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Differentiating kinds of systemic stressors with relation to psychotic-like experiences in late childhood and early adolescence: the stimulation, discrepancy, and deprivation model of psychosis

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Abstract

INTRODUCTION: Conceptualizations that distinguish systems-level stress exposures are lacking; the Stimulation (lack of safety and high attentional demands), Discrepancy (social exclusion and lack of belonging), and Deprivation (lack of environmental enrichment) (SDD) theory of psychosis and stressors occurring at the systems-level has not been directly tested.

METHODS: Exploratory factor analysis was conducted on 3,207 youth, and associations with psychotic-like experiences (PLEs) were explored.

RESULTS: Though model fit was suboptimal, five factors were defined, and four were consistent with the SDD theory, and related to PLEs. Objective and subjective/self-report exposures for *deprivation* showed significantly stronger PLE associations compared to *discrepancy* and objective *stimulation* factors. Objective and subjective/self-report measures converged overall, though self-report *stimulation* exhibited a significantly stronger association with PLEs compared to objective *stimulation*.

DISCUSSION: Considering distinct system-level exposures could help clarify putative mechanisms and psychosis vulnerability. The preliminary approach potentially informs health policy efforts aimed at psychopathology prevention and intervention.

Keywords

stress; deprivation; neighborhood crime; neighborhood population density; psychosis; schizophrenia; psychotic-like experiences; belonging; social exclusion

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Conflict of Interest.

The authors report no biomedical financial interests or conflicts of interest.

Ethical Standards.

All studies were approved by IRB and complied with ethical standards for research with human subjects.

Introduction.

Stress exposure has been widely implicated to play a causal role in the etiology of psychosis (Mayo et al., 2017; McEwen, 2004; Mittal & Walker, 2019; Pruessner, Cullen, Aas, & Walker, 2017; Shah & Malla, 2015). A wide array of work has examined individual-level stressors and their relation to psychosis risk. More recently, however, the field has looked toward examining systems-level factors, such as neighborhood features. A recent review synthesizing the literature on systemic environmental risk factors for psychotic disorders hypothesized that many previously explored exposures fall within three domains (Vargas, Conley, & Mittal, 2020). These hypothesized environmental risk domains include *stimulation* (systemic factors conferring lack of safety and high attentional demands), *discrepancy* (systemic factors conferring lack of belonging and social exclusion), and *deprivation* (systemic factors conferring lack of needed environmental enrichment). To date, relevant systemic environmental risk literature has primarily focused on adult populations, whereas late childhood and early adolescent periods could represent a highly informative timespan for early detection and prevention efforts (Anniko, Boersma, & Tillfors, 2019; Felner et al., 1995; Zinzow et al., 2009). Further, while a body of literature supports the important roles for each of these three domains, they have yet to be directly tested together. The present investigation directly tested this theory in three stages: (1) first by examining whether risk factor exposures would separate into the hypothesized domains, (2) then relating the resulting domains to psychotic-like experiences (PLEs) to assess relevance to psychosis risk, and (3) finally, by comparing the magnitude of effects for observed associations by domain, in order to explore differences in degrees of vulnerability. Examining systems-level stress by synthesizing these factors into environmental domains of influence is a critical priority. Despite the considerable research attention dedicated to psychotic spectrum disorders, the field also lacks a clear understanding of environment x liability interactions, particularly in the pediatric developmental periods. Given the challenging prognosis of the condition, a better understanding of causal factors and systems-level prevention efforts are paramount.

Psychotic disorders are chronic in nature, difficult to treat, and highly debilitating, constituting one of the top 15 leading causes of disability worldwide (Vos et al., 2017). After psychotic illness onset, confounds related to factors such as medication use and functional decline make it difficult to distill factors driving illness onset. As such, assessment of associated symptoms or experiences on the psychosis spectrum, such as PLEs, provides a promising alternative for identifying factors relating to psychosis etiology (Van Os, Linscott, Myin-Germeys, Delespaul, & Krabbendam, 2009). PLEs, including experiences such as unusual beliefs, suspiciousness, and perceptual abnormalities, have been associated with pathogenic factors implicated in formal psychosis (Kelleher & Cannon, 2011; Morgan et al., 2009; Olin & Mednick, 1996; Orr, Turner, & Mittal, 2014; Papanastasiou et al., 2020; Yung et al., 2006). Further, PLEs are experienced by 13-15% of children (Laurens et al., 2007; Poulton et al., 2000), and childhood experiences of PLEs have been shown to increase later risk for psychotic disorder onset (Kline et al., 2014; Poulton et al., 2000; Welham et al., 2009). Investigating PLEs in childhood provides an opportunity to understand environmental risk factors early in development, prior to illness-related confounds. PLEs may also be

of key importance during a critical developmental period in which prevention could be particularly effective.

Stress exposure is a central contributing factor in the development of psychotic disorders (Green et al., 2010; McLaughlin et al., 2012). Robust and varied evidence suggests a wide host of stressors can cumulatively contribute to psychosis risk (Mayo et al., 2017; McEwen, 2004; Mittal & Walker, 2019; Pruessner et al., 2017; Shah & Malla, 2015). The neural diathesis-stress model, for example, posits that the accumulation of stressors can comprise “multiple hits” which, acting on a vulnerable system, can increase the likelihood of developing a psychotic disorder (Pruessner et al., 2017; Walker, Mittal, & Tessner, 2008). Although this theory highlights the importance of conceptualizing stressors collectively, isolating qualitatively distinct stressors could also be uniquely informative to psychosis etiology. Work on trauma exposure, for instance, has illuminated differing neurodevelopmental consequences depending on the type of trauma (Gibson, Alloy, & Ellman, 2016; McGrath et al., 2017; McLaughlin, Sheridan, & Lambert, 2014). Beyond individual-level factors such as trauma, distinct domains of systemic environmental risk factors may also contribute to vulnerability for developing a psychotic disorder. Systemic environmental risk factors have received less attention compared to individual-level factors (e.g., trauma, bullying, family environment). Conceptualizing systemic environmental factors into domains could ultimately aid in understanding the complex and multifaceted nature of psychotic illness presentation. Isolating the impacts of different dimensions of experience could be informative to psychotic disorder etiology. Indeed the nonpsychiatric literature has successfully spearheaded conceptualizing neurodevelopment in this manner with individual-level stressors (McLaughlin, Sheridan, & Lambert, 2014). Despite this fact, the psychotic disorder literature has largely conceptualized stressors collectively, with less attention given to understanding specific kinds of exposures or systemic environmental factors.

