Neural Impact of Neighborhood Socioeconomic Disadvantage in Traumatically Injured Adults

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Neural impact of neighborhood socioeconomic disadvantage in traumatically injured adults

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ABSTRACT
Nearly 14 percent of Americans live in a socioeconomically disadvantaged neighborhood. Lower individual socioeconomic position (iSEP) has been linked to increased exposure to trauma and stress, as well as to alterations in brain structure and function; however, the neural effects of neighborhood SEP (nSEP) factors, such as neighborhood disadvantage, are unclear. Using a multi-modal approach with participants who recently experienced a traumatic injury (N = 185), we investigated the impact of neighborhood disadvantage, acute post-traumatic stress symptoms, and iSEP on brain structure and functional connectivity at rest. After controlling for iSEP, demographic variables, and acute PTSD symptoms, nSEP was associated with decreased volume and alterations of resting-state functional connectivity in structures implicated in affective processing, including the insula, ventromedial prefrontal cortex, amygdala, and hippocampus. Even in individuals who have recently experienced a traumatic injury, and after accounting for iSEP, the impact of living in a disadvantaged neighborhood is apparent, particularly in brain regions critical for experiencing and regulating emotion. These results should inform future research investigating how various levels of socioeconomic circumstances may impact recovery after a traumatic injury as well as policies and community-developed interventions aimed at reducing the impact of socioeconomic stressors.

1. Introduction
The role environmental context (e.g., social milieu, natural and built environments, etc.) plays in biological functioning and subsequent behavior cannot be overstated: in nearly every society, relative socioeconomic position (SEP) is tied to health status (Farah, 2017, 2018; Hackman and Farah, 2009). Although individual and neighborhood socioeconomic position, iSEP and nSEP respectively, are associated with a host of psychiatric conditions, including depression (Panaite et al., 2019; Richardson et al., 2019; Richardson et al., 2015) and post-traumatic stress disorder (PTSD; Nayback, 2008; Shalev et al., 2019), the neural impact of such indicators is poorly defined. Substantial societal emphasis on the individual has influenced neuroscience research, and historically bypassed the impact of community characteristics (and more broadly the environment) in favor of focusing on how iSEP (e.g., education, income) impacts neural functioning (Brito and Noble, 2014; Diez Roux and Mair, 2010; Farah, 2018; Gianaros and Hackman, 2013; Hackman and Farah, 2009; Harrett, 2020; Johnson et al., 2016). With nearly fourteen percent of Americans living in a socioeconomically disadvantaged neighborhood (Kneebone, 2014), it is imperative to identify whether there are neural effects of nSEP and how these variables compare to the known effects of individual characteristics.

The mechanisms by which the environment impacts the brain and concurrent behavior have not been fully elucidated (Harrett, 2020;
Residents of disadvantaged communities may be exposed to adverse factors, such as environmental toxins, known to have a detrimental neural impact (de Prado Bert et al., 2018; Marshall et al., 2020; Pujol et al., 2016). Physical geography may also dictate an individual’s exposure to crime and police violence as well as the availability of educational or employment opportunities, all of which are known risk factors for stress-related psychopathology (McCoy et al., 2016; Shalev et al., 2019; Sun et al., 2020). Critically, processes that are highly correlated with residing in poorer communities, including childhood trauma (Baglivio et al., 2017; Maguire-Jack and Font, 2017), biological aging (as indexed by shorter telomere length; Massey et al., 2018; Needham et al., 2014) and altered immune system activation (Fineood et al., 2020; Janusek et al., 2017; Karb et al., 2012), can trigger modifications to brain regions involved in necessary everyday function, including emotion regulation, attention, and memory (Hagg et al., 2017; Marusak et al., 2015; Weaver et al., 2002).

Notably, all of the aforementioned biological processes (e.g., immune system activation) are significantly associated with mental health outcomes, including PTSD (Baker et al., 2012; Daskalakis et al., 2018; Hertbrink et al., 2006; Li et al., 2017; Neigh and Ali, 2016). Trauma exposure is wide-spread – nearly 90% of American adults will experience a traumatic event in their lifetime, but individuals who live in disadvantage neighborhoods are at an elevated risk of both trauma exposure and developing PTSD (Collins et al., 2010). The given prevalence of trauma, past work on the relationships between iSEP, nSEP, and the biological systems subserving stress responding may have been confounded by the presence of trauma. Conversely, research on trauma and stress-responding, in trauma-exposed or healthy participants, may have captured the effects of chronic stress related to nSEP or iSEP (e.g., Harnett et al., 2019).

