family income was in the \$40,000 to \$59,000 range; the sample was 58% White, 29% African-American, 1% Asian, 1% Hispanic, .5% Native American, 8% mixed race, and 2% other races/ethnicities). Students were recruited via an initial mailing to all parents of students in the school, along with follow-up contact efforts at school lunches. Adolescents who indicated they were interested in the study were contacted by telephone. Of all students eligible for participation, 63% agreed to participate either as target participants or as peers providing collateral information.

Three times during late adolescence to early adulthood, eligible participants came to the laboratory with their romantic partners. Each wave of romantic partner data collection spanned 3 years to maximize the number of dyads that could participate. Participants in a romantic relationship of at least 3 months were invited to complete videotaped interaction tasks with their romantic partners. During the *M* age of 18 years data collection, 85 (46%) of the original participants were in eligible romantic relationships and, of these, 75 dyads (88% of eligible dyads) provided interaction data. Participants reported an average relationship length of 1.18 years (*SD* = 1.25 years). During the *M* age of 21 years data collection, 124 participants were eligible (67% of original sample) and 99 dyads (80% of those eligible) provided interaction data. They reported an average relationship duration of 1.82 years (*SD* = 1.76 years). During the *M* age of 24 years data collection, 124 (67%) participants were eligible and 84 dyads (68% of those eligible) provided interaction data. Participants reported an average relationship duration of 2.40 years (*SD* = 2.24 years). Five participants (4.17%) brought the same romantic partner to all three visits.

For the purposes of the present study, data were drawn from six time points: Two consecutive years in early adolescence (participant *M* age = 13.35, *SD* = .64 and *M* age = 14.27, *SD* = .77); in late adolescence and early adulthood, three assessments of target participants and their romantic partners (participant *M* age = 18.33, *SD* = .95, range = 16.7–22.7; participant *M* age = 20.98, *SD* = 1.08, range = 19.3–24.6; participant *M* age = 23.78, *SD* = .97, range = 22.1–27.6). Finally, participants completed an adult assessment of their cardiovascular and behavioral responses to a standardized stress task (*M* age = 28.55, *SD* = 1.03, range = 26.6–31.0).

### 2.1 | Attrition

Attrition analyses were conducted to determine whether individuals who did versus did not participate at a given wave differed in terms of the previously measured constructs. Adolescents who were rated as less securely attached at the age of 14 years were slightly less likely to have any observation data with romantic partners from the ages of 18–24 years ( $t = -2.10, p = .04$ ). Men were slightly less likely to participate than women at the age of 29 years ( $\chi^2 = 4.82, p = .03$ ). There were no other significant differences between those who did versus did not participate in any of the waves in terms of gender, family SES, or earlier levels of the variables measured.

To best address any potential biases due to attrition and missing data in longitudinal analyses, full information maximum likelihood methods were used, with analyses including all variables that were linked to future missing data (i.e., where data were not missing completely at random). Because these procedures have been found to yield less biased estimates than approaches (e.g., simple regression) that use listwise deletion of cases with missing data, the entire original sample of 184 for the larger study was utilized for these analyses (Arbuckle et al., 1996).

## 2.2 | Procedure

In the initial introduction and throughout all sessions, confidentiality was assured to all study participants and adolescents/adults were told that no one would be informed of any of the answers they provided. Participants' data were protected by a Confidentiality Certificate issued by the U.S. Department of Health and Human Services, which protected information from subpoena by federal, state, and local courts. Transportation and childcare were provided if necessary. Adolescent/adult participants and participants' romantic partners were all paid for participation.

## 2.3 | Measures

### 2.3.1 | SES (ages 13 and 29 years)

When adolescents were 13 years old, parents or caregivers reported on the total household income before taxes, the number of people supported by the income, and the highest level of education they had obtained. Using total income and family size, we created a continuous variable that represented the percentage of the federal poverty level of income for each family and standardized this number. According to the concurrent federal poverty guidelines, 22 families (12%) were at or below 100% of the poverty line, 45 families (24.59%) were at or below 150%, 61 families (33%) were at or below 200%, and 74 (40.44%) of families were at or below 250%. We standardized the highest education level obtained by either parent (or the level obtained by a single caregiver). Responses were coded from 1 (less than an eighth grade education) to 9 (postcollege degree). Looking at the highest level of education completed by either parent, one parent (.54%) completed less than eighth grade; five parents (2.72%) completed some high school; 21 parents (11.41%) were regular high school graduates; six parents (3.26%) earned a general equivalency diploma (GED); 47 parents (25.54%) completed some college or technical training beyond high school; 14 parents (7.61%) completed an associate's degree; 27 (14.67%) completed a bachelor's degree; 13 (7.07%) completed some graduate work; and 50 parents (27.17%) completed a postcollege degree. We then averaged the standardized values for percentage of the poverty level and highest parental education level to create a marker of SES. When participants were 29 years old, they reported on their own total income before taxes, as well as their romantic partners' (if they lived together) and the number of people supported by the income. According to concurrent federal poverty guidelines, 26 adult participants (20.31% of those who provided income data) were at or below 100% of the poverty line; 44 (34.38%) were at or below 150%; 55 (42.97%) were at or below 200% while 63 (49.22%) were at or below 250%. Participants also reported the highest level of education they had obtained. Nine participants (5.88%) completed some high school; 20 participants (13.07%) obtained a GED; 45 participants (29.41%) earned a high school diploma; 12 participants (7.84%) completed an associate's degree; 35 participants (22.88%) completed a bachelor's degree; eight participants (5.23%) completed some gradu-

ate work; whereas 24 participants (15.69%) completed a postcollege degree. We created an SES variable for participants at the age of 29 years using the same approach described above.

### 2.3.2 | Racial/ethnic minority status (age 13 years)

When participants were 13 years old, they self-reported on their own racial/ethnic identity. This information was used to create a dichotomous variable of racial/ethnic minority status (i.e., participants who solely identified as White were assigned a dummy code of 0 while participants of color were assigned a code of 1).

### 2.3.3 | Observed social support from partners (ages 18–24 years)

Three times between the ages of 18 and 24 years, participants and their romantic partners participated in a 6-min observed Supportive Behavior Task, during which they asked their partner for help with a "problem they were having that they could use some advice or support about." These interactions were coded using the Supportive Behavior Coding System (Allen et al., 2001) on the degree to which partners were engaged in the support-provision task. Observed support was reliably coded as the extent to which the partner appeared to be connected and engaged with the target participant during the interaction based on both quantity and quality of signs of connection. Examples of low levels of support were little eye contact, turning away from the participant, or ignoring or interrupting the participant. High levels of support included behaviors like finishing sentences, asking open-ended questions to draw the support seeker out, and using nonverbal cues such as nodding, facing the participant, and eye contact. The coding system employed yields ratings from zero to four for the partner's engagement in supporting their partner in the interaction, with lower scores indicating less engagement in providing support. Interrater reliability was calculated using intraclass correlation coefficients and was in what is considered the "good" to "excellent" range for this statistic across years (intraclass  $r = .69$  to  $.85$ ; Cicchetti & Sparrow, 1981). Support from partners (rated 0–4) was averaged across the three waves of interactions ( $M = 2.87$ ,  $SD = .62$ ).

### 2.3.4 | Social stressor task (age 29 years)

Adult participants were invited to come into the laboratory to participate in a modified version of the Trier Social Stress Task (TSST; Kirschbaum et al., 1993) a well-established protocol for studies of stress reactivity (see Cacioppo et al., 1995 for the modified protocol). When participants entered the laboratory, there were one or two research assistants present who were blind to study hypotheses. Participants had their height and weight measured and were then equipped with the heart-rate, skin-conductance, and blood-pressure monitoring equipment. The modified TSST protocol consisted of a 10-min baseline resting period, a 6-min speech task (including a 3-min

preparation period and a 3-min speech delivery), a 6-min math task, and a 5-min recovery period. During the resting period, participants watched a relaxing nature video. Participants were given instructions just before the stressor tasks began to mitigate anticipatory stress. The research assistants were instructed to remain neutral in face and body language throughout the tasks. For the speech task, participants were told to imagine that they were in a department store shopping and the security guard falsely accused them of shoplifting a belt. They were to think about what they would say to the store manager for three minutes then give a 3-min speech defending themselves to the store manager. The participant was instructed to continue talking throughout the 3-min speech period and the research assistant had a list of prompts to give if the participant stopped talking. Next, participants were asked to subtract numbers out loud for six 1-min segments. If they gave an incorrect response, they were corrected and told to begin from the corrected number. For both tasks, there was a video camera in the room and participants were told that their responses would be video recorded and rated later to compare their performance to other participants in the study.

