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Social victimization, default mode network connectivity, and psychotic-like experiences in adolescents

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ABSTRACT

Social victimization (SV) and altered neural connectivity have been associated with each other and psychotic-like experiences (PLE). However, research has not directly examined the associations between these variables, which may speak to mechanisms of psychosis-risk. Here, we utilized two-year follow-up data from the Adolescent Brain Cognitive Development study to test whether SV increases PLE through two neural networks mediating socio-affective processes: the default mode (DMN) and salience networks (SAN).

We find that a latent SV factor was significantly associated with PLE outcomes. Simultaneous mediation analyses indicated that the DMN partially mediated the SV-PLE association while the SAN did not. Further, multigroup testing found that while Black and Hispanic adolescents experienced SV differently than their White peers, the DMN similarly partially mediated the effect of SV on PLE for these racial groups. These cross-sectional results highlight the importance of SV and its potential impact on social cognitive neural networks for psychosis risk.

1. Introduction

Approximately 17 % of children and 7 % of adults experience psychotic-like experiences (PLE; Kelleher et al., 2012; Linscott and van Os, 2013). While PLE are transient for the majority of people, PLE can cause distress and are linked with increased risk for both psychotic and non-psychotic disorders (Healy et al., 2019; Lindgren et al., 2022). The prevalence of PLE and their risk for later disorders, highlight the importance of better understanding PLE and the mechanisms that underly PLE.

A growing literature implicates chronic social victimization (SV)—social experiences in which a person suffers physical or psychological harm, such as bullying, interpersonal conflict, and discrimination—as a contributor to increased and more distressing PLE. For example, longitudinal studies on bullying, show that bullied adolescents are more likely to have PLE years later (Crush et al., 2018; Mackie et al., 2013; Schreier et al., 2009; Wolke et al., 2014). Further, research has shown family discord, such as elevated parent-child conflict and poor family communication, has been associated with increased adolescent PLE, increased symptom severity, and less clinical improvement (Healy et al., 2020; Otero et al., 2011). Similarly, others have shown greater expressed emotion—spontaneous negative talk from caregivers toward patients with mental illness (Butzlaff and Hooley, 1998)—precedes the onset or worsening of psychosis-spectrum disorders (PSDs; Aguilera et al., 2010; Cechnicki et al., 2013; Marom et al., 2002).

The effect of SV continues to predict PLE when examining structural stressors, particularly among racial minorities. Studies examining racial microaggressions and discrimination have shown a robust positive association between racism and PLE (Anglin and Lui, 2023; DeVylder et al., 2023; Oh et al., 2014; Pearce et al., 2019). Moreover, research has shown that racist experiences partially explain the elevations in PLE seen between Black and White individuals in the United States (US; Anglin and Lui, 2023; Oh et al., 2022). Relatedly, DeVylder and colleagues have found linear dose-dependent relationships between victimization by police and PLE in US adults (DeVylder et al., 2023, 2017). Further, research has found a cumulative effect of personal and neighborhood victimization on PLE, with a variety of neighborhood characteristics, including low social cohesion, high neighborhood disorder, and neighborhood social disconnectedness, contributing to increased risk for PLE (Marsh et al., 2022; Newbury et al., 2018).

Despite the clear association between SV and psychotic experiences, the mechanism by which SV influences psychosis-risk is still largely

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unclear. Selten and colleagues (Selten et al., 2013; Selten and Cantor-Graae, 2005) posit a social defeat theory of psychosis in which repeated exclusionary experiences over time lead to sensitization of the mesolimbic dopamine system which in turn increases risk for psychosis. Additionally, Friston and others (Friston, 1998; Friston et al., 2016; Stephan et al., 2006), have hypothesized that psychosis arises from altered brain connectivity associated with the prefrontal cortex, a key brain region responsible for executive functioning and socio-emotional control. Increasing work has demonstrated that PSDs and psychosis-risk individuals experience marked abnormalities in large-scale resting networks, including those that play a central role in social information processing, specifically the default mode network (DMN) and salience network (SAN; Andrews-Hanna et al., 2014; Buckner et al., 2008; Doucet et al., 2020; M.-L. Hu et al., 2017; Huang et al., 2020; Palaniyappan and Liddle, 2012; Wang et al., 2016; White et al., 2010, 2013; Whitfield-Gabrieli and Ford, 2012). An unexplored possibility that we evaluate in the current study is that SV impacts psychosis-risk by altering these networks, especially given that the DMN and SAN are robustly related to socioemotional processes.

The DMN is comprised of the posterior cingulate cortex (PCC), medial prefrontal cortex (MPFC), and angular gyri, and is implicated in a variety of self-directed, social, and stimulus-independent processes, including self-referential processing, episodic memory, and mental state attribution (Andrews-Hanna et al., 2014; Buckner et al., 2008; Whitfield-Gabrieli and Ford, 2012). The SAN, which includes the insula and anterior cingulate cortex, has been implicated in the detection and integration of emotional and sensory information, as well as switching between the DMN and central executive network (Corr et al., 2022; Palaniyappan and Liddle, 2012). Altered DMN and SAN connectivity have been repeatedly demonstrated in psychosis-risk, first-episode, and chronically-ill psychotic-spectrum disorder samples (Del Fabro et al., 2021; Hu et al., 2017; Huang et al., 2020; Karcher et al., 2019; Mennigen and Bearden, 2020; O'Neill et al., 2020, 2019; Wang et al., 2016; White et al., 2013, 2010; Whitfield-Gabrieli and Ford, 2012).