Neuroscience literature uses the term ‘chronic stress’ to encompass prolonged exposure to a multitude of psychological and physiological stressors (e.g., poverty, sensory deprivation, maternal separation, physical insult, etc.), however, the convergence of neural consequences from the different modes of stress is noteworthy (Jaggi et al., 2011; McEwen, 2000; Uys et al., 2003; Veenema, 2009). To summarize: exposure to chronic stress, including lower socioeconomic circumstances, elicits prolonged neuroendocrine and stress system responding (Carlson and Chamberlain, 2005; McEwen, 2000, 2012). Regions in the medial temporal lobe (i.e., amygdala and hippocampus) and prefrontal cortex, which underlie processing and regulating response to biologically relevant stimuli, appear highly vulnerable to stressors. Chronic stressors are associated with reduced size and atypical functioning (as assessed by fMRI) of these regions (McEwen et al., 2012; Sandi and Pinelo-Nava, 2007).

These regions are also susceptible to the psychological consequences of a traumatic injury (i.e., a physical injury, not synonymous with traumatic brain injury; Liberzon and Sripada, 2007; Shin, 2006), further complicating researcher’s ability to parse apart the unique effects of socioeconomic circumstances and that of specific traumatic experiences. This nuance is critical: if analyses with iSEP or nSEP are also capturing recent trauma exposure. Although investigations into nSEP factors are more scarce, recent developments have suggested the neural elements identifiable neural “marks”, which are similar to those related to a recent trauma exposure. Although investigations into nSEP indicators are less numerous, recent developments have suggested the neural elements described above are likewise impacted by nSEP indicators (Anseau et al., 2008; Fineood et al., 2017; Harnett et al., 2019; Saxbe et al., 2018; Tomlinson et al., 2020; Tooley et al., 2020). For example, reduced hippocampal volume is linked to greater community violence in adolescents (Saxbe et al., 2018) and greater neighborhood disadvantage in adulthood (Hunt et al., 2020). In adults, neighborhood disadvantage is
associated with diminished amygdala reactivity to threat (Harnett et al., 2019). In children, growing up in a disadvantaged neighborhood contributes to wide-spread functional alterations in brain networks (Tooley et al., 2020) and deficits in behavioral response inhibition (Tomlinson et al., 2020), suggesting adolescents growing up in these neighborhoods have disrupted development (Tooley et al., 2020).

These initial studies highlight the important role that socioeconomic context beyond the individual and household can have on brain structure and function. Immersion in a disadvantaged neighborhood may affect neural circuits supporting adaptive stress-responding over and above iSEP factors. Crucially, the majority of previous studies have selected either brain structure or function to examine in relation to socioeconomic circumstances; herein, we describe multi-modal associations between PTSD symptoms related to a recent traumatic injury, iSEP, and nSEP.

1.2. Current study

Over two-hundred adult participants were recruited from a metropolitan area following a traumatic injury. We assessed how a nSEP variable, derived through geocoding, uniquely impacted brain structure as well as functional connectivity at rest. Based on previous studies, we expected to identify a neural mark of nSEP, after adjusting for two iSEP indicators (education and income), age, gender, and PTSD symptoms. We hypothesized neighborhood disadvantage would uniquely impact neurocircuitry critical for emotion regulation and that these effects would remain significant after accounting for the symptoms related to a recent clinically significant traumatic event.

In light of mounting evidence implying lower nSEP and iSEP are independent chronic stressors (Ross and Mirowsky, 2008), we anticipated greater neighborhood disadvantage would be uniquely associated with smaller amygdala, vmPFC, and hippocampus volumes (e.g., Morey et al., 2016; Noble et al., 2012; Saxbe et al., 2018). We hypothesized greater neighborhood disadvantage would be associated with decreased resting state functional connectivity (rsFC) between the amygdala and insula-prefrontal cortex as well as reduced hippocampus-prefrontal cortex rsFC. By demonstrating this in a traumatically injured sample at the outset and examining how nSEP affects the brain beyond symptoms of the indexed trauma, future work may feel more confident that acute trauma and socioeconomic circumstances are distinct factors. This paves the way to continue probing how nSEP and iSEP interact to alter trauma outcomes.

