EFFECTS OF NEIGHBORHOOD DISADVANTAGE ON ADOLESCENT CORTISOL REACTIVITY AND MENTAL HEALTH

by
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A dissertation submitted to the Faculty of the University of Delaware in partial fulfillment of the requirements for the degree of Doctor of Philosophy in Psychological and Brain Sciences

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ABSTRACT

Millions of youth in the United States are living in neighborhoods where they are at risk for exposure to adverse conditions that predict a variety of mental health concerns, but it is unclear how neighborhood disadvantage confers risk for these outcomes. Cortisol reactivity to acute stress is a candidate mechanism, as it is thought to be a link between adverse experiences and psychopathology. The present study examined the associations between neighborhood disadvantage, cortisol reactivity and anxiety symptoms in a sample of adolescents living in an urban environment. Results revealed that living in neighborhoods characterized by more severe crimes and higher rates of poverty was associated with blunted cortisol reactivity, as compared to living in neighborhoods with less severe crime and lower poverty rates. Litter, a metric of neighborhood disorder, was positively associated with cortisol reactivity. Sex emerged as a significant moderator of the association between neighborhood crime and cortisol reactivity and parent-adolescent relationship quality moderated the association between litter and cortisol reactivity. Neighborhood poverty was positively associated with higher self-reported anxiety, whereas crime and disorder were not significantly associated with anxiety. Cortisol reactivity was not associated with anxiety symptoms, which ruled cortisol out as a mediator of the association between neighborhood disadvantage and anxiety in this

sample. Findings stand to inform the development of interventions to prevent and ameliorate the effects of neighborhood disadvantage on adolescent mental health.

Chapter 1

INTRODUCTION

Neighborhood disadvantage often creates a context of adversity that is associated with maladaptive mental health outcomes for adolescents (Aneshensel & Sucoff, 1996; Jocson & Mcloyd, 2015; Linares et al., 2001). It is important to examine mechanisms that underlie this association to inform the development of interventions and policy efforts to improve adolescent outcomes. Given that cortisol dysregulation has been linked to both neighborhood-level adversity (Busso et al., 2017; Joos et al., 2019; Theall et al., 2017) and mental health outcomes (Harkness et al., 2011; Keenan et al., 2013; Van Goozen et al., 2007) in adolescence, this metric of neurobiological regulation has emerged as a potential mechanism. The present study seeks to examine longitudinal associations between neighborhood disadvantage, cortisol reactivity and mental health outcomes, as well as moderators of these associations, in a sample of adolescents living in an urban environment.

Neighborhood Disadvantage Negatively Impacts Adolescent Mental Health

Over 8.5 million children in the United States are living in neighborhoods where the overall poverty rate exceeds 30 percent (U.S. Census Bureau, 2018). High rates of neighborhood poverty are often the result of historic disinvestment in urban neighborhoods, which leaves these areas with limited health promoting amenities,

employment and educational opportunities (Acevedo-Garcia et al., 2014). Living in a neighborhood with limited resources often contributes to high rates of violence, crime, and social disorder (Friedson & Sharkey, 2015). Neighborhood factors can directly impact children and adolescents, as well as interact with other aspects of the environment to influence outcomes (Bronfenbrenner, 1979); therefore, it is not surprising that youth living in disadvantaged neighborhoods are often negatively impacted, as evidenced by academic (Smart et al., 2021), socio-emotional, and behavioral outcomes (Leventhal & Brooks-Gunn, 2000).

While mental health disorders can emerge across the lifespan, adolescence appears to be a sensitive period when youth are at risk for the onset of these concerns. Of note, current estimates suggest that nearly 50% of all mental health disorders emerge by age 14 (Kessler et al., 2005). The development of mental illness is a complex interplay of several factors. The biopsychosocial model (Engel, 1977) of mental illness suggests that biological, psychological and social factors contribute to the development and maintenance of mental health concerns. Relatedly, adolescence is a developmental period characterized by rapid social, physiological, and psychological changes. This period of destabilization may present as a vulnerability for the development of maladaptive outcomes (Steinberg & Morris, 2001). Moreover, adolescence is also a period when children are negotiating developmentally appropriate separation from their parents. As such, factors external to the family, including neighborhood disadvantage, may have an increased influence on functioning during adolescence (Steinberg & Morris, 2003).

In examining the effects of specific measures of disadvantage, attributes such as neighborhood-level poverty, disorder and crime have emerged as predictors of mental health outcomes for adolescents. High levels of neighborhood disorder have been associated with increased externalizing behavior (Jocson & Mcloyd, 2015), perceived powerlessness (Geis & Ross, 1998), risk for developing psychotic symptoms (Newbury et al., 2016), and drug use in adolescents (Furr-Holden et al., 2011). Low levels of neighborhood safety have been associated with behavior problems (Linares et al., 2001) and increased anxiety, depression, and conduct disorder symptoms in adolescence (Aneshensel & Sucoff, 1996). In addition, neighborhood-level poverty has been associated with elevated internalizing concerns (Ip et al., 2022; King et al., 2022) and antisocial behavior (Odgers et al., 2012). Taken together, these findings suggest that neighborhood-level disadvantage serves as a psychosocial stressor that threatens healthy adolescent development.

Cortisol Reactivity as a Candidate Mechanism by Which Neighborhood Influences Mental Health

The association between neighborhood disadvantage and adolescent mental health outcomes has been well-established in the literature; however, it is unclear how neighborhood factors confer risk for these outcomes. Discovering links between adverse experiences and mental health disorders can facilitate early identification of individuals at risk for developing maladaptive outcomes. Given the stressful nature of neighborhood-level adversity, a candidate mechanism for this association is the dysregulation of cortisol activity in response to acute psychosocial stress.

Cortisol is a hormone that is implicated in several key physiological processes, including metabolism, circadian rhythms, and the inflammatory response. Cortisol is secreted in a diurnal pattern, with the highest concentration occurring in the morning and the nadir occurring at bedtime. In addition to this pattern across the day, cortisol is released in response to acute stressors. As part of a healthy stress response, cortisol levels increase approximately 15 minutes after the onset of the stressor. This influx of cortisol into the body is designed to support the 'flight or fight' response to stress; this process helps to mobilize energy to the body, increase heart rate and breathing, and slow non-essential bodily functions to facilitate survival until the threat dissipates. Once the immediate threat has ended, cortisol concentration gradually decreases back to baseline. Following chronic stress and trauma, these normative patterns of cortisol often begin to exhibit signs of dysregulation. In the case of the acute cortisol response to stress, this dysregulation can take the form of either elevated or blunted cortisol reactivity. Elevated cortisol reactivity presents as an increase in cortisol concentration that is higher than expected and a blunted cortisol response to stress is one that is lower than expected. These altered patterns of cortisol regulation have been observed following experiences with child abuse (Trickett et al., 2014), institutionalization (Hostinar et al., 2015), and war (Feldman et al., 2013).

There is limited literature that explores the specific effects of the neighborhood context on adolescent cortisol reactivity. The sparse body of work that explores the association between neighborhood factors and cortisol reactivity in adolescence presents seemingly contradictory findings. Studies that employ census tract data as their sole

measure of neighborhood quality find that heightened cortisol reactivity is associated with disadvantage. Hackman and colleagues examined the association between cortisol reactivity and neighborhood factors in a racially homogenous sample of adolescents. They found that adolescents living in disadvantaged neighborhoods, as measured by low neighborhood-level socio-economic status (SES; e.g., low adult income, educational attainment, and occupational status), tend to exhibit more elevated cortisol reactivity than those in less disadvantaged neighborhoods (Hackman et al., 2012). This finding was also replicated with a nationally representative sample of adolescents from the United States (Rudolph et al., 2014). Census data on the SES of the neighborhood provides useful information regarding the ecology of the neighborhood, but this metric alone may not capture the most salient and stressful aspects of the neighborhood context for adolescents. Moreover, census tracts can vary in spatial size and population density (U.S. Census Bureau, 2018), therefore these units of measure may not accurately reflect the direct neighborhood experience of each adolescent.

Conversely, when examining the effect of factors such as community violence, findings suggest that adolescents who live in neighborhoods with high levels of violence exhibit blunted, or dampened, cortisol reactivity when compared to adolescents living in less violent contexts (Busso et al., 2017; Joos et al., 2019; Peckins et al., 2020; Theall et al., 2017). For example, Theall and colleagues (2017) found that heightened community violence rates were associated with blunted cortisol reactivity in early adolescence (Theall et al., 2017). When examining person-centered cortisol reactivity profiles (i.e., reactive, moderate, and blunted reactivity), adolescents experiencing high levels of

community violence were more likely to exhibit functioning in the blunted profile relative to adolescents experiencing low levels of community violence (Joos et al., 2019). Moreover, this blunted pattern of cortisol reactivity is also found in youth who experience other forms of adversity (Bunea et al., 2017), which suggests that this dampened cortisol response to stress may be unique to contexts with direct experiences of adversity rather than solely low socioeconomic status per se.