### 2.3.5 | Heart rate response during stressor tasks (age 29 years)

Before the resting period, five-lead electrodes were placed according to standard ECG placement recommendations (Hoetink et al., 2002). Heart rate was continuously monitored (with sampling at 1 kHz) using a Mindware 2000D module and each waveform was verified or edited prior to analyses. Baseline heart rate was subtracted from the average heart rate across the two stressor tasks to create the measure of heart rate reactivity (i.e., a higher score would indicate a greater increase in heart rate during the stressor tasks).

### 2.3.6 | RSA reactivity during stressor tasks (age 29 years)

RSA provides a noninvasive measure of parasympathetic control of the heart and was calculated based on the digitized interbeat intervals that were checked and edited for artifacts using the detection algorithm of Berntson et al. (1990). Following linear detrending, the heart period time series was band pass filtered from .12 to .40 Hz (Berntson et al., 1993; Litvack et al., 1995). The power spectrum of the heart period time series was calculated using a Fast Fourier Transform and scaled to  $\text{ms}^2/\text{Hz}$ . RSA was calculated as the natural log of the area under the heart period power spectrum within the corner frequencies of the band pass filter (Litvack et al., 1995). RSA was calculated on a minute-by-minute basis and aggregated across minutes within each epoch to increase measurement reliability. RSA reactivity was calculated as task RSA minus baseline RSA (a higher score would indicate a greater decrease in RSA during the task; in other words, a greater RSA withdrawal response, whereas a lower score would indicate a more blunted withdrawal response).

### 2.3.7 | Behavioral persistence during stressor tasks (age 29 years)

During the math task, the total number of math problems attempted during the 6 min were recorded. The difficulty of problems was calibrated based on the participant's performance (e.g., a higher number of correct answers during the first minute would lead to harder questions during the second minute, etc.). Total attempts across all 6 min ranged from 24 to 200. Research assistants administering the math task were blind to study hypotheses and were trained to administer a standard protocol. The speech that participants gave during the speech task was recorded and transcribed by research assistants blind to study hypotheses. The total number of words spoken by participants, excluding interjections such as "um" or "uh," ranged from 18 to 667, with a mean of 369 and a standard deviation of 122.

### 2.3.8 | Body mass index (age 29 years)

Body mass index (BMI) was assessed at the age of 29 years when participants came in for the stressor tasks. Height (in meters) and weight (in kilograms) were assessed with light clothing, and BMI was calculated using the standard formula ( $\text{BMI} = \text{weight (kg)}/\text{height (m)}^2$ ) ( $M = 29.53$ ,  $SD = 9.75$ ), which was then log-transformed due to skewness from particularly high BMI scores. (Three BMI scores were greater than three SDs above the mean and the skewness was 1.95. Analyses using the untransformed variable and the variable with outliers removed yielded very similar results.)

### 2.3.9 | Attachment security (age 14 years)

The structured Adult Attachment Interview (AAI) and Q-set were utilized to assess attachment security (George et al., 1996; Kobak et al., 1993). Interviews probed adolescents' childhood relationships with caregivers and lasted about an hour. All interviews were blindly rated by at least two reliable raters with extensive training in both the Q-sort and the main AAI Classification System. These Q-sorts were then compared with a dimensional prototype: secure versus anxious interview strategies, reflecting the overall degree of coherence of discourse, the integration of episodic and semantic attachment memories, and a clear objective valuing of attachment. We used the overall security score as a measure of adolescents' perceptions/expectations of social support ( $M = .25$ ,  $SD = .42$ ). The Spearman-Brown interrater reliability for the overall security scale score was .82.

### 2.3.10 | Grade point average (age 13 years)

Participants' academic records were collected and their GPA was calculated on a 0.0–5.0 scale (participants could earn higher than a 4.0 due to grade weighting, where a set number was added to the total GPA for each advanced, honors, and advanced placement course). At the age of

13 years, the mean GPA was 3.0 (SD = .72), ranging from a low of 1.0 to a high of 4.07.

### 2.3.11 | Subjective stress (age 29 years)

Immediately following the baseline resting period and the laboratory stressor tasks, participants reported on their subjective feelings of stress using the short form of the Spielberger State-Trait Anxiety Inventory (Marteau & Bekker, 1992). Participants responded on a one to four scale, from “Not at all” to “Very much” to six statements (e.g., “I am tense,” “I feel calm”) at three points: following the initial resting period and following the speech and math tasks, respectively. Positive emotional states were reverse coded and averaged with negative emotional states to create a baseline stress score ( $M = 8.34$ ,  $SD = 2.63$ ) and a task stress score ( $M = 11.17$ ,  $SD = 3.24$ ). Total change in stress ( $M = 2.84$ ,  $SD = 3.02$ ) was calculated by subtracting stress level reported immediately following the tasks from baseline stress report (i.e., a higher score would indicate a greater increase in subjective stress).

## 3 | RESULTS

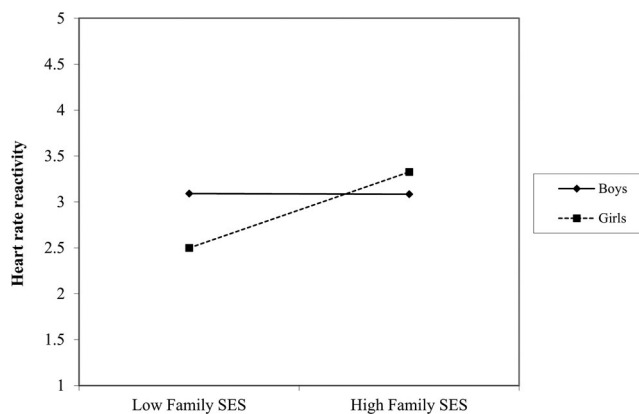
### 3.1 | Analytic plan and descriptive statistics

All primary analyses were conducted in MPlus using FIML (Version 7.2; Muthén & Muthén, 2007). Hierarchical regressions were conducted, where control variables of participant gender, age of 14 years attachment security, age of 13 years GPA (for behavioral outcomes), and age of 29 years BMI (for physiological outcomes) were entered first, followed by hypothesized predictors. We also examined the possible moderating effects of gender and racial/ethnic minority status with family SES on each of the markers of freezing-type responses in adulthood (i.e., blunted heart rate, blunted RSA responding, number of math problems attempted, and number of words spoken during the speech task). All moderating effects analyzed were obtained by creating interaction terms based on the product of mean-centered variables. Next, mediational models were tested in MPlus using bootstrapped confidence intervals (5000 bootstrap iterations were specified). Table 1 presents means, standard deviations, and intercorrelations of substantive variables.

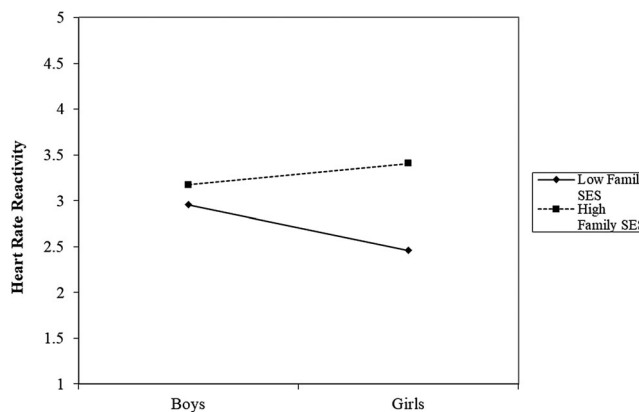
### 3.2 | Primary analyses

**Hypothesis 1:** Lower SES at the age of 13 years would predict higher propensity to freezing-type responses during stressor tasks at the age of 29 years, reflected in blunted heart rate reactivity, blunted RSA reactivity, and less behavioral persistence.

