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a Network Approach

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ORIGINAL ARTICLE

Understanding Affective Symptoms and Substance Use in Older Adolescents in an Urban Context: a Network Approach

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Abstract

Global urbanization may present mental health challenges for youth. We investigated relationships between affective symptoms, substance use, and urban characteristics in 17–18-year-old adolescents from the Amsterdam Born Children and their Development study ($N = 1682$). Objectively measured urban neighbourhood characteristics (e.g. safety, poverty) were obtained from the Geoscience and Health Cohort Consortium in addition to self-report assessments. Cross-sectional networks showed strong clustering between affective symptoms, substance use behaviours, and urban characteristics. Self-reported safety and drug-related nuisance were key bridge nodes between clusters. Higher levels of unsafety and urban hassles were linked to affective symptoms and substance use. Fatigue, sadness, and cannabis use were the most important symptoms. Objective social safety was also connected to perceptions of safety, drug-related nuisance, fatigue, sad mood, and cannabis use. These findings indicate a complex interplay between environment and individual health, with objective safety and social cohesion serving as key connectors between urban characteristics and mental health symptoms and substance use.

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Late adolescence is a critical life-stage for first emergence of many common mental disorders (Gouin et al., 2023). Globally, the prevalence of mental illnesses among youth increased considerably during COVID, with roughly 25% suffering from depression and 20% from anxiety (Gouin et al., 2023; Racine et al., 2021). Similarly, in the Netherlands, mental health and well-being of older adolescents has significantly declined, alongside raising concerns about problematic substance use behaviours (Nuijen et al., 2023). Substance use is often interrelated with mental health symptoms, as older adolescents facing depression and anxiety may turn to substances as a potential coping mechanism (Magee & Connell, 2021). Yet, how environmental stressors might uniquely interact with these mental and behavioural domains requires further clarification.

There is established evidence that recurring daily stressors—such as safety concerns, overcrowding, and environmental nuisance or neighbourhood crime—can significantly impact overall mental health and well-being, often more persistently than isolated life events (Baranyi et al., 2021; Crielaard et al., 2021; Kanner et al., 1981; Pettit et al., 2010). These urban hassles tend to accumulate in certain urban neighbourhoods and may increase the risk for depression, anxiety, and problematic substance use among adolescents (Krabbendam et al., 2021; Midouhas et al., 2021; Miller & Bennett, 2016; Wiers et al., 2025). Urban youth may be exposed to social and environmental stressors such as inadequate housing, public intoxication, drug trafficking, or community violence, all of which may contribute to feelings of unsafety, fear, or developmental instability (Crielaard et al., 2021; Krabbendam et al., 2021; Min et al., 2018; Mize & Kliewer, 2017; Wiers et al., 2025). However, the type and intensity of stressors may differ across urban and non-urban contexts, underscoring the need to understand which specific urban characteristics are linked to mental health outcomes in older adolescents.

Urbanization is a global phenomenon characterized by the rapid growth of cities and the increasing population density in urban areas (United Nations, 2019). Although cities have positive social, economic, and environmental characteristics that make them attractive, there is accumulating evidence that they have a negative impact on mental well-being (Finnemann et al., 2024; Guite et al., 2006). As urban populations become younger, with 60% expected to be under 18 by 2030 (United Nations, 2019), the mental health of urban youth needs particular attention. Urban living often appeals to older adolescents transitioning into adulthood, as it aligns with their developmental needs and aspirations during this life stage (Visser et al., 2021). During late adolescence, individuals pursue key developmental tasks such as identity exploration, engaging in personal growth, and building meaningful social connections (Arnett, 2024). Urban environments tend to support this through a wide range of educational, cultural, and social opportunities (Wiers et al., 2025).