These altered patterns of cortisol reactivity have been thought to be an adaptation that occurs to help the body manage chronic stress (Fries et al., 2005); however, these alterations in cortisol have also been found to be associated with problematic mental health outcomes for youth. In examining longitudinal associations, studies suggest that dysregulation of the acute cortisol response to stress may precede the onset of these mental health concerns (Badanes et al., 2011). It should be noted that the literature on the dysregulation of the acute cortisol response to stress and mental health outcomes for youth also presents mixed findings, with both blunted (Fairchild et al., 2018; Harkness et al., 2011; Keenan et al., 2013) and elevated (Laurent et al., 2015; van West et al., 2008) cortisol reactivity associated with outcomes in youth. For individuals who experience adversity early in life, a blunted response appears to be consistent with psychopathology (Lovallo, 2013). Collectively, these findings suggest that blunted cortisol reactivity may serve as a mechanism by which the most salient forms of neighborhood-level disadvantage impact adolescent mental health. Cortisol regulation has also been found to be influenced by psychosocial interventions for children and adolescents (Slopen et al., 2014; Wadsworth et al., 2022). If revealed as a mediator, this neurobiological process

may serve as a novel target for programs designed to prevent or ameliorate the effects of neighborhood disadvantage on adolescent mental health.

Moderators of the Association Between Neighborhood Disadvantage and Adolescent Outcomes

Current research recommendations suggest including moderating variables in studies examining the effects of the neighborhood context on child and adolescent development (Leventhal & Dupéré, 2019; Sharkey & Faber, 2014). This emphasis stems from the idea that additional factors may play an interactive role in the influence that neighborhood-level disadvantage has on adolescent development. Identifying moderators, such as adolescent sex, provides critical information about the ways in which outcomes of interest may differ based on sociodemographic variables. In addition, the identification of malleable moderators, such as parent-adolescent relationship quality, provides information about potential intervention targets to help prevent and ameliorate the effects of neighborhood disadvantage on adolescent neurobiological functioning.

Child Sex

Child sex has been identified as a factor that influences the association between neighborhood quality and adolescent development. There is a body of research that suggests that the outcomes associated with neighborhood disadvantage differentially impact boys, as compared to girls. Studies suggest that boys from disadvantaged neighborhoods are more likely to exhibit cortisol dysregulation (Aiyer et al., 2014; Hackman et al., 2012) and engage in antisocial behaviors (Clampet-Lundquist et al., 2011; Odgers et al., 2015) than girls. One explanation offered is that adolescent males

may be more likely to witness acts of violence in their neighborhoods than girls (Weist et al., 2001). In addition, a recent study found that 25% of boys surveyed reported being victimized in their community, compared to 12% of surveyed girls (Chen, 2009). This differential exposure to neighborhood-level stress may contribute to sex differences in outcomes for adolescents living in disadvantaged neighborhoods.

Parent-adolescent Relationship Quality

As discussed above, adolescence is a developmentally appropriate period for adolescents to begin to seek support from peers and other figures outside of the home. This network-building outside of their family of origin serves as preparation for learning to live on their own as adults. Despite this shift in support needs, parents remain important parts of the adolescent support system, particularly for youth at risk of maladaptive outcomes. There is evidence that positive parenting qualities, such as validation and warmth, buffer the cortisol stress response for youth in early adolescence (Hostinar et al., 2015)

There are no studies to my knowledge that explore the buffering role of parenting on the association between neighborhood disadvantage and cortisol reactivity in adolescence. There are promising studies that support parenting as a moderator of the association between neighborhood quality and other outcomes. High quality parent-child relationships have been found to protect against the negative effects of neighborhood disadvantage on brain development (Whittle et al., 2017), allostatic load (Brody et al., 2014), and problematic behavior (Vanderbilt-Adriance & Shaw, 2008) in youth. In a longitudinal study, Mrug and colleagues examined the impact of parenting on the

association between neighborhood quality in early adolescence and physical health in adulthood (Mrug et al., 2022). Findings suggested that warm and supportive caregiving buffered the impact of adolescent neighborhood disadvantage on later health outcomes. These data suggest that for adolescents living in disadvantaged neighborhoods, the support of parents is particularly important given that youth may be exposed to an elevated level of risk in the community (Leventhal & Brooks-Gunn, 2000).

Present Study

Neighborhood disadvantage has been associated with depression, anxiety, and conduct disorder in adolescents, although it is unclear exactly how neighborhood disadvantage confers risk for these mental health outcomes. Cortisol reactivity to acute stress is a candidate mechanism, given that this process is thought to be a link between adverse experiences and psychopathology (Koss & Gunnar, 2018). However, little is known about the degree to which neighborhood disadvantage influences adolescent cortisol reactivity. To explore this association, it is important to include several key methodological strategies. First, it is important to ensure that measures of the neighborhood capture the most salient aspects of the adolescent environment. Second, to understand the differential associations between neighborhood disadvantage and cortisol regulation, the inclusion of moderating variables will be key. Last, longitudinal research methods are helpful in establishing temporal precedence among the study variables. The present sought to understand the associations between neighborhood disadvantage, cortisol reactivity and adolescent mental health through the following aims and hypotheses:

Aim 1: Determine the extent to which geographic information systems (GIS) coded neighborhood disadvantage (i.e., poverty, physical disorder, and crime) assessed at age 10 is associated with cortisol reactivity to acute stress in adolescents at age 13. I hypothesized that adolescents living in neighborhoods characterized by higher levels of disadvantage (i.e., high rates of crime, high percentages of neighborhood inhabitants living in poverty and high ratings of physical disorder) would have blunted, or lowered, cortisol reactivity to stress relative to adolescents residing in less disadvantaged neighborhoods.

Aim 2: Examine the moderating effects of adolescent sex and parent-adolescent relationship quality on the associations between each neighborhood variable at age 10 and cortisol reactivity at age 13. Separate moderation analyses were conducted to examine:

Aim 2a, moderating effects of adolescent sex: The effect of neighborhood disadvantage on cortisol reactivity was expected to vary by adolescent sex, such that boys living in neighborhoods characterized by high levels of disadvantage would exhibit significantly more blunted cortisol reactivity than girls.

Aim 2b, moderating effects of parent-adolescent relationship quality: The effect of neighborhood disadvantage on cortisol reactivity was expected to vary by relationship quality, such that adolescents who reported higher quality parental relationships living in neighborhoods characterized by high levels of disadvantage would exhibit significantly higher cortisol reactivity to the TSST-C than adolescents who reported lower quality parental relationships.

Aim 3: Examine whether cortisol reactivity at age 13 mediates the association between observed neighborhood disadvantage at age 10 and adolescent mental health at age 14. Higher levels of neighborhood disadvantage were expected to be associated with higher levels of adolescent-reported anxiety symptoms, mediated by blunted cortisol reactivity.

Chapter 2

METHOD

Participants

Participants included 81 adolescents from the mid-Atlantic region of the United States who were recruited in infancy as part of a longitudinal follow-up of a randomized clinical trial (RCT) of Attachment and Biobehavioral Catch-up (ABC), an intervention for parents of children who have experienced early adversity. Table 1 has a listing of the sociodemographic characteristics of the sample. Starting in 2006, families were referred to the study by Child Protective Services (CPS) as part of a foster care diversion program when the target adolescent was an infant. Although CPS records were unavailable to the study team, factors such as housing instability, domestic violence, and risk for child neglect have been cited as qualifications for the diversion program. Upon enrollment, families were randomized to participate in one of two brief, in-home, manualized parenting interventions: ABC, which targets increasing parental nurturance to distress and sensitivity to non-distress and decreasing frightening parenting behaviors; or a control intervention, Developmental Education for Families (DEF), which supports parents in enhancing their child's cognitive and motor development. These interventions occurred when the target adolescents were infants (i.e., under the age of two).