In addition to being associated with psychosis, functional connectivity within and between DMN and SAN hubs have been linked to experiences of victimization in adolescents and young adults (Corr et al., 2022; McIver et al., 2019; Rudolph et al., 2021). For example, Corr and colleagues (Corr et al., 2022) found that adolescents exposed to acute stressors exhibited decreased connectivity between the DMN and SAN, and this was further reduced among those that had experienced greater levels of victimization over their life. These alterations in connectivity have also been linked to psychopathology. In a group of young adults, McIver and colleagues (McIver et al., 2019) found functional connectivity between the amygdala (a subcortical hub of the SAN) and the MPFC moderated the relationship between depressive symptomology and peer victimization. Provided this evidence, we hypothesize that SV may influence PLE through dysregulated activity in networks associated with emotional and social information, particularly the SAN and DMN.

While SV and abnormal brain connectivity have been examined separately across the psychosis spectrum, no studies to our knowledge have examined whether SV influences the PLE through neural connectivity. Interestingly adolescence and young adulthood are the developmental periods strongly characterized by peak risk for psychosis, expanding and changing social networks, and by critical neurodevelopmental processes such as synaptic pruning and intracortical myelination, suggesting the relationship between PLE, SV, and network connectivity may be present as early as adolescence. Thus, we utilized data from the second-year follow-up of the Adolescent Brain Cognitive Development (ABCD) study (abcdstudy.org), which is nationwide study of nearly 12,000 children across the United States that collects data on social, psychological, and neural processes (Barch et al., 2018; Casey et al., 2018; Garavan et al., 2018). We used data from the 2-year follow-up as it was the first wave that measured a variety of variables indexing SV, network connectivity, and PLE. To test our hypotheses, we used confirmatory factor analysis (CFA) to identify a latent SV factor constructed from child and parent self-report data. Using this SV latent factor, we conducted structural equation modeling (SEM) to examine the association between SV and PLE, and the mediating effect of resting-state fMRI connectivity on the association between SV and PLE (Casey et al., 2018; Karcher et al., 2020, 2018). Additionally, to examine the specificity of these relationships, we also tested models using internalizing and externalizing symptoms, rather than PLE. Further, considering the elevations in SV and PLE seen among racial minorities, we performed an exploratory moderated mediation analysis to determine if connectivity mediated the SV to PLE link even when considering racial differences. Together, through the use of this dataset from a large and diverse group of adolescents, we were able to evaluate a potentially subtle, but critical set of associations that may speak to the complex developmental pathophysiology of psychosis-risk.

2. Methods

2.1. Participants

This study was approved by the University of Rochester Research Subject Review Board (Study Approval ID STUDY00004264). De-identified data were obtained from participants in the ABCD study; a longitudinal study following children beginning at ages 9- and 10-years from 21 research sites across the US. The sociodemographic makeup of the sample closely matches that of the US as a whole, with a slight oversampling of Black/African American and Other Race children that corresponds to a slight under-sampling of White and Hispanic children (Garavan et al., 2018). We used 2-year follow-up data from the ABCD Data Release 4.0, which was accessed through the National Institute of Health Data Archive (https://nda.nih.gov/abcd). Of the 11,878 participants who contributed baseline data, 10,414 participants (88 %) contributed two-year follow-up data. However, due to delays associated with the COVID-19 pandemic, only 7857 had contributed two-year follow-up neuroimaging data. Of those, 557 adolescents were removed for not passing resting-state imaging quality control recommendations suggested by the ABCD study team (Hagler et al., 2019). An additional 343 participants who were missing data on one or more of the primary variables described below were removed. This left a final sample of 6957 participants with complete data (Supplemental Table 2). To avoid a third level of clustering at the family level, one child per family was randomly selected for inclusion in mediation models, resulting in a sample of 5991 (hereafter, "main sample"). To assess robustness of the findings, analyses were rerun including a different sibling for families that contributed more than one child to the ABCD dataset (results available at https://osf.io/54f72/). Findings were similar across both samples of children.

2.2. Measures

2.2.1. Social Victimization (SV) indicators

In order to measure experiences of SV, a latent variable was estimated using a variety of self- and caregiver-report measures. Potential indicators were chosen by identifying ABCD variables that involved chronically negative socio-interpersonal experiences and perceptions, either directly or indirectly. They included 6 variables representing responses from the adolescent themselves and 2 variables representing responses from a caregiver of the adolescent. We chose not to include one variable (cyberbullying) because it was the only dichotomous variable which would have further complicated a complex model and required a change to an estimation method less suited for continuous and skewed data. Descriptive statistics for each of the indicators in the main sample are provided in Table 1. Intercorrelations and variable inflation factors are provided in Table 2.