Besides offering many positive opportunities, the urban environment also has its downsides. Urban residents can experience stressors such as overcrowded public places and lack of spacious housing (Sharifi & Khavarian-Garmsir, 2020) or (noise) pollution and higher crime rates (van der Wal et al., 2021). Previous findings suggest that urban youth are more likely to suffer from depression and anxiety (Rudolph et al., 2014; Xu et al., 2022) and exhibit more hostile behaviour compared to their rural counterparts (Schwinn et al., 2010). These issues are also linked to higher substance use, including alcohol and illicit drugs (Quednow et al., 2022; Schwinn et al., 2010). Similarly, evidence from Denmark shows higher rates of depression, anxiety, alcohol-use disorders, and cannabis use among those

born and raised in urban areas (Vassos et al., 2016). Urban youth living in neighbourhoods with higher drug activities might be at increased risk to engage in drug use (i.e. easy accessibility), highlighting the susceptibility of young people to the living context (Leifheit et al., 2015). Building on recent findings from the NEMESIS-3 study, a national Dutch survey, higher levels of urbanization have been linked to an increased prevalence of DSM-classified mental health disorders —particularly among young urban residents—highlighting the potential vulnerability of Dutch urban youth to challenges such as anxiety, mood disorders, and substance use (Ten Have et al., 2023).

In summary, growing evidence links urbanicity to youth mental health, but specific domain connections between urban characteristics and depression/anxiety as well as problematic substance use in older adolescents, remain unclear. Understanding cities as dynamic landscapes shaped by individual, social, and infrastructural elements (van der Wal et al., 2021) highlights the need for a systematic, dynamic perspective to identify and understand potential mutual relationships. To conceptually ground the complex interplay between adolescents' mental health and urban living conditions, we draw on Bronfenbrenner's ecological systems model (Bronfenbrenner & Morris, 2007). This theory posits that child development is a complex system of relationships that are influenced by multiple levels of the surrounding environment (van der Wal et al., 2021). These interconnected levels are divided into five systems: microsystem, mesosystem, exosystem, macrosystem, and chronosystem, which range from the immediate surroundings (e.g. family) to broad social structures (e.g. culture) (Bronfenbrenner & Morris, 2007). In this way, the model helps us think about how different layers of a young person's environment—from close surroundings like family and neighbourhood, to broader systems like city infrastructure—can affect their well-being. We use this model to guide how we interpret both personal experiences (such as feeling unsafe) and objective neighbourhood characteristics (such as crime or noise pollution).

We also build on urban health frameworks, which highlight how cities can shape mental health through multiple interacting systems, including social, economic, and environmental dimensions (Kim et al., 2022; Pykett et al., 2023; van der Wal et al., 2021). These frameworks argue that urban health is not only about individual risk but about how urban design, policy, and inequality come together to influence health patterns across populations. Finally, we build on insights from Lazarus' transactional model of stress (Lazarus & Folkman, 1984), which conceptualizes stress as a relational process: stress arises not only from external events but from the interactions between individuals and their surroundings and the appraisal of the situation by individuals. This idea fits well with recent complexity-based thinking in public health (Crielaard et al., 2021), which sees mental health outcomes as emerging from ongoing interactions between biological, psychological, and environmental factors—especially in challenging urban settings (Finnemann et al., 2024; Kim et al., 2022; van der Wal et al., 2021).

In this study, we employed a cross-sectional network approach to explore how specific affective symptoms and problematic substance use, respectively, relate to experienced urban stressors and objectively assessed neighbourhood characteristics (e.g. safety). This network perspective allows us to uncover how different symptoms and behaviours are interrelated and how urban characteristics play a unique role in these relationships (Borsboom, 2017). The use of both objective and self-reported data of neighbourhood characteristics enhances the validity of our measures of the urban context. This study is among the first to comprehensively link all these factors with such a high level of detail. Investigating mental health at the symptom-level offers a nuanced understanding of its complex and heterogeneous nature (Borsboom, 2017). Rather than

merely focusing on the presence or absence of a mental disorder, examining varying levels of symptom severity allow us to pinpoint the core symptoms and their relation to specific urban characteristics. Hence, network analysis offers a particular advantage in studying late adolescent mental health and substance use, as it allows for the exploration of how symptoms and behaviours are interconnected as a system, rather than treating them in isolation. This approach provides a detailed, holistic understanding of individual health and its environmental context, instead of capturing latent constructs and linear relationships, limiting the granularity and depth of the findings.