Table 1 Sample Sociodemographic Characteristics and Descriptive Statistics

Characteristic	Values	
Adolescent sex, n (%)		
Male	43 (53.1)	
Female	38 (46.9)	
Adolescent racial-ethnic identity, n (%)		
Black/African-American	58 (71.6)	
Biracial	14 (17.3)	
Hispanic/Latine	18 (22.2)	
White	3 (3.7)	
Child age, mean (SD)		
13-year visit (*years*)	13.3 (.04)	
Parent education, n (%)	13.0 - 14.3	
Did not complete high school	19 (23.5)	
Obtained a GED	15 (18.5)	
Obtained a high school diploma	32 (39.5)	
Attended some college	14 (17.3)	
Completed a four-year degree	1 (1.2)	
Family-level SES composite score	1.73 (1.23)	
Intervention	0.00-4.00	
ABC	40 (49.4)	
DEF	41 (50.6)	
Neighborhood factors		
Litter Index	1.70 (0.28)	1.11 - 2.33
Average Crime Severity	452.40 (107.68)	300 - 600
Total poverty rate	33.84 (12.71)	5.20 - 65.1
Child poverty rate	40.48 (20.02)	0 – 76
Self-reported anxiety symptoms	3.86 (0.75)	1.96-5.00
Cortisol reactivity (AUC; μg/dl)	0.14 (0.21)	-0.35-0.79
Parent-adolescent Relationship Quality	1.96-5.00	3.00-67.00

N=81

SES: socioeconomic status; AUC: area under the curve

As part of the longitudinal study, participants completed a series of follow-up research visits at the University of Delaware in early childhood, middle childhood, and early adolescence. Given the longitudinal nature of the current study, data collected during the 10-year, 13-year, and 14-year follow-up visits were employed in analyses. The 10-year data were collected from participants during the years 2016-2018, the 13-year data were collected from 2018-2021, and the 14-year data were collected from 2019-2022. At each assessment time point, participants and their parents were contacted to schedule a laboratory visit at the University of Delaware. During this visit, the adolescent and their parent completed a series of surveys and assessments to examine the long-term effects of the study interventions. The present study did not examine intervention effects on study variables; however, assigned intervention was explored as a potential confounding variable.

Measures and Protocols

Neighborhood Disadvantage

Participants' addresses reported at their 10-year research follow-up assessment were used in the present study analyses. Neighborhood characteristics were assessed using ArcGIS Online Software (Environmental Systems Research Institute, 2020). A 500-foot buffer zone was drawn around each participant's address; this buffer zone was used to designate the boundaries of each participant's neighborhood. To assess neighborhood disadvantage, a repository of publicly available datasets was used. The City of Philadelphia hosts a website that provides access to data collected by various organizations in the region (https://opendataphilly.org/datasets/). Using these data,

participants' neighborhoods were coded for the following characteristics: physical disorder, crime, and poverty.

Physical disorder. In 2017-2018, the Philadelphia Streets Department trained surveyors to code the amount of litter, garbage, and debris present on each city block. The timing of litter coding corresponds to the study period when participants were completing their 10-year follow-up research assessments. This index was scored on a 4-point scale: 1 is *little to no litter*, 2 *is an amount of litter that can be quickly cleaned up by one person*, 3 *is an amount of litter that would need a team to clean it up* and 4 *is an amount of litter that would require a large cleanup effort and/or heavy machinery to clear it.* These ratings are positively associated with other forms of neighborhood-level physical disorder such as the presence of vacant and dilapidated buildings (Lockwood et al., 2021). A subset of blocks was double coded by surveyors; these ratings had an average standard deviation of ±0.33, which was below the expected variation between block scores of ±0.44 (Lockwood et al., 2021). The average litter rating of all coded blocks in each participant neighborhood buffer zone was calculated and used in analyses.

Neighborhood-level crime. Philadelphia Police Department crime reports dated from January 2016 to December 2018 were collected to reflect the study period when participants were completing their 10-year follow-up research assessments. Given that these datasets often contain a large number of crime incidents, it is common practice to randomly sample 5% of the data to use for analysis in an effort to account for spatial autocorrelation (Rowland et al., 2015). To reflect the most salient crimes, violent (i.e., homicide, rape, robbery, and assault) and drug crimes (narcotic and drug law violations)

were included in the analysis. Each crime is assigned a unified crime reporting code with lower numbers indicative of more severe crimes: homicide (100), rape (200), robbery (300), assault (400) and drug violations (500). A variable was created that reflects the average severity of all crimes reported within each participant's buffer zone, with lower values being indicative of more severe crimes reported in the neighborhood on average.

Neighborhood-level poverty. For the measurement of neighborhood poverty, data from the United States Census Bureau American Community Survey (ACS) were employed. The ACS reports a 5-year estimate of neighborhood attributes, including a measure of poverty. This measure of poverty includes an income-to-needs ratio based on household size. The 5-year estimates of these data tend to have larger samples and smaller margins of error than single year estimates. These data are aggregated at the census block group level, which is a small geographic region containing between 600 - 3,000 people (U.S. Census Bureau, 2018). The 2021 report included data that were collected between 2016 and 2020. Neighborhood poverty was defined as the percentage of people living in the participant's census block group that live at or below the poverty line.

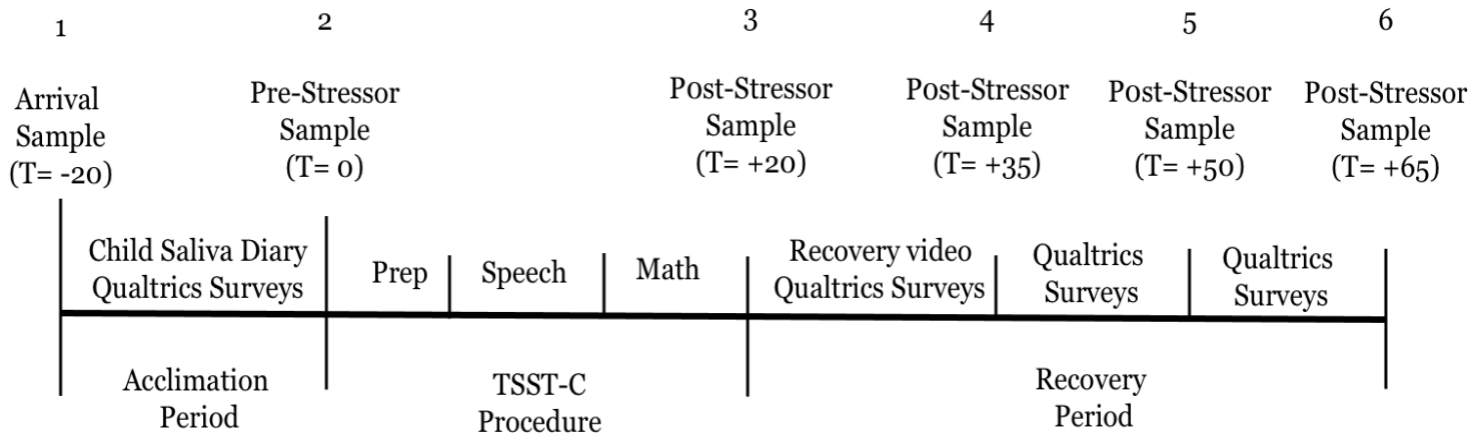
Trier Social Stress Test for Children

Adolescents completed the Trier Social Stress Test for Children (TSST-C), a well-validated paradigm (Buske-Kirschbaum et al., 1997) that has been shown to reliably evoke a stress response in children and adolescents. The TSST-C was completed as part of the 13-year laboratory visit at the University of Delaware. The paradigm included a

public speaking task completed in front of judges that is thought to elicit a social evaluative threat. During this task, timed saliva samples were collected to be assayed for cortisol concentration. Current research suggests that a 15.5% increase in cortisol above baseline constitutes a significant response to the TSST-C (Miller et al., 2013). Based on this criterion, 47 (58%) of the present study participants mounted a significant cortisol response to the TSST-C. In addition, study participants were asked to rate their stress levels during the public speaking portion of the TSST-C on a scale from 1 ("not stressed at all") to 5 ("a whole lot of stress)". On average, participants rated the stress tasks as a 4.15 (speech; SD=1.20) and 3.97 (math; SD=1.29), which are indicative of an experience that elicits "a lot of stress". Taken together, this suggests that the present study participants experienced a significant amount of stress during the TSST-C protocol.

TSST-C protocol. After parent consent and adolescent assent procedures, adolescents were escorted to a room with an experimenter to begin the TSST-C. See Figure 1 for an outline of the procedure. The protocol starts with a 20-minute acclimation period, which included the viewing of a relaxing nature sounds video. During the acclimation period, the adolescent completed a questionnaire that assessed

Figure 1 Outline of Trier Social Stress Test for Children (TSST-C) Procedure.



factors found to impact the cortisol concentration of their saliva samples, including wake time, food and drink intake, and medications taken. Following this period, adolescents were prompted to take five minutes to prepare a speech that could be used to introduce themselves to a hypothetical classroom of new peers. At the end of the five-minute preparation period, adolescents were escorted to a conference room with 2 live judges, one male and one female research assistant whom the participants had never met. The judges were wearing white lab coats, maintained a neutral emotional expression and recorded notes on clipboards throughout the protocol.

Adolescents were prompted to give their speech over the course of five minutes, with prompts to continue speaking ("Please continue") following 20 seconds of silence. Following the speech task, participants completed 5 minutes of mental math, where they were instructed to start at the number 758 and verbally subtract by 7s. The math task was adjusted to be appropriately difficult in the case of adolescents with lower levels of cognitive functioning. When adolescents gave an incorrect response during the math task, they were prompted to restart subtraction from the beginning. Following mental math, adolescents were escorted back to the acclimation room where they started a recovery period in which they watched a relaxing, nature sounds video and then completed non-evocative survey measures until the end of the protocol.