Three of the indicator variables came from adolescent responses to the Revised Peer Experiences Questionnaire (RPEQ; Prinstein et al., 2001); specifically the relational, reputational, and overt victimization

Table 1
Descriptive statistics.

Variable	Sample range	*M* (*SD*) or *N* (%)	Skew	Kurtosis	ω_h
Age (months)	[127, 166]	143.253 (7.745)			
Sex assigned at birth					
Female		2822 (47)			
Male		3169 (53)			
Race					
Asian		127 (2)			
Black		748 (12)			
Hispanic		1199 (20)			
Other Race		615 (10)			
White		3302 (55)			
Psychopathology					
PQ-BC Total Score	[0, 21]	1.535 (2.720)	2.568	7.750	0.854
PQ-BC Distress Score	[0, 89][a]	3.442 (7.450)	3.892	20.788	0.823
CBCL Internalizing T-Score[b]	[33, 90][c]	47.774 (10.485)	0.445	−0.386	0.874
CBCL Externalizing T-Score[b]	[33, 83][c]	44.459 (9.703)	0.665	−0.143	0.904
Social Victimization Indicators					
RPEQ Relational Victimization	[3, 15]	4.779 (1.924)	1.404	2.595	0.755
RPEQ Reputational Victimization	[3, 15]	3.988 (1.811)	2.540	7.930	0.825
RPEQ Overt Victimization	[3, 15]	3.680 (1.377)	2.949	11.419	0.719
PDS Discrimination	[1, 5]	1.134 (0.326)	4.116	24.019	0.427
FES Family Conflict – Child	[0, 9]	1.849 (1.810)	1.058	0.685	0.651
FES Family Conflict – Parent	[0, 9]	2.410 (1.975)	0.732	−0.077	0.710
NSC Neighborhood Crime – Child	[1, 5]	1.921 (0.995)	1.002	0.559	–
NSC Neighborhood Crime – Parent	[1, 5]	2.129 (0.920)	0.802	0.416	0.872
Average Within-Network Neural Connectivity					
Default Mode Network (DMN)	[0.073, 0.552]	0.247 (0.060)	0.316	0.089	
Salience Network (SAN)	[−0.025, 0.866]	0.383 (0.119)	0.244	0.205	

Abbreviations: ω_h = McDonald's Hierarchal Omega Reliability; CBCL = Child-Behavior Checklist; FES = Family Environment Scale; M = Mean; N = Number of Participants; NSC = Neighborhood Safety/Crime Survey; PDS = Perceived Discrimination Scale; PQ-BC = Prodromal Questionnaire-Brief, Child Version; RPEQ = Revised Peer Experiences Questionnaire; SD = Standard Deviation.
[a] Possible Range is 0–126.
[b] *N* = 5166.
[c] Possible Range is 0–100.

subscales. Each subscale is the sum of 3-items rated on frequency (1 = *Never*, 5 = *A few times a week*). The relational victimization subscale of the RPEQ assesses experiences of exclusion from social interactions (e.g., "A kid left me out of what they were doing"), the reputational victimization subscale assesses experiences of reputational harm (e.g., "Another kid gossiped about me so others would not like me"), and the overt victimization subscale assess experiences of threats or actual physical harm (e.g., "A kid threatened to hurt or beat me up.").

Another indicator variable was the mean score of the ABCD Perceived Discrimination Scale (PDS), which is a 7-item measure that examines the frequency (1 = *almost never*, 5 = *very often*) with which the adolescent feels discriminated against due to their ethnicity (e.g., "I feel that others behave in an unfair or negative way toward my ethnic group"). Additionally, both the adolescent and their caregiver provided reports of family conflict on the PhenX Family Conflict Subscale of the Family Environment Scale (FES; Moos and Moos, 1994). The family conflict of the FES assess how anger is expressed and resolved in families, using 9 True/False statements (0 = *False*, 1 = *True*; e.g., "We fight a lot in our family."). Finally, both the adolescent and their caregiver provided reports on neighborhood safety, using PhenX Neighborhood Safety/Crime Survey Modified (NSC), which is described in reference (Zucker et al., 2018) and consists of 3- items rated on level of agreement for parents and a single item for children (e.g., "My neighborhood is safe from crime."). Scores on the NSC were reverse coded such that higher scores indicated less safety (1 = *strongly agree*, 5 = *strongly disagree*).

2.2.2. *Psychotic-like experiences & psychopathology*

PLE were assessed with the Prodromal Questionnaire-Brief Child Version (PQ-BC; Karcher et al., 2018). The PQ-BC is a 21-item self-report questionnaire modified and validated for children from the Prodromal Questionnaire-Brief (Loewy et al., 2011) that assess a range of PLE such as unusual thought content, suspiciousness/persecutory ideas, grandiosity, and perceptual aberrations (Karcher et al., 2018). Adolescents first indicated whether they had experienced the PLE. Those who indicated that they had experienced the PLE then indicated whether the PLE was bothersome. For each PLE that was identified as bothersome, participants rated how bothersome the experience was using a 1 to 5 visual response scale with higher scores denoting higher distress. Following other studies using the PQ-BC we calculated the total score and distress score (Karcher et al., 2020, 2018).