We first considered cardiovascular reactivity. Accounting for control variables, we found a main effect of family SES on heart rate



**FIGURE 1** Gender interaction predicting heart rate reactivity



**FIGURE 2** SES interaction predicting heart rate reactivity

reactivity. In addition, there was an interaction between family SES and gender in predicting heart rate during stressor tasks in adulthood ( $t = -2.61$ ,  $p = .01$ ). As shown in Figure 1, when examined separately by gender, lower family SES significantly predicted a more blunted heart rate for girls ( $\beta = -.43$ ,  $p = .001$ ), whereas the effect was nonsignificant for boys.

As shown in Figure 2, when the sample was split by the median of family SES, female gender predicted a more blunted heart rate response ( $\beta = -.31$ ,  $p = .01$ ) in the lower SES group, whereas there was no significant prediction of heart rate response by gender in the higher SES group.

This suggests the possibility that girls from low SES backgrounds were at greater risk of developing blunted heart rate responses in adulthood when compared with boys. When included in the same model, both family SES and the interaction between gender and family SES positively predicted heart rate reactivity during stressor tasks at the age of 29 years (family SES  $\beta = .23$ ,  $p = .006$ ; family SES  $\times$  gender  $\beta = .19$ ,  $p = .02$ ; see Table 2). This suggests that, even accounting for potential confounds and the differential gender effects, lower family SES at the age of 13 years was associated with more blunted heart rate in adulthood. On the other hand, accounting for control variables, family SES at the age of 13 years did not significantly predict RSA withdrawal during stressor tasks.

**TABLE 1** Correlations among and descriptive statistics for key study variables

	M(SD)	N	1.	2.	3.	4.	5.	6.	7.	8.	9.	10.	11.	12.	13.	
1. Family SES (13 years)	4.56 (1.66)	184	-	54***	30***	49***	38***	-23**	33***	14	50***	22**	17*	03	-17	
2. SES (29 years)	5.13 (2.04)	154		-	35***	59***	35***	-23**	37***	22**	36***	32***	08	12	02	
3. Attach. Security (14 years)	.25 (.42)	174			-	47***	25**	02	18*	12	21**	28**	00	09	12	
4. GPA (13 years)	3.00 (.72)	145				-	32***	-19*	27**	12	34***	26**	00	09	12	
5. Observed support from partner (18–24 years)	2.87 (.62)	127					-	-05	40***	25**	45***	15	12	05	-24**	
6. BMI (29 years)	29.53 (9.75)	145						-	-22**	-14	-10	01	-17*	00	10	
7. Heart rate reactivity (29 years)	8.22 (6.63)	138							-	46***	35***	28**	00	12	-11	
8. RSA withdrawal (29 years)	.02 (.77)	141								-	16	13	02	15	01	
9. Math attempts (29 years)	89.36 (36.06)	146									-	35***	-06	-01	-47***	
10. Speech words (29 years)	368.52 (121.72) 8.34 (2.63)	132										-	-06	22**	-10	
11. Base stress (29 years)																
12. Stress change (29 years)	2.84 (3.02)	146											-	-35***	08	
13. Gender (1 = M, 2 = F)		184														09
																-

\* $p \leq .05$ , \*\* $p \leq .01$ , \*\*\* $p \leq .001$ . Note: Correlations multiplied by 100.

**TABLE 2** Predicting heart rate reactivity and number of math attempts (age 29 years) from family SES (age 13 years)

	Heart rate reactivity (age 29 years)				Math attempts (age 29 years)			
	$\beta$ entry	$\beta$ final	$\Delta R^2$	Total $R^2$	$\beta$ entry	$\beta$ final	$\Delta R^2$	Total $R^2$
Step I.								
Gender (1 = M; 2 = F)	-.12	-.07			-.51***	-.45***		
GPA (13 years)	-	-			.27**	.05		
Attachment security (14 years)	.19*	.10			.17*	.10		
BMI (29)	-.22**	-.15			-	-		
<i>Statistics for step</i>			.092*	.092*			.350***	.350***
Step II.								
Family SES (13 years)	.25**	.23**			.33***	.23**		
			.040*	.132**			.077***	.427***
Step III.								
Gender $\times$ family SES (13 years)	.19**	.19*			-	-		
			.017	.149**			-	-
Step IV.								
Adult SES (29 years)	-	-			.24**	.24**		
			-	-			.036**	.463***

Note. \*\*\* $p \leq .001$ , \*\* $p \leq .01$ , \* $p < .05$

In terms of behavioral persistence, after accounting for control variables, family SES positively predicted the number of math attempts ( $\beta = .33$ ,  $p = .001$ ; see Table 2). We also considered whether higher adult levels of education and income might explain this link. This effect of family SES remained significant even accounting for concurrent SES (concurrent SES  $\beta = .24$ ,  $p = .003$ ; family SES  $\beta = .23$ ,  $p = .004$ ). This suggests that participants from low SES backgrounds ventured fewer attempts at answering math problems than their peers from more privileged backgrounds, even accounting for current education level and income. In contrast, after accounting for control variables, family SES did not significantly predict fewer words spoken during the speech task.

**Hypothesis 2:** Lower SES at the age of 13 years would predict lower observed social support from romantic partners from the ages of 18–24 years and lower SES at the age of 29 years.

As shown in Table 3, after accounting for control variables, family SES at the age of 13 years positively predicted levels of observed social support from romantic partners from the ages of 18–24 years ( $\beta = .24$ ,  $p = .01$ ). This suggests, after accounting for gender and markers of adjustment in early adolescence, individuals from lower SES backgrounds had romantic partners who were observably less supportive through early adulthood.

In addition, family SES at the age of 13 years positively predicted SES at the age of 29 years ( $\beta = .35$ ,  $p = .001$ ; see Table 3), suggesting a sizable degree of continuity in SES from early adolescence to adulthood.

**Hypothesis 3:** Lower social support from romantic partners from the ages of 18–24 years would predict a greater propensity to freezing-type responses during stressor tasks at the age of 29 years.

We first considered cardiovascular markers of freezing-type responses. As shown in Table 4, accounting for control variables, social support from romantic partners from the ages of 18–24 years positively predicted heart rate reactivity during stressor tasks at the age of 29 years ( $\beta = .33$ ,  $p = .001$ ). In addition, social support from romantic partners from the ages of 18–24 years positively predicted RSA withdrawal response during stressor tasks at the age of 29 years ( $\beta = .21$ ,  $p = .03$ ; see Table 4). These results suggest that participants with less supportive romantic partner experiences through early adulthood were more likely to show blunted cardiovascular responding (i.e., relatively lower sympathetic and/or higher parasympathetic engagement) consistent with a freezing-type reaction.

Next, we considered behavioral markers of freezing-type responses. As shown in Table 5, accounting for adolescent-era control variables, social support from romantic partners from the ages of 18–24 years positively predicted math attempts at the age of 29 years ( $\beta = .27$ ,  $p = .001$ ). This effect remained even after accounting for concurrent SES (support  $\beta = .19$ ,  $p = .02$ ). This suggests that participants with less supportive romantic partner experiences through early adulthood ventured fewer math attempts, even accounting for indicators of academic and attachment functioning in adolescence and SES in adulthood. However, social support from romantic partners from the ages of 18–24 years did not significantly predict words spoken during the speech task at the age of 29 years.