Cortisol reactivity. At timed intervals over the course of the TSST-C protocol, adolescents provided 6 saliva samples via passive drool. Table 2 has descriptive statistics for saliva samples collected in the present study. To control for

Table 2 Saliva Sampling Descriptive Statistics

		Mean (SD) [Range]	
Sample	**Time of Sample**	**Cortisol (µg/dL*)**	**Log transformed Cortisol (µg/dL*)**
Sample 1	12:56 (1:03)	0.15 (0.12)	-0.82 (-0.92)
	[10:41-15:35]	[0.007-0.84]	[-2.15 to -0.08]
Sample 2	13:19 (1:04)	0.14 (0.12)	-0.85 (-0.92)
	[11:07- 15:56]	[0.006-0.88]	[-2.22 to -.06]
Sample 3	13:41 (1:05)	0.17 (0.16)	-0.77 (-0.79)
	[11:27-16:20]	[0.04-1.10]	[-1.39 to 0.04]
Sample 4	13:56 (1:04)	0.23 (0.25)	-0.64 (-0.60)
	[11:42-16:35]	[0.004-1.63]	[-2.40 to 0.21]
Sample 5	14:12 (1:03)	0.21 (0.20)	-0.68 (-0.70)
	[11:57-16:30]	[0.04-1.21]	[-1.39 to 0.08]
Sample 6	14:25 (1:05)	0.17 (0.16)	-0.77 (-0.80)
	[12:13-17:05]	[0.03-1.08]	[-1.52 to 0.03]

Note. To convert cortisol values from micrograms per deciliter to nanomoles per liter, multiply by 27.59

the diurnal variation in cortisol concentration, all protocols began between 11am and 2pm (M= 12:56pm, SD=1:03). Prior to arriving in the lab, adolescents and parents were instructed that the adolescents should not eat or drink at least one hour prior to arrival. Following consent/assent procedures, adolescents provided saliva sample 1. Samples were then collected after a 20-minute acclimation period (sample 2), 20 minutes after the start of the TSST-C (sample 3), 15 minutes after the end of the TSST-C (sample 4), 30 minutes after the end of the TSST-C (sample 5), and 45 minutes after the end of the TSST-C (sample 6). Given that saliva samples generally reflect cortisol concentration approximately 15-20 minutes prior to collection, these samples are intended to correspond with adolescents' cortisol at arrival (sample 1), baseline (sample 2), response to stressors (samples 3 and 4) and recovery from the TSST-C protocol (samples 5 and 6). Samples were stored in a -20 C freezer at the University of Delaware prior to assay for cortisol content. Samples were processed using enzyme linked immunosorbent assay (ELISA) procedures on-site by a trained technician. All samples from a single participant were processed, in duplicate, on the same tray along with a set of control samples.

Cortisol data were prepared for analysis using methods outlined in previous studies. There were no values in this sample that were biologically implausible (cortisol concentration >2.0 μg/dL). There were 9 values that were more than four standard deviations above the mean. There is precedent for retaining these values in analyses to account for natural variations in cortisol reactivity (Perry et al., 2022). Cortisol values that were below the detectable limit (1 value) were replaced with the .004 μg/dL, the lower-level sensitivity of the assay. Missing values (2 values) were replaced by averaging

the values of the samples collected immediately before and after the missing values (Perry et al., 2020). Finally, cortisol values were log transformed to account for the positive skew of the data.

To calculate cortisol reactivity, area under the curve with respect to increase (AUCi) was calculated (Perry et al., 2022; Pruessner et al., 2003). This formula captures change in cortisol over the course of the TSST-C protocol. Sample 1 was not used to calculate AUCi, given that this sample is a measure of cortisol response to arrival in the lab. Thus, AUCi was calculated for the area under the curve created by graphing the values of samples 2 through 6. The method for calculating the AUCi is based on the trapezoid formula. Trapezoids are comprised of a series of triangles and rectangles; summing the areas of these shapes allows for the computation of the area under the curve (*see Pruessner et al. (2003) for a detailed explanation of the formula)*. Of note, this calculation did not include the area below the baseline of the curve. Higher AUCi values represent a greater cortisol reactivity to the TSST-C protocol.

Parent-Adolescent Relationship Quality

Adolescents completed the Inventory of Parent and Peer Attachment-Revised (IPPA-R; Gullone & Robinson, 2005) at age 13. This measure assesses adolescent attachment to their best friend and primary caregiver. The parental attachment subscale was employed as a measure of parent-adolescent relationship quality. The IPPA-R is an assessment that has shown both concurrent and predictive validity and evaluates adolescents' trust in, communication with, and (inversely) anger/alienation from their parent. There are 28 items on the IPPA-R, with response items ranging from 1 (never

true) to 3 (always true). The IPPA-R has been shown to have an adequate internal consistency (Gullone & Robinson, 2005). Items on the anger/alienation subscale were reverse scored and an average IPPA-R score was calculated across all parental attachment scales, with a higher score indicative of higher quality parent-adolescent relationship.

Adolescent Mental Health

The Screen for Child Anxiety Related Emotional Disorders (SCARED), a self-report screening measure, was completed by adolescent participants during their 14-year visit. The SCARED screens for common anxiety disorders in children and adolescents such as separation anxiety disorder, panic disorder, school avoidance, general anxiety disorder, and social phobia. The SCARED has 41 items, with participants reporting on their functioning using response options 0 (not true or hardly ever true), 1 (somewhat true or sometimes true) or 2 (very true or often true). The SCARED has shown good internal consistency (Birmaher et al., 1999). A total score of all items was used as a measure of adolescent anxiety, with higher scores indicating more endorsement of anxiety symptoms.

Potential Covariates and Confounding Variables

Sociodemographic Interview. Parents completed interviews that provide information on the adolescent's age, sex, and race and/or ethnicity. In addition, parents reported on family-level socioeconomic factors. A composite score was calculated by taking the sum of 4 dichotomized socioeconomic indicators: *parental education level* (0=did not finish high school), *employment* (0=unemployed), *financial support from a significant other* (0=no additional support) and *public assistance receipt* (0=received

public assistance). Socioeconomic scores ranged from 0 – 4, with higher scores indicating higher socioeconomic status.

Pubertal Development. Adolescents completed the Pubertal Development Scale (PDS; Petersen et al., 1988). The PDS has been used widely as a brief, non-invasive measure of pubertal status. Adolescents reported on items that cover developmental changes associated with puberty such as body hair growth, changes in skin, voice (males only), breast development and the onset of menses (females only). Responses range from 1 (not started yet) to 4 (seems complete); scores were averaged to create a score for pubertal status.

COVID-19 pandemic. Data for the present study were collected during the COVID-19 pandemic, which led to worldwide shutdowns of schools, business and non-essential sectors starting in March 2020. Given the stress associated with this transition, study variables were assessed for differences in the values of data collected prior to and after March 2020.

Data Analytic Plan

All study analyses were carried out using SPSS, version 28 (IBM Corp, 2021). Preliminary analyses included assessing variables of interest for differences related to sociodemographic factors. The following primary analyses were run to explore each of the present study aims:

Aim 1: Determine the extent to which neighborhood disadvantage is associated with cortisol reactivity in adolescents. To examine the extent to which neighborhood disadvantage is associated with cortisol reactivity to acute stress, a series of multivariate

regression analyses were conducted. Separate regression analyses were run to examine the association between neighborhood factors (i.e., rates of violent and drug crimes, mean ratings of neighborhood litter, and neighborhood-level poverty) and adolescent cortisol reactivity.

Aim 2: Examine moderating effects of adolescent sex and parent-adolescent relationship quality on the association between neighborhood disadvantage and cortisol reactivity. To examine the moderating effect of adolescent sex and parent-adolescent relationship quality on the association between each neighborhood and cortisol reactivity, PROCESS macro in SPSS (Hayes, 2013) was employed. Separate regression analyses were conducted to examine whether sex or relationship quality emerged as moderators of the association between each of the neighborhood factors and cortisol regulation.

Aim 3: Examine whether cortisol reactivity mediates the association between observed neighborhood disadvantage and adolescent mental health. To determine whether cortisol reactivity to the TSST-C mediates the association between neighborhood disadvantage and adolescent mental health outcomes, a series of regression pathways were modeled through PROCESS macro in SPSS (Hayes, 2013). The association between neighborhood disadvantage and cortisol reactivity, as well as between cortisol reactivity and adolescent anxiety, was examined. In addition, the association between neighborhood disadvantage at age 10 and adolescent anxiety at age 14 was examined to test the total, direct and indirect effects of the mediation pathway (i.e., neighborhood disadvantage on adolescent anxiety via cortisol reactivity).

