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Exposure to Community Violence as a Mechanism Linking Neighborhood Disadvantage to Amygdala Reactivity and the Protective Role of Parental Nurturance

Gabriela L. Suarez[1], S. Alexandra Burt[2], Arianna M. Gard[3], Kelly L. Klump[2], and Luke W. Hyde[1, 4]

[1] Department of Psychology, The University of Michigan
[2] Department of Psychology, Michigan State University
[3] Department of Psychology, University of Maryland
[4] Survey Research Center at the Institute for Social Research, The University of Michigan

Emerging literature links neighborhood disadvantage to altered neural function in regions supporting socioemotional and threat processing. Few studies, however, have examined the proximal mechanisms through which neighborhood disadvantage is associated with neural functioning. In a sample of 7- to 19-year-old twins recruited from disadvantaged neighborhoods (354 families, 708 twins; 54.5% boys; 78.5% White, 13.0% Black, 8.5% other racial/ethnic group membership), we found that exposure to community violence was related to increased amygdala reactivity during socioemotional processing and may be one mechanism linking neighborhood disadvantage to amygdala functioning. Importantly, parenting behavior appeared to modulate these effects, such that high parental nurturance buffered the effect of exposure to community violence on amygdala reactivity. These findings elucidate the potential impact of exposure to community violence on brain function and highlight the role parents can play in protecting youth from the neural effects of exposure to adversity.

Public Significance Statement

Although prior studies have primarily focused on family-level adversities, developmental researchers are now paying increased attention to the effect of neighborhood-level adversity on youth brain development. We find that increased exposure to community violence is related to heightened amygdala reactivity to threat and may be a mechanism explaining the link between neighborhood disadvantage and brain function in youth. Further, the study highlights that nurturing parenting can protect children from the risks posed by living in a disadvantaged and dangerous neighborhood.

Keywords: neighborhood disadvantage, community violence, parenting, amygdala reactivity

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Gabriela L. Suarez https://orcid.org/0000-0002-7220-5860
Luke W. Hyde https://orcid.org/0000-0002-5947-7896

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Correspondence concerning this article should be addressed to Luke W. Hyde, Department of Psychology, The University of Michigan, 2229 East Hall, 530 Church Street, Ann Arbor, MI 48109, United States. Email: lukehyde@umich.edu

In 2020, approximately 6.4 million children in the United States were living in neighborhoods with poverty rates of 30% or greater (The Annie E. Casey Foundation, 2021). Unfortunately, youth growing up in these disadvantaged neighborhoods are more likely to experience maladaptive outcomes, from psychiatric and behavioral problems to academic difficulties (Aneshensel & Sucoff, 1996; Kohen et al., 2008; Leventhal & Brooks-Gunn, 2000; Sastry, 2012; Xue et al., 2005). The high prevalence of neighborhood disadvantage and the maladaptive outcomes associated with it underscore the need to better understand how neighborhood disadvantage affects development, which can inform public policy to promote positive youth outcomes (National Academies of Sciences, Engineering, and Medicine, 2019). Although a large literature has established how exposure to neighborhood disadvantage predicts maladaptive academic, behavioral, and psychiatric outcomes, less is known about how neighborhood disadvantage "gets under the skin" to impact brain development.

Neighborhood disadvantage may influence development via the impact of stress on the structure and function of brain regions involved in socioemotional functioning, threat processing, and fear learning (Hyde et al., 2020). The amygdala, the hub of the stress response system, is highly sensitive to socioemotional faces, especially those signaling threat, uncertainty, or other salient information (Fusar-Poli et al., 2009; Shi et al., 2013; Tottenham & Sheridan, 2010). Adversity, including maltreatment, social deprivation, and poverty, has been linked to amygdala reactivity during socioemotional processing. For example, a meta-analysis found that maltreatment exposure (e.g., abuse, neglect) was associated with heightened amygdala reactivity during emotional face processing (e.g., fear, anger, neutral, sad) among youth (10–18 years) and adults (Hein & Monk, 2017). Previously institutionalized children (aged 9–10) also showed increased amygdala activity during an emotional faces go/no-go task, including fear and neutral facial expressions (Tottenham et al., 2011). Also, childhood poverty has been linked to greater amygdala reactivity in adulthood during the processing of threat-related emotional faces (e.g., fear) compared to happy faces (Javanbakht et al., 2015). In parallel, altered amygdala activation is associated with several related psychiatric outcomes, including depression and antisocial behavior (Etkin et al., 2004; Hyde et al., 2016; Monk, 2008). Though most studies have examined the impact of more proximal stressors (e.g., family poverty, harsh parenting, maltreatment) on amygdala function (Gard, Hein, et al., 2021; Hein & Monk, 2017; Javanbakht et al., 2015; Tottenham et al., 2011), recent work suggests that stressors in the child's broader context, especially neighborhood-level adversity, are also associated with amygdala structure and function (Gard et al., 2017; Gard, Maxwell, et al., 2021; Whittle et al., 2017). Moreover, these associations appear to persist even when accounting for family-level experiences and resources. Thus, these studies provocatively suggest that where a child lives can impact their developing brain (Hyde et al., 2022). Critically, however, these studies do not illuminate how living in a disadvantaged neighborhood acts to alter brain development.

Disadvantaged neighborhoods confer increased risks for children and adolescents beyond family-level factors by increasing their exposure to violent crime (Evans, 2004; Hyde et al., 2022). Concentrated neighborhood disadvantage undermines social and institutional controls of local crime and violence putting youth at increased risk for exposure (Morenoff et al., 2001; Sampson et al., 1997; Sampson & Groves, 1989). An alarming 68% of children in the United States have reported direct or indirect exposure to at least one form of violence within a year (Finkelhor et al., 2015), and youth growing up in disadvantaged neighborhoods have more than double the exposure to community violence (Stein et al., 2003). These high rates of violence exposure are troubling, particularly considering the link between exposure to community violence and multiple maladaptive outcomes for youth, including internalizing (e.g., posttraumatic stress disorder and anxiety) and externalizing problems (e.g., antisocial behavior and aggression) (Fowler et al., 2009; Mrug & Windle, 2010; Wilson et al., 2009; Zinzow et al., 2009). Research suggests that exposure to community violence is a consistent mechanism linking neighborhood disadvantage to maladaptive behavioral outcomes; however, few studies have examined whether exposure to community violence is related to amygdala reactivity during socioemotional processing (Aim 1) and no research has examined exposure to community violence as a mechanism linking neighborhood disadvantage to altered amygdala reactivity (Aim 2), primary aims of the current study.

The third core aim of the current study relates the fact that neither exposure to community violence nor neighborhood disadvantage predicts psychopathology or brain development for all youth. Many youth exhibit resilience in the face of adversity (Masten, 2001). What might account for their unexpectedly good outcomes? Parents play a critical role in promoting healthy development for youth in adverse contexts (Luthar, 2006). Aspects of parental nurturance, including warmth, involvement, and parental knowledge and monitoring may help youth avoid exposures to violence in the first place, and also, buffer the effects of violence exposure on mental health outcomes (Luthar & Goldstein, 2004). For example, studies find that youth from families with poor discipline, monitoring, and structure, and lower levels of emotional closeness, communication, and support were exposed to the highest levels of community violence (Gorman-Smith et al., 2004; Matjasko et al., 2013). In contrast, consistent parental monitoring over a 5-year period was associated with a steady decline in adolescent exposure to community violence in high poverty neighborhoods (Spano et al., 2011). Moreover, high levels of parental nurturance, including warmth, closeness, engagement, and support, mitigated the impact of violence exposure on adolescent internalizing and externalizing problems (Ozer et al., 2017); however, no study has examined whether parental nurturance buffers the effect of exposure to community violence on the brain. Numerous studies suggest that high-quality caregiving can exert powerful regulatory influences, including reducing stress, preventing the release of stress hormones, and modulating emotional reactivity and behavior (Caldji et al., 1998; Egliston & Rapee, 2007; Hostinar et al., 2014). Furthermore, the amygdala is part of a complex neural architecture involved in social buffering effects (Eisenberger, 2013), making the amygdala a likely candidate to observe potential parental buffering effects among youth exposed to community violence. Thus, our third aim was to examine whether greater parental nurturance (i.e., warmth, involvement) buffered the associations between neighborhood disadvantage and exposure to community violence, and exposure to community violence and amygdala reactivity.