**TABLE 3** Predicting observed social support (age 18–24 years) and adult SES (age 29 years) from family SES (age 13 years)

	Observed social support (ages 18–24 years)				SES (age 29 years)			
	$\beta$ entry	$\beta$ final	$\Delta R^2$	Total $R^2$	$\beta$ entry	$\beta$ final	$\Delta R^2$	Total $R^2$
Step I.								
Gender (1 = M; 2 = F)	-.28***	.24**			.0054***	.0739***		
GPA (age 13 years)								
Attachment security (14 years)	.17	.14			.12	.06		
Statistics for step			.181**	.181**			.363***	.363***
Step II.								
Family SES (age 13 years)	.24**	.24**			.35***	.35***		
			.049**	.230***			.078***	.441***

Note. \*\*\* $p \leq .001$ , \*\* $p \leq .01$ , \* $p \leq .05$ .

**TABLE 4** Predicting heart rate reactivity and RSA withdrawal (age 29 years) from observed social support (ages 18–24 years)

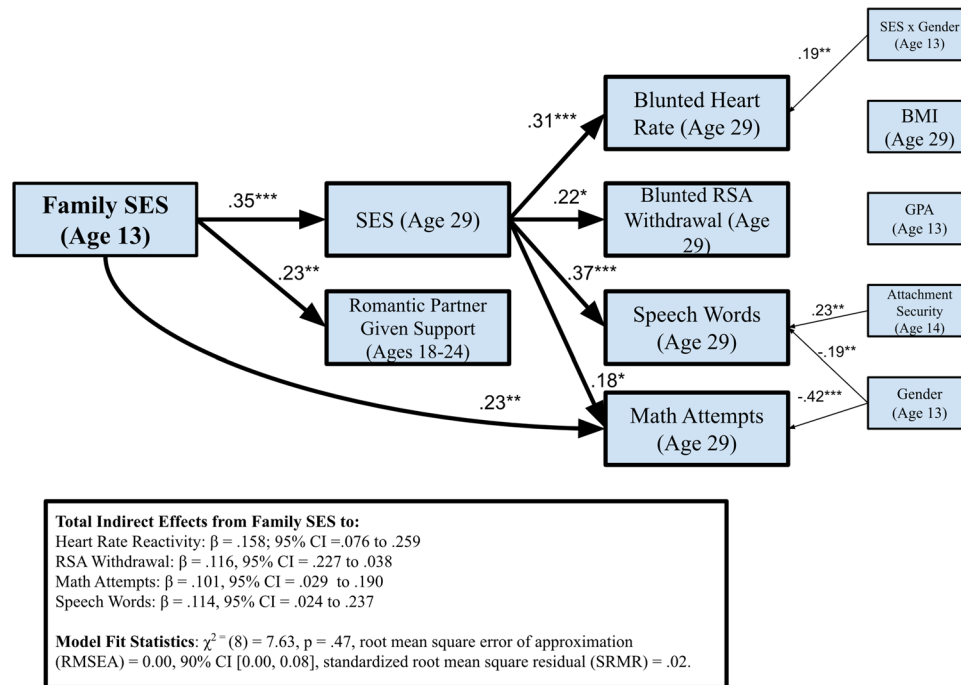
	Heart rate reactivity (age 29 years)				RSA withdrawal (age 29 years)			
	$\beta$ entry	$\beta$ final	$\Delta R^2$	Total $R^2$	$\beta$ entry	$\beta$ final	$\Delta R^2$	Total $R^2$
Step I.								
Gender (1 = M; 2 = F)	-.13	-.04			.01	.04		
GPA (age 13 years)	.19	.10			.06	.02		
Attachment security (14 years)	.11	.06			.09	.05		
BMI (age 29 years)	-.18*	-.19*			-.14	-.14		
Statistics for step			.124*	.124*			.039	.039
Step II.								
Observed social support (ages 18–24 years)	.33***	.33***			.21*	.21*		
			.092***	.216***			.036*	.075

Note. \*\*\* $p < .001$ , \*\* $p \leq .01$ , \* $p < .05$ .

**TABLE 5** Predicting number of math attempts and during stressor tasks (age 29 years) from observed social support (ages 18–24 years)

Math attempts (age 29 years)				
	$\beta$ entry	$\beta$ final	$\Delta R^2$	Total $R^2$
Step I.				
Gender (1 = M; 2 = F)	-.51***	-.46***		
GPA (13 years)	.27***	.04		
Attachment security (14 years)	.16*	.09		
Statistics for step			.350***	.350***
Step II.				
Observed social support (18–24 years)	.27***	.19*		
			.064***	.414***
Step III.				
Adult SES (29 years)				
	.27***	.27***		
			.037**	.451***

Note. \*\*\* $p \leq .001$ , \*\* $p < .01$ , \* $p < .05$ .



**FIGURE 3** Mediation model

**Hypothesis 4:** Lower social support from partners from the ages of 18–24 years and concurrent SES would mediate the relations between SES at the age of 13 years and propensity to freezing-type responses during stressor tasks at the age of 29 years.

Using bootstrapped confidence intervals (5000 bootstrap iterations) and control variables previously specified, potential indirect effects through social support from partners and concurrent SES were examined (see Figure 3 for the full model; model fit indices indicated that the model fit the data well).

We first examined cardiovascular markers of freezing-type responses. When examining predictions from family SES to blunted heart rate, we found that the interaction between family SES and participant gender was significant after including the mediators ( $\beta = .19$ ,  $p = .01$ ). Therefore, we examined mediation models for males and females separately. There was no significant indirect effect for either group. However, for girls, lower family SES continued to directly predict a more blunted heart rate over and above concurrent SES ( $\beta = .22$ ,  $p = .04$ ).

When looking at males and females together, there was an omnibus significant indirect effect of family of origin SES at the age of 13 years on heart rate reactivity during stressor tasks at the age of 29 years through concurrent SES and social support from romantic partners from the ages of 18–24 years (total indirect  $\beta = .158$ ; 95% CI = .076 to .259;  $p = .002$ ). After including the mediators, the direct effect of family SES on heart rate was not significant. In terms of specific paths, only the indirect effect of concurrent SES was significant ( $\beta = .107$ ; 95% CI = .041 to .199;  $p = .008$ ). This suggests that the overall association of

family SES in early adolescence on heart rate reactivity during stressor tasks in adulthood may have been mediated by later SES.

Though there was no direct effect from family SES at the age of 13 years to RSA withdrawal during stressor tasks at the age of 29 years, there was a significant omnibus indirect effect through concurrent SES and social support from romantic partners from the ages of 18–24 years (total indirect  $\beta = .116$ , 95% CI = .038 to .227,  $p = .01$ ). When the mediators were examined individually, only the indirect path through concurrent SES was statistically significant ( $\beta = .075$ ; 95% CI = .014 to .163;  $p = .04$ ). This suggests that there was a significant indirect effect of low family SES to lower RSA withdrawal through concurrent SES.

In terms of behavioral markers of freezing-type responses, there was a significant omnibus indirect effect of family SES on number of math problems attempted at the age of 29 years via concurrent SES and social support from romantic partners (total indirect  $\beta = .101$ , 95% CI = .029 to .190,  $p = .01$ ). The relation between family SES and number of math problems attempted remained significant with the mediators in the model ( $\beta = .23$ ,  $p = .002$ ). However, neither individual indirect path was significant on its own. This suggests that there was an omnibus association of family SES on persistence in attempting math problems in adulthood through concurrent SES and social support from romantic partners but that neither of these two paths was statistically significant without the other.

Though there was no direct effect from family SES to number of words spoken during a speech task at the age of 29 years, there was a significant omnibus indirect effect through concurrent SES and social support from romantic partners from the ages of 18–24 years (total indirect  $\beta = .114$ , 95% CI = .030 to .239,  $p = .04$ ). In terms of specific paths, only the indirect effect through concurrent SES was significant

( $\beta = .129$ ; 95% CI = .051 to .244;  $p = .01$ ). This suggests that family SES was indirectly associated with the number of words spoken during a speech task via later SES.