Individuals operate within a larger environmental, social, and cultural context (i.e., structural/systems-level factors); as such, stress can also occur at the systems-level (Bronfenbrenner, 1994; Glass & McAtee, 2006). Local structural characteristics (such as neighborhood socioeconomic status or cultural integration) could systematically affect well-being and risk for psychopathology. Increasing understanding of structural barriers to mental health has strong potential to inform health policy initiatives, along with prevention and intervention efforts at the societal level. To this end, our group has developed a literature-backed theoretical model of different types of structural exposures, along with distinct intermediary mechanisms of impact and proposed relevant neural systems (Vargas et al., 2020)—the Stimulation Discrepancy Deprivation (SDD) model of psychosis. While each hypothesized SDD domain benefits from support from the psychotic disorder literature, the distinctiveness of the domains has yet to be tested as they relate to the psychosis continuum. As a result, the degree to which each domain contributes to psychosis risk is unclear. Understanding each domain as it relates to degrees of risk for psychopathology could be immensely useful in identifying and prioritizing treatment targets. Further, existing evidence in support of each domain has often honed in on adolescent or young adult populations. Determining whether structural, environmental risk exposures are also impactful in earlier development (during childhood and early adolescence) in a way that is

relevant to sub-threshold psychotic symptoms, would lend granularity to our understanding of environmental risk exposure across developmental periods.

The ABCD dataset is the largest investigation of brain development and child health in the United States (Garavan et al., 2018; Volkow et al., 2018). The study constitutes a nationally representative collaboration across 21 sites aiming to understand child and adolescent development. Previous investigations on the ABCD dataset have indeed explored similar questions, lending unique insights in the process. Some of these have targeted systems-level features—Karcher and colleagues found that urbanicity, deprivation, and lead exposure risk related to PLEs (Karcher, Shiffman, & Barch, 2020), as well as system-level environmental risk and neural features (Karcher, Shiffman, et al., 2020; Marshall et al., 2020). At the individual level, adverse childhood experiences were also found to relate to PLEs (Karcher, Niendam, & Barch, 2020). While these investigations have provided an invaluable perspective, there are several outstanding questions that remain. First, while the existing evidence suggests systems-level factors are impactful, the theoretical understanding is more limited. It is unclear to what extent types of systemic stressors relate to psychosis vulnerability—examining differences in the magnitude of such associations would expand and inform the SDD theory, aiding understanding of degrees of impact. Further, while it is clear that there are converging mechanisms through which systemic stressors could be impactful, efforts to distinguish qualitatively distinct stressors have been limited. Distinguishing types of systemic stressors is a first and necessary preliminary step toward identifying and understanding how structural/systemic factors can contribute to stress, psychosis etiology, and symptomatology.

The current study utilized a nationally representative sample of youth aged 9 to 11 years old to further understand exposure to environmental stressors in relation to PLEs. The first aim was to directly test the SDD theory by exploring whether relevant items would load into factors consistent with the 3 hypothesized domains. The second aim was to determine whether the environmental stress domains would relate to PLEs, consistent with the SDD theory. The third aim was to then compare relative strengths of existing associations between environmental exposures and PLEs (in order to see whether certain exposures would show greater associations with psychosis risk than others). Finally, given investigations that have found divergences in self-reported versus objective environmental and neighborhood measures (Gallagher et al., 2016; Hidalgo, Kaphingst, Stafford, Lachance, & Goodman, 2015), a final exploratory aim sought to determine whether associations between objective, Census derived neighborhood metrics of environmental exposures and self-report measures indexing the same exposure would exhibit relations similar in magnitude.

Methods.

Participants.

The ABCD dataset includes a large representative sample of children aged 9-11 years old across 21 centers in the United States (see supplementary table 1 for demographic information) (Barch et al., 2018; Garavan et al., 2018). All centers obtained the parents' informed consent as well as the children's assent. Research procedures followed ethical guidelines laid out by respective Institutional Review Boards (doi: 10.15154/1519171). The

current sample used baseline data for participants who had available data for items in the final factor solution, as well as PLE data. In the case that there were two or three siblings that completed the study, one youth per family was randomly chosen for inclusion, which resulted in 1020 participants being excluded. A total of 6,415 were used to do the random sample split for EFA and CFA since they had available data on all self-report items that were initially considered, and a subset of 6072 also had available data on "objective" neighborhood measures, PLEs, and self-report items used in the factor analysis. Group demeaning per site was conducted to account for possible effects of nesting within sites according to recommendations (Bear, Gaskins, Blank, & Chen, 2011; Huang, 2016; Huang & Cornell, 2016). PLE analyses were conducted with site demeaned values.

PLEs.

The Prodromal Questionnaire-Brief Child version (PPS) was used to assess psychotic-like experiences (Cicero, Krieg, & Martin, 2019; Karcher et al., 2018; Loewy, Pearson, Vinogradov, Bearden, & Cannon, 2011). The 21-item self-report questionnaire has been previously validated in the ABCD study sample (Karcher et al., 2018). The questionnaire asked participants about specific PLEs that were endorsed with a binary response (yes/no). Participants also indicated whether there was distress related to endorsed symptoms on a 5-item Likert scale. Consistent with prior research, PLE scores accounting for distress were calculated whereby the total number of endorsed symptoms were weighed by the level of distress (0 indicates zero endorsement, 1 indicates endorsement without distress, and 2-6 indicate endorsement with incremental distress levels) (Karcher et al., 2018; Loewy et al., 2011). PLE scores accounting for distress were used for all analyses. For the current sample, the average item endorsement accounting for distress was 6.49, SD=10.77. Of our total sample, 57.4% of participants had a rating of >0 on the PPS.

Self-report questionnaires.

Self-report measures relevant to theoretical interest in the three domains of *deprivation, discrepancy,* and *stimulation* (see supplementary table 2 for full item prompts) were chosen across numerous administered scales (Vargas et al., 2020). These included the ABCD Parent Multi-Group Ethnic Identity-Revised Survey (MEIM) (Phinney & Ong, 2007), which separates into "ethnic identity search" and "affirmation, belonging and commitment" (Phinney & Ong, 2007). The ABCD Parent Vancouver Index of Acculturation (VIA)—Short Survey (Ryder, Alden, & Paulhus, 2000), which subdivides into "heritage" and "American" subscores (Ryder et al., 2000). Other scales administered included the ABCD Parent neighborhood safety/crime survey modified from PhenX (NSC) (Echeverria, Diez-Roux, & Link, 2004; Mujahid, Diez Roux, Morenoff, & Raghunathan, 2007), ABCD Parent Acculturation Survey Modified from PhenX (ACC), ABCD Youth ACC (Alegria et al., 2004; Marin, Sabogal, Marin, Otero-Sabogal, & Perez-Stable, 1987), and the ABCD Parents Demographics survey. Primary guardians/parents of the youth completed the ABCD Parent MEIM, ABCD Parent neighborhood safety/crime survey modified from PhenX (NSC), ABCD Parent VIA, and ACC. Items related to English proficiency were omitted due to the lack of theoretical relevance to the current study. Measures were developed by the ABCD team to index environmental and cultural factors that could be relevant to development (Alegria et al., 2004; Zucker et al., 2018). As such, these measures index exposures that

occur at the systems-level, which have been shown to increase vulnerability to experiencing chronic stress (Vargas et al., 2020).