In the current study, we examined pathways through which neighborhood disadvantage was associated with amygdala reactivity to socioemotional faces in a relatively large sample of youth (aged 7–19 years [94% of youth were age 10–17], $N = 708$ in 354 families), recruited from birth records from neighborhoods with above average levels of

disadvantage. First, we assessed whether exposure to community violence was associated with greater amygdala reactivity to threat (i.e., fearful and angry faces) as our primary aim. Additionally, since recent studies find that amygdala reactivity to neutral facial expressions can also be influenced by neighborhood-level adversities (Gard et al., 2017; Gard, Maxwell, et al., 2021), in exploratory analyses, we also examined associations between exposure to community violence and amygdala reactivity to ambiguity (i.e., neutral faces). Neutral faces can be perceived as hostile or threatening, particularly for individuals exposed to adversity (Gard et al., 2017; Marusak et al., 2017; Pollak et al., 2000). Second, we evaluated exposure to community violence as a potential mechanism linking neighborhood disadvantage to amygdala reactivity during socioemotional processing. Lastly, we examined whether parental nurturance moderated the associations between neighborhood disadvantage and exposure to community violence and violence exposure and amygdala reactivity. We examined these questions during late childhood and adolescence, a key period of brain development (Casey et al., 2019; Somerville et al., 2010) and one in which youth spend greater time in the neighborhood (Smetana et al., 2006). Finally, we controlled for family socioeconomic status (SES), to confirm that results were specific to neighborhood, rather than family-level resources and conducted sensitivity analyses in which we controlled for exposure to violence within the home to assess the specificity of exposure effects within the community. We hypothesized that (a) exposure to community violence would be associated with greater amygdala reactivity to threat, (b) neighborhood disadvantage would be indirectly associated with amygdala reactivity to threat through increased exposure to community violence, and (c) parental nurturance would moderate the pathways from neighborhood disadvantage to exposure to community violence and violence exposure to amygdala reactivity to threat. Lastly, we considered our examination of amygdala reactivity to ambiguity (i.e., neutral faces) to be exploratory and, thus, did not have a priori hypotheses for these analyses.

Method

Participants

Participants were part of the Michigan Twins Neurogenetics Study (MTwiNS), recruited from the Twin Study of Behavioral and Emotional Development—Child (TBED-C), a project within the broader Michigan State University Twin Registry (Burt & Klump, 2019). Using birth records, the TBED-C identified twin families living within 120 miles of East Lansing, Michigan, including urban (e.g., Detroit, Flint, and Lansing), suburban, and rural areas. The study included a population-based sample (528 twin families) with children aged 6–10 years, and an "at-risk" sample (502 twin families) from the same geographic region, but only recruited from neighborhoods with above average levels of poverty (>10.5% of families in the neighborhood living below the poverty line, the mean at study onset; Burt & Klump, 2019). In a follow-up neuroimaging study of the TBED-C, MTwiNS recruited families from the "at-risk" sample, as well as those in the population-based sample that would have met criteria for the at-risk sample (i.e., living in neighborhoods with above average levels of poverty). The current sample included 708 twins in 354 families (54.5% boys; 78.5% White, 13.0% Black, 8.5% other racial/ethnic group membership). Youth were between 7 and 19 years, though most of the sample was between 10 and 17 years ($M_{\text{age}} = 14.14$, $SD = 2.24$; 94.2% of the sample was between 10 and 17 years and 83.6% between 12 and 17 years; 48 twin pairs < 12 years; 10 twin pairs > 17 years; Figure S1 in the online supplemental materials). At the MTwiNS wave, 64.1% of twin families lived in neighborhoods with > 10.5% of families living below the poverty line ($M = 20\%$; ranged 0% to 77%). All participants met basic functional magnetic resonance imaging (fMRI) eligibility criteria, such as the absence of metal in their body and willingness to participate in the scanning session (i.e., 557 of 708 twins were eligible for scanning and agreed to scan; Table S1 in the online supplemental materials). Lastly, prior work evaluating power analyses and simulations for moderated mediation analyses suggest that sample sizes between 300 and 500 individuals have sufficient power to detect small effects (Preacher et al., 2007). Since our sample includes more than 300 families and well over 500 individuals, we should be sufficiently powered for the proposed analyses.

Procedure

Youth and their primary caregivers participated in a day-long visit to the University of Michigan (UM), including a 1-hr fMRI scan for each twin at the UM fMRI lab. Twins completed a mock scan and practice versions of the fMRI tasks. Youth were scanned using blood-oxygen-level-dependent (BOLD) fMRI. Families completed a battery of questionnaires, a demographic interview, and were provided lunch and compensated for their time. Twins provided assent and parents provided informed consent for themselves and their children. The study was approved by the UM Institutional Review Board.

Measures

Neighborhood Disadvantage

Neighborhood disadvantage was assessed using the Area Deprivation Index (ADI) at the census block group level (Kind et al., 2014), which measured concentrated neighborhood disadvantage via indicators of neighbors' education, employment, income, and poverty (e.g., home ownership rates, percentage of single-parent households, percentage of families living below the poverty line, percentage of those ≥ 16 years old unemployed). We used ADI scores from the 2015 American Community Survey 5-year estimate, which is a 5-year average of data obtained from 2011 to 2015. Higher ADI scores indicate higher levels of neighborhood disadvantage.

Exposure to Community Violence

Twins completed the child self-report version of the Screen for Adolescent Violence Exposure, assessing the severity of each twin's individual exposure to violence in their school or neighborhood in the past year (Flowers et al., 2000). We used the Indirect Violence frequency subscale for the current study (15 items; $\alpha = .86$), which contains items specifically related to exposure to community violence, including witnessing interpersonal violence (e.g., "Have you seen someone pull a gun on someone else?") or hearing about violent events (e.g., "Have you heard about someone getting badly beat up?"). We excluded one item from the original subscale, "I have seen a grownup hit a kid," as this item is not specifically related to community violence. Higher scores on the

Indirect Violence scale indicate more frequent exposure to violence in the community in the past year.

Parental Nurturance

Twin's perceptions of parenting were assessed using the Parental Environment Questionnaire, a 42-item inventory assessing five factorially derived aspects of the parent–child relationship (Elkins et al., 1997). For the present study, we used the Involvement subscale (12 items; $\alpha = .75$), which contains items assessing the extent to which the parent–child relationship is characterized by communication (e.g., "I talk about my concerns and my experiences with my parent"), closeness (e.g., "My parent and I do not do a lot of things together"), knowledge of the child's activities (e.g., "My parent doesn't know much about how I spend my time"), and support (e.g., "My parent comforts me when I am discouraged or have had a disappointment"). We focused on youth reports, which may be less influenced by social desirability bias, as parents are more motivated to report their parenting and parent–child relationship as more positive than it may be (Weis & Lovejoy, 2002). Higher scores on the Involvement subscale indicate greater twin-reported parental nurturance (i.e., closeness, communication, warmth, and support) within the parent–child relationship.