2. Results

2.1. Structure

Zero-order correlations between ADI and regional brain volumes are depicted in Fig. 1; results of GLMs are presented in Table 1. After adjusting for estimated intracranial volume, individual education, individual income, and PCL-5 total scores, higher ADI rankings (indicative of greater neighborhood disadvantage) were significantly associated with smaller bilateral hippocampus ($B = -0.01, t(159) = -2.20, p = .030$; full model: $R^2 = 0.27$) and smaller vmPFC volume ($B = -0.01, t(159) = -2.05, p = .042$; full model: $R^2 = 0.47$). Higher individual income and PCL-5 total scores were also significantly associated with larger vmPFC volume, $B = 0.06, t(159) = 2.50, p = .014$ and $B = 0.01, t(159) = 2.11, p = .036$, respectively. There was no significant relationship between neighborhood disadvantage and bilateral amygdala ($B < 0.01, t(159) = -1.19, p = .238$; full model: $R^2 = 0.35$), or bilateral anterior insula volume ($B < -0.01, t(159) = -0.31, p = .761$; full model: $R^2 = 0.50$).

2.2. Resting-state functional connectivity

Results of the rsFC analysis are presented in Table 2. Higher ADI rankings were significantly associated with increased bilateral amygdala connectivity with the left inferior parietal lobule (IPL), even after adjusting for individual education, individual income, gender, age, and PCL-5 total scores (MNI coordinates $x: -40, y: -58, z: 28$; cluster size $k = 84$; $pFDR = .030$; Fig. 2A). After controlling for covariates, greater connectivity between bilateral anterior insula and right ventrolateral prefrontal cortex was associated with higher ADI rankings (MNI coordinates: $x: 36, y: 52, z: -6$; cluster size $k = 88$; $pFDR = .048$; Fig. 2B).

![Fig. 1. Bivariate relationship between neighborhood socioeconomic disadvantage and bilateral A) hippocampus, B) ventromedial prefrontal cortex (vmPFC), C) amygdala, and D) insula, structural volumes (mm$^3$). Note: Zero-order correlation coefficients ($r$) are provided on the figure.](image-url)
Altered functional connectivity associated with neighborhood disadvantage after adjusting for relevant individual variables.

<table>
<thead>
<tr>
<th>ROI</th>
<th>Contrast</th>
<th>Brain Region</th>
<th>No. of voxels</th>
<th>pFDR-corrected</th>
<th>Peak Coordinates (MNI)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amygdala</td>
<td>Positive</td>
<td>Inferior Parietal Lobule L</td>
<td>84</td>
<td>0.030*</td>
<td>X: 40 Y: 58 Z: 28</td>
</tr>
<tr>
<td>Insula</td>
<td>Positive</td>
<td>Ventrolateral PFC R</td>
<td>88</td>
<td>0.048*</td>
<td>X: 40 Y: 52 Z: -6</td>
</tr>
</tbody>
</table>

Note. Covariates: Education, Income, Age, Gender, PCL-5 scores; *pFDRCorrected < .05, L: left; R, right; PFC, prefrontal cortex; ROI: seed region of interest, N = 165.
A. Amygdala – Inferior Parietal Lobule

B. Insula – Ventrolateral PFC

Fig. 2. Results of seed-to-voxel analyses revealed greater neighborhood socioeconomic disadvantage was significantly associated with A) increased connectivity between bilateral amygdala and left inferior parietal lobule (IPL; MNI coordinates x: −40, y: −58, z: 28; cluster size k = 84; pFDR = 0.030) B) greater connectivity between bilateral anterior insula and right ventrolateral prefrontal cortex (vIPFC; 36, 52, −6; cluster size k = 88; pFDR = 0.048).

as Tomlinson et al., 2020 should explore how different levels of socioeconomic circumstances interact to modulate neural activation during affective tasks and the associated behavioral measures.

These findings indicate the effects of chronic stressors, both nSEP and iSEP, as well as recent trauma can be disentangled in both structural and functional (i.e., rsFC) neuroimaging data. Our results, however, are tempered by the fact our sample is limited geographically. Individuals were largely from urban neighborhoods and therefore the implications of our results may not apply to those experiencing resource deprivation in rural areas or even urban settings with different characteristics. In addition, the sample consisted of individuals who had recently experienced a traumatic injury and did not include a non-trauma control group. As such these relationships may not be identical to those found in a sample of non-injured adults. Furthermore, this study was observational and cross-sectional, meaning we did not consider other important variables such as residential instability and childhood socioeconomic position.