Objective neighborhood features.

Residential history was collected through addresses where participants had lived across their lifetime. Addresses were used to determine Census tracts corresponding to each location. Each tract represents Census-delineated neighborhoods. Census and Federal Bureau of Investigation (FBI) data was used to calculate neighborhood population density, total crimes occurring in a certain neighborhood, and the area deprivation index (ADI). The ADI metric has been successfully adapted to measure neighborhood deprivation; it is calculated based on the American Community Survey 2015 5-year summary (Kind et al., 2014). Since these metrics are compiled based on government data, they will be referred to as "objective neighborhood features," drawing a contrast from neighborhood features of interest that are also assessed through self-report (such as the NSC).

Theorized systemic environmental exposure domains.

As mentioned above, the present investigation was not interested in exposure to individual level stressors, which have traditionally received more exposure in the clinical literature (such as bullying, family conflict, and other individual-level stress exposures). Rather, the study sought to hone in on environmental risk exposure occurring at the systems-level, building on a broader literature of various systemic environmental exposures and their relations to psychotic disorder incidence. As such, the variables that were chosen for inclusion reflect only exposure to system-level factors. The ABCD dataset provided us with a valuable opportunity to pull as many relevant variables that were theoretically consistent with the three previously hypothesized domains of systemic exposures: discrepancy, deprivation, and stimulation (Vargas et al., 2020). For discrepancy, the MEIM, VIA, and ACC scales were used, consistent with evidence that a lack of sense of belonging within one's culture, along with lack of participation and engagement with the majority culture and with one's culture, are cultural/systems-level factors that can confer a lack of social capital and social exclusion (Emerson, Minh, & Guhn, 2018; Veling et al., 2008; Yang, Lei, & Kurtulus, 2018). For the *deprivation* domain, the ABCD parent's demographic survey was used to index lack of access to environmental enrichment (through questions indexing access to resources such as access to doctors if needed, food, and utilities). For objective measures, the area deprivation index was used as a measure of neighborhood deprivation. Lastly, for the *stimulation* domain, high crime regions, along with urban/areas with high population density, have been theorized to comprise high attentional demands, engaging threat neural correlates and conferring higher arousal of stress systems (Freeman et al., 2015; Gong, Palmer, Gallacher, Marsden, & Fone, 2016; Newbury et al., 2017). As such, the NSC survey was chosen, which assesses neighborhood safety. For objective measures, total neighborhood crimes and population density were chosen as part of the *stimulation* domain.

Exploratory factor analysis[1].

To determine whether environmental risk factors would fall within hypothesized domains (Vargas et al., 2020), an exploratory factor analysis (EFA) was conducted on the self-report scales using the minimum residuals method (Comrey, 1962) with the "psych" package in *r*

(Revelle, 2016). An EFA was not conducted for the objective measures given they spanned 2 theorized domains (*stimulation* and *deprivation*) with only 3 items/objective measures, likely not comprising enough items for a stable multi-factor EFA (Raubenheimer, 2004). Given the theoretical expectation that some factors would correlate, an oblimin rotation was chosen. The number of factors were decided based on inspection of the scree plot, as well as based on theoretical consistency and interpretability. A cut-off value of 0.4 was chosen for factor loadings; items falling beneath this threshold were excluded (Peterson, 2000). The total sample of 6,415 was randomly split in half to create two samples, one for the EFA (n=3207) and the other for the confirmatory factor analysis (CFA; n=3208, see supplementary tables 3,4 for factor correlations and correlation matrix).

Confirmatory factor analysis.

The solution found in the first sample using EFA was tested in the second sample using CFA with R packages psych, lavaan, and semTools (Jorgensen, Pornprasertmanit, & Schoemann, 2018; Revelle, 2017; Rosseel, 2012). In the case that the model did not achieve adequate fit according to conventional thresholds, modification indices were used to make theoretically consistent modifications to improve the final model fit (Brown & Moore, 2012). Conventional thresholds include Model Chi-Square (X^2) p-value > 0.05, comparative fit index (CFI) ≥ 0.90, Tucker Lewis index (TLI) ≥ 0.90, root mean square error of approximation (RMSEA) < 0.08, and standardized root mean square residual (SRMR) < 0.08 (Hooper, Coughlan, & Mullen, 2008). Given the Chi-Square test's sensitivity to large sample sizes, this index was de-emphasized when assessing model fit given the size of our sample (Hu & Bentler, 1999).

Associations between self-report factors, objective neighborhood features, and PLEs.

To determine whether PLEs and self-report factors (from CFA solution) related to each other, nonparametric Spearman correlations were conducted adjusting for age and sex. Spearman correlations adjusting for age and sex were also conducted to test the association between PLEs and objective neighborhood features. A central aim was to compare the strength of associations between psychotic-like experiences and self-report items, as well as between objective neighborhood features and psychotic-like experiences. Differences between correlations between PLEs, self-report and objective neighborhood features indexing the same construct were also tested (i.e., self-report *stimulation*/neighborhood safety and *stimulation*/total number of crimes in neighborhood, neighborhood deprivation index, and self-reported *deprivation*/lack of resources). To test whether associations were significantly different, correlation coefficients were converted into a z-score using Fisher's r-to-z transformation (Meng, Rosenthal, & Rubin, 1992). Then, the asymptotic covariance of the estimates was computed and used in an asymptotic z-test to determine whether one correlation was significantly greater than the other (Lee & Preacher, 2013; Steiger, 1980). All analyses were Bonferroni corrected by dividing α=0.05 by the number of tests conducted (Bonferroni, 1935; Shaffer, 1995).

[1]Originally, an EFA was conducted on the entire sample, n=6,415, and CFA was not conducted. At reviewers' request, the sample was subsequently split into an exploratory and confirmatory sample during revisions to facilitate exploring fit and model modification.

Results.

Exploratory factor analysis for self-report items.

The Kaiser-Meyer-Olkin (KMO) and Bartlett's test of sphericity indicated the data was appropriate to analyze. The KMO measure of sampling adequacy was 0.89 (Kaiser, 1970, 1974; Kaiser & Rice, 1974). Bartlett's test of sphericity was significant, $\chi^2(435)=59580.6$, $p<0.05$ (Bartlett, 1951). The five-factor solution was chosen (a) after inspection of the scree plot, as well as (b) based on previous theoretical support, and (c) considering that six-and seven-factor solutions were difficult to interpret and had an insufficient number of primary loadings. One item was eliminated from the original variable set due to failure to meet the minimum criteria of having a primary factor loading of 0.4 or above ("In the past 12 months, were evicted from your home for not paying the rent or mortgage"). After item removal, the five-factor exploratory factor analysis solution using minimum residuals with an oblimin rotation explained 55% of the variance. All items in the analysis had primary loadings greater than 0.4 (Table 1). Reliability across items was adequate, $\omega_{total}=0.94$ (Revelle & Zinbarg, 2009).