Socioemotional Face Processing fMRI Task

Amygdala reactivity was assessed using the socioemotional face matching paradigm, consisting of four perceptual face processing blocks interleaved with five sensorimotor control blocks (Hariri et al., 2002; Manuck et al., 2007; Suarez et al., 2022). Participants viewed a trio of faces and selected one of two faces (bottom) identical to a target face (top). Each face processing block included 18 images, balanced for sex and race, all derived from the NimStim standard set of facial affect pictures (Tottenham et al., 2009). Each face processing block consisted of a different emotional facial expression (i.e., anger, fear, happy, neutral), and participants were randomly assigned to one of four different block presentation orders. During the sensorimotor control blocks, participants viewed 12 trios of simple geometric shapes (circles, squares, and triangles) and selected one of two shapes (bottom) identical to a target shape (top). In the face processing blocks, each of the 18 face trios was presented for 2 s with a variable interstimulus interval of 2–6 s, used to minimize habituation and expectancy effects and maximize amygdala reactivity, for a total block length of 98 s. In the sensorimotor control blocks, each of the 12 shape trios was presented for 2 s followed by a fixation cross for 0.5 s, for a total block length of 30 s. An additional 4 s of crosshair presentation followed each block. Total task time was 578 s.

Covariates

Parents reported on their twin's race/ethnicity, gender (1 = *girls*, 0 = *boys*), and age. To control for race/ethnicity, a socially constructed category indexing unequal treatment, exposure, and opportunity in the United States, we coded: 0 = *Black, Asian American, Latino/a, Native American, and other* (i.e., identities most frequently marginalized in the United States and more likely to be exposed to discrimination and structural racism; Pager & Shepherd, 2008) and 1 = *White* (the largest single category). We also controlled for family-level socioeconomic context (family income, parent education) to assess whether findings were specific to neighborhood resources, rather than family resources. Family income was defined via primary caregiver reported annual household gross income including any outside additional sources of income (e.g., government assistance, child support). Income ranged from $4,999 or less (0.6%) to $90,000 or more (38%), and the mean annual household income was $60,000 to $69,999. Education was measured via the primary caregiver's highest level of education. The majority of primary caregivers completed some college (at least 1 year) or specialized training beyond high school (91%) and many were college graduates or had completed a graduate or professional degree (52%). Lastly, in sensitivity analyses, we included additional covariates, including quadratic age and pubertal status, measured using parent report on the Pubertal Development Scale (Carskadon & Acebo, 1993), as well as harsh and inconsistent parenting and interpartner violence. We measured harsh and inconsistent parenting using twin report on the Alabama Parenting Questionnaire (Essau et al., 2006; Frick, 1991). We calculated a mean score for harsh parenting using the six-item inconsistent discipline scale (e.g., "Your parents threaten to punish you and then do not do it") and one item of the corporal punishment scale (e.g., "Your parents yell or scream at you when you have done something wrong") (seven items total). We measured interpartner violence using primary caregiver report on the Conflict Tactics Scale (Straus, 1979; Straus et al., 1996). We calculated a mean score for interpartner violence using items from the violence/physical (i.e., the use of physical force against another person as a means of resolving the conflict) and verbal (i.e., the use of verbal and nonverbal acts, or the use of threats to hurt the other) aggression subscales.

fMRI Data Acquisition and Processing

Each participant was scanned with a general electric Discovery MR750 3T scanner located at the UM fMRI Laboratory (Suarez et al., 2022). To take advantage of improvements in magnetic resonance imaging data acquisition and harmonize our protocol with the adolescent brain cognitive development study (Casey et al., 2018), we altered our acquisition protocol after the first 140 families (i.e., 280 twins). For the first 140 families, one run of 298 volumes was collected for each participant with BOLD functional images acquired via an eight-channel head coil and a reverse spiral sequence (repetition time/echo time = 2,000/30 ms, flip angle = 90°, field of view = 22 cm), covering 43 interleaved oblique slices of 3 mm thickness. High-resolution, T1-weighted spoiled gradient recall images (156, 1-mm-thick slices) were aligned with the anterior commisure-posterior commisure plane, and later used during normalization of the functional images. For the subsequent 214 families (i.e., 428 twins), one run of 730 volumes was collected for each participant in which BOLD functional images were acquired with a 32-channel head coil and a gradient-echo sequence with multiband acquisition (repetition time/echo time = 800/30 ms, flip angle = 52°, field of view = 21.6 cm), covering 742 interleaved axial slices of 2.4-mm thickness. High-resolution, T1-weighted spoiled gradient recall images (208, 1-mm-thick slices) were aligned with the anterior commisure-posterior commisure plane and used during normalization of the functional images. For both acquisition sequences, BOLD functional images encompassed the entire cerebrum and most of the cerebellum to maximize coverage of limbic structures.

As previously described in this sample (Suarez et al., 2022), functional data for both acquisition sequences were preprocessed and analyzed using Statistical Parametric Mapping Version 12 (SPM12;

Wellcome Trust Centre, London, United Kingdom), with postprocessing control for artifacts using the Artifact Detection Tools (ART) software package (https://www.nitrc.org/projects/artifact_detect/). Furthermore, participants with low amygdala coverage (<90% signal coverage), low task performance (<70% accuracy), and >5% motion outliers identified using ART were excluded from analyses (Table S1 in the online supplemental materials). Twin characteristics, including gender, race/ethnicity, and age, were associated with missing data on one or more measure; thus, these were included as covariates in all models examined in SPM12 and in the path models in Mplus (see the online supplemental materials).