The total score was calculated by summing the number of items endorsed (possible score: 0–21). The distress score was calculated by weighting the total score by the level of distress. A score of 0 indicates no PLE endorsed, 1 indicates one PLE endorsed with no distress, and scores of 2–6 indicate that a PLE was endorsed with some distress (possible score: 0–126). Prior work has demonstrated the PQ-BC to exhibit construct validity and adequate psychometric properties (Karcher et al., 2020, 2018). Because findings with the total and distress score were similar, we focused on the total score in the main text and distress score results are provided in the supplement.

To assess the specificity of the association between SV and PLE, we evaluated externalizing and internalizing symptoms using the respective broad-band T-scores from the parent-report of the Child Behavior Checklist (CBCL; Achenbach, 2009). The externalizing broad-band score indexes rule-breaking and aggressive behaviors, while the internalizing broad-band score indexes anxiety and depressed symptoms, and somatic

Table 2
Intercorrelations and variable inflation factor results for candidate social victimization indicators (*N* = 6597).

	1	2	3	4	5	6	7	8
1. Relational Victimization	–	0.538***	0.416***	0.209***	0.170***	0.072***	0.116***	−0.002
2. Reputational Victimization		–	0.541***	0.306***	0.192***	0.053***	0.152***	0.044***
3. Overt Victimization			–	0.280***	0.225***	0.070***	0.161***	0.042***
4. Discrimination				–	0.204***	0.046***	0.193***	0.123***
5. Family Conflict – Child					–	0.257***	0.186***	0.061***
6. Family Conflict – Caregiver						–	0.011	0.075***
7. Neighborhood Crime – Child							–	0.307***
8. Neighborhood Crime – Caregiver								–
Variable Inflation Factor	1.460	1.730	1.496	1.158	1.162	1.075	1.098	1.148

*** $p < .001$.

complaints.

2.2.3. Neural connectivity

Resting state functional connectivity data was collected during two functional runs (Casey et al., 2018). Thirteen networks were defined using Gordon parcellations (Gordon et al., 2016). For this study, within-network connectivity for the default mode network (DMN) and the salience network (SAN) were used. The DMN was defined by Destrieux parcels in the middle-posterior cingulate cortex, precuneus and 11 other parcels, while the SAN was defined by the anterior cingulate cortex and anterior insula. A complete list of regions included within each network are provided in Supplemental Table 1. Based on the recommendations from the ABCD study team (Hagler et al., 2019) for resting-state data, cases were removed ($N = 557$) if they did not pass FreeSurfer quality control and/or had fewer than 375 frames after removing frames with excessive head motion (framewise displacement<0.2 mm).

2.3. Analyses

We used structural equation modeling (SEM) to analyze the data. For each analysis, robust maximum likelihood estimation (MLR) was used to account for the non-normality of the outcome variables (Table 1). Huber-White robust standard errors and Yuan-Butler test-statistic estimates are reported and accompanied by 95 % confidence intervals based on 10,000 bias-corrected (BC) bootstrap samples. Due to the multilevel nature of the data, cluster robust estimates were calculated with MRI scanner defining the clusters. By using the MRI scanner as the clustering variable, both site-level and machine-level variances were accounted for.

2.3.1. Latent Factor: Social Victimization (SV)

To estimate an SV factor, an iterative confirmatory factor analysis (CFA) process was implemented. A final model was identified when the model demonstrated acceptable fit, and the indicator variables had acceptable loadings on the latent factor (>0.3). Acceptable model fit was identified using a combination of fit indices cutoffs: a comparative fit index (CFI) >0.95, a root-mean square error of approximation (RMSEA) <0.08, and a standardized root mean squared residual (SRMR) <0.05 (Hu and Bentler, 1999). While we report chi-square (χ^2) values, we did not expect the χ^2 $p > .05$ in any model because χ^2 calculations are highly influenced by sample size. The iterative refinement process included removing a single indicator after examining factor loadings and modification indices to determine which indicators loaded poorly (<0.3) and would also have the greatest impact on improving fit.

2.3.2. Simultaneous mediation analysis

Utilizing SEM, a simultaneous mediation model was specified. Similar to the CFAs, MLR and clustering (MRI scanner) were used for this analysis, and 95 % BC CIs were generated from 10,000 bootstrap samples. The model was specified such that PLE was predicted both directly and indirectly by SV, with the default mode network (DMN) and salience (SAN) within-network connectivity as simultaneous mediators (Fig. 1). The residual covariance between DMN and SAN within-network connectivity was modeled. While sex-assigned-at-birth and age-in-months were initially included as covariate predicators of PLE and network connectivity, the models resulted in Heywood errors (negative residual variances) due to model overspecification and thus the variables were removed. In addition to standardized β coefficients, we provide the absolute proportion mediated (Alwin and Hauser, 1975), which denotes the proportion of the total effect that can be attributed to the indirect effect (i.e., a1*b1/ (a1*b1 + c'), where a1 and b1 refer to the paths associated with one mediator).