Factor loadings were partially consistent with theoretical predictions. Factor 5 was theoretically consistent with the *deprivation* domain. Factor 3, in turn, was theoretically consistent with the *stimulation* domain. The *discrepancy* domain comprised the remaining 3 factors. Factors 1 and 4 index participation in heritage and American culture, respectively. Factor 2, in turn, indexes an individual's sense of belonging with ethnic group. Factors were named according to corresponding items and theoretical hypotheses. Factor 1 was named "heritage culture participation"; Factor 2 was deemed "Sense of belonging with ethnic group"; Factor 3 was named "Neighborhood safety"; Factor 4 was deemed "American culture participation"; Factor 5 was deemed "Deprivation" (see Figure 1, Table 1).

Confirmatory factor analysis and post-hoc modification indices.

The initial CFA of the 5- factor model found using EFA did not reach adequate fit thresholds, robust Chi-square=7927.997, $p<0.0001$, robust CFI=0.820, robust TLI=0.802, robust RMSEA=0.087, robust SRMR=0.056. Modification indices were run to identify contributors to the inadequate fit. These included likely cross-loadings between the "American culture participation" and "heritage culture participation" factors, including in items indexing participation in heritage versus American/mainstream cultural traditions, comfortability interacting with individuals of same heritage culture versus typical American people, and interest in having friends from heritage culture versus typical American friends. It is also likely that there was some redundancy within the "sense of belonging with ethnic group" factor, as residuals correlated across several items, including items assessing strong sense of belonging and strong attachment to ethnic group, doing things to understand ethnic background and talking to others to learn more about ethnic group, and participating in heritage versus American cultural traditions. Within the "American culture participation" factor, items related to maintaining/developing American mainstream cultural practices, believing in mainstream American values, as well as comfortability interacting with typical American people and enjoying typical American entertainment showed correlations. Finally, within the "deprivation" factor, items related to limited doctor availability versus limited

dentist availability showed correlated residuals. After modifications allowing residual correlations for these items, the model achieved adequate fit thresholds (except for the Chi-square test, which was expected given the sample size): robust Chi-square=4520.459, p <0.0001, robust CFI=0.909, robust TLI=0.897, robust RMSEA=0.06, robust SRMR=0.049 (see supplementary table 5 for individual item loadings).

Associations between self-report factors and PLEs.

Greater endorsement of the "deprivation" factor/*deprivation* domain related to greater PLEs (r=0.10) (Table 2, Figure 2a). Similarly, endorsement of safer neighborhoods/*stimulation* domain related to less PLEs (r=−0.09), consistent with predictions. Contrary to predictions, the "heritage cultural participation" factor was not found to significantly relate to PLEs. However, the other hypothesized *discrepancy* domain factors ("sense of belonging with ethnic group" and "American culture participation") related to PLES such that less sense of belonging with ethnic group (r=−0.05) and greater American culture participation (r=−0.03) predicted less PLEs. The strength of the correlations was subsequently compared to gauge the relative strength of observed associations; the "deprivation" factor association with PLEs was significantly greater than that of the *discrepancy* domain "American culture participation" and "sense of belonging with ethnic group" factors, which survived Bonferroni correction (see Table 2, Figure 2a). Likewise, the *stimulation*/neighborhood safety factor-PLE association was significantly stronger than that of the *discrepancy* domain "American culture participation" and "sense of belonging with ethnic group" factors. However, the association between self-report *deprivation* and PLEs was not significantly stronger than the association between self-report *stimulation*/neighborhood safety and PLEs.

Associations between objective neighborhood features and PLEs.

With regards to objective neighborhood measures, increased *stimulation*/neighborhood population density (r=0.07) related to increased experience of PLEs. This was not the case for *stimulation*/neighborhood total crimes, which did not observe a significant association. *Deprivation*/neighborhood deprivation (r=0.14) related to increased experience of PLEs. The strength of the correlations was compared; The association between *deprivation*/ neighborhood deprivation and PLEs was significantly stronger than the associations observed for both *stimulation*/total crimes and *stimulation*/population density (Table 2, Figure 2b).

Exploratory comparison of objective and self-report measures.

Finally, as an exploratory aim self-report measures and their corresponding objective measures were compared in terms of strength of the association observed. The *deprivation*/ neighborhood deprivation-PLE association was significantly stronger from the self-reported "deprivation factor"-PLE association. However, the self-reported *stimulation*/ "neighborhood safety"-PLE association was significantly stronger than that of *stimulation*/neighborhood total crimes (which did not observe a significant association with PLEs).

Discussion.

The current study used a large representative sample to examine whether structural environmental exposures could be distinguished as theorized in the SDD model of psychosis. Further, exposures (self-report and objective) were explored in relation to PLEs. Although we expected three factors to emerge, the EFA of self-report data identified 5 factors, corresponding to heritage culture participation, sense of belonging with ethnic group, American culture participation, neighborhood safety, and deprivation. Though more factors were fit than anticipated and fit indices were suboptimal prior to modification indices being applied, these factors were partially consistent with the SDD model. Critically, the present investigation is among the first to compare the relative strength of the association between these distinct domains of environmental exposure to stress and psychosis risk. Environmental exposure to stress across the three domains related to PLEs (|*r*| ranging from 0.03-0.14): the "deprivation" factor association with PLEs was significantly greater than that of the *discrepancy/*"American culture participation" and *discrepancy/*"sense of belonging with ethnic group" factors, suggesting deprivation exposures could relate more strongly to psychosis vulnerability. Consistent with this interpretation, in terms of objective neighborhood measures, the association of neighborhood deprivation and PLEs was also significantly stronger than the association for *stimulation*/neighborhood population density and *stimulation*/neighborhood crime. Self-report *stimulation* exposures (neighborhood safety) also showed a stronger association compared to *discrepancy/*"American culture participation" and *discrepancy/*"sense of belonging with ethnic group". Taken together, results aid in refining and building on the SDD theory of psychosis, which could in time be informative to relevant public policy conceptualizations of prevention and intervention.