Methods

Study Population

ABCD Study

We used data from the Amsterdam Born Children and their Development study (ABCD), which is a longitudinal birth-cohort study examining the physical and mental health of 8000 children born in Amsterdam in 2003 (van Eijsden et al., 2011). The cohort was initiated by inviting all pregnant women living in Amsterdam ($N = 12.373$) during their first prenatal consultation to complete a questionnaire. The variables included in the present study were measured in wave six when the cohort participants reached late adolescence (June–September 2021). During the period from study conception to wave six, about half of the study population moved from Amsterdam to other places in the Netherlands. A total of 1678 participants aged 17–18 years completed a digital questionnaire via an application for smartphones or a website, after which they received a web shop voucher worth €10. The main topics assessed included mental health, lifestyle, living environment, and substance use. Some participants completed only parts of the questionnaire, hence we excluded 95 participants with missing data on depressive symptoms, anxiety symptoms, or substance use resulting in a total sample of $N = 1682$ (56.6% women; $M_{age} = 17.44$ ($SD = 0.36$)).

Measures

Affective Symptoms

Depressive symptoms were assessed using The Patient Health Questionnaire (PHQ-9) (Kroenke & Spitzer, 2002), a self-report instrument consisting of nine questions related to different aspects of depressive symptoms. Participants were asked to rate the occurrence of each symptom over the past 2 weeks, where the response options ranged from 0 ('not at all') to 3 ('almost every day'). The total score of the PHQ-9 ranges from 0 to 27. *Anxiety symptoms* were assessed using the 7-item General Anxiety Disorder – scale (GAD-7) (Spitzer et al., 2006). Similarly, the response options to indicate the severity of experienced anxiety complaints ranged from 0 ('not at all') to 3 ('almost every day'). The total score of the GAD-7 ranges from 0 to 21. We used each depressive and anxiety symptom (item) as separate node in the main analysis.

Problematic Substance Use (Last 3 Months)

Alcohol use was assessed by asking how often the respondents had consumed alcohol and *drunkenness* by asking how often they had been drunk during this period, with response options ranging from 1 ('not') to 9 ('daily'). *Tobacco use* was assessed by asking how often the respondents had smoked cigarettes/cut tobacco, ranging from 1 ('once or less in last 3 months') to 6 ('daily'). *Cannabis use* was assessed by asking how often respondents had used hashish/weed, ranging from 1 ('not') to 6 ('more than 19 times'). The use of *illicit drugs* was assessed by asking whether the respondents had used drugs [e.g. *ecstasy, cocaine… and ketamine*], ranging from 1 ('no') to 3 ('yes, multiple times'). Respondents who indicated to have never used alcohol, tobacco, cannabis, or drugs were assigned a zero accordingly.

Subjective Urban Environment

Perceived urban hassles were assessed using the urban hassles index (Miller & Bennett, 2016), which consists of 16 items specifically designed to evaluate stressors that are distinctive to urban adolescents. Respondents were asked to indicate how often they experienced these urban stressors over the past three months, ranging from 0 ('never') to 3 ('very frequently'). Due to a technical mistake, the last question of the UHI-16 was not included (item 'waited for a bus near a dirty, smelly bus stop', belonging to subscale 'environmental nuisance'), which resulted in 15 items with four subscales: *safety concerns* (range = 0–18), *coercion* (range = 0–6), *environmental nuisance* [i.e. noise at night; bothered by people hanging on streets] (range = 0–12), and *drugs* [i.e. being asked to sell/carry drugs; people begged you for money] (range = 0–9). We used the sum score of each subscale (four nodes). Higher scores indicate more reoccurring experiences of daily hassles from an urban-living perspective.