Examining the impact of family-level adversity. There are a number of factors that influence family decisions to move to (and remain in) a particular neighborhood, including family relationships, income, social bonds, educational opportunities, etc. Given that these factors can also influence health outcomes, it is important to account for family-level variables to avoid overstating neighborhood influence. In the present study, separate models were run with family-level SES included to determine whether the inclusion of family-level adversity influenced study findings.

Chapter 3

RESULTS

Preliminary Analyses

Covariate selection. Data on several potential covariates and confounding variables were collected. Descriptive statistics can be found in Table 1 and Table 3 displays the zero order correlations among study variables. Prior literature suggested that factors that influence cortisol reactivity, such as pubertal development (Doom et al., 2015; Gunnar et al., 2019), adolescent sex (Hollanders et al., 2017), and time of sample collection (Keil, 2012) should be considered as in covariates in models predicting this outcome. In the present sample, there were no differences in cortisol reactivity based on sex ($t(79) = -0.611$, $p = 0.543$), whether the data were collected during or prior to the onset of the COVID-19 pandemic ($t(79) = -0.354$, $p = 0.724$), or parenting intervention assigned in infancy ($t(79) = -1.288$, $p = 0.202$). In addition, there were no significant associations between cortisol reactivity to acute stress and pubertal development ($r(75) = -0.191$, $p = .100$), child age ($r(81) = 0.118$, $p = 0.294$), time lapsed between wake-up and the start of the TSST-C protocol ($r(73) = 0.094$, $p = .431$), and timing of saliva sample collection ($r(81) = 0.046$, $p = 0.648$). These variables were included in each model and presented as non-significant predictors. As such, these variables were removed from the model for parsimony.

Table 3 Intercorrelations Between Study Variables

Study Variables	1	2	3	4	5	6	7	8	9	10
Cortisol reactivity										
Pubertal Status	-0.19									
Time of saliva sampling	0.05	-0.19								
Time since waking	0.09	0.19	0.72**							
Child Age	0.12	0.33**	0.21	0.23						
Neighborhood Poverty Rate	-0.25*	0.18	-0.07	-0.11	0.09					
Litter Rating	0.25*	-0.16	0.05	0.02	-0.01	0.36**				
Crime Rate	0.22*	-0.07	-0.13	0.07	0.03	-0.26*	-0.22*			
Self-reported anxiety	-0.07	0.19	-0.16	-0.12	-0.06	0.31**	0.11	-0.160		
Socioeconomic composite	0.24*	0.06	0.00	0.08	0.18	-0.03	0.15	0.064	-0.028	
Relationship Quality	0.17	-0.18	-0.02	0.00	0.03	-0.07	0.14	0.137	-0.084	0.180

* $p < 0.05$
** $p < 0.01$

There were no differences in self-reported anxiety symptoms based on whether the data were collected during or prior to the COVID-19 pandemic ($t(70) = -1.495$, $p = 0.139$) or parenting intervention assignment ($t(70) = 0.321$, $p = 0.749$). There were also no significant associations between self-reported anxiety symptoms and pubertal status ($r(68) = 0.185$, $p = 0.137$), family-level SES ($r(70) = -0.022$, $p = 0.854$), and child age ($r(75) = -0.059$, $p = 0.621$). As such, these variables were not included in analyses with anxiety as an outcome. However, males reported fewer anxiety symptoms (M = 21.432, SD = 15.19) than females (M = 29.514, SD = 15.65) ($t(70) = 2.302$, $p = .024$). Given that prior literature has shown differences in anxiety outcomes for males and females (Perry et al., 2022), adolescent sex was included as a covariate in analyses with anxiety as an outcome.

Of note, 45 (55.6%) of participants moved to new addresses between 10-year and 13-year follow-up visits. There were no differences in neighborhood poverty ($t(78) = 0.037$, $p = 0.971$), neighborhood crime ($t(79) = -0.597$, $p = 0.552$), neighborhood disorder ($t(79) = 0.663$, $p = 0.509$), cortisol reactivity ($t(79) = -1.392$, $p = 0.168$) or anxiety symptoms ($t(70) = -0.501$, $p = 0.618$) for participants who moved as compared to participants who did not move.

Primary Analyses

Aim 1. Direct effects of neighborhood factors on cortisol reactivity

Neighborhood-level crime was associated with cortisol reactivity to acute stress ($\beta = 0.220$, $p = .049$; $R^2 = 0.048$, F (1,79) = 4.005, p=0.049). Adolescents who lived in neighborhoods characterized by more severe crimes at age 10 exhibited a more blunted

cortisol response at age 13, as compared to adolescents who lived in neighborhoods with less severe crime. Neighborhood-level poverty at age 10 was also significantly inversely associated with cortisol reactivity to acute stress (β = -0.247, p = .027) at age 13 (R^2= 0.061, F (1, 78) = 5.059, p=0.027). Adolescents who lived in neighborhoods with a higher poverty rate at age 10 exhibited a more blunted cortisol response at age 13, as compared to adolescents who lived in a neighborhood with lower levels of poverty. Mean ratings of neighborhood disorder were positively associated with cortisol reactivity to acute stress (β = 0.246, p = 0.027; F (1,79) = 5.097, p=0.027). Adolescents living in neighborhoods with higher ratings of neighborhood disorder at age 10 were found to have higher cortisol reactivity to stress at age 13 than adolescents who lived in neighborhoods with lower ratings of disorder. Model results are displayed in Table 4.

Aim 2. Moderation analyses

Aim 2a, Adolescent sex. The association between neighborhood crime and cortisol reactivity was moderated by adolescent sex (b = 0.001, p = .040), such that the association between neighborhood crime and cortisol reactivity was attenuated for girls as compared to boys (R^2= 0.100, F (3, 77)=2.868, p=0.042). This interaction was probed and displayed in Figure 2. However, adolescent sex did not emerge as a significant moderator of the association between neighborhood disorder and cortisol reactivity (b = 0.193, p = .250; F (3, 77)=2.219, p=0.093). Similarly, the association between neighborhood poverty and cortisol reactivity was not significantly moderated by adolescent sex (b = 0.002, p = .679; F (3, 76)=1.746, p=0.165). Model results are displayed in Table 5.

Aim 2b, Parent-adolescent relationship quality. The association between neighborhood litter and cortisol reactivity was moderated by adolescent self-reported relationship quality (b = 0.271, p = .026). This interaction was probed by plotting values that are 1.5 standard deviations above and below the mean attachment value (Figure 3). When adolescents rated their relationship with their caregivers as low or moderate quality, the association between neighborhood litter and cortisol reactivity was non-significant. However, when adolescents reported a high quality relationship with their parent, there was a significant, positive association between neighborhood litter and cortisol reactivity (R^2= 0.138, F (3, 77)= 4.126, p=0.009). Relationship quality was not a significant moderator of the association between neighborhood crime and cortisol reactivity (b = 0.000, p = .805; F (3, 77)= 1.934, p=0.131). In addition, the association between neighborhood poverty and cortisol reactivity was not significantly moderated by parent-adolescent t (b= -0.002, p = .410; F (3, 76)= 2.681, p=0.053). Model results are displayed in Table 6.

Table 4 Regression Analyses: Direct Effects on Cortisol Reactivity

	R^2	Beta	SE	p	C.I. lower	C.I. upper
Neighborhood Poverty	***0.061***			***0.027***		
Constant			0.066	<0.001	0.140	0.404
Neighborhood Poverty		-0.247	0.002	0.027	-0.008	0.000
Neighborhood Crime	***0.048***			***0.049***		
Constant			0.102	0.550	-0.264	0.141
Neighborhood Crime		0.220	0.000	0.049	0.00	0.001
Neighborhood Disorder	***0.061***			***0.027***		
Constant			0.142	0.211	-0.461	0.104
Neighborhood Disorder		0.246	0.082	0.027	0.022	0.350

Aim 3. Mediation analyses

Neighborhood-level poverty was significantly associated with adolescent self-reported anxiety symptoms (β = 0.301, p = 0.009), controlling for child sex (R^2= 0.157, F (2, 68) = 6.341, p=0.003). Adolescents who lived in neighborhoods with higher poverty rate at age 10 reported experiencing more anxiety symptoms at age 14, as compared to adolescents who lived in a neighborhood with lower rates of poverty. Mean ratings of neighborhood litter were not associated with adolescent self-reported anxiety symptoms (β = 0.129, p = 0.268), controlling for child sex (F (2, 69) = 3.283, p=0.043). Similarly, neighborhood-level crime was not associated with adolescent self-reported anxiety symptoms (β = -0.126, p = 0.283), controlling for child sex (F (2, 69) = 3.242, p=0.045). In addition, cortisol reactivity was not significantly associated with adolescent self-reported anxiety symptoms (β = -0.056, p = 0.630), controlling for child sex (F (2, 69) = 2.738, p=0.072). Given that there was no significant association between cortisol reactivity and self-reported anxiety symptoms, cortisol reactivity was not examined as a mediator of the association between neighborhood factors and anxiety.