2.3.3. Exploratory race analyses

Because research has shown that that experiences of SV and psychosis vary across racial and ethnic groups, an exploratory aim was to examine whether the mediation models varied by race (Anglin and Lui, 2023; DeVylder et al., 2023; Kirkbride et al., 2017; O'Donoghue et al., 2021; Oh et al., 2014). Only Black, Hispanic, and White adolescents were included in these analyses. Asian adolescents were not included due to sample size limitations ($N = 127$). We also did not include Other Race individuals given the heterogeneity of race included, which would have made results uninterpretable. Further, increased risk for psychosis is most robustly seen in Black and Hispanic groups (DeVylder et al., 2023; Kirkbride et al., 2017; O'Donoghue et al., 2021; Schwartz and Blankenship, 2014).

In order to examine differences between these three racial groups, we conducted moderation analyses. This involved a multistep process that compared the psychometric equivalence of the models across two or more groups by comparing iteratively more constrained models until the most constrained model that does not significantly worsen fit was identified (i.e., the most parsimonious model). Specifically, iterative

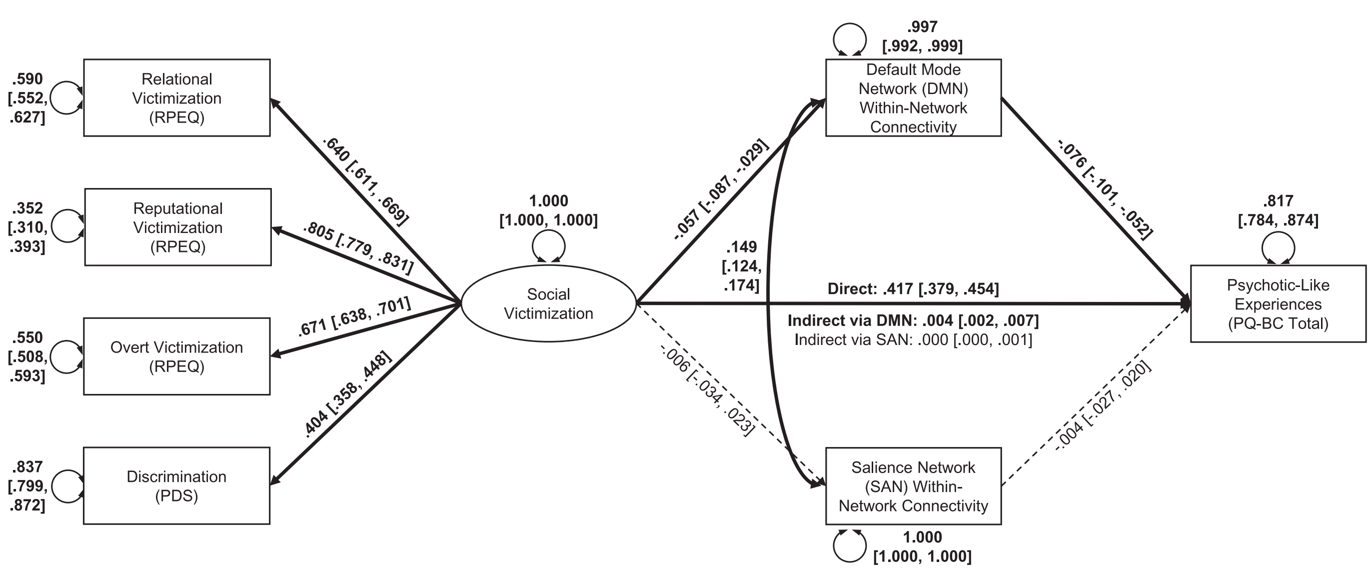

Fig. 1. Simultaneous mediation model with standardized estimates and 95 % confidence intervals. (Note: Bolded estimates and full lines indicate significant paths at $p < .05$.)
Abbreviations: PDS = Perceived Discrimination Scale; PQ-BC = Prodromal Questionnaire-Brief, Child Version; RPEQ = Revised Peer Experiences Questionnaire.

constraints were placed on model parameters (i.e., loadings, intercepts, residuals) one at a time and then compared to the previous model using Likelihood Ratio Tests (LRTs), which provided χ^2 test statistics. An LRT χ^2 with a $p < .05$ indicates that a more constrained model does not significantly improve fit, and thus the less constrained model should be selected.