McLaughlin and Sheridan (2017) proposed a comprehensive theory that adversity (originally conceptualized as childhood adversity but extended to adults here), is multi-dimensional. Although many experiences are described as “chronic stress”, this model better encapsulates the events by distinguishing experiences by low versus high threat (e.g., typical environment versus physical abuse) and low versus high deprivation (e.g., physical abuse versus institutionalization; McLaughlin and Sheridan, 2016). Dimensionality of adversity may be an important consideration in our study. For example, despite a significant association between ADI rankings and structure, we did not find an effect of ADI rankings on hippocampal or vmPFC rsFC; however, the rsFC of these particular regions may be more associated with other variables, such as exposure to community violence (e.g., higher threat but lower deprivation), police presence, or air pollution (e.g., Saxbe et al., 2018). Future directions include leveraging large data consortiums to examine multiple neighborhood-level measures.

Nevertheless, we have presented a multi-modal investigation which documents the neural features of neighborhood disadvantage. The brain regions critical for emotion regulation are susceptible to the effects of nSEP. Beyond iSEP indicators and acute PTSD symptoms from a recent trauma, ADI rankings were significantly associated with altered structure and functional connectivity. It is noteworthy, that after accounting for these individual-level measures (e.g., individual education and income, and stress symptoms), which researchers widely recognize as potent factors underlying individual differences in psychopathology, the circumstances of where people live are independently associated with brain circuits regulating emotion in trauma-exposed individuals. Although the overarching goal should be to reduce and eliminate systems which generate and maintain poverty, our work suggests that while these steps are being taken, clinicians and scientists should consider the role socioeconomic circumstances are playing in their patients’ and participants’ lives.

4. Methods

4.1. Participants

Two hundred and fifteen participants were recruited from an Emergency Department (ED) at an urban Level 1 trauma center as part of a longitudinal observational study investigating neurobiological and socioenvironmental predictors of PTSD (study name: iSTAR; Webb et al., 2020; Bird et al., 2021; Weis et al., 2021). Briefly, individuals were considered eligible if they were English-speaking, between the ages of 18–65 years old, and had experienced a traumatic injury. Full inclusion/exclusion criteria can be found in Table 3. All participants provided written consent and were financially compensated for their time. Study procedures were approved by the local Institutional Review Board at the Medical College of Wisconsin.

Of the recruited participants, 198 completed a structural and resting-state scan two-weeks post-injury. Not all participants could be successfully geo-coded (required to derive neighborhood SEP); of the 185 participants who had useable resting-state and structural scans, 165 had complete demographic and geo-coded data.

4.2. Individual measures

Sample characteristics can be found in Table 4. Individual demographics (gender, age, income, and education) were self-reported at the first study visit. Household income and educational attainment (two iSEP variables) were assessed on a semi-continuous scale. Acute PTSD symptoms were assessed using the PTSD-Checklist Scale for DSM-5 (PCL-5; Blevins et al., 2015) which consists of 20 items that evaluate the presence and severity of PTSD symptoms corresponding to
Neighborhood socioeconomic disadvantage, the nSEP variable, was measured using the Area Deprivation Index (ADI; Kind et al., 2014; Kind and Buckingham, 2018; Singh, 2003). Block-group is the smallest ACS geographic area and represents a maximum of 3,000 people or 1,200 housing units (U.S. Census Bureau, 2020).

Briefly, National ADI rankings, which range from 1 (most advantaged) to 100 (most disadvantaged), are factor-based percentile scores representing 17 variables (see Singh, 2003 for more information on development of this index and a list of exact variables). ADI rankings incorporate measurements of income, education, housing, and employment (Kind et al., 2014). In this way, the individually reported education and income of all the neighborhood’s residents were averaged within each block-group. These averages were then incorporated as components of the block-group’s ADI ranking.

ADI rankings range from 1 to 100. A score of 50 indicates, compared to that specific block-group, approximately half of the neighborhoods in the nation are more disadvantaged and approximately half are more advantaged. The current sample was largely disadvantaged (mean ADI = 68, standard deviation = 22), though the range in ADI rankings was sufficient to test hypotheses (see Fig. 3 for distribution).

### 4.4. MRI data acquisition

All images were collected on a General Electric Discovery MR750 3.0 T scanner with a 32-channel head-coil (Waukesha, WI). For co-registration with functional images and structural analysis, T1-weighted high-resolution anatomical scans were acquired (FOV = 240 mm; matrix = 256 × 224; slice thickness = 1 mm; 150 slices; TR/TE = 8.2/3.2; flip angle = 12°; voxel size = 0.9375 × 1.071 x 1). Resting-state images were obtained during an 8-min scan (240 vol) with the following parameters: FOV = 22.4 mm; matrix = 64 × 64; slice thickness = 3.5 mm; 41 sagittal slices; repetition time (TR)/echo time (TE) = 2000/25 ms; flip angle = 77°.