Examining the impact of family-level adversity

When family-level adversity was included in the model, findings remained largely unchanged. The direct effect of neighborhood level poverty (β = -0.241, p = .028; R^2= 0.119, F (2,77) = 5.124, p=0.008), crime (β = 0.217, p = .049; R^2= 0.100, F (2,77) = 4.435, p=0.015)), and disorder (β = 0.210, p = 0.058; F (2, 77) = 4.272, p=0.017)

Figure 2 Simple Slopes for the Association Between Neighborhood Crime and Cortisol Reactivity Based on Sex

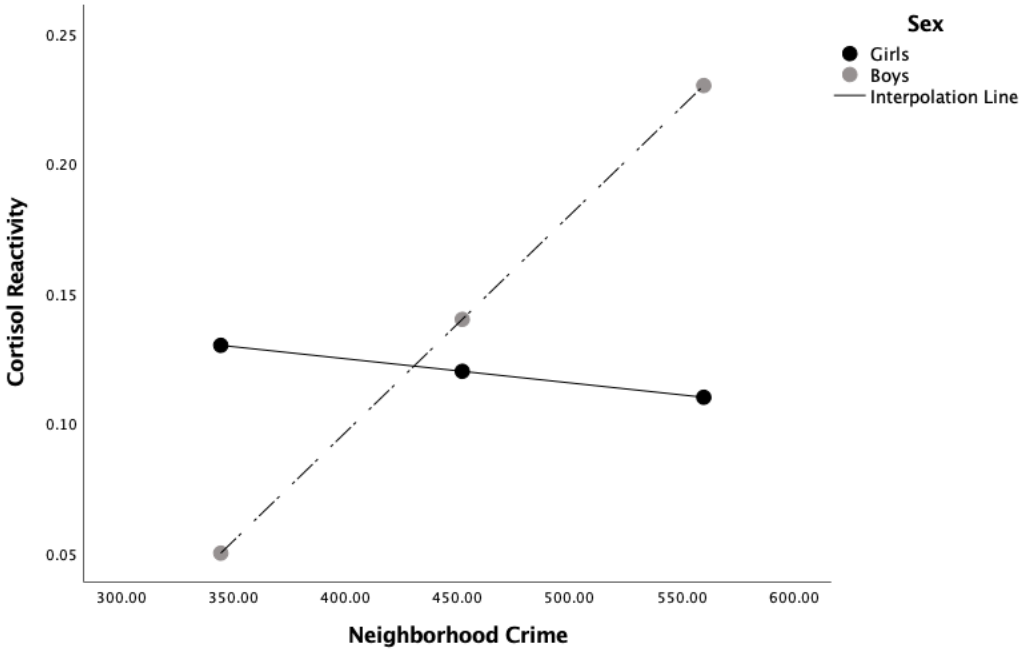
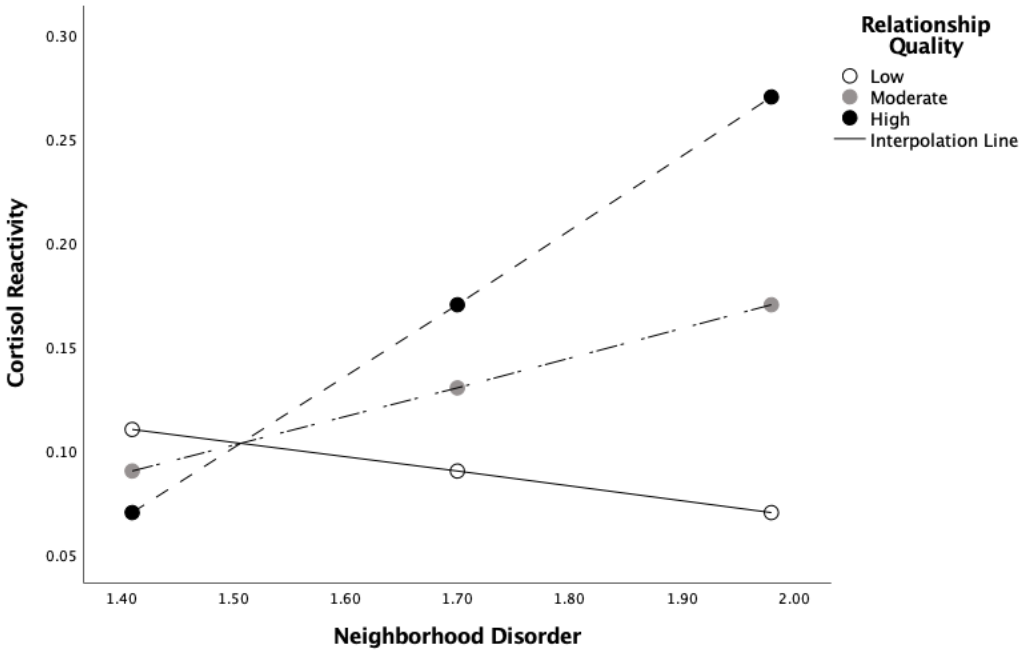


Table 5 Moderation Analyses: Association Between Neighborhood Factors and Cortisol Reactivity Based on Adolescent Sex

	R^2	*b*	SE	p	C.I. lower	C.I. upper
Poverty	***0.06***			***0.16***		
Constant		0.30	0.11	0.01	0.08	0.51
Neighborhood Poverty		-0.03	0.00	0.09	-0.01	0.00
Sex		-0.40	0.14	0.78	-0.31	0.24
Neighborhood Poverty X Sex		0.00	0.00	0.68	-0.01	0.01
Neighborhood Crime	***0.10***			***0.04***		
Constant		0.16	0.15	0.29	-0.13	0.45
Neighborhood Crime		*0.00*	0.00	0.80	0.00	0.00
Sex		-0.40	0.20	0.05	-0.80	0.01
Neighborhood Crime X Sex		0.00	0.00	0.04	0.00	0.00
Disorder	***0.08***			***0.09***		
Constant		-0.01	0.21	0.96	-0.43	0.40
Neighborhood Disorder		0.08	0.12	0.52	-0.16	0.32
Sex		-0.30	0.29	0.29	-0.87	0.27
Neighborhood Disorder X Sex		0.19	0.17	0.25	-0.14	0.52

Figure 3 Simple Slopes for the Association Between Neighborhood Disorder and Cortisol Reactivity at Values of Relationship Quality



Note. Low: 1 standard deviation below the mean value of parent-adolescent relationship quality; Moderate: mean value of parent-adolescent relationship quality; High: 1 standard deviation above the mean value of parent-adolescent relationship quality.

Table 6 Moderation Analyses: Association Between Neighborhood Factors and Cortisol Reactivity Based on Relationship Quality

	R^2	*b*	SE	p	C.I. lower	C.I. upper
Poverty	***0.10***			***0.05***		
Constant		-0.21	0.38	0.59	-0.97	0.56
Neighborhood Poverty		0.00	0.03	0.65	-0.02	0.03
Relationship Quality		0.12	0.09	0.21	-0.07	0.31
Neighborhood Poverty X Relationship Quality		0.00	0.00	0.41	-0.01	0.00
Crime	***0.07***			***0.13***		
Constant		-0.34	0.55	0.54	-1.43	0.76
Neighborhood Crime		0.00	0.00	0.58	0.00	0.00
Relationship Quality		0.08	0.14	0.59	-0.20	0.35
Neighborhood Crime X Relationship Quality		0.00	0.00	0.81	0.00	0.00
Disorder	***0.14***			***0.01***		
Constant		1.47	0.80	0.07	-0.12	3.06
Neighborhood Disorder		-0.90	0.48	0.06	-1.86	0.05
Relationship Quality		-0.41	0.20	0.04	-0.81	-0.01
Neighborhood Disorder X Relationship Quality		0.27	0.12	0.03	0.03	0.51

on adolescent cortisol reactivity remained significant. In addition, adolescent sex was a significant moderator (β = 0.001, p = .021; R^2= 0.167, F (4, 75)=5, p=0.008) of the association between neighborhood crime and cortisol reactivity. Moreover, the association between neighborhood disorder and cortisol reactivity was significantly moderated by parent-adolescent relationships (β = 0.261, p = .031; F (4, 75)= 3.755, p=0.008). The association between neighborhood poverty and adolescent anxiety symptoms also remained significant (β = 0.280, p = 0.015; R^2= 0.140, F (3,69) = 3.740, p=0.015). The association between cortisol reactivity and anxiety symptoms was not significant (β = 0.055, p= 0.657). As such, the indirect effect of neighborhood poverty on adolescent self-reported anxiety symptoms via cortisol reactivity was non-significant (β = -0.014, CI: -0.091, p= 0.055) with family SES included in the model.