Experimental Design and Statistical Analyses

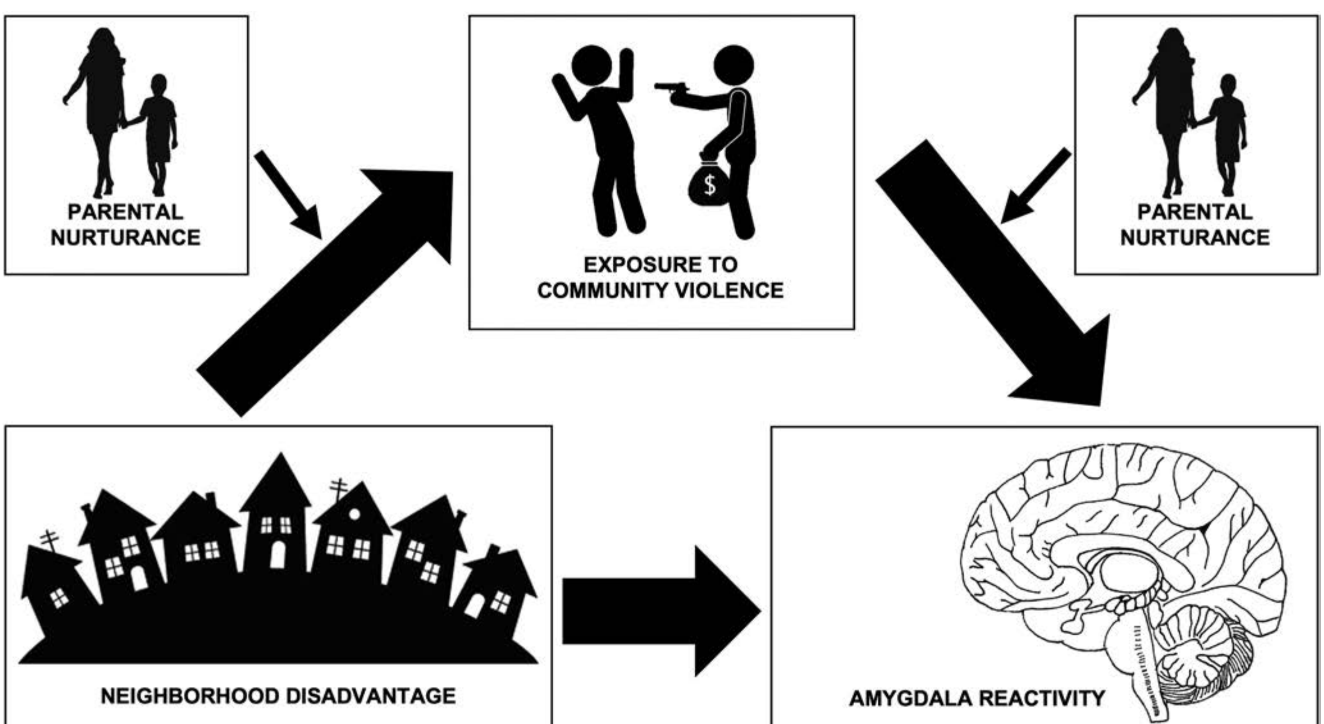
Statistical Analysis

To evaluate the pathways through which neighborhood disadvantage was associated with amygdala reactivity (Figure 1), we extracted amygdala activation with scan acquisition type as a covariate (i.e., multiband vs. spiral acquisition) from the main effects of the socioemotional faces task using an anatomical region of interest (ROI) for each participant to be used in structural equation models in MPlus v.8.1 (Muthén & Muthén, 2011). Consistent with past publications from our laboratory (e.g., Gard et al., 2018), we extracted data from a bilateral amygdala ROI defined structurally using the automated anatomical labeling Atlas definition in the Wake Forest University PickAtlas Tool, Version 1.04 (Maldjian et al., 2003). Importantly, these values were only extracted from the main effects of the task, not from regressions including neighborhood disadvantage or exposure to community violence, and thus, not susceptible to bias via double correlation (Kriegeskorte et al., 2009). Our primary aim was to examine amygdala reactivity to emotional faces relative to a nonfaces condition (shapes), with a primary focus on threat and distress conditions (i.e., fearful and angry faces). However, previous studies suggest that amygdala reactivity to ambiguity (i.e., neutral faces) may also be impacted by neighborhood-level adversities (Gard et al., 2017; Gard, Maxwell, et al., 2021). The unpredictability of ambiguous neutral faces may be interpreted as hostile or threatening, particularly for youth growing up in disadvantaged neighborhoods or exposed to community violence. Therefore, we extracted amygdala activation from the main effects of two contrasts: (a) fearful + angry faces > shapes to evaluate our primary aim and (b) neutral faces > shapes to evaluate our exploratory aim. Extracting amygdala activation for the main effects of these two planned contrasts allows us to evaluate the mean level of activity across all of the voxels in the amygdala ROI that show more activation for the emotional faces condition (i.e., fearful + angry faces and neutral faces) relative to the shapes condition.

In preliminary analyses, we examined zero-order correlations between neighborhood disadvantage, exposure to community violence, and amygdala reactivity to threat and ambiguity. Also, given that participants were from rural, urban, and suburban communities, we examined whether youth from different neighborhood settings differed in the primary study variables, including neighborhood disadvantage, exposure to community violence, parental nurturance, and amygdala reactivity to threat and ambiguity. We used the Department of Defense's definitions for rural, urban, and suburban zip codes created for the Medicare Modernization Act of 2003 (Texas A&M Transportation Institute, 2017). To address our first aim, we computed four multiple regression

Figure 1

Proposed Path Model Linking Neighborhood Disadvantage to Amygdala Reactivity via Exposure to Community Violence and the Moderating Role of Parental Nurturance



models examining exposure to community violence as a predictor of (a) right and (b) left amygdala reactivity to threat (our primary aim), and (c) right and (d) left amygdala reactivity to ambiguity (our exploratory aim). We only proceeded with testing our path models if two conditions were met: First, left or right amygdala reactivity from either the angry + fearful faces > shapes or the neutral face > shapes contrast was correlated with exposure to community violence. Second, neighborhood disadvantage was also significantly correlated with exposure to community violence. That is, if we have significant a and b paths, we proceeded with testing our overall path model (Figure 1). We further tested whether variability in twin-reported parental nurturance moderated pathways from neighborhood disadvantage to exposure to community violence and from exposure to community violence to amygdala reactivity. To evaluate significant moderation effects, we tested a moderated mediation model in which we also examined indirect effects at 1 *SD* above and below the mean to probe the nature of the moderated mediation effect (Preacher et al., 2007). Predictors were grand-mean-centered, and the interaction term was created as the product of the centered predictors outside the model and treated as a manifest variable. All analyses were conducted in Mplus v.8.1. We used the CLUSTER command to account for nesting within families and maximum likelihood estimation with robust standard errors to allow for missing data and protect against distortion of effects from violations of distributional assumptions (Falk, 2018). All models controlled for covariates, including twin demographic characteristics (age, sex, and race/ethnicity), as well as family income and primary caregiver education, in order to assess whether findings were unique to neighborhood-level adversity over and above family-level adversities.

Lastly, in sensitivity analyses we evaluated the strength and specificity of our results. First, in exploratory analyses, we examined the association between exposure to community violence and amygdala reactivity to fearful faces > shapes and angry faces > shapes separately in order to determine which type of face may be most important in the association. Second, given the wide age range of our sample, we examined age as a continuous moderator of the paths from neighborhood disadvantage to exposure to community violence and amygdala reactivity and from neighborhood disadvantage to exposure to community violence. Additionally, to focus more narrowly on adolescence, we tested our path model in a subset of participants that were 12- to 17-years-old ($N = 592$). Third, previous work demonstrates that amygdala reactivity to socioemotional faces varies across development (Bloom et al., 2022; Guyer et al., 2008), with some studies finding nonlinear associations and peaks in midadolescence (Hare et al., 2008; Vijayakumar et al., 2019). Also, studies report associations between pubertal development and amygdala reactivity to socioemotional faces (Ferri et al., 2014; Forbes et al., 2011; Moore et al., 2012; Spielberg et al., 2015). Therefore, we also included quadratic age and pubertal status as covariates in sensitivity analyses. Lastly, to examine whether our findings were specific to exposure to community violence and not violence and threat within the home, we examined harsh parenting and interpartner violence as additional covariates.

Functional Data Analysis/Visualization

Because our main analyses treat amygdala reactivity as mean activation across the entire ROI, if we found a significant association between exposure to community violence and amygdala reactivity for one of our planned contrasts, we also visualized the localization of the voxels most strongly related to exposure to community violence in SPM12. As the amygdala is a relatively large brain region made up of hundreds of voxels, this functional data analysis allows us to take a closer look and visualize the specific voxels that are associated with exposure to community violence. The general linear model in SPM12 was used to estimate condition-specific BOLD activation for each individual scan. Individual contrast images were then used in second-level random effects models to determine mean emotion-specific reactivity using one-sample *t*-tests (Gard et al., 2017; Gard, Maxwell, et al., 2021). All analyses were conducted using the most updated cluster correction method (3dttest++) via the 3dClustSim program using analysis of functional neuroimages software Version 16.1.14 (within the amygdala ROI) (Cox, 1996; Cox et al., 2017). We ran regression models within SPM12 (at the group level, across all participants) to examine the associations between exposure to community violence and amygdala reactivity for the contrasts fearful + angry faces > shapes and neutral faces > shapes. Group-level activation was analyzed within the same anatomically defined bilateral amygdala ROI from Wake Forest University PickAtlas, using a voxel-wise threshold of $p < .005$ (which resulted in a cluster threshold of $k = 8$, to achieve a region-wide $p < .05$ corrected for multiple comparison). Our models controlled for twin demographics (i.e., age, sex, race/ethnicity) and scan type (i.e., multiband vs. spiral acquisition).