### 3.2.1 | Post hoc analyses

While our hypotheses centered around predictions of freezing-type responses during stressor tasks, there is an important alternate explanation: perhaps individuals from lower SES backgrounds, who had likely experienced chronic stressors in day-to-day life, were simply less affected by our laboratory tasks. To address this possibility, we included participants' self-reported change in stress from baseline to their average stress following the social-evaluative tasks as an indicator of how affected participants reported feeling by the tasks. We found that, even with the inclusion of change in subjective stress, all significant predictions from SES to freezing-type responses remained significant. These results suggest that perceptions of stress in response to the tasks cannot account for effects observed, which is consistent with prior blunted cardiovascular reactivity research (Whittaker et al., 2021).

Next, we considered whether the observed predictions to freezing-type responses might also be driven by racial/ethnic minority status, another source of marginalization and chronic stress for many (Troxel et al., 2003). Family SES was very highly correlated with minority status ( $r = .60$ ,  $p = .001$ ), so we examined predictions without family SES included to avoid multicollinearity. We found that, accounting for gender, attachment security, early adolescent GPA (for behavioral outcomes), and BMI (for physiological outcomes), minority status did not predict freezing-type responses with the exception of math attempts ( $\beta$  minority status on math attempts = .31,  $p = .001$ ). This effect held even when we included concurrent SES (minority status  $\beta = .24$ ,  $p = .01$ ). Gender also remained a significant predictor in all models predicting math attempts. In other words, it appears that two included marginalized statuses (female gender and racial/ethnic minority status) in adolescence were predictive of fewer math attempts ventured in adulthood, even accounting for adult educational attainment and income. Descriptively, participants who identified as White and male at the age of 13 years attempted an average of 121 math problems at the age of 29 years. On the other hand, participants who had identified as female and a person of color at the age of 13 years attempted half as many (an average of 62).

Since there was a three-year window for participants to provide romantic partner data each wave, we examined participant age as a control variable in predicting social support from romantic partners. We found that participant age was unrelated to partner-provided social support from the ages of 18–24 years.

To examine whether social support from romantic partners might moderate (rather than mediate) relations between family SES and freezing-type responses in adulthood, we created a mean-centered interaction term between family SES and romantic partner social support from the ages of 18–24 years. We found no significant predictions to freezing-type responses from this moderation variable.

## 4 | DISCUSSION

This 16-year prospective study identified long-lasting associations from family SES in early adolescence to physiological and behavioral reactions to social-evaluative stressors in adulthood that are consistent with freezing-type responses. Low family SES encompasses persistent sources of stress that are not easily escapable and are often self-perpetuating due to unfair social systems and discrimination. Individuals from low SES backgrounds may begin to conserve energy required for an active fight-or-flight response and thus rely more on freezing-type responses (Niermann et al., 2015).

Predictions remained after accounting for a variety of potential confounds such as participant gender, attachment security, BMI, and early adolescent academic achievement. In addition, we found evidence that some of these associations were mediated by concurrent SES. This suggests that adults from low SES backgrounds who remain in a low SES status in adulthood are subsequently more likely to display freezing-type responses as a strategy during adulthood. Such a pattern likely reflects an adaptive strategy to conserve physical and emotional energy when individuals are chronically under-resourced, both socially and economically. However, in the long term, there are likely some negative consequences to freezing-type responses: blunted cardiovascular reactivity is associated with cardiovascular disease and even death (Eguchi et al., 2009) and lower levels of behavioral persistence could be associated with difficulty in academic or vocational tasks. These findings are consistent with several lines of theory, including social baseline theory, attachment theory, and the biopsychosocial model of challenge and threat (Beckes & Coan, 2011; Bowlby, 1980; Hase et al., 2020), all of which converge on the idea that expectations of resources allow for adequate physical and emotional regulation.

An important alternate explanation for our findings was the possibility that participants from low SES backgrounds were simply less affected by our laboratory stressors. However, post hoc analyses showed that all significant paths to freezing-type responses were independent of change in self-reported stress from baseline to stressor tasks. This is consistent with previous work that has found that physiological responses are typically only weakly related to self-perceived stress (DePierro et al., 2013).

An unexpected finding of note was that there was a significant gender interaction with family SES in predicting blunted heart rate response. Participants from low SES backgrounds who identified as girls at the age of 13 years showed significant heart rate blunting during stressor tasks in adulthood, whereas the same was not true for boys. We would posit that perhaps girls from disadvantaged backgrounds experience more chronic stressors in terms of gender discrimination, sexual harassment, more caregiving expectations, and so on. In other words, low SES may relate to girls' later heart rate reactivity, whereas boys—even those from low SES backgrounds—are able to enjoy male privilege which could counteract the effects of early stressors in predicting heart rate blunting (Brown et al., 2016). Overall, more research is needed to better understand the interplay of gender and family SES in predicting cardiovascular responses.

In addition, reduced engagement specifically during the math task was much more prevalent in individuals from certain marginalized groups: female-identified and participants of color attempted fewer math problems at the age of 29 years than their more privileged counterparts, even accounting for early adolescent academic achievement and adult SES. This may be at least partially reflective of stereotype threat (Croizet & Claire, 1998; Spencer et al., 1999), where girls and participants of color have internalized the message that they are not as capable in math as others.

We initially hypothesized direct links, not just from low family SES to blunted heart rate and fewer math attempts, as were found, but also from low family SES to blunted RSA withdrawal and the number of words spoken during the speech task. However, neither of these latter direct paths were significant. Nonetheless, significant indirect effects through concurrent SES are consistent with a “chains of risk” perspective: Participants from low SES backgrounds are exposed to disadvantages and stressors that help maintain their low SES status, which then predicts freezing-type responses. However, although we accounted for early adolescent attachment and academic functioning, we did not have access to adolescent stress responses. It is possible that adolescents who showed a dispositional tendency toward active stress responses were more likely to have upward socioeconomic mobility. Prior research, though, suggests that upward socioeconomic mobility likely involves external opportunities such as attending a higher performing school or having a caring natural mentor (Hao & Pong, 2008; Hurd et al., 2012; Timpe & Lunkenheimer, 2015). More research with larger samples is needed to untangle these complex relations.

Even given the advantages of an intensive longitudinal study that incorporated observational and physiological measurements, there are important limitations to note. First, the study did not include an adolescent response to a standardized stressor task. This limits our ability to delineate the developmental trajectory of cardiovascular changes. For example, children from low SES backgrounds may initially show *heightened* fight-or-flight responses, which may develop into freezing-type responses after repeated exposure to chronic stress (Miller et al., 2007). Future research should incorporate indicators of cardiovascular functioning and behavioral persistence throughout development to better understand these patterns. Next, our findings were somewhat inconsistent regarding direct predictions from family SES and mediating variables. This may reflect the relative lack of power: Though our sample size was consistent with or larger than those of other intensive longitudinal studies of health outcomes (Turner et al., 2020), we may not have had sufficient power to detect more subtle effects (especially in terms of differences between racial/ethnic identities since we had to combine several groups together). In addition, we utilized a modified version of the TSST, which is a widely used standardized stressor task (Goodman et al., 2017). However, a laboratory stressor task is necessarily somewhat artificial and may not reflect situations that arise in an individual's day-to-day life. In particular, our speech prompt (defending oneself against the accusation of shoplifting a belt) may elicit different reactions for participants from more versus less

privileged backgrounds. Future studies should include a more neutral speech prompt where possible. Similarly, although we completed follow-up analyses that accounted for participants' subjective stress, it is possible that participants from lower SES backgrounds may have engaged less with the tasks, particularly if they had experienced more extreme forms of stress in their day-to-day lives. In addition, because we did not have a control math task under non evaluative conditions, we cannot ascertain whether participants were showing a freezing-type response specifically to stress or would generally have reduced performance on these types of tasks overall due to relative deprivation earlier in life (McLaughlin et al., 2019). Controlling for concurrent SES helps address this issue (in that it accounts somewhat for general levels of “success” in academic and vocational functioning outside of the laboratory tasks), but does not definitively show that fewer math attempts are part of a stress-specific freezing response rather than a general blunting of effort or performance.