Chapter 4

DISCUSSION

Prior research has provided evidence for the association between neighborhood disadvantage and mental health concerns for adolescents. However, the mechanisms underlying this association have not been made clear. Cortisol regulation has been proposed as a potential mediator, given that cortisol reactivity has been found to be associated with both neighborhood quality and psychopathology. In the present study, GIS-assessed neighborhood factors (i.e., poverty, crime severity, and disorder) were explored as predictors of cortisol reactivity and self-reported anxiety symptoms in adolescence. In addition, adolescent sex and parent-adolescent relationship quality were explored as moderators of this association. Cortisol reactivity was also explored as a mediator of the association between neighborhood factors and anxiety symptoms. Understanding how these neighborhood factors influence adolescent development has important implications for the development and implementation of interventions and policies to support healthy adolescent development.

Neighborhood Disadvantage on Cortisol Reactivity

Neighborhood poverty. Present study findings suggest that adolescents who live in neighborhoods with higher poverty rates have lower cortisol reactivity than adolescents who live in neighborhoods with lower poverty rates. This finding is consistent with prior literature that focuses on the impact of neighborhood-level adversity on adolescent

cortisol regulation, in which higher levels of adversity are associated with blunted cortisol reactivity. This work suggests that neighborhood poverty is an important aspect of the neighborhood ecology that impacts adolescent neurobiology. Of note, this finding differs from previous studies that examine neighborhood SES, which found that low neighborhood disadvantage is associated with elevated cortisol reactivity (Hackman et al., 2012; Rudolph et al., 2014). These disparate findings may be explained by differences in the conceptualization and measure of neighborhood-level economic adversity. The studies examining neighborhood-level SES included factors such as education, occupational prestige, racial composition, and percentage of female-headed households, whereas the present study examined poverty (i.e., the percentage of people with incomes below the poverty line) only. There are studies that suggest that poverty and SES are unique predictors of adolescent outcomes. For example, Santiago et al. (2011) explored the impact of SES and income on internalizing concerns. They found that income was negatively associated with internalizing concerns, whereas SES was positively associated with internalizing concerns (Santiago et al., 2011). These seemingly contradictory findings may arise due to the potential differences in the types and chronicity of the stress associated with each predictor. This underlines the importance of further research into understanding the unique contributions of various economic factors on adolescent outcomes.

Neighborhood crime. Neighborhood crime was found to have a significant negative association with cortisol reactivity. This finding is consistent with prior research on neighborhood crime and cortisol regulation (Joos et al., 2019; Theall et al., 2017).

Neighborhood crime poses a significant threat to the personhood of young people. As adolescents, youth are in the process of negotiating independence from their parents, which often includes spending more time in other aspects of their context, including their neighborhood. This added exposure makes adolescence a period when youth are at an increased risk for susceptibility to the adversity present in the neighborhood environment.

When including sex as a moderator in the association between neighborhood crime and cortisol reactivity, the significant negative association stands for boys, but not girls. This finding is also consistent with a wealth of neighborhood research that explores differential effects by sex (Aiyer et al., 2014; Gaylord-Harden et al., 2011; Hackman et al., 2012). There is research that suggests that boys may be victimized by and witness more violence in the community; it may be the case that this elevated exposure to violence creates a context of stress for boys that contributes to cortisol dysregulation. It should be noted that the present study employed objective measures of neighborhood crime, which only include crimes that are reported to the police. While boys are more likely to be exposed to crimes, it is also the case that crimes that disproportionally impact women and girls (e.g., rape and sexual assault) are under reported (Thompson & Tapp, 2022). Future studies may also benefit from research methods that can account for the sex-based gap in crimes reported. In addition, sex (i.e., biological factors) and gender (i.e., psychosocial, environmental and cultural factors) are related, yet distinct multidimensional constructs (Bates et al., 2022). The present study used a measure of sex assigned at birth, based on parent report. Future studies may benefit from understanding

how gender, including genders outside of the binary and self-reported gender, influences the association between neighborhood disadvantage and cortisol reactivity.

Neighborhood disorder. Adolescents who live in neighborhoods characterized by high ratings of disorder have heightened cortisol reactivity, as compared to adolescents who live in neighborhoods with lower ratings of disorder. Moreover, there was a significant moderation of this association by adolescent-reported parental attachment quality. For adolescents who rated their attachment to their parent as moderate to high quality, there was a significant positive association between cortisol reactivity and neighborhood disorder; however, there was no significant association between disorder and cortisol reactivity in adolescents with a low-quality relationship with their parents. This finding was unexpected, as the present study hypotheses posited that neighborhood disorder would be negatively associated with cortisol reactivity and that high quality relationships with their parents would buffer adolescents from the effects of the neighborhood. The present study is the first to my knowledge to investigate the association between neighborhood disorder and cortisol reactivity in adolescents. As such, study hypotheses were informed by the previous literature on neighborhood adversity and cortisol reactivity, which suggest a negative association between the variables. Given that experiences of adversity have been found to be associated with both elevated and blunted cortisol reactivity, it is possible that this finding highlights the diversity of ways in which experiences of neighborhood adversity influence adolescent neurobiological outcomes. Given that adverse factors, such as low neighborhood SES, have been found to be associated with elevated cortisol reactivity in prior studies, it may

be the case that neighborhood disorder has a similar effect on this outcome in adolescence.

Another explanation for these findings is the truncated range of the neighborhood disorder variable. Many of the participants in the study experienced a neighborhood with relatively low ratings of disorder, with a mean value of disorder indicative of a neighborhood with litter that can be cleaned up quickly by one person. Based on the hypocortisolism theory put forth by Fries et al., blunted cortisol is the result of repeated activation of the cortisol stress response following chronic experiences with adversity (Fries et al., 2005). It is possible that the level of disorder experienced by the participants in the present study may not have risen to the level of adversity necessary to produce blunted cortisol reactivity. In addition, there are a number of other metrics of neighborhood disorder such as the presence of dilapidated buildings and lots, abandoned cars, and vandalism. Given that this is the first study to investigate the association between neighborhood disorder and cortisol reactivity in adolescence, studying the impact of a variety of disorder measures will be important to get a full understanding of the association between these variables. It was also unexpected that a moderate to high quality parenting relationship would be associated with a significant positive association between neighborhood disorder. It was hypothesized that high quality parenting may buffer adolescents from the stress associated with the disorder, resulting in a null or attenuated association between disorder and cortisol reactivity. Based on the present study findings, it appears that moderate to high quality parenting relationships may instead preserve the function of the cortisol stress response, even in adverse conditions

such as high neighborhood disorder. As such, adolescents with higher quality relationships may have cortisol reactivity patterns that are associated with their neighborhood quality, for better or worse.

Cortisol Reactivity as a Potential Mediator of the Neighborhood Disadvantage on Anxiety

Neighborhood poverty had a significant positive association with adolescent self-reported anxiety. This finding is consistent with the previous literature examining the association between neighborhood factors and youth mental health outcomes. Unexpectedly, neighborhood crime and disorder were not found to be significantly associated with anxiety in the present study. Current research recommendations (Leventhal, 2018; Sampson et al., 2002) suggest that the inclusion of moderating variables may help to shed light on the impact of neighborhood factors on the functioning of its inhabitants. It is possible that the exclusion of moderators from the mediator analyses may have contributed to the unexpected null findings. In addition to the present study moderators (i.e., adolescent sex and parent-adolescent relationship quality), factors such as race/ethnicity (Dulin-Keita et al., 2012; Humphrey & Root, 2017), may also be included in future studies as they have been found to alter the association between neighborhood adversity and mental health outcomes.

Also contrary to study hypotheses, cortisol reactivity was not significantly associated with self-reported anxiety symptoms. Given this non-significant association, cortisol reactivity did not emerge as a mediator of the association between neighborhood disadvantage and anxiety symptoms in adolescents. Even though the association between

cortisol reactivity and mental health outcomes is supported in the literature, the mechanisms by which these variables influence one another have not been made clear by current research. This suggests that more studies are necessary to elucidate the links between cortisol regulation and mental health outcomes for youth. In addition to replicating the present study, it will be important to explore the impact of neighborhood factors on other common mental health concerns, such as depression and externalizing concerns.

Implications

These findings highlight the importance of research that explores the unique associations between neighborhood factors, neurobiological regulation, and adolescent mental health. In addition to advancing our knowledge of adolescent development in the context of neighborhood stress, the present study also provides important information that can be leveraged to help develop intervention and prevention strategies aimed at preventing maladaptive outcomes for children living in disadvantaged neighborhoods.