EFA was utilized for self-report scales measuring systemic factors applicable to the SDD theory. Using self-report items completed by the parents alleviated concerns common to self-report scales regarding state effects (such as mood and fatigue) influencing ratings of exposure (the inclusion of objective measures was also helpful in this regard). As expected, items taken from the NSC survey loaded onto a "Neighborhood safety" factor (Echeverria et al., 2004). These items reflected feelings of safety in one's living environment, consistent with the *stimulation* SDD domain. Items inquiring about income/resource availability, indexing degrees of environmental enrichment, consistent with the *deprivation* domain, loaded onto a "deprivation" factor. Lastly, items related to culture separated into factors relating to "heritage culture participation", "American culture participation," and "sense of belonging with ethnic group". Of these factors, "sense of belonging with ethnic group" and "American culture participation" are conceptually consistent with the *discrepancy* domain, as they index current feelings of belonging and participation. The fact that these items did separate into three factors could indicate that the *discrepancy* domain requires further granularity in conceptualization—perhaps separate domains or distinct subdomains more closely represent these exposures. Future investigations will benefit from these insights in further refining and modifying the SDD theory.

It is necessary to highlight that CFA did not show adequate model fit for the 5-factor solution supported by the EFA in sample 1. As a result, any interpretations relating results to the SDD theory should be considered to be preliminary. Future investigations will be

essential in further refining the model as well as identifying ideal self-report measures for each of the domains. Modification indices suggest that cross-loadings between the "American culture participation" and "heritage culture participation" factors contributed to the degree of model fit (possibly at least partially due to similar wording across items). Further, items for the "American culture participation" and "heritage culture participation" factors did not explicitly assess for relative degrees of participation/comfortability; the items did not directly assess to what degree someone participates in mainstream American culture relative to heritage culture, which could have resulted in correlated residuals between items.

Modification indices also revealed the presence of correlated residuals among items within the "sense of belonging with ethnic group" factor, as well as for items within the "deprivation" factor, possibly due to redundancy across items within each factor. Although the ABCD dataset provided an invaluable opportunity to test the SDD theory in a preliminary fashion, it also included items were not originally designed to test the SDD theory. As such, some "noise" is likely attributable to the fact that the items do not fully capture the theoretical domains. Perhaps the domains represent formative, rather than reflective, latent variables. Future refining of current measures to improve granularity and theoretical consistency to the SDD theory will be helpful, along with further refining and revising of the SDD theory itself. Nonetheless, given the limited existing literature on qualitatively distinct systemic stressors and their relation to psychosis vulnerability, the current investigation offers a preliminary starting point to understanding these exposures through self-report items.

Further, the SDD theory concerns itself with stressors occurring at the systems-level while also recognizing the multitude of individual-level factors that could also contribute to indicators—as such, cross-loadings would be expected. Though cross-loadings could likely be present, and the items were not uniquely designed for measuring the intended latent constructs, the observed factors could nonetheless be useful in conceptualizing systemic stressors and predicting psychosis vulnerability. For example, big 5 personality models, which have often shown cross-loadings and suboptimal fit with a 5-factor CFA structure, are nonetheless highly useful models and reliably predict outcomes of interest (Gurven, Von Rueden, Massenkoff, Kaplan, & Lero Vie, 2013; Marsh et al., 2010; McCrae & Costa Jr, 1997). As such, despite suboptimal CFA fit, the current study proceeded to correlate the self-report factors to PLEs, as we did with objective measures of the domains (neighborhood crime, population density, and deprivation), to increase our understanding of whether the factors are indeed useful in predicting psychosis vulnerability. Associations with PLEs should be treated as preliminary and interpreted with caution.

Collectively, findings showed that both objective (neighborhood deprivation and *stimulation*/neighborhood population density) and subjective endorsement of *stimulation* and *deprivation* exposures contribute to the association with PLEs. Decreased reports of *stimulation*/neighborhood safety (along with higher *stimulation*/neighborhood population density) predicted greater PLE endorsement. Results are consistent with previous investigations on adolescents and adults finding *stimulation* exposures to relate to increased risk for developing a psychotic disorder (Bhavsar, Boydell, Murray, & Power, 2014; Freeman et al., 2015; Gong et al., 2016; Kirkbride, Jones, Ullrich, & Coid, 2012; Newbury et

al., 2018; Wilson-Genderson & Pruchno, 2013). Increased reporting of *deprivation* and higher objective neighborhood deprivation predicted greater endorsement of PLEs. Similar to *stimulation* exposures, results are consistent with a strong body of literature which suggests that exposure to both individual and neighborhood deprivation can confer risk for psychosis (Bhavsar et al., 2014; Bhavsar, Fusar-Poli, & McGuire, 2018; Kirkbride et al., 2012; Lasalvia et al., 2014; O'Donoghue et al., 2015; Omer et al., 2014), along with adversely affecting an individuals' physical health and functional outcomes (Akman, Zhao, Liu, & Holmes, 2004; Beckett et al., 2006; Gee et al., 2013; Kobayashi et al., 2017; Lang et al., 2009; Mackes et al., 2020; McCann et al., 2018; McLaughlin, Sheridan, Winter, et al., 2014; Mensah & Hobcraft, 2008; Richards, Chapple-McGruder, Williams, & Kramer, 2015; Uysal et al., 2005; Wiesel & Hubel, 1965). Further, results suggest that the relation between these environmental exposures and psychosis spectrum symptoms extends to non-clinical psychosis and is evident as early as late childhood to late adolescence. Of interest, self-report factors for *stimulation*/neighborhood safety and *deprivation* were correlated (r=−0.3)—which was not the case for self-report factors relating to the *discrepancy* domain. This is consistent with our theory that the systemic exposures share common underlying mechanisms, along with phenomenologically distinct effects and manifestations.

Of the self-report factors relevant to the *discrepancy* domain, decreased "sense of belonging with ethnic group" and increased "American culture participation" related to less endorsement of PLEs. Observed associations are congruent with evidence that high ethnic density (Schofield et al., 2017; Termorshuizen, Smeets, Braam, & Veling, 2014; Veling et al., 2008) and social cohesion (Crush, Arseneault, Jaffee, Danese, & Fisher, 2018) can serve as protective factors. Results extend the existing literature by providing evidence that *discrepancy* systemic exposures could relate to PLEs as early as late childhood to early adolescence (Allardyce et al., 2005; Crush et al., 2018; Lasalvia et al., 2014; Schofield et al., 2017; Silver, Mulvey, & Swanson, 2002; Termorshuizen et al., 2014; Van Os, Driessen, Gunther, & Delespaul, 2000; Veling et al., 2008). The "heritage culture participation" factor, on the other hand, was not associated with PLEs. The lack of significant association between "heritage culture participation" and PLEs could be due to insufficient factor specificity with regards to feelings of belonging. That is, one could participate in one's heritage culture and yet not feel a sense of belonging with their surroundings more broadly or with the majority culture. Psychosis environmental risk factors theorized by the SDD theory *discrepancy* domain include ethnic minority status (Lasalvia et al., 2014; Termorshuizen et al., 2014), low ethnic density (Schofield et al., 2017; Veling et al., 2008), and social fragmentation (Allardyce et al., 2005; Silver et al., 2002; Van Os et al., 2000). Perhaps the "heritage culture participation" factor does not fully capture these experiences of social exclusion or lack of belonging. "American culture participation," on the other hand, did relate to PLEs. The association makes sense as American culture in the United States would comprise the "majority" culture. Given the vast evidence of low ethnic density and minority status conferring psychosis risk (Lasalvia et al., 2014; Schofield et al., 2017; Termorshuizen et al., 2014; Veling et al., 2008), perhaps "American culture participation" indexes comfortability within the majority culture, which could directly impact overall social capital and sense of social cohesion, effecting psychosis risk through this mechanism (Butler & Muir, 2017; Crush et al., 2018; Schellenberg, Lu, Schimmele, & Hou, 2018; Verhaeghe & Tampubolon,

2012). The ABCD dataset provided an opportunity to test some systemic exposures that fall within the discrepancy domain. Future investigations assessing other environmental exposures theorized to fall under the *discrepancy* domain and further establishing specificity could aid in offering more nuance to current results.