### 4.5. MRI data preprocessing and analytic strategy

#### 4.5.1. Structure

Freesurfer was used to perform volumetric quantification of regions of interest (v5.30; Fischl, 2012). Prior to extracting volumetric measurements, each participant’s image was visually inspected and manual edits were performed as needed. As we had no specific hypotheses regarding laterality, left and right ROI measurements were combined. Volume measures (mm³) were extracted for the amygdala, hippocampus, and insula. As previously done, bilateral vmPFC volumes were created by summing the left and right medial orbitofrontal and lateral orbitofrontal cortices (Desikan et al., 2006; Morey et al., 2016).

Univariate outliers (±3 standard deviations) were removed (N = 6) during the National 2014–2018 American Community Survey (ACS; Hu et al., 2018; Kind et al., 2014; Kind and Buckingham, 2018; Singh, 2003). Block-group is the smallest ACS geographic area and represents a maximum of 3,000 people or 1,200 housing units (U.S. Census Bureau, 2020).

#### 4.3. Neighborhood socioeconomic disadvantage

Neighborhood socioeconomic disadvantage, the nSEP variable, was measured using the Area Deprivation Index (ADI; Kind and Buckingham, 2018). Participants provided their home address at the same study visit that they underwent neuroimaging. This address was then used to derive ADI rankings from a publicly available database hosted by the University of Wisconsin School of Medicine and Public Health [https://www.neighborhoodatlas.medicine.wisc.edu/](https://www.neighborhoodatlas.medicine.wisc.edu/) (downloaded February 2020, geocoding completed approximately 3 months after all data was collected) which provides census block-group ADI rankings from data collected during the National 2014–2018 American Community Survey (ACS; Hu et al., 2018; Kind et al., 2014; Kind and Buckingham, 2018; Singh, 2003). Block-group is the smallest ACS geographic area and represents a maximum of 3,000 people or 1,200 housing units (U.S. Census Bureau, 2020).

- Adverse childhood experiences (ACEs) are defined as cumulative traumas experienced during childhood that can have long-term effects on mental and physical health. ACEs can include events such as abuse, neglect, or family dysfunction, and they are strongly associated with PTSD.

### Table 3

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD) or %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age (years)</td>
<td>32.30 (10.45)</td>
</tr>
<tr>
<td>Sex</td>
<td>Female 55%</td>
</tr>
<tr>
<td>Individual Education</td>
<td>Did not complete high school 10%</td>
</tr>
<tr>
<td>High school/GED</td>
<td>32%</td>
</tr>
<tr>
<td>Some post-secondary education/college</td>
<td>41%</td>
</tr>
<tr>
<td>Bachelor’s degree</td>
<td>12%</td>
</tr>
<tr>
<td>Master’s degree, JD, MD, PhD</td>
<td>5%</td>
</tr>
<tr>
<td>Individual Income</td>
<td>$10,000–20,000 21%</td>
</tr>
<tr>
<td>$20,000–30,000</td>
<td>15%</td>
</tr>
<tr>
<td>$30,000–40,000</td>
<td>9%</td>
</tr>
<tr>
<td>$40,000–50,000</td>
<td>9%</td>
</tr>
<tr>
<td>$50,000–60,000</td>
<td>7%</td>
</tr>
<tr>
<td>$60,000–70,000</td>
<td>6%</td>
</tr>
<tr>
<td>$70,000–80,000</td>
<td>7%</td>
</tr>
<tr>
<td>$80,000–90,000</td>
<td>&lt;5%</td>
</tr>
<tr>
<td>$90,100,000</td>
<td>&lt;5%</td>
</tr>
<tr>
<td>$100,000 and above</td>
<td>6%</td>
</tr>
<tr>
<td>Race and Ethnicity</td>
<td>African American and/or Black 58%</td>
</tr>
<tr>
<td>White</td>
<td>27%</td>
</tr>
<tr>
<td>Hispanic or Latino</td>
<td>8%</td>
</tr>
<tr>
<td>Other racial/ethnic identity*</td>
<td>10%</td>
</tr>
<tr>
<td>Not reported</td>
<td>5%</td>
</tr>
<tr>
<td>Mechanism of Injury</td>
<td>Motor vehicle crash 67%</td>
</tr>
<tr>
<td>Physical assault</td>
<td>16%</td>
</tr>
<tr>
<td>Other</td>
<td>17%</td>
</tr>
<tr>
<td>Acute PTSD Symptoms (PCL-5)</td>
<td>26.75 (17.86)</td>
</tr>
</tbody>
</table>

Note: PCL-5, PTSD Checklist for DSM-5. * Due to small sample sizes, additional self-reported racial identities have been combined.