Clinical Implications

The present study adds to the existing literature base that highlights the associations between neighborhood quality and mental health outcomes. It would benefit psychologists, social workers, therapists, and other mental health providers to consider the impact of the neighborhood environment when determining factors that may contribute to the onset and exacerbation of mental health concerns. Moreover, when selecting evidence-based interventions for adolescents living in disadvantaged neighborhoods, prioritizing those that have been shown to improve cortisol regulation,

such as mindfulness-based and emotion regulation interventions (McCraty et al., 1998; Wadsworth et al., 2022) may help to alleviate and prevent adverse outcomes associated with neighborhood disadvantage. In addition to interventions geared towards adolescents, enhancing parenting has also been found to be protective for youth outcomes. High quality parenting experiences have been found to be an important buffer to the effects of neighborhood disadvantage and have been found to regulate cortisol following stressful experiences. As such, interventions and strategies that strengthen the quality of parent-adolescent relationships may also be important to consider for treatment.

Implications For Neighborhood Policy

It appears that solely moving families to new neighborhoods is not enough to prevent maladaptive outcomes for youth. In experimental studies where youth were moved to less disadvantaged neighborhoods, boys in particular did not show improvements in mental health outcomes (Gennetian et al., 2012). This calls for efforts that allow for youth to be supported in familiar environments. A recent report out of the Brookings Institute found that increases in factors such as local economic growth, presence of community building organizations, homeownership, and housing density were associated with significant decreases in neighborhood poverty rates without the displacement of inhabitants (Acharya & Morris, 2022). This suggests that efforts to reinvest into disadvantaged communities may be a direction that helps to influence adolescent outcomes on a larger scale. There are several metrics of neighborhood advantage that have been linked to positive benefits for youth well-being that could be targets for reinvestment efforts. In a sample of adults, an intervention that aimed to reduce neighborhood disorder by

transforming littered, vacant lots into green space improved mental health in the intervention group, as compared to the control group (South et al., 2018). Controlling for urbanicity and sociodemographic factors, exposure to neighborhood green space in youth was associated with a lower risk of developing a mental health concern in adulthood (Engemann et al., 2019). Community strengths, such as social cohesion (i.e., connection and solidarity among community inhabitants), have also been found to have positive impacts on both cortisol regulation (Hajat et al., 2015) and mental health outcomes (Kingsbury et al., 2015). Moreover, studies show that increases in social cohesion have also been associated with reductions in neighborhood crime, including violent crime (Stuart & Taylor, 2021). These studies suggest that strengthening aspects of the neighborhood may have positive effects on neurobiological and mental health outcomes for youth.

Study Limitations and Strengths

Limitations. While the present study has important clinical and policy implications, it is important to note the limitations of the findings. First, the present study included a small sample of Black and Latine adolescents living in an urban environment. Moreover, this sample is primarily from a low SES background and has prior CPS involvement. As such, it is important to note that these findings may not generalize to other populations or other timepoints in development across the lifespan. Given that significant neighborhood effects tend to have a small effect size, it will be important to replicate study questions with a larger sample size to ensure adequate power to detect effects. In addition, area under the curve is an assessment of the full course of the cortisol response to acute stress,

including both reactivity and recovery in the calculation. It may be possible that disentangling the unique processes associated with the acute cortisol stress response (i.e., reactivity and recovery) may be important to understand how adverse experiences influence cortisol regulation. The present study used objective measures of the neighborhood environment, including neighborhood quality and boundaries. There is evidence to suggest that objective and subjective measures of the neighborhood factors have differential associations with physical and mental health outcomes (Zhang et al., 2019). Future studies may benefit from including subjective measures of the adolescent's experience of their neighborhood to understand the full scope of how neighborhood factors influence outcomes.

Strengths. Despite the limitations shared, the present study benefited from several methodological strengths. The present study examined the impact of objective neighborhood factors using GIS coded neighborhood boundaries that represent a spatial area centered on the participant's home. This smaller, person-centered study area may represent a more accurate picture of the adolescent's neighborhood context than the boundaries imposed by zip codes or census tracts. There are a variety of lab-based stress induction paradigms for youth and the present study's use of the TSST-C represents a strength. The TSST-C is a well-validated paradigm that has been shown to reliably evoke a stress response (Kudielka et al., 2004) in youth. In addition, the present study employed self-report measures of adolescent anxiety. Research shows that when measuring internalizing concerns, such as anxiety, adolescent-parent report agreement was low to moderate and youth tend to report more symptoms than their parents (Rappaport et al.,

2017). Given that internalizing concerns can be hard for parents to detect, having self-report may be more indicative of the concerns that adolescents are experiencing than relying on parent report.

Conclusion

Neighborhood conditions have been linked to the development of mental health conditions across the lifespan. Given that adolescence represents a window of vulnerability for the onset of psychopathology, it is important to understand the mechanisms by which this occurs. The present study highlighted the unique associations between various metrics of neighborhood disadvantage, cortisol reactivity, and adolescent anxiety symptoms. These differential findings support continued research in this area to fully understand the impact of neighborhood quality on adolescent neurobiology and mental health.

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Appendix

INSTITUTIONAL REVIEW BOARD APPROVALS

Institutional Review Board
210H Hullihen Hall
Newark, DE 19716
Phone: 302-831-2137
Fax: 302-831-2828

DATE:	February 7, 2020
TO:	Mary Dozier, PhD
FROM:	University of Delaware IRB
STUDY TITLE:	[547621-19] Intervening Early with Neglected Children: Key Middle Childhood Outcomes
SUBMISSION TYPE:	Continuing Review/Progress Report
ACTION:	APPROVED
APPROVAL DATE:	February 7, 2020
EXPIRATION DATE:	February 14, 2021
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category # *(8)*

Thank you for your Continuing Review/Progress Report submission to the University of Delaware Institutional Review Board (UD IRB). The UD IRB has reviewed and APPROVED the proposed research and submitted documents via Expedited Review in compliance with the pertinent federal regulations.

As the Principal Investigator for this study, you are responsible for and agree that:

- All research must be conducted in accordance with the protocol and all other study forms as approved in this submission. Any revisions to the approved study procedures or documents must be reviewed and approved by the IRB prior to their implementation. Please use the UD amendment form to request the review of any changes to approved study procedures or documents.
- Informed consent is a process that must allow prospective participants sufficient opportunity to discuss and consider whether to participate. IRB-approved and stamped consent documents must be used when enrolling participants and a written copy shall be given to the person signing the informed consent form.
- Unanticipated problems, serious adverse events involving risk to participants, and all non-compliance issues must be reported to this office in a timely fashion according with the UD requirements for reportable events. All sponsor reporting requirements must also be followed.

Oversight of this study by the UD IRB REQUIRES the submission of a CONTINUING REVIEW seeking the renewal of this IRB approval, which will expire on February 14, 2021. A continuing review/progress report form and up-to-date copies of the protocol form and all other approved study materials must be submitted to the UD IRB at least 45 days prior to the expiration date to allow for the required IRB review of that report.

If you have any questions, please contact the UD IRB Office at (302) 831-2137 or via email at hsrb-research@udel.edu. Please include the study title and reference number in all correspondence with this office.

Institutional Review Board
210H Hullihen Hall
Newark, DE 19716
Phone: 302-831-2137
Fax: 302-831-2828

DATE:	October 18, 2021
TO:	Mary Dozier, PhD
FROM:	University of Delaware IRB
STUDY TITLE:	[1437200-13] Intervening Early: Key Behavioral and Neurobiological Outcomes in Adolescence
SUBMISSION TYPE:	Amendment/Modification
ACTION:	APPROVED
APPROVAL DATE:	October 18, 2021
EXPIRATION DATE:	May 14, 2022
REVIEW TYPE:	Expedited Review
REVIEW CATEGORY:	Expedited review category per 45 CFR 46.110 (b)(1)(ii)

Thank you for your Amendment/Modification submission to the University of Delaware Institutional Review Board (UD IRB). The UD IRB has reviewed and APPROVED the proposed research and submitted documents via Expedited Review in compliance with the pertinent federal regulations.

As the Principal Investigator for this study, you are responsible for and agree that:

- All research must be conducted in accordance with the protocol and all other study forms as approved in this submission. Any revisions to the approved study procedures or documents must be reviewed and approved by the IRB prior to their implementation. Please use the UD amendment form to request the review of any changes to approved study procedures or documents.
- Informed consent is a process that must allow prospective participants sufficient opportunity to discuss and consider whether to participate. IRB-approved and stamped consent documents must be used when enrolling participants and a written copy shall be given to the person signing the informed consent form.
- Unanticipated problems, serious adverse events involving risk to participants, and all non-compliance issues must be reported to this office in a timely fashion according with the UD requirements for reportable events. All sponsor reporting requirements must also be followed.

Oversight of this study by the UD IRB REQUIRES the submission of a CONTINUING REVIEW seeking the renewal of this IRB approval, which will expire on May 14, 2022. A continuing review/progress report form and up-to-date copies of the protocol form and all other approved study materials must be submitted to the UD IRB at least 45 days prior to the expiration date to allow for the required IRB review of that report.

If you have any questions, please contact the UD IRB Office at (302) 831-2137 or via email at hsrb-research@udel.edu. Please include the study title and reference number in all correspondence with this office.