The literature thus far has been limited in comparing the magnitude of associations between distinct environmental exposures and psychosis vulnerability, with the proposed SDD model originally being more-or-less agnostic with regards to the relative magnitude of the associations between differing systemic exposures. The three domains showed differential associations with PLEs, demonstrating their relative contribution could be informative to consider, as well as highlighting the importance of considering individual domains (as opposed to an aggregate of systemic environmental stress exposure). In the current sample, observed associations between *deprivation* (objective and self-report) exposures and PLEs were significantly stronger than associations between PLEs and *discrepancy* exposures, with effect sizes for *deprivation* being twice as large (from r=0.09-0.14 for *deprivation* to 0.03-0.05 for *discrepancy*). The observed difference is consistent with animal and human literature suggesting that lack of neurodevelopmentally appropriate enrichment can have widespread consequences, impacting a host of key systems necessary for general functioning, as well as overall health and well-being (Akman et al., 2004; Beckett et al., 2006; Gee et al., 2013; Kobayashi et al., 2017; Lang et al., 2009; Mackes et al., 2020; McCann et al., 2018; McLaughlin, Sheridan, Winter, et al., 2014; Mensah & Hobcraft, 2008; Richards et al., 2015; Uysal et al., 2005; Wiesel & Hubel, 1965). Notably, the *deprivation* exposure objective measures also exhibited significantly stronger associations with PLEs (r=0.14) compared to objective *stimulation*/population density (r=0.07) and *stimulation*/neighborhood crimes (r=0.02). Future investigations will be necessary in order to clarify possible mechanisms through which systemic exposures could differ in magnitude.

PLEs are complex, with a multitude of putative contributing factors. Likewise, systemic environmental exposures are complex and multifaceted, with a rich variety of complex protective and exacerbating factors (including potent individual-level stressors) to moderate and mediate relationships. This can lead to measures of systemic effects and neighborhood effects tending toward what could be considered small effect sizes (Barrington et al., 2014; Crump, Sundquist, Sundquist, & Winkleby, 2011; Cubbin & Winkleby, 2005; Cummins, McKay, & MacIntyre, 2005; Forsberg, Ohlsson, & Sundquist, 2018; Gale, Magzamen, Radke, & Tager, 2011; Jaffe, Eisenbach, Neumark, & Manor, 2005; Kirkbride et al., 2012; Lang et al., 2009). However, it is critical to interpret effect sizes in the context of the relationships they are depicting (Funder & Ozer, 2019). Effect sizes could be small in the face of single events and prove more ultimately consequential as effects accumulate over the medium and long term (Funder & Ozer, 2019). As such, effects observed during childhood could accumulate over many years and have a nontrivial impact across the lifetime. Thus, observed effects, though small, can be meaningful when considered in context, especially when assessing aggregate effects for communities, regions, or even countries as a whole; indeed a host of rather small effects have served as springboards for effective health policy initiatives (Arnett, 2019; Funder & Ozer, 2019; Schwingshackl et al., 2015).

An exploratory aim sought to compare the magnitude of PLE associations between self-report versus objective environmental exposures. The PLE association with objective neighborhood deprivation was significantly stronger in magnitude than the PLE association with self-report deprivation. However, this was not the case with *stimulation* exposures. The PLE association with self-report *stimulation*/neighborhood safety was significantly stronger in magnitude compared to objective *stimulation*/neighborhood total crimes (which did not show a significant association with PLEs). While preliminary, results suggest that perhaps the association between PLEs and *stimulation*/crime exposure is at least partially contingent on conscious awareness: in this case, self-reported lack of safety could represent heightened awareness of the "objective" circumstances, or it could represent inaccurate reporting due to heightened vigilance. Alternatively, it could be the case that collection sites had different average crime rates, which could have blunted an existing effect when the variance related to site was partialled out in analyses. Future investigations are needed in order to parse out these possibilities.

Current results constitute a promising, though preliminary, start to broader questions with the potential to inform models of psychosis vulnerability, highlighting the value of targeting specific environmental factors in preventive health policy efforts for psychotic disorders. Results ought to be treated as preliminary and interpreted with caution. Initial findings aid in refining and modifying the SDD theory moving forward and must be contextualized within certain limitations. There is the problem of intra-category variability that characterizes many if not most stressful life event measures (Dohrenwend, 2006). The self-report measures utilized in this study showed robust reliability (Alegria et al., 2004; Echeverria et al., 2004; Marin et al., 1987; Phinney & Ong, 2007; Ryder et al., 2000). Yet, future studies may benefit from further building on practices recommended for limiting intra-category variability, such as implementing more closed probes as well as more stringent inclusion and exclusion criteria for considering an experience endorsed (Dohrenwend, 2006). Thankfully, our concerns related to self-report and intra-category variability were tempered by the inclusion of objective measures of the constructs of interest. Future investigations will benefit from continuing to benefit from self-report data while also complementing it with corroborating evidence or objective measures. Likewise, future investigations may benefit from increasing granularity and more fully incorporating other facets of systems-level environmental exposures and integrating them to build on and improve conceptual frameworks of systems-level environmental stressors.