Transparency and Openness

For the current study, we report all data exclusions and measures in the study, and we follow the American Psychological Association-Style Journal Article Reporting Standards (Kazak, 2018). All data for the current study will be shared publicly via the National Institute of Mental Health Data Archive, as mandated in our funding agreement, and will be publicly available at https://nda.nih.gov/edit_collection.html?id=2818. This study's design and its analysis were not preregistered. Data were analyzed using Mplus (Version 8.1), simple slopes for significant interactions were visualized in RStudio (Version 1.2.1335) with the package interactions (Long, 2022), and functional data analysis was conducted using SPM12 (Version 12). The code behind this analysis has been made publicly available at GitHub https://github.com/gabrielalsuarez/MTwiNS_Exposure_to_Community_Violence.

Results

Preliminary correlations indicated expected (though modest) positive associations between a census-derived measure of neighborhood disadvantage, twin reports of exposure to community violence, and right amygdala reactivity to threat (Table S2 in the online supplemental materials). The very modest correlation between neighborhood disadvantage and right amygdala reactivity to threat ($r = .09$) did not survive correction for multiple comparison. Of the 708 twins, 350 lived in rural neighborhoods (<1,000 people per square mile), 232 in suburban neighborhoods (between 1,000 and 3,000 people per square mile), and 120 in urban neighborhoods (>3,000 people per square mile)—six twins were missing neighborhood classification data. Using one-way analyses of variance, we found that youth living in different neighborhood settings (i.e., urban, rural, and suburban) did not differ in terms of neighborhood disadvantage, $F(2, 680) = 0.71$, $p = .49$, exposure to

community violence, $F(2, 670) = 2.03$, $p = .13$, parental nurturance, $F(2, 611) = 1.57$, $p = .21$, amygdala reactivity to threat, right: $F(2, 496) = 0.01$, $p = .99$; left: $F(2, 496) = 0.52$, $p = .60$, or amygdala reactivity to ambiguity, right: $F(2, 496) = 0.25$, $p = .78$; left: $F(2, 496) = 0.64$, $p = .53$.

Youth Exposed to More Community Violence Exhibit Greater Right Amygdala Reactivity to Threat

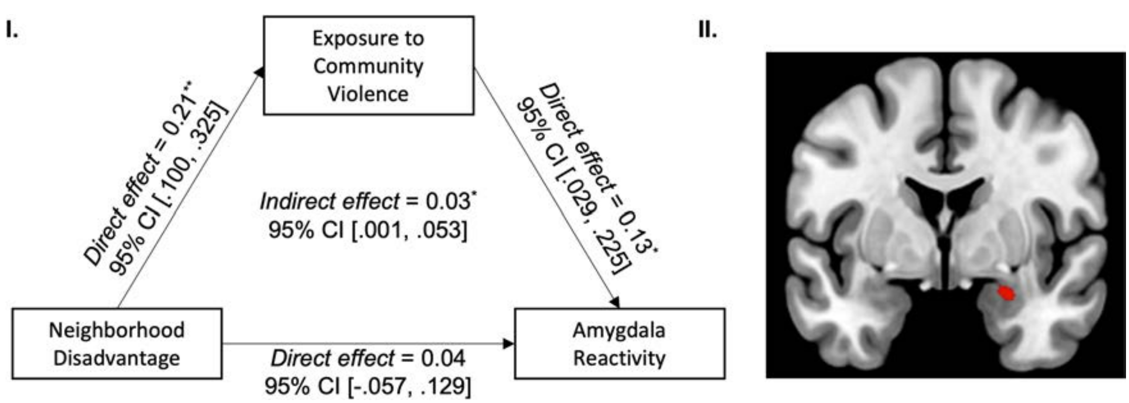
Accounting for twin demographic characteristics (i.e., age, gender, race/ethnicity) and family SES (i.e., income and primary caregiver education), we found that exposure to community violence was significantly associated with greater right ($\beta = .14$, $B = .14$, 95% confidence interval [CI] [.04, .23], $p_{\mathrm{fdr}} < .05$) but not left ($\beta = .03$, $B = .03$, 95% CI [−.06, .11]) amygdala reactivity to threat (i.e., angry + fearful faces > shapes; Table S3 in the online supplemental materials). In exploratory analyses, we did not find any associations between exposure to community violence and amygdala reactivity to ambiguity (i.e., neutral faces > shapes; Table S3 in the online supplemental materials). Because our main analyses treat amygdala reactivity as mean activation across the entire ROI, we visualized the voxels most strongly related to exposure to community violence using SPM12 (Figure 2). Consistent with our extracted data, exposure to community violence was related to greater right amygdala reactivity to threat—peak centered within right amygdala: $(x, y, z) = (28, 4, -20)$; T extent threshold = 3.40; k cluster size = 8 (Figure 2). Exploratory analyses aimed at examining the specificity of activation to fearful versus angry faces revealed that the effect size of association with fearful faces ($Z = 3.95$) was larger than angry faces ($Z = 2.94$), suggesting potential specificity to fearful faces with a directed eye gaze. Lastly, in the supplement, using extracted data, we provide the correlations between left and right amygdala reactivity to fearful faces > shapes and angry faces > shapes in order to show how related amygdala reactivity was for these two contrasts (Table S6 in the online supplemental materials). Amygdala reactivity to fearful and angry faces was only modestly correlated (right: $r = .09$; left: $r = .08$).

Neighborhood Disadvantage Predicts Amygdala Reactivity to Threat Indirectly via Exposure to Community Violence

Using path modeling that accounted for the nesting of twins within families and all covariates (age, gender, race/ethnicity, family income, and primary caregiver education), we found that neighborhood disadvantage predicted exposure to community violence ($\beta = .21$, $p < .001$), which in turn predicted right amygdala reactivity to threat ($\beta = .13$, $p = .011$). Importantly, we found evidence for an indirect effect in which neighborhood disadvantage predicted amygdala reactivity to threat via exposure to community violence ($\alpha\beta = .027$, $SE = .013$, $p = .042$, bootstrapped 95% CI [.001, .053]; Figure 2 and Table S4 in the online supplemental materials). That is, twins living in more disadvantaged neighborhoods were more exposed to community violence, and those who were more exposed showed heightened right amygdala reactivity to threat. There was no significant direct effect of neighborhood disadvantage on amygdala reactivity to threat. In supplemental analyses, age did not moderate the paths from neighborhood disadvantage to exposure to community violence or amygdala reactivity to threat or from exposure to community violence to amygdala reactivity to threat (Table S7 in the online supplemental materials). Additionally, in order to focus more narrowly on the adolescent period, we examined the same mediation model including only adolescents (12- to 17-year-olds; $N = 592$), which made up a majority of the sample. The results all remained significant in the restricted sample of adolescents (Table S8 in the online supplemental materials).

Figure 2

Neighborhood Disadvantage Is Indirectly Associated With Amygdala Reactivity via Increased Exposure to Community Violence



Note. (I) Path results for the mediation model controlling for twin demographic characteristics, including gender (1 = *girls*, 0 = *boys*), race/ethnicity (1 = *White*, 0 = *Non-White*), and age, and family SES (i.e., family income and primary caregiver education). (II) Visualization of a significant cluster in SPM controlling for twin demographic characteristics and scan type (i.e., multiband vs. spiral). Exposure to community violence is associated with right amygdala reactivity to the contrast fearful and angry faces > shapes: $(x, y, z) = (28, 4, -20)$, $T = 3.40$, $k = 8$. CI = confidence interval; SES = socioeconomic status; SPM = statistical parametric mapping. See the online article for the color version of this figure.
* $p < .05$. ** $p < .001$.