A potential limitation of our RSA measurement is that we did not control respiration rate or depth which can influence measures of RSA. However, “corrected” and “uncorrected” RSA are often highly correlated (Denver et al., 2007; Kotani et al., 2007) and RSA is not susceptible to speech artifacts within many behavioral contexts (e.g., listening and speaking periods) (Cribbet et al., 2020). In addition, RSA during both speech and math tasks as used in this study reflect parasympathetic influences as revealed by pharmacological blockade studies (Berntson et al., 1993). Finally, this research can be complemented by experimental designs.

To our knowledge, this is the first study to examine long-term associations between SES in early adolescence and freezing-type responses in adulthood. Our findings provide further evidence of low family SES as a source of chronic developmental stress and contribute to understanding physiological and behavioral associations of socioeconomic disadvantage with stress responses in adulthood.

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## CONFLICT OF INTEREST

The authors have no conflicts of interest to report.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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## REFERENCES

- Adler, N. E., & Ostrove, J. M. (1999). Socioeconomic status and health: What we know and what we don't. *Annals of the New York Academy of Sciences*, 896, 3–15. <https://doi.org/10.1111/j.1749-6632.1999.tb08101.x>
- Allen, J., Hall, F., Insabella, G., Land, D., Marsh, P., & Porter, M. (2001). *The supportive behavior task coding system*. University of Virginia.
- Arbuckle, J. L., Marcoulides, G. A., & Schumacker, R. E. (1996). Full information estimation in the presence of incomplete data. *Advanced Structural Equation Modeling: Issues and Techniques*, 243, 277.
- Azevedo, T. M., Volchan, E., Imbiriba, L. A., Rodrigues, E. C., Oliveira, J. M., Oliveira, L. F., & Vargas, C. D. (2005). A freezing-like posture to pictures of mutilation. *Psychophysiology*, 42(3), 255–260. <https://doi.org/10.1111/j.1469-8986.2005.00287.x>
- Bartley, M., & Plewis, I. (2007). Increasing social mobility: An effective policy to reduce health inequalities. *Journal of the Royal Statistical Society: Series A (Statistics in Society)*, 170(2), 469–481.
- Beckes, L., & Coan, J. A. (2011). Social baseline theory: The role of social proximity in emotion and economy of action. *Social and Personality Psychology Compass*, 5(12), 976–988. <https://doi.org/10.1111/j.1751-9004.2011.00400.x>
- Berntson, G. G., Cacioppo, J. T., & Quigley, K. S. (1993). Respiratory sinus arrhythmia: Autonomic origins, physiological mechanisms, and psychophysiological implications. *Psychophysiology*, 30(2), 183–196. <https://doi.org/10.1111/j.1469-8986.1993.tb01731.x>
- Berntson, G. G., Quigley, K. S., Jang, J. F., & Boysen, S. T. (1990). An approach to artifact identification: Application to heart period data. *Psychophysiology*, 27(5), 586–598.
- Bloomfield, M. A., McCutcheon, R. A., Kempton, M., Freeman, T. P., & Howes, O. (2019). The effects of psychosocial stress on dopaminergic function and the acute stress response. *eLife*, 8, 46797. <https://doi.org/10.7554/eLife.46797>
- Bowlby, J. (1980). *Attachment and loss: Separation: Anxiety and anger*. Vol. 2: Vintage.
- Brotman, D. J., Golden, S. H., & Wittstein, I. S. (2007). The cardiovascular toll of stress. *The Lancet*, 370(9592), 1089–1100. [https://doi.org/10.1016/S0140-6736\(07\)61305-1](https://doi.org/10.1016/S0140-6736(07)61305-1)
- Brown, T. H., Richardson, L. J., Hargrove, T. W., & Thomas, C. S. (2016). Using multiple-hierarchy stratification and life course approaches to understand health inequalities: The intersecting consequences of race, gender, SES, and age. *Journal of Health and Social Behavior*, 57(2), 200–222.
- Buss, K. A., Davis, E. L., Ram, N., & Coccia, M. (2018). Dysregulated fear, social inhibition, and respiratory sinus arrhythmia: A replication and extension. *Child Development*, 89(3), e214–e228. <https://doi.org/10.1111/cdev.12774>
- Bylsma, L. M., Salomon, K., Taylor-Clift, A., Morris, B. H., & Rottenberg, J. (2014). RSA reactivity in current and remitted major depressive disorder. *Psychosomatic Medicine*, 76(1), 66–73. <https://doi.org/10.1097/PSY.000000000000019>
- Cacioppo, J., Malarkey, W., Kiecolt-Glaser, J., Uchino, B., Sgoutas-Emch, S., Sheridan, J., Berntson, G., & Glaser, R. (1995). Heterogeneity in neuroendocrine and immune responses to brief psychological stressors as a function of autonomic cardiac activation. *Psychosomatic Medicine*, 57, 154–164. <https://doi.org/10.1097/00006842-199503000-00008>
- Cavanagh, L., & Obasi, E. M. (2021). The moderating role of coping style on chronic stress exposure and cardiovascular reactivity among African American emerging adults. *Prevention Science*, 22(3), 357–366. <https://doi.org/10.1007/s11121-020-01141-3>
- Chapman, B. P., Fiscella, K., Duberstein, P., Coletta, M., & Kawachi, I. (2009). Can the influence of childhood socioeconomic status on men's and women's adult body mass be explained by adult socioeconomic status or personality? Findings from a national sample. *Health Psychology*, 28(4), 419–427. <https://doi.org/10.1037/a0015212>
- Chantry, A. J., Williams, S. E., & Whittaker, A. C. (2019). Blunted cardiovascular responses to acute psychological stress predict low behavioral but not self-reported perseverance. *Psychophysiology*, 56(11), 13449. <https://doi.org/10.1111/psyp.13449>
- Cicchetti, D. V., & Sparrow, S. A. (1981). Developing criteria for establishing interrater reliability of specific items: Applications to assessment of adaptive behavior. *American Journal of Mental Deficiency*, 86(2), 127–137.
- Cohen, S., Janicki-Deverts, D., Chen, E., & Matthews, K. A. (2010). Childhood socioeconomic status and adult health. *Ann N Y Acad Sci*, 1186, 37–55. <https://doi.org/10.1111/j.1749-6632.2009.05334.x>
- Conger, R. D., Conger, K. J., & Martin, M. J. (2010). Socioeconomic status, family processes, and individual development. *Journal of Marriage and Family*, 72(3), 685–704. <https://doi.org/10.1111/j.1741-3737.2010.00725.x>
- Considine, N. S., Sabag-Cohen, S., & Krivoshekova, Y. S. (2007). Ethnic, gender, and socioeconomic differences in young adults' self-disclosure: Who discloses what and to whom? *Cultural Diversity and Ethnic Minority Psychology*, 13(3), 254–263. <https://doi.org/10.1037/1099-9809.13.3.254>
- Cribbet, M. R., Smith, T. W., Uchino, B. N., Baucom, B. R. W., & Nealey-Moore, J. B. (2020). Autonomic influences on heart rate during marital conflict: Associations with high frequency heart rate variability and cardiac pre-ejection period. *Biological Psychology*, 151, 107847. <https://doi.org/10.1016/j.biopsycho.2020.107847>
- Croizet, J.-C., & Claire, T. (1998). Extending the concept of stereotype threat to social class: The intellectual underperformance of students from low socioeconomic backgrounds. *Personality and Social Psychology Bulletin*, 24(6), 588–594. <https://doi.org/10.1177/0146167298246003>
- Cundiff, J. M., Jennings, J. R., & Matthews, K. A. (2019). Social stratification and risk for cardiovascular disease: Examination of emotional suppression as a pathway to risk. *Personality and Social Psychology Bulletin*, 45(8), 1202–1215. <https://doi.org/10.1177/0146167218808504>
- Davies, P. T., Martin, M. J., Sturge-Apple, M. L., Ripple, M. T., & Cicchetti, D. (2016). The distinctive sequelae of children's coping with interparental conflict: Testing the reformulated emotional security theory. *Developmental Psychology*, 52(10), 1646–1665. <https://doi.org/10.1037/dev0000170>
- Del Giudice, M., Ellis, B. J., & Shirtcliff, E. A. (2011). The adaptive calibration model of stress responsivity. *Neuroscience & Biobehavioral Reviews*, 35(7), 1562–1592. <https://doi.org/10.1016/j.neubiorev.2010.11.007>
- Demaree, H. A., Robinson, J. L., Everhart, D. E., & Schmeichel, B. J. (2004). Resting RSA is associated with natural and self-regulated responses to negative emotional stimuli. *Brain and Cognition*, 56(1), 14–23. <https://doi.org/10.1016/j.bandc.2004.05.001>
- Denver, J. W., Reed, S. F., & Porges, S. W. (2007). Methodological issues in the quantification of respiratory sinus arrhythmia. *Biological Psychology*, 74(2), 286–294. <https://doi.org/10.1016/j.biopsycho.2005.09.00>
- DePierro, J., D'Andrea, W., & Pole, N. (2013). Attention biases in female survivors of chronic interpersonal violence: Relationship to trauma-related symptoms and physiology. *European Journal of Psychotraumatology*, 4. <https://doi.org/10.3402/ejpt.v4i0.19135>
- Eguchi, K., Hoshida, S., Ishikawa, J., Pickering, T. G., Schwartz, J. E., Shimada, K., & Kario, K. (2009). Nocturnal nondipping of heart rate predicts cardiovascular events in hypertensive patients. *Journal of Hypertension*, 27(11), 2265–2270. <https://doi.org/10.1097/HJH.0b013e328330a938>
- Estes, Z., & Verges, M. (2008). Freeze or flee? Negative stimuli elicit selective responding. *Cognition*, 108(2), 557–565. <https://doi.org/10.1016/j.cognition.2008.03.003>
- Fuhrmann, D., Knoll, L. J., & Blakemore, S.-J. (2015). Adolescence as a sensitive period of brain development. *Trends in Cognitive Sciences*, 19(10), 558–566. <https://doi.org/10.1016/j.tics.2015.07.008>
- Gallo, L. C., Smith, T. W., & Cox, C. M. (2006). Socioeconomic status, psychosocial processes, and perceived health: An interpersonal perspective. *Annals of Behavioral Medicine*, 31(2), 109–119. [https://doi.org/10.1207/s15324796abm3102\\_2](https://doi.org/10.1207/s15324796abm3102_2)
- Garnezy, N., Masten, A. S., & Tellegen, A. (1984). The study of stress and competence in children: A building block for developmental