### Table 4

<table>
<thead>
<tr>
<th>Variable</th>
<th>Mean (SD) or %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Experience a traumatic injury that led to ED visit</td>
<td>Moderate to severe traumatic brain injury (Glasgow Coma Scale score of &lt;13)</td>
</tr>
<tr>
<td>18–65 years of age</td>
<td>Suffered a spinal cord injury with neurological deficits</td>
</tr>
<tr>
<td>English-speaking</td>
<td>Apparent (as indicated by medical records) substance abuse disorder</td>
</tr>
<tr>
<td>Ability to schedule a study appointment within 2-weeks of trauma</td>
<td>Visit to ED was a result of suicide or self-harm</td>
</tr>
</tbody>
</table>

Note: a. Rothbaum et al. (2014) b. Sternbach (2000). Of the 215 recruited participants, 165 had useable structural and resting-state fMRI data and were successfully geocoded.

Fig. 3. Histogram of neighborhood socioeconomic disadvantage (national ADI; Mean ADI ranking in current sample = 68 [vertical dashed line], standard deviation = 22; N = 165).
from all structural analyses and volumes were z-standardized. Four separate General Linear Models (GLM) were conducted in R (‘glm’ function) to evaluate the relationship between sub-cortical (bilateral amygdala and hippocampus) and cortical volumes (grey matter volume; vmPFC and insula), individual education, individual income, acute PTSD symptoms (PCL-5 scores), and ADI rankings. Individual estimated intracranial volume (ICV) from Freesurfer was used as covariate of no interest (Morey et al., 2016). An example of one of the statistical models is as follows:

\[
\text{Amygdala volume } \sim \text{ education } + \text{ income } + \text{ PCL-5 scores } + \text{ ICV } + \text{ ADI}
\]

Although both biological sex and age can impact structural volumes, we had no specific hypothesis regarding these demographic characteristics, and after controlling for estimated intracranial volume, these variables were not significant and therefore excluded from final reported models. As these were a priori analyses, alpha was set at 0.05, uncorrected.

4.5.2. Resting state

Images were preprocessed using the Matlab-based (version 2019b; Mathworks) SPM (version 12) CONN toolbox (Whitfield-Gabrieli and Nieto-Castanon, 2012; version 20; http://www.nitrc.org/projects/conn). Default preprocessing steps included: discarding the first three TRs, motion correction using a six-parameter linear transformation, normalization to Montreal Neurological Institute (MNI 152) template, and spatial blurring with a 4-mm full-width-at-half-maximum smoothing kernel. To address any confounding effects of motion, volumes with frame-wise displacement over 0.3 mm were excluded from analysis. Nuisance covariates (head motion and cerebrospinal fluid signal) were regressed out during first-level analysis. Participants were removed from analyses (both structural and functional) if more than 20% of the resting-state volumes were scrubbed. This criterion excluded seven participants (final N = 165).

The default ROIs provided in the CONN toolbox (AAL atlas) for the bilateral hippocampus, amygdala, and anterior insula, were used as seed regions for separate GLMs. As the vmPFC is not clearly defined by bilateral hippocampus, amygdala, and anterior insula, were used as seed regions from NeuroSynth (http://neurosynth.org/; Chen et al., 2020). We conducted seed-to-voxel analyses in which the mean BOLD signal from each ROI was correlated with all other voxels in the brain. In the group-level GLMs, individual education, individual income, gender, age, and acute PTSD symptoms (PCL-5 total scores) were included in the model as covariates. The effect of interest was the association between ADI (independent variable) and resting-state connectivity of the two seed regions. The rsFC statistics were thresholded at \( p < .05 \), with a height threshold of \( p < .001 \) uncorrected and a cluster-size threshold of an adjusted \( p < .05 \) false discovery rate (FDR) corrected.

4.5.3. Sensitivity analyses

To determine whether the results were driven by the most disadvantaged neighborhoods, we excluded the top 10% of participants with the highest ADI rankings (\( n = 19 \)) and reran all analyses (\( N = 146 \)). More information on these follow-up tests and the results are included in the supplementary materials.

Author contributions


Declaration of competing interest

The authors report no competing interests.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jynstr.2021.100385.

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