For the purposes of these analyses, moderation analyses were conducted in two steps. First, multigroup CFA (MG-CFA) were applied to the SV latent factor to determine if experiences of SV varied by race. In the case of MG-CFA, four types of increasingly constrained invariance models are tested: configural (completely unconstrained), weak/metric (loadings constrained), strong/scalar (loadings and intercepts constrained), and strict invariance (loadings, intercepts, and residuals constrained). Configural invariance would imply that the pattern of loading of the indicators on the latent factor is invariant or equivalent across groups (Bikos, 2022). Weak/metric invariance builds on the configural invariance and implies that the (unstandardized) loadings (i.e., slope) for each indicator are additionally invariant across groups. Strong/scalar invariance then builds on the weak/metric model to imply that the indicator intercepts (i.e., starting values) are also invariant across groups. Lastly, strict invariance would indicate the error variances and covariances in the model did not differ across groups.

It is possible for the best fitting model to fall somewhere between the aforementioned models, achieving partial invariance, such that some—but not all—groups exhibit a similar pattern of constraints. Partial invariance is identified by first determining configural, weak/metric, or strong/scalar invariance, and then constraining groups in a pairwise manner such that a partially invariant model is created for every pair. Each of these models are independently compared with the best fitting model so far to determine if the partially invariant model improves fit even more. Through this process, a best fitting configuration of the SV latent factor was identified and used in subsequent models.

Next, moderated mediation analyses were conducted on the simultaneous mediation model. To examine whether the indirect effect of a specific network varied by race, changes to constraints were only made to one network at a time (i.e., DMN or SAN) such that two sets of comparison were made. Both groups of comparisons contained a model where no paths were constrained suggesting the indirect paths varied by race, as well as a model where both indirect pathways were constrained across all groups suggesting the indirect paths were invariant across race. The third model in each group had only one of the indirect paths, within-DMN connectivity or within-SAN connectivity constrained across all groups to examine if a single indirect path is invariant by race.

3. Results

All analyses were conducted in R (*v3.5.2*; R Core Team, 2018) using RStudio (*v1.1.456*; RStudio Team, 2015). All SEM analyses were conducted using the R package *lavaan* (Rosseel, 2012). The code and output for this manuscript are available on Open Science Framework (https://osf.io/54f72/).

3.1. Latent factor: Social Victimization (SV)

Through iterative CFA refinement, a final SV factor (Supplemental Table 4, Model 4) was identified with the following manifest indicators: three victimization subscales of the RPEQ and the discrimination variable from the PDS. All indicators evidenced statistically significant ($p < .05$) and acceptable factor loadings (>0.3). The CFA evidenced good fit to the data, χ^2 (2) = 13.669, p = .001; CFI =0.994; RMSEA = 0.048 [90% CI: 0.026, 0.074]; SRMR = 0.014. Fit indices for each iterative CFA are provided in Supplemental Table 4.

3.2. Simultaneous mediation analysis

The simultaneous mediation model (Fig. 1) demonstrated good fit to the data; χ^2(11) = 117.948, $p < .001$; CFI = 0.965; RMSEA = 0.058 [90%CI: 0.051, 0.066]; SRMR = 0.026. Greater SV significantly associated with more concurrent PLE (β = 0.417, SE = 0.019, 95%CI: [0.379, 0.454], $p < .001$) and lesser concurrent within-DMN connectivity (β = −0.057, SE = 0.015, 95%CI: [−0.087, −0.029], $p < .001$), but SV was not significantly related to concurrent within-SAN connectivity (β = −0.006, SE = 0.015, 95%CI: [−0.034, 0.023], p = .667). Similarly, more PLE were significantly associated with lesser within-DMN connectivity (β = −0.076, SE = 0.013, 95%CI: [−0.101, −0.052], $p < .001$), but not by within-SAN connectivity (β = −0.004, SE = 0.012, 95%CI: [−0.027, 0.020], p = .765).

Mediation analyses indicated that the SV-PLE association was partially mediated by within-DMN connectivity (indirect: β = 0.004, SE = 0.001, 95%CI: [0.002, 0.007], p = .001) accounting for about 1 % of the association. However, within-SAN connectivity did not mediate the SV-PLE association (indirect: β = 0.000, SE = 0.000, 95%CI: [0.000, 0.001], p = .909). On specificity of the associations, internalizing and externalizing scores were associated with greater SV, but the associations were not mediated by network connectivity (see Supplemental Material).

3.3. Moderation by race

3.3.1. Social Victimization (SV)

The SV latent factor demonstrated acceptable model fit when tested within each racial group (Black, Hispanic, White) independently (Table 3). The MG-CFA comparing the configural model (unconstrained) to weak/metric model (loadings constrained) indicated that the configural model was the most parsimonious model, χ^2 (6) = 48.28, $p < .001$. To identify which group(s) differed, pairwise MG-CFA were conducted.

Pairwise comparisons indicated White adolescents differed from both Black, $\Delta\chi^2$(3) = 25.850, $p < .001$ and Hispanic adolescents, $\Delta\chi^2$(3) = 35.951, $p < .001$. However, Black and Hispanic adolescents did not differ, $\Delta\chi^2$(3) = 3.219, p = .359. Thus, a model where the loadings were constrained to be the same for Black and Hispanic adolescents, but not White adolescents, was examined. This model displayed acceptable fit, χ^2(9) = 31.305, $p < .001$; CFI =0.991; RMSEA = 0.052 [90%CI: 0.033, 0.072]; SRMR = 0.020, and all indicators evidenced statistically significant and acceptable factor loadings (Supplemental Table 5). Further, the model showed improved fit over the configural model, $\Delta\chi^2$(3) = 3.219, p = .359. Thus, this partially invariant model was selected as the final SV latent factor for use in further analyses.