The present work focused on systems-level environmental exposures, aiming to distinguish distinct components of systemic exposures that could confer stress. The theoretical interest was identifying qualitatively distinct systemic exposures with theorized intermediary mechanisms (based on prior research). We chose not to include race in our models given the overwhelming evidence of systemic disadvantage that disproportionally affects black indigenous people of color (BIPOC) and ethnic minorities (Adler & Stewart, 2009; P. Braveman, 2014; P. A. Braveman et al., 2011; Brondolo, Gallo, & Myers, 2009; Jackson, Knight, & Rafferty, 2010; Joynt, Orav, & Jha, 2011). If the effect of "race" is partialled out, one may miss impactful signal due to ethnic minorities and BIPOC being disproportionately more likely to experience systemic environmental risk factors. Thus, the aim of the present study was to detail differing components of systemic exposures

such that these may be better understood and conceptualized as a whole when considering systemic disadvantage. While race was beyond the scope of the study questions, future investigations could further investigate interactions of types of systemic exposures with race and other factors, building on this knowledge. Beyond this point, it is necessary to consider that the current investigation utilized one (albeit well-powered) sample, and thus did not replicate the established factor structure in an independent sample. Therefore, it will be critical for future work to confirm the observed factor structure in independent samples, thus establishing replicability and increasing generalizability of the work. The current results ought to be interpreted as preliminary until replicability is established. Future work would also benefit from exploring neural and biological mechanisms that could underlie the associations observed between environmental exposures and psychosis vulnerability. Collecting information on the precise timing of exposure would further add richness to neurodevelopmental conceptualizations of risk and resilience. Examining interactions between individual level factors (e.g., trauma, family environment, exposure to bullying), systemic factors, and relations to psychosis vulnerability in children and adolescents would also be a worthwhile line of inquiry. Lastly, longitudinal investigations would aid our ability to predict the directionality of the associations and account for confounds such as social drift.

Supplementary Material

Refer to Web version on PubMed Central for supplementary material.

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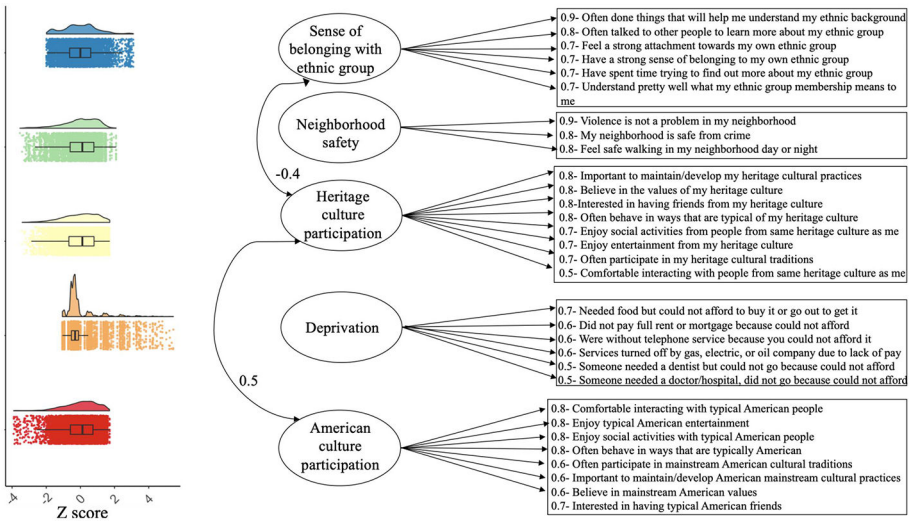

Figure 1.

Exploratory factor analysis of self-report items. “Neighborhood safety” is part of the *stimulation* domain. “Sense of belonging with ethnic group” and “American culture participation” comprise the *discrepancy* domain. “Deprivation” constitutes the *deprivation* domain. “Heritage culture participation” did not relate to PLEs and was not included within the three SDD domains. Factor correlations with medium effect sizes were included. The rest of the factor correlations are in supplementary table 4. The left panel represents the distribution and interquartile range for endorsement of items for each respective factor.

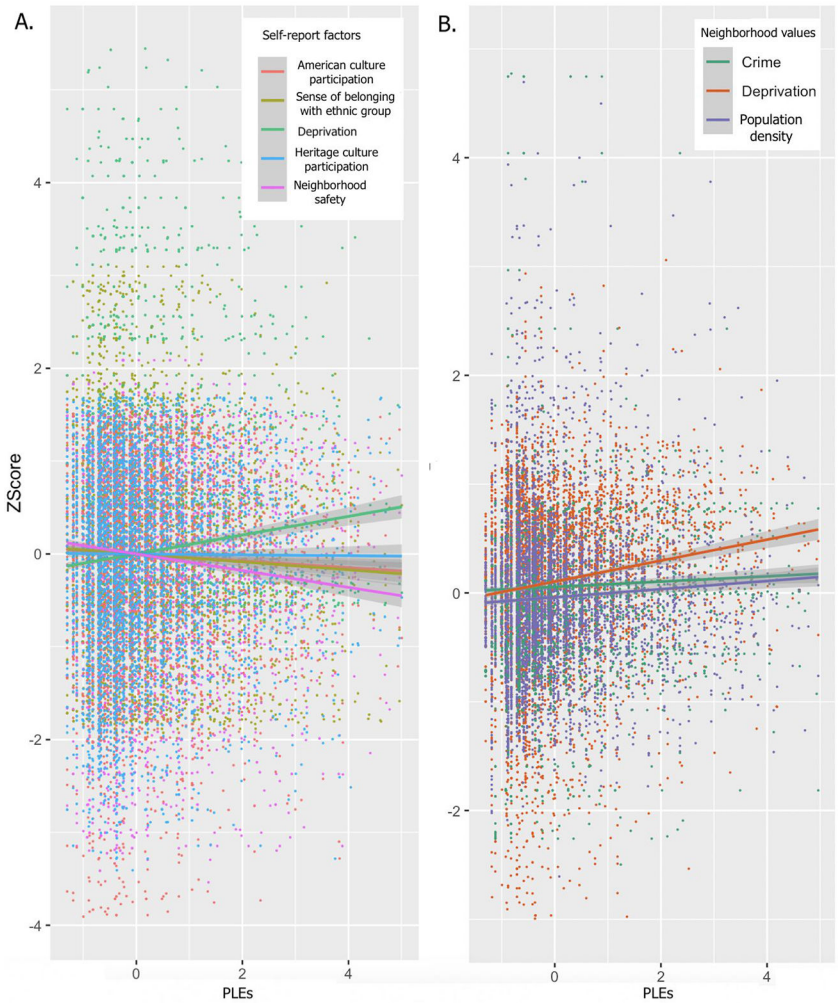

Figure 2.

Associations between self-report factors *discrepancy*/sense of belonging with ethnic group, *discrepancy*/American culture participation, *deprivation, stimulation*/neighborhood safety, and heritage culture participation (A), objective neighborhood metrics (B) and PLEs.

Table 1.

Exploratory factor analysis loadings, uniqueness and communality metrics; h^2 represents the communalities metrics, u^2 represents the uniqueness metrics, and com represents the complexity of component loadings per item.