- psychopathology. *Child Development*, 55(1), 97–111. <https://doi.org/10.2307/1129837>
- George, C., Kaplan, N., & Main, M. (1996). *Adult attachment interview (3rd ed.)*. Unpublished manuscript, Department of Psychology, University of California, Berkeley.
- Goodman, W. K., Janson, J., & Wolf, J. M. (2017). Meta-analytical assessment of the effects of protocol variations on cortisol responses to the Trier Social Stress Test. *Psychoneuroendocrinology*, 80, 26–35. <https://doi.org/10.1016/j.psyneuen.2017.02.030>
- Gorman, B. K., & Sivaganesan, A. (2007). The role of social support and integration for understanding socioeconomic disparities in self-rated health and hypertension. *Social Science & Medicine*, 65(5), 958–975. <https://doi.org/10.1016/j.socscimed.2007.04.017>
- Hagenaars, M. A., Oitzl, M., & Roelofs, K. (2014). Updating freeze: Aligning animal and human research. *Neuroscience & Biobehavioral Reviews*, 47, 165–176. <https://doi.org/10.1016/j.neubiorev.2014.07.021>
- Hao, L., & Pong, S.-L. (2008). The role of school in the upward mobility of disadvantaged immigrants' children. *The Annals of the American Academy of Political and Social Science*, 620(1), 62–89. <https://doi.org/10.1177/0002716208322582>
- Hase, A., Rot, M., Miranda Azevedo, R., & Freeman, P. (2020). Threat-related motivational disengagement: Integrating blunted cardiovascular reactivity to stress into the biopsychosocial model of challenge and threat. *Anxiety, Stress, & Coping*, 33(4), 355–369. <https://doi.org/10.1080/10615806.2020.1755819>
- Hasl, A., Kretschmann, J., Richter, D., Voelkle, M., & Brunner, M. (2019). Investigating core assumptions of the “American Dream”: Historical changes in how adolescents' socioeconomic status, IQ, and GPA are related to key life outcomes in adulthood. *Psychology and Aging*, 34(8), 1055.
- Heleniak, C., McLaughlin, K. A., Ormel, J., & Riese, H. (2016). Cardiovascular reactivity as a mechanism linking child trauma to adolescent psychopathology. *Biological Psychology*, 120, 108–119.
- Hoetink, A. E., Faes, T. J. C., Schuur, E. H., Gorkink, R., Goovaerts, H. G., Meijer, J. H., & Heethaar, R. M. (2002). Comparing spot electrode arrangements for electric impedance cardiography. *Physiological Measurement*, 23(2), 457–467. <https://doi.org/10.1088/0967-3334/23/2/319>
- Hoggard, L. S., Hill, L. K., Gray, D. L., & Sellers, R. M. (2015). Capturing the cardiac effects of racial discrimination: Do the effects “keep going”? *International Journal of Psychophysiology*, 97(2), 163–170. <https://doi.org/10.1016/j.ijpsycho.2015.04.015>
- Hughes, B. M. (2007). Social support in ordinary life and laboratory measures of cardiovascular reactivity: Gender differences in habituation-sensitization. *Annals of Behavioral Medicine*, 34(2), 166–176. <https://doi.org/10.1007/BF02872671>
- Hughes, B. M., Lü, W., & Howard, S. (2018). Cardiovascular stress-response adaptation: Conceptual basis, empirical findings, and implications for disease processes. *International Journal of Psychophysiology*, 131, 4–12. <https://doi.org/10.1016/j.ijpsycho.2018.02.003>
- Hurd, N. M., Sánchez, B., Zimmerman, M. A., & Caldwell, C. H. (2012). Natural mentors, racial identity, and educational attainment among African American adolescents: Exploring pathways to success. *Child Development*, 83(4), 1196–1212. <https://doi.org/10.1111/j.1467-8624.2012.01769.x>
- Jelen, P., Soltysik, S., & Zagrodzka, J. (2003). 22-kHz Ultrasonic vocalization in rats as an index of anxiety but not fear: Behavioral and pharmacological modulation of affective state. *Behavioural Brain Research*, 141(1), 63–72. [https://doi.org/10.1016/S0166-4328\(02\)00321-2](https://doi.org/10.1016/S0166-4328(02)00321-2)
- Kirschbaum, C., Pirke, K.-M., & Hellhammer, D. (1993). The ‘Trier Social Stress Test’ – A tool for investigating psychobiological stress responses in a laboratory setting. *Neuropsychobiology*, 28, 76–81. <https://doi.org/10.1159/000119004>
- Kobak, R. R., Cole, H. E., Ferenz-Gillies, R., Fleming, W. S., & Gamble, W. (1993). Attachment and emotion regulation during mother-teen problem solving: A control theory analysis. *Child Development*, 64(1), 231–245. <https://doi.org/10.1111/j.1467-8624.1993.tb02906.x>
- Kotani, K., Tachibana, M., & Takamasu, K. (2007). Respiratory-phase domain analysis of heart rate variability can accurately estimate cardiac vagal activity during a mental arithmetic task. *Methods of Information in Medicine*, 46(3), 376–385. <https://doi.org/10.1160/ME0352>
- Litvack, D. A., Oberlander, T. F., Carney, L. H., & Saul, J. P. (1995). Time and frequency domain methods for heart rate variability analysis: A methodological comparison. *Psychophysiology*, 32(5), 492–504. <https://doi.org/10.1111/j.1469-8986.1995.tb02101.x>
- Liu, S., Cui, Z., Duprey, E. B., Kogan, S. M., & Oshri, A. (2020). Adverse parenting is indirectly linked to delayed reward discounting via blunted RSA reactivity: The protective role of a shift-and-persist coping strategy. *Adversity and Resilience Science*, 1(3), 149–163. <https://doi.org/10.1007/s42844-020-00012-8>
- Loeb, E. L., Davis, A. A., Narr, R. K., Uchino, B. N., Kent de Grey, R. G., & Allen, J. P. (2021). The developmental precursors of blunted cardiovascular responses to stress. *Developmental Psychobiology*, 63(2), 247–261. <https://doi.org/10.1002/dev.21977>
- Lojowska, M., Ling, S., Roelofs, K., & Hermans, E. J. (2018). Visuocortical changes during a freezing-like state in humans. *NeuroImage*, 179, 313–325. <https://doi.org/10.1016/j.neuroimage.2018.06.013>
- Lovallo, W. R. (2013). Early life adversity reduces stress reactivity and enhances impulsive behavior: Implications for health behaviors. *International Journal of Psychophysiology: Official Journal of the International Organization of Psychophysiology*, 90(1), 8–16. <https://doi.org/10.1016/j.ijpsycho.2012.10.006>
- Lovallo, W. R., Farag, N. H., Sorocco, K. H., Cohoon, A. J., & Vincent, A. S. (2012). Lifetime adversity leads to blunted stress axis reactivity: Studies from the Oklahoma family health patterns project. *Biological Psychiatry*, 71(4), 344–349. <https://doi.org/10.1016/j.biopsych.2011.10.018>
- Löw, A., Weymar, M., & Hamm, A. O. (2015). When threat is near, get out of here: Dynamics of defensive behavior during freezing and active avoidance. *Psychological Science*, 26(11), 1706–1716. <https://doi.org/10.1177/0956797615597332>
- Luo, Y., & Waite, L. J. (2005). The impact of childhood and adult SES on physical, mental, and cognitive well-being in later life. *The Journals of Gerontology: Series B*, 60(2), 93–101. <https://doi.org/10.1093/geronb/60.2.S93>
- Marteau, T. M., & Bekker, H. (1992). The development of a six-item short-form of the state scale of the Spielberger State–Trait Anxiety Inventory (STAI). *British Journal of Clinical Psychology*, 31(3), 301–306. <https://doi.org/10.1111/j.2044-8260.1992.tb00997.x>
- Matthews, K. A., Gallo, L. C., & Taylor, S. E. (2010). Are psychosocial factors mediators of socioeconomic status and health connections? *Ann NY Acad Sci*, 1186(1), 146–173. <https://doi.org/10.1111/j.1749-6632.2009.05332.x>
- McLaughlin, K. A., Sheridan, M. A., Alves, S., & Mendes, W. B. (2014). Child maltreatment and autonomic nervous system reactivity: Identifying dysregulated stress reactivity patterns using the biopsychosocial model of challenge and threat. *Psychosomatic Medicine*, 76(7), 538–546. <https://doi.org/10.1097/PSY.000000000000098>
- McLaughlin, K. A., Weissman, D., & Bitrán, D. (2019). Childhood adversity and neural development: A systematic review. *Annual Review of Developmental Psychology*, 1, 277–312.
- McMahon, G., Creaven, A.-M., & Gallagher, S. (2020). Perceived social support mediates the association between attachment and cardiovascular reactivity in young adults. *Psychophysiology*, 57(3), 13496. <https://doi.org/10.1111/psyp.13496>
- Miller, G. E., Chen, E., & Zhou, E. S. (2007). If it goes up, must it come down? Chronic stress and the hypothalamic-pituitary-adrenocortical axis in humans. *Psychol Bull*, 133(1), 25–45. <https://doi.org/10.1037/0033-2909.133.1.25>
- Muthén, L. K., & Muthén, B. O. (2007). *Mplus user's guide*. 5th (Vol. 7).