Parental Nurturance Moderates the Pathways From Neighborhood Disadvantage to Amygdala Reactivity via Exposure to Community Violence

To examine the impact of parental nurturance on twin-reported violence exposure and amygdala reactivity, we conducted a moderated mediation analysis. First, as expected, neighborhood disadvantage was only associated with greater exposure to community violence at low (i.e., −1 *SD* below the mean) and mean levels of parental nurturance ($\beta = .32$, $B = .36$, $p = .001$ and $\beta = .18$, $B = .20$, $p = .003$, respectively; Figure 3). Neighborhood disadvantage was not associated with exposure to community violence exposure at high levels (i.e., +1 *SD* above the mean) of parental nurturance ($\beta = .04$, $B = .05$, $p = .521$). Second, results revealed that exposure to community violence was associated with heightened right amygdala reactivity to threat only at low levels of parental nurturance ($\beta = .21$, $B = .17$, $p = .002$; Figure 3). Exposure to community violence was not associated with amygdala reactivity at high and mean levels of parental nurturance ($\beta = -.04$, $B = -.03$, $p = .68$ and $\beta = .08$, $B = .07$, $p = .22$, respectively). Importantly, when testing a moderated mediation model, the indirect pathway linking neighborhood disadvantage to amygdala reactivity via exposure to community violence was also conditional on parental nurturance as indicated by a significant indirect effect at low, but not high or average, levels of parental nurturance (Table 1 and Table S5 in the online supplemental materials).

Sensitivity Analyses

The results reported in the mediation and moderated mediation models were robust to multiple sensitivity analyses. First, our findings remained when controlling for quadratic age and pubertal status (Tables S9 and S10 in the online supplemental materials): In the mediation model, the same path results and indirect effect remained significant (Table S9 in the online supplemental materials), and within the moderated mediation model, the same interactions and conditional indirect effect at low, but not high or average, levels of parental nurturance all remained significant when controlling for quadratic age and pubertal status (Table S10 in the online supplemental materials). Second, our findings appear unique to exposure to violence in the neighborhood over and above threatening and violent experiences within the home, as controlling for harsh parenting and interparental violence did not change the pattern of results (Tables S11 and S12 in the online supplemental materials).

Discussion

In the current study, we examined associations between exposure to community violence and amygdala reactivity to threat, whether exposure to community violence serves as a mechanism linking neighborhood disadvantage to amygdala reactivity to threat, and whether nurturing parenting could modulate these associations in a large sample of adolescent twins residing in disadvantaged neighborhoods. Importantly, we investigated these questions during late childhood and adolescence, a key period of youth brain development (Casey et al., 2019; Somerville et al., 2010) and increased time spent in the neighborhood (Smetana et al., 2006). Youth exposed to greater community violence displayed greater right amygdala reactivity to threat. Moreover, greater neighborhood disadvantage was associated with amygdala reactivity indirectly via greater exposure to community violence, suggesting that exposure to community violence may be one route through which living in a disadvantaged neighborhood impacts brain development. Importantly, however, parental nurturance buffered these effects, such that living in a disadvantaged neighborhood was not associated with increased exposure to community violence for youth with highly nurturing parents. Moreover, for youth who were exposed, high parental nurturance decreased the link between exposure to community violence and heightened amygdala reactivity. These strength-based results suggest that parents can buffer the adverse effects of exposure to community violence on their child's brain.

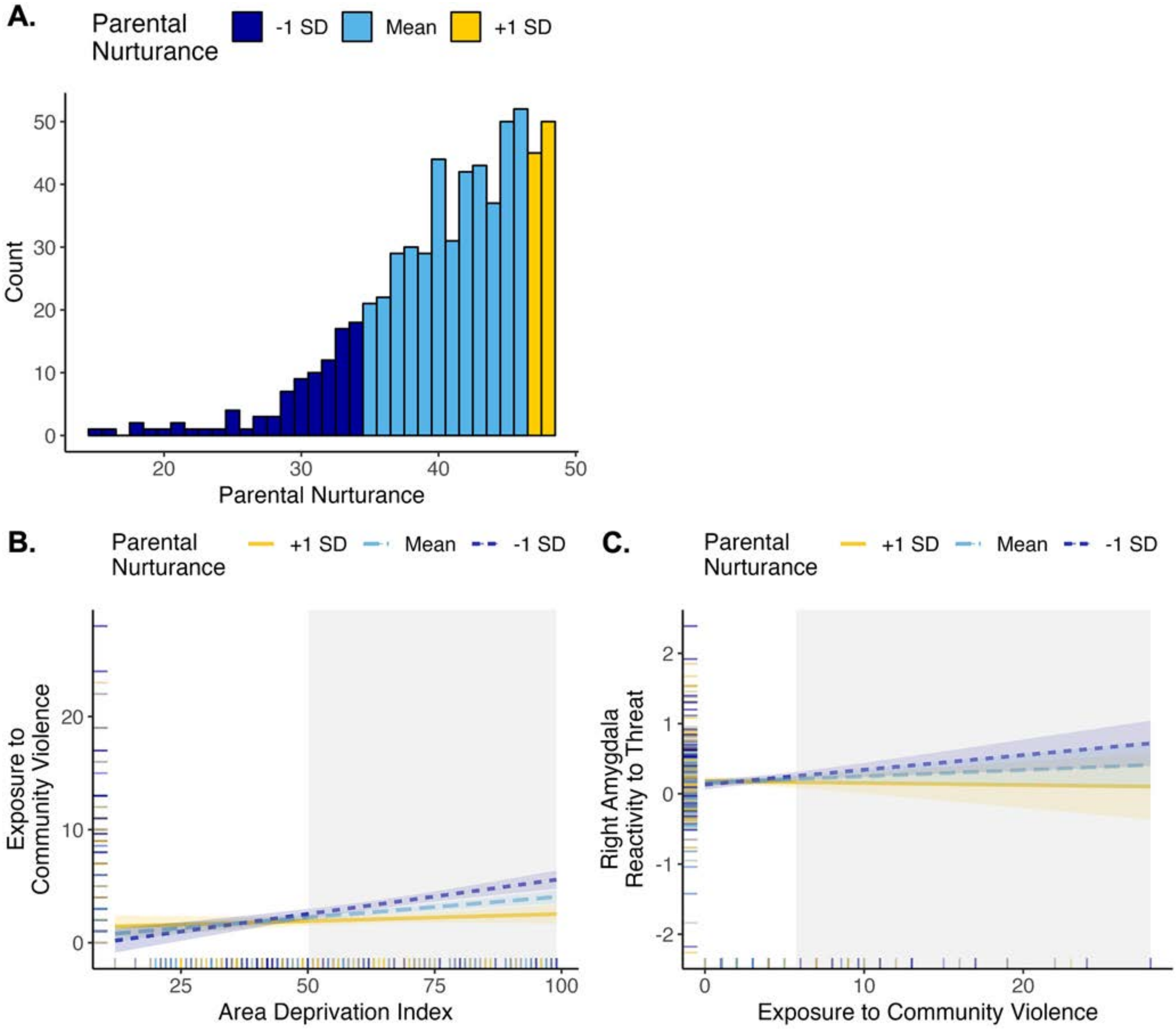
Exposure to Community Violence and Amygdala Reactivity to Threat