Item	Factor	Factor 1	Factor 4	Factor 2	Factor 3	Factor 5	h2	u2	com
I have spent time trying to find out more about my ethnic group	2	0.05	0.00	0.70	0.00	0	0.46	0.54	1
I have a strong sense of belonging to my own ethnic group	2	−0.08	−0.04	0.71	−0.04	0.03	0.57	0.43	1
I understand what my ethnic group membership means to me	2	−0.02	−0.07	0.68	−0.03	0.05	0.49	0.51	1
I have often done things that will help me understand my ethnic background better	2	0.03	0.03	0.89	0.02	0	0.76	0.24	1
I have often talked to other people I order to learn more about my ethnic group	2	0.03	0.03	0.85	0.03	−0.04	0.7	0.3	1
I feel a strong attachment towards my own ethnic group	2	−0.11	−0.03	0.75	0	−0.02	0.66	0.34	1
I often participate in my heritage cultural traditions	1	0.69	−0.06	−0.13	0	−0.03	0.54	0.46	1.1
I often participate in mainstream American cultural traditions	4	0.00	0.6	−0.09	0.06	−0.07	0.42	0.58	1.1
I enjoy social activities with people from the same heritage culture as myself	1	0.74	0.09	−0.01	−0.01	−0.01	0.63	0.37	1
I enjoy social activities with typical American people	4	−0.03	0.82	−0.04	0	−0.02	0.66	0.34	1
I am comfortable interacting with people of the same heritage culture as myself	1	0.47	0.37	0.08	0.01	−0.03	0.5	0.5	2
I am comfortable interacting with typical American people	4	0.00	0.82	0.04	0.02	−0.02	0.68	0.32	1
I enjoy entertainment from my heritage culture	1	0.71	−0.01	0.06	−0.04	0.04	0.47	0.53	1
I enjoy typical American entertainment	4	−0.04	0.8	0.03	−0.02	0.01	0.6	0.4	1
I often behave in ways that are typical of my heritage culture	1	0.77	−0.04	0.07	0.05	−0.02	0.54	0.46	1
I often behave in ways that are typically American	4	−0.11	0.77	0.01	0.03	−0.01	0.53	0.47	1
It is important for me to maintain or develop the practices of my heritage culture	1	0.84	−0.06	−0.09	0.01	−0.02	0.75	0.25	1
It is important for me to maintain or develop American mainstream cultural practices	4	0.14	0.59	−0.1	−0.01	0	0.48	0.52	1.2
I believe in the values of my heritage culture	1	0.83	0.02	0	−0.01	0	0.7	0.3	1
I believe in mainstream American values	4	0.10	0.63	−0.01	−0.01	0.02	0.46	0.54	1
I am interested in having friends from my heritage culture	1	0.77	0.07	−0.01	−0.01	0.04	0.65	0.35	1
I am interested in having typical American friends	4	0.17	0.65	−0.03	−0.01	0.05	0.56	0.44	1.2
I feel safe walking in my neighborhood, day or night	3	0.00	0.00	0.00	0.79	0.02	0.62	0.38	1
Violence is not a problem in my neighborhood	3	0.01	0.00	0.01	0.92	0	0.84	0.16	1
My neighborhood is safe from crime	3	0.00	0.01	−0.01	0.84	−0.01	0.71	0.29	1
Needed food but could not afford to buy it or go out to get it?	5	0.00	0.01	0.00	0.00	0.69	0.47	0.53	1
Were without telephone service because you could not afford it?	5	0.02	−0.03	0.03	−0.01	0.6	0.37	0.63	1

Item	Factor	Factor 1	Factor 4	Factor 2	Factor 3	Factor 5	h2	u2	com
Didn't pay the full amount of the rent or mortgage because you could not afford it?	5	−0.02	0.03	−0.02	−0.02	0.62	0.39	0.61	1
Had services turned off by the gas or electric company, or the oil company wouldn't deliver oil because payments were not made?	5	−0.03	0.01	0.01	0.03	0.57	0.31	0.69	1
Had someone who needed to see a doctor or go to the hospital but didn't go because you could not afford it?	5	−0.01	−0.01	−0.03	0.03	0.48	0.23	0.77	1
Had someone who needed a dentist but couldn't go because you could not afford it?	5	0.02	−0.03	−0.02	0.01	0.51	0.27	0.73	1

Table 2.

Spearman partial correlations for self-report and objective measures controlling for sex and age, along with comparisons of the strength of association. Factor 3 (neighborhood safety), neighborhood population density and crime are part of the *stimulation* domain. Factor 2 (sense of belonging with ethnic group), Factor 1 (heritage culture participation), and Factor 4 (American culture participation) comprise the *discrepancy* domain. Factor 5 (deprivation) and neighborhood deprivation constitute the *deprivation* domain. CI represents confidence intervals.

Association with PLEs	***95% CI***	***r***	$P_{uncorrected}$	**Survived bonferroni correction?**[a]
Self-report				
Factor 1 heritage culture participation	−0.03- 0.02	−0.003	0.829	No
Factor 2 sense of belonging with ethnic group	−0.07- −0.02	−0.045	0.000264	Yes
Factor 3 neighborhood safety	−0.12- −0.07	−0.094	4.52E-14	Yes
Factor 4 American culture participation	−0.06- −0.01	−0.032	0.011	No
Factor 5 deprivation	0.07- 0.12	0.098	3.49E-15	Yes
Objective neighborhood characteristics				
Neighborhood population density	0.04- 0.09	0.067	1.91E-7	Yes
Neighborhood crime	−0.01- 0.04	0.016	0.214	No
Neighborhood deprivation	0.11- 0.16	0.137	5.89E-27	Yes
Strength of correlation comparisons		**|Z| score**	$P_{uncorrected}$	**Survived bonferroni correction?**[a]
Self-report comparison				
Sense of belonging with ethnic group/neighborhood safety		2.807	0.005	Yes
American culture participation/neighborhood safety		3.848	0.000119	Yes
Deprivation/neighborhood safety		0.207	0.83591	No
Sense of belonging with ethnic group/American culture participation		0.67	0.50299	No
Sense of belonging with ethnic group/deprivation		2.966	0.00302	Yes
American culture participation/deprivation		3.59	0.00033	Yes
Self-report/objective measure comparison				
Self-report deprivation/ neighborhood deprivation		2.397	0.01655	Yes
Self-report neighborhood safety/ crime		4.009	0.00006	Yes
Objective measure comparison				
Pop density/ crime		3.342	0.000832	Yes

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Association with PLEs	*95% CI*	*r*	$P_{uncorrected}$	Survived bonferroni correction?[a]
Neighborhood deprivation/pop density		4.72	0.000002	Yes
Neighborhood deprivation/crime		7.037	0	Yes

[a]Whether the association survived correction for multiple comparisons. The threshold was determined by dividing the alpha level (0.05) by the number of comparisons (5 for self-report measures, 3 for objective measures). The self-report value is 0.01. The objective measure value is 0.01667.

For self-report comparisons (6), the bonferroni-corrected threshold was 0.00833. For self-report/objective measure comparisons, the bonferroni-corrected threshold was 0.025. For objective measure comparisons, the Bonferroni-corrected threshold was 0.01667.