- Niermann, H. C. M., Ly, V., Smeekens, S., Figner, B., Riksen-Walraven, J. M., & Roelofs, K. (2015). Infant attachment predicts bodily freezing in adolescence: Evidence from a prospective longitudinal study. *Frontiers in Behavioral Neuroscience*, 0, . <https://doi.org/10.3389/fnbeh.2015.00263>
- Phillips, A. C. (2011). Blunted cardiovascular reactivity relates to depression, obesity, and self-reported health. *Biological Psychology*, 86(2), 106–113. <https://doi.org/10.1016/j.biopsycho.2010.03.016>
- Phillips, A. C., Ginty, A. T., & Hughes, B. M. (2013). The other side of the coin: Blunted cardiovascular and cortisol reactivity are associated with negative health outcomes. *International Journal of Psychophysiology*, 90(1), 1–7. <https://doi.org/10.1016/j.ijpsycho.2013.02.002>
- Roelofs, K. (2017). Freeze for action: Neurobiological mechanisms in animal and human freezing. *Philosophical Transactions of the Royal Society B: Biological Sciences*, 372(1718), 20160206. <https://doi.org/10.1098/rstb.2016.0206>
- Roelofs, K., Hagenaaars, M. A., & Stins, J. (2010). Facing freeze: Social threat induces bodily freeze in humans. *Psychological Science*, 21(11), 1575–1581. <https://doi.org/10.1177/0956797610384746>
- Sandner, M., Lois, G., Streit, F., Zeier, P., Kirsch, P., Wüst, S., & Wessa, M. (2020). Investigating individual stress reactivity: High hair cortisol predicts lower acute stress responses. *Psychoneuroendocrinology*, 118, 104660. <https://doi.org/10.1016/j.psyneuen.2020.104660>
- Spencer, S. J., Steele, C. M., & Quinn, D. M. (1999). Stereotype threat and women's math performance. *Journal of Experimental Social Psychology*, 35(1), 4–28. <https://doi.org/10.1006/jesp.1998.1373>
- Stringhini, S., Berkman, L., Dugravot, A., Ferrie, J. E., Marmot, M., Kivimaki, M., & Singh-Manoux, A. (2012). Socioeconomic status, structural and functional measures of social support, and mortality: The British Whitehall II Cohort Study, 1985–2009. *American Journal of Epidemiology*, 175(12), 1275–1283. <https://doi.org/10.1093/aje/kwr461>
- Timpe, Z. C., & Lunkenheimer, E. (2015). The long-term economic benefits of natural mentoring relationships for youth. *American Journal of Community Psychology*, 56(1), 12–24. <https://doi.org/10.1007/s10464-015-9735-x>
- Troxel, W. M., Matthews, K. A., Bromberger, J. T., & Sutton-Tyrrell, K. (2003). Chronic stress burden, discrimination, and subclinical carotid artery disease in African American and Caucasian women. *Health Psychology*, 22(3), 300–309. <https://doi.org/10.1037/0278-6133.22.3.300>
- Turner, A. I., Smyth, N., Hall, S. J., Torres, S. J., Hussein, M., Jayasinghe, S. U., & Clow, A. J. (2020). Psychological stress reactivity and future health and disease outcomes: A systematic review of prospective evidence. *Psychoneuroendocrinology*, 114, 104599. <https://doi.org/10.1016/j.psyneuen.2020.104599>
- Volchan, E., Souza, G. G., Franklin, C. M., Norte, C. E., Rocha-Rego, V., Oliveira, J. M., & Figueira, I. (2011). Is there tonic immobility in humans? Biological evidence from victims of traumatic stress. *Biological Psychology*, 88(1), 13–19. <https://doi.org/10.1016/j.biopsycho.2011.06.002>
- Whittaker, A. C., Ginty, A., Hughes, B. M., Steptoe, A., & Lovallo, W. R. (2021). Cardiovascular stress reactivity and health: Recent questions and future directions. *Psychosomatic Medicine*, 83(7), 756–766. <https://doi.org/10.1097/PSY.0000000000000973>

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