Our results provide important evidence that exposure to community violence is associated with greater right amygdala reactivity to threat. Our exploratory analysis did not reveal associations between exposure to community violence and amygdala reactivity to ambiguity, suggesting that effects may be more specific to faces signaling threat and distress. Interestingly, the findings were also specific to the right amygdala. The right amygdala automatically activates in response to an emotional stimuli and is thought to play a role in dynamically detecting the emotional significance of a stimulus (Gläscher & Adolphs, 2003; Wright et al., 2001). Moreover, dimensional models of adversity posit that the right amygdala may have a more important role in detecting and responding to threatening or hazardous experiences and situations, whereas the left amygdala may be more sensitive to conditions of deprivation (e.g., absence of support, nurturance, or cognitive/social stimulation) (Teicher & Khan, 2019). Overall, our findings fit with a wealth of literature demonstrating the negative behavioral effects of exposure to community violence (Cuartas & Leventhal, 2020; Fowler et al., 2009; Mrug & Windle, 2010; Wilson et al., 2009; Zinzow et al., 2009). Moreover, our results align with dimensional models of adversity, which posit that threat-related adversities (e.g., physical and sexual abuse, witnessing domestic violence) will selectively impact neural regions and systems, such as the amygdala and corticolimbic circuit, which are involved in threat detection and learning, salience processing, and emotion regulation (Sheridan & McLaughlin, 2014). Exposure to community violence represents a threat of harm and is therefore expected to impact amygdala sensitivity to threat. Studies consistently report heightened amygdala reactivity to threat-related stimuli in children and adolescents who were exposed to violence, threat, and hostile conditions (McLaughlin et al., 2019), and our findings extend this work to exposure to community violence.

Our findings further align with prior work linking increased exposure to community violence to greater amygdala reactivity to threat cues in children and adolescents (van Rooij et al., 2020; White et al., 2019). Consistent with our results, White et al. (2019) similarly found that exposure to community violence was associated with right amygdala reactivity. However, these studies found associations with different fMRI tasks using different emotional faces. van Rooij et al. (2020) found that greater violence exposure was associated with increased bilateral amygdala activity during an emotional go/no-go task with alternating runs of fear as the target face and neutral as the distractor face, and vice versa, whereas White et al. (2019) used a morphed faces task, which measured BOLD response modulated by angry face intensity (and did not test fearful faces).

Figure 3

Nurturing Parenting Buffers Youth From Exposure to Community Violence and Its Neural Correlates



Note. We visualized the interactions from our moderated mediation model in RStudio (Version 1.2.1335). These figures are for visualization purposes only and may slightly differ from results using Mplus due to differences in the way R handles missing data and the nesting of children within families. Low parental nurturance was defined as −1 *SD* and high parental nurturance as +1 *SD* from the mean. The range of observed values of parental nurturance is [15.00, 48.00]. The shaded rectangle represents the region of statistical significance for the interaction and the rug plots display individual cases for the X and Y variables. (A) Histogram of parental nurturance with the bars color coded for −1 *SD* below the mean, between ± 1 *SD*, and +1 *SD* above the mean. (B) Simple slopes for the interaction between neighborhood disadvantage at different levels of parental nurturance predicting exposure to community violence. The slope is significant when the level of parental nurturance is outside of the interval [45.43, 62.52]. Forty-seven percentage of twins reported their parent's nurturance was below this interval and lived in neighborhoods where the Area Deprivation Index was above 50.12. (C) Simple slopes for the interaction between exposure to community violence at different levels of parental nurturance predicting right amygdala reactivity to threat. The slope is significant when the level of parental nurturance is outside of the interval [38.96, 76.72]. Six percentage of twins reported their parent's nurturance was below this interval and reported a frequency of violence exposure above 5.72. See the online article for the color version of this figure.

These differences in study design are important because emotional faces vary in terms of type or degree of threat or salience. For example, angry faces coupled with direct eye gaze indicates a clear and direct threat, whereas fearful faces with direct eye gaze may indicate an ambiguous or unclear threat in the environment (Adams et al., 2003).

Research on the neurobiological stress response explains how environmental stressors, such as exposure to community violence, can lead

Table 1

High Parental Nurturance Protects Children From Being Exposed to Violence and Buffers the Effects of Exposure to Community Violence on the Amygdala

Outcome/predictors (path)	β	*B*	*SE*	*p*	LLCI	ULCI
Violence exposure						
Neighborhood disadvantage (a1)	.202	.203	.056	.000**	.094	.312
Parenting (a2)	−.155	−.155	.050	.002*	−.254	−.056
Parenting × Neighborhood Disadvantage (a3)	−.139	−.155	.076	.041*	−.304	−.006
Amygdala reactivity to threat						
Violence exposure (b1)	.066	.066	.054	.218	−.039	.171
Parenting (b2)	−.011	−.011	.043	.789	−.095	.072
Parenting × Violence Exposure (b3)	−.127	−.100	.042	.017*	−.183	−.018
Neighborhood disadvantage (c1′)	.030	.031	.048	.525	−.064	.125
Conditional indirect effects						
Low parental nurturance	.066	.060	.022	.007**	.016	.103
Mean parental nurturance	.013	.013	.011	.233	−.009	.035
High parental nurturance	−.004	−.002	.004	.681	−.010	.006

Note. Results of the moderated mediation analysis, evaluating the moderating effect of parental nurturance on youth exposure to community violence and amygdala reactivity to threat controlling for twin demographic characteristics, including gender (1 = *girls*, 0 = *boys*), race/ethnicity (1 = *White*, 0 = *Non-White*), and age, and family SES, including family income and primary caregiver education. β = standardized estimate; *B* = unstandardized estimate; LLCI = lower limit of 95% confidence interval; ULCI = upper limit of 95% confidence interval; SES = socioeconomic status.
* $p < .05$. ** $p < .001$.

to alterations in stress signaling hormones (e.g., cortisol), which, in turn, can target brain regions with high concentrations of stress hormone receptors (e.g., the amygdala), potentially shaping functioning within these regions over time (Gunnar & Quevedo, 2006; Tottenham & Sheridan, 2010). A positive correlation between exposure to community violence and amygdala reactivity to threat may reflect that youth exposed to higher levels of community violence exhibit an appropriate level of increased vigilance and attention toward threatening stimuli (Heissel et al., 2018). Thus, increased amygdala reactivity to threat in this context possibly reflects an adaptive neurobiological response to growing up in a disadvantaged neighborhood with higher levels of violent crime (Varnum & Kitayama, 2017).

It should be noted that we did not examine direct exposure to community violence in the current study, which is not uncommon among youth growing up in disadvantaged neighborhoods. We may have observed larger effects among youth who experienced direct victimization, as the individual victim is most directly impacted by a violent incident. However, sociologists argue that the impact is not limited to the victim (Sharkey, 2018), but also extends to those who were present and watched the violence unfold and those who heard about the event. Also, Sharkey (2018) discusses that the impacts may extend even further, such that community violence exposes youth to dangerous situations and violent residential environments, which can alter an individual's decision making, routines, functioning, and behavior without youth ever being victimized themselves or directly witnessing ongoing violence. Therefore, future studies may consider measuring exposure to community violence at multiple levels, including both direct and indirect victimization and a broader conceptualization of violence exposure, to assess how results may differ.