3.3.2. Moderated mediation

The simultaneous mediation model demonstrated acceptable model fit when estimated within each racial group (Black, Hispanic, White) independently (Table 3). When iteratively constraining the within-DMN connectivity pathway, multigroup moderation testing suggested that the within-DMN connectivity pathway did not significantly differ across the three racial groups. Multigroup moderation testing on the within-SAN connectivity pathway also showed that the pathway did not significantly differ across the three racial groups. Thus, the final model suggests that measurement of the SV latent factor varies for White adolescents compared to Black and Hispanic adolescents, but the within-DMN and within-SAN connectivity pathways did not. In other words, while SV is experienced differently between Black/Hispanic and White adolescents, SV, itself, appears to be partially related to PLE, in part, through hypoconnectivity in the DMN for all racial groups.

4. Discussion

This analysis of the Adolescent Brain Cognitive Development (ABCD) study revealed that experiences of social victimization (SV) increase risk for psychotic-like experiences (PLE) in adolescents as young as age 10. Importantly, this association is accounted for, in part, by

Table 3
Multigroup confirmatory factor analysis statistics for social victimization latent factor and moderated mediation models.

Social Victimization Latent Factor Model	Model Fit Statistics[a]						Comparison Statistics			
	χ^2	df	*p*-Value	CFI	RMSEA (95%CI)	SRMR	Base Model	$\Delta\chi^2$	Δdf	*p*-value
Black (*N* = 748)	2.566	2	0.277	0.999	0.022 (0.000–0.088)	0.012				
Hispanic (*N* = 1199)	6.801	2	0.033	0.992	0.061 (0.015–0.115)	0.017				
White (*N* = 3302)	12.865	2	0.002	0.987	0.071 (0.037–0.110)	0.020				
M1: Configural	25.110	6	<0.001	0.991	0.063 (0.039–0.090)	0.018				
M2: Partial Invariance[b]	31.305	9	<0.001	0.991	0.052 (0.033–0.072)	0.020	M1	3.219	3	0.359
M3: Weak/Metric	68.702	12	<0.001	0.977	0.070 (0.055–0.087)	0.039	M2	40.766	3	<0.001
M4: Strong/Scalar	338.898	18	<0.001	0.908	0.114 (0.104–0.125)	0.065	M3	1607.940	6	<0.001
M5: Strict	804.276	26	<0.001	0.597	0.200 (0.188–0.211)	0.246	M4	307.250	8	<0.001

Moderated Mediation Models	Model Fit Statistics[a]						Comparison Statistics			
	χ^2	df	*p*-value	CFI	RMSEA (95%CI)	SRMR	Base Model	$\Delta\chi^2$	Δdf	*p*-value
Black (*N* = 748)	31.949	11	0.001	0.972	0.055 (0.033–0.077)	0.030				
Hispanic (*N* = 1199)	32.000	11	0.001	0.979	0.047 (0.029–0.067)	0.022				
White (*N* = 3302)	55.473	11	<0.001	0.977	0.045 (0.034–0.057)	0.020				
M1: Fully Unconstrained	117.902	38	<0.001	0.977	0.043 (0.035–0.052)	0.024				
M2d: DMN-Constrained	125.707	42	<0.001	0.977	0.042 (0.033–0.050)	0.025	M1	5.250	4	0.263
M2s: SAN-Constrained	123.234	42	<0.001	0.978	0.041 (0.033–0.049)	0.024	M1	0.643	4	0.958
M3: Fully Constrained	130.503	46	<0.001	0.978	0.039 (0.031–0.047)	0.025	M2d	0.426	4	0.980
							M2s	5.042	4	0.283

Abbreviations: CI = Confidence Interval; CFI = Comparative Fit Index; df = degrees of freedom; RMSEA = Root Mean Square Error Approximation; SRMR = Square Root Mean Residual.
Note: Reported χ^2 are based on standard estimates and not the robust estimates used in comparison analyses.
[a] Yuan-Butler estimates.
[b] Model where loadings for Black and Hispanic adolescents were constrained to be the equal, while White adolescents were allowed to have different loadings.

hypoconnectivity within the default mode network (DMN); a network consistently found to be dysregulated in psychotic and other mental disorders (Del Fabro et al., 2021; Doucet et al., 2020; Hu et al., 2017; Mennigen and Bearden, 2020; O'Neill et al., 2019). Relatedly, these analyses showed that neither SV nor PLE were significantly associated within salience network (SAN) connectivity, another network that has been implicated in psychotic disorders (Del Fabro et al., 2021; Huang et al., 2020; Wang et al., 2016; White et al., 2013, 2010). Further, we found that the SV-connectivity-PLE associations are similar across Black, Hispanic, and White adolescents, even when taking into account that Black and Hispanic adolescents experience SV differently than White adolescents.