Exposure to Community Violence as a Mechanism Linking Neighborhood Disadvantage to Neural Function

Identifying exposure to community violence as a possible mechanism through which neighborhood disadvantage is linked to amygdala reactivity to threat is an important contribution of the current study. Youth living in neighborhoods with greater disadvantage reported more frequent exposure to community violence, and those reporting higher exposure exhibited greater amygdala reactivity to threat. Importantly, adjusting for family-level SES (family income and primary caregiver education) and violence within the home (harsh parenting and interpartner violence), we found that the indirect effect of exposure to community violence was significant, supporting the notion that disadvantaged neighborhoods can confer risk via increased exposure to a multitude of stressors, including greater exposure to violent crime. Surprisingly, although recent studies have reported links between neighborhood disadvantage and structural and functional changes within the amygdala and the broader corticolimbic circuit (Bell et al., 2021; Gard, Maxwell, et al., 2021; Ramphal et al., 2020; Whittle et al., 2017), we did not find evidence for a strong direct relationship between neighborhood disadvantage and amygdala reactivity in this sample. Although the effects of neighborhood disadvantage were in the expected direction, the effects were relatively small and barely significant in zero-order correlations. In the path models there was no significant direct effect of neighborhood disadvantage on amygdala reactivity. In contrast exposure to community violence appeared to be a much stronger predictor of amygdala reactivity, possibly because it is a more proximal and specific experience. Alternatively, the neural effects of neighborhood disadvantage may be sensitive to developmental timing, whereas the effects of violence exposure are not. Supporting this notion, a recent study utilizing two diverse samples of U.S. children from low-income families found that neighborhood disadvantage experienced during childhood was more predictive of amygdala reactivity, whereas neighborhood disadvantage experienced during adolescence was more strongly related to prefrontal cortex activation (Gard, Maxwell, et al., 2021). In contrast, in our sample, which mostly covers adolescence, a weak association between neighborhood disadvantage and amygdala reactivity may be due to the developmental stage of our participants and measures of neighborhood disadvantage. In contrast, exposure to community violence appears to be a robust predictor of amygdala reactivity to

threat during this age period. Collectively, these results highlight exposure to community violence as an important mechanism through which neighborhood disadvantage impacts youth brain development. Of course, exposure to community violence is only one of many potential risk factors that are increased in disadvantaged neighborhoods. More research is needed to delineate the many other potential mechanisms (e.g., toxicant exposure, school quality differences) linking neighborhood disadvantage to brain structure and function (Hyde et al., 2022).

Parenting as a Buffer

Another major contribution of this work is in showing that parenting behavior has a buffering impact on the pathway linking neighborhood disadvantage to amygdala reactivity. For youth who reported their parents to be highly nurturing (i.e., warm, supportive, and communicative), living in a disadvantaged neighborhood did not seem to result in increased exposure to community violence, and for those that were exposed, nurturing parenting appeared to decrease the link between exposure to community violence and amygdala reactivity. Presumably, parents helped to guide children away from neighborhood stressors in the first place and then helped them cope with exposures in ways that buffered the effect of these experiences on amygdala function. Our results align with recent studies highlighting the protective effects of nurturing parenting. First, studies find that adolescents are more likely to be exposed to community violence when they experience lower levels of positive parenting, including nurturance, warmth, and support, and involvement and monitoring (Gorman-Smith et al., 2004; Matjasko et al., 2013). Second, recent studies demonstrate the regulatory influence that caregivers can have on their child's amygdala function. For example, maternal cues, warmth, and support attenuated amygdala responses to threat-related stimuli in healthy children and adolescents (Gee et al., 2014; Romund et al., 2016). Furthermore, greater security within the parent–child relationship and greater social support appeared to buffer the impact of adversity on amygdala reactivity in previously institutionalized (Callaghan et al., 2019) and maltreated youth (Wymbs et al., 2020). Also, maternal warmth protected against a pattern of amygdala sensitization in children exposed to violence in the home (Stevens et al., 2023). Our results align with these findings yet are novel in showing that nurturing parenting can also protect against the neural effects of adversity experienced outside of the home, in the neighborhood. They also align with recent work showing that positive relationships in the neighborhood can buffer the impacts of disadvantage and exposure to violence on amygdala reactivity (Gard et al., 2022; Suarez et al., 2022). Taken together, our findings, alongside existing research, provide a neuromechanistic framework for how caregiving behavior may buffer the impacts of adversity on the brain and increase resilience among youth.

Limitations

The present study had several methodological strengths, including recruitment of a large population-based sample with a specific sampling frame that included families from rural, urban, and suburban communities, with oversampling for families living in impoverished neighborhoods. Additionally, we examined the pathway between neighborhood disadvantage and amygdala reactivity within a sample of adolescents, an important sensitive period of brain development during which youth spend more time in their neighborhoods. At the same time, there are several limitations worth noting. First, the research findings are limited by the cross-sectional design, limiting any conclusions about the direction of effects or formal "mediation" of effects which are ideally tested with multiple time points. For example, although we conceptualize that neighborhood disadvantage predicts increased exposure to community violence, the association may be reversed. Increased community violence may lead to the outflow of vital resources, such as quality education and businesses, consequently worsening neighborhood disadvantage. As another example, rather than exposure to community violence leading to increased amygdala reactivity, it may be that youth who exhibit greater amygdala reactivity are more likely to be sensation-seeking and seek out dangerous or risky situations in the community. Second, due to the cross-sectional design, we could not examine whether the developmental timing of exposure to community violence is important in shaping neurobehavioral outcomes, a key next step in this research. Although we tried to account for important developmental processes in sensitivity analyses, including age, pubertal maturation, and nonlinear alterations in brain function, due to the cross-sectional design and the wide age range of our sample, we could not completely address these important issues. Future research is needed to examine the developmental unfolding of these processes and whether there are sensitive periods for exposure to risk. Third, though the current sample is relatively large for a developmental neuroimaging study, it is only modestly powered for moderated mediation analyses (Preacher et al., 2007), and links between brain and behavioral phenotypes have been found to stabilize and become more reproducible with samples sizes of $N \geq 2{,}000$. Thus, future replication of these findings is encouraged, particularly in even larger samples. Fourth, we focused exclusively on amygdala reactivity during socioemotional processing. Although we chose this ROI carefully and focused on data extracted from the main effects of task to examine more complex moderated mediation hypotheses, we did not examine effects across the entire brain, an important next step. Lastly, our measure of parental nurturance was only from adolescent reports, and we do not know how adolescents' perceptions might compare with parents' reports of their own behavior or observers' reports. Still, studies suggest that the adolescent's point of view should take precedence, as parental knowledge and parent–child communication comes mainly from child disclosure (Kerr et al., 2010; Stattin & Kerr, 2000). Adolescents' feelings toward the parent–child relationship, including their perception of their parents' trustworthiness, responsiveness, and warmth, and the absence of ridicule or punishment for confiding in them, are likely more important for adolescent outcomes.

Conclusions

The current study addresses important risk and protective factors contributing to brain function within a region important for socioemotional functioning, threat detection and fear learning. The findings have important implications for prevention and intervention efforts that aim to reduce the adverse consequences of community risk factors and provide instrumental support to youth and their families who are living in high-risk environments. First, elucidating exposure to community violence as an active ingredient within disadvantaged neighborhoods, including its impact on amygdala function, can help inform neighborhood-level interventions and public

policy to strengthen communities and improve child outcomes. Second, demonstrating the protective role of parents in mitigating the effect of exposure to community violence on amygdala function may help explain why, even in the face of adversity, some youth exhibit resilience, and also indicates the power of positive social support and experiences. Ultimately, this work highlights the need for structural solutions to protect children from the negative impact of exposure to community violence, while also highlighting the ways in which strong, positive parents are helping to promote resilience among youth exposed to adversity.

In conclusion, within a relatively large, well-sampled and enriched cohort of twins, we demonstrate how exposure to community violence may shape brain function and explain the link between neighborhood disadvantage and amygdala function, during adolescence, a period of substantial neural and social change. Further, we highlight how social exposures may serve as both risk (community violence) and protective factors (nurturing parenting) and elucidate the positive role parents can play in protecting their children from the toxic effects of exposure to concentrated neighborhood disadvantage and community violence. These findings can help inform future intervention and policy to promote healthy youth development and highlight the ways in which structural factors (e.g., concentrated neighborhood disadvantage that leads to increased community violence) undermine positive development, as well as highlight the ways in which so many parents work to protect their children from these structural risk factors.

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