Each individual finding is in line with previous findings: SV has been repeatedly shown to increase psychosis-risk (Crush et al., 2018; DeVylder et al., 2017; Healy et al., 2020; Mackie et al., 2013; Pearce et al., 2019; Schreier et al., 2009; Wolke et al., 2014); SV has been linked to DMN hypoconnectivity (Corr et al., 2022); and PLE has also been linked to DMN hypoconnectivity (Karcher et al., 2019; O'Neill et al., 2020; Orr et al., 2014), while SAN connectivity has a less consistent linked to both SV and PLE (Karcher et al., 2019). Although this study confirms previous findings, it is also novel in that it is the first to examine SV, PLE, and resting-state connectivity simultaneously, particularly in a developmental sample. Further these findings did not extend to internalizing or externalizing symptoms, suggesting that the SV-DMN-PLE relationship may be specific to PLE.

While the percent of the SV-PLE association being mediated by DMN connectivity was small (~1 %), this finding is striking given that these children are about a decade from the peak age of onset for psychotic disorders. Additionally, it should be noted that much smaller effect sizes should be expected from analyses utilizing ABCD data and that even small effect sizes may have large impacts over the long-run (Funder and Ozer, 2019; Owens et al., 2021). At the same time, these findings also highlight that neural dysconnectivity is just one putative mechanism by which SV impacts PLE. As many have pointed out, psychosis is preceded by numerous biological changes all of which likely play small role in psychosis-risk (Davis et al., 2016; Thomas and Zakharenko, 2021; Uher and Zwicker, 2017). Thus, it is no surprise that DMN connectivity accounted for only a very small percentage of the SV-PLE association.

Further, this study is among the first to examine if the relationship between SV, PLE, and resting-state connectivity relationship differs between racial groups (Black, Hispanic, and White). Research has found that racial minorities experience disproportionate levels of SV and varied risk for PLE, but it has been less clear whether this increase in SV and PLE risk works through the same underlying neural mechanisms across races (Anglin and Lui, 2023; Cohen and Marino, 2013; DeVylder et al., 2023; Kirkbride et al., 2017; O'Donoghue et al., 2021; Oh et al., 2014). Additionally, neural connectivity has been shown to have varied ability to predict behavior across races, including in the ABCD dataset (Li et al., 2022). However, this study suggests that, at least for the DMN and SAN resting-state connectivity, the underlying neural mechanism connecting SV and PLE does not differ by race.

While this study has several advantages, including use of a large diverse sample of adolescents, several limitations exist. First, the data utilizes a concurrent data structure which prohibits causal interpretation. Second, given limitations in the data collected, our SV latent factor relied heavily on peer victimization. This did not allow for us to take into account many other types of victimization such as partner, family, and law enforcement victimization that have been shown to increase risk for psychosis (Anglin et al., 2021; DeVylder et al., 2023, 2017; Otero et al., 2011). Lastly, the exploratory MG-CFA excluded Asian, other race, and mixed-race adolescents, who are all among the fastest growing racial groups in the United States (Vespa et al., 2018). However, each of these limitations may be addressed by future ABCD data releases, as the study is ongoing with behavioral data collected yearly and resting state connectivity collected every 2 years, and with plans for MRI data collection delayed due to the COVID-19 pandemic to be included in future releases.

5. Conclusions

In summary, this study shows that as early as 10 years of age SV may be associated with PLE through its putative impact on neural networks implicated in social information processing. While few that experience PLE go on to develop psychosis, the measurable associations between SV, PLE, and dysregulated DMN activity in adolescence found here is disquieting particularly this early in adolescence. However, given the plasticity of the adolescent brain, it may be possible to prevent or reduce DMN dysconnectivity (Patel et al., 2021). Still the relationship between SV and PLE is alarmingly strong. Assuming the current findings can be replicated and evaluated with longitudinal data that can assess possible causal associations, future work should evaluate interventions that reduce SV among school-aged children and their peers such as those that teach socio-emotional skills to counteract bullying and harassment (Dodge et al., 2015; Wahlbeck et al., 2017). Such interventions may not only decrease risk for PLE, but risk for other mental disorders and the adverse consequences of social stress (Anglin et al., 2020; Kirkbride and Jones, 2011). However, it remains important that interventions are made relevant and adapted for the community in which they are implemented as SV appears to differ between racial groups and likely differs across other cultural groups.

CRediT authorship contribution statement

Abhishek Saxena: Conceptualization, Data curation, Formal analysis, Methodology, Visualization, Writing – original draft, Writing – review & editing, Project administration, Software, Supervision. **Shangzan Liu:** Conceptualization, Methodology, Writing – review & editing. **Elizabeth D. Handley:** Methodology, Supervision, Writing – review & editing. **David Dodell-Feder:** Conceptualization, Methodology, Supervision, Writing – review & editing.

Declaration of competing interest

The authors have no interests to declare.

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Appendix A. Supplementary data

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