Perceived social contact was assessed by asking the participants: 'How much do you have contact with people from your neighbourhood?', ranging from 1 ('I do not talk to anyone from my neighbourhood') to 4 ('I have contact with more than 8 people from my neighbourhood'); *safety* with the question 'To what extent do you feel safe in the neighbourhood where you live?', ranging from 1 ('totally disagree') to 5 ('totally agree'); *sleep problems* with the question 'How often did you experience sleep problems in the last month due to streetlight shining through the bedroom window?', ranging from 1 ('not') to 4 ('three or more times per week') and 'How often did you experience sleep problems in the last month due to noise from inside/outside, ranging from 1 ('not') to 4 ('three or more times per week').

Objective Urban Environment

Objectively measured urban-neighbourhood exposure data from various sources was provided by the Geoscience and Health Cohort Consortium (GECCO) (Lakerveld et al., 2020; Timmermans et al., 2018). Specifically, we used data on population density, urbanization degree, green space, noise, distance to coffee shops/alcohol suppliers, neighbourhood poverty, socioeconomic status (SES), and liveability.

Population density and *urbanization degree* indicated the number of residents per hectare (500 m buffer) and the number of residential addresses (1 km buffer), respectively, in

2021. *Green space* was expressed as percentage of total vegetation in 2017 (500 m buffer), and *noise* included a mixed exposure score in decibels aggregated from different noise sources centred around the year 2020. Distance to most nearby *coffee shops* and *alcohol suppliers* in 2020 was expressed in meters. *Poverty* was assessed as percentage households with an income-level in 2021 at or below 101% of the social minimum. *SES* was based on education, income, and position in the labour market. The SES score is on average 0 for the whole of the Netherlands in 2019. A positive/negative score indicates a higher/lower SES value than the national average. *Liveability* scores in 2020 ranged from 'insufficient' (≤ 3.67) to 'excellent' (≥ 4.27). Positive values on the dimensions *safety* and *social cohesion* correspond with higher social cohesion and safety than the national average. Finally, based on postal codes, we created a variable indicating whether participants were still living in Amsterdam or moved out (*place of residence Amsterdam* 0 'no'/1 'yes').

We used recent exposure data that were closely aligned in time with wave six to ensure an accurate representation of participants' current residential environments. In the wave six questionnaire, participants were asked if they had moved from their previously recorded address. If a move was indicated, they provided an updated (six-digit) postal code, allowing us to categorize their residence accurately as either 'Amsterdam' or 'outside Amsterdam'. Environmental exposure data were merged with ABCD-data based on participants' home addresses in the Netherlands. Some variables were only available based on neighbourhood level or postal codes (SES, poverty, and liveability measures).

Covariates

The assessed covariates included participants' *sex* (1 'boy'/2 'girl'); *current educational program*, ranging between 0 ('none'), 1 ('Vocational'), 2 ('Further Education'), 3 ('Senior General'), 4 ('Pre-university'), and 5 ('Applied Sciences/University'); *working-hours paid job (weekly)*; *level of concern to which COVID-19-related measures and disruptions affected their mental health* (as measurements took place during the COVID-19 period, there was no lockdown at the time), ranging from 1 ('not worried at all') to 4 ('very much worried'); *number of days per week being at least an hour moderate-intense physically active* [i.e. sports, bicycling, hiking]; and finally self-rated *overall sleep quality (last month)* (Buysse et al., 1989), ranging from 0 ('very good') to 3 ('very bad').

Statistical Procedure

We estimated cross-sectional networks (Epskamp et al., 2018) to understand the association between chronic stressors, affective symptoms, and substance use from an urban-living perspective. Given the cross-sectional nature of this study, our analysis does not establish temporal sequence or directional causality; as such, it cannot confirm whether individual health outcomes influence relocation to areas with distinct characteristics or vice versa. Undirected network analysis enables us to examine how individual variables are interrelated rather than viewing each in isolation. In this approach, bridge nodes are points in the network that serve as connections between different groups or clusters of variables, potentially indicating how various domains (such as symptoms and environmental stressors) influence each other. Identifying such nodes helps us understand through which variables different domains interact, and they may point to mechanisms by which external factors (e.g. urban stressors) potentially impact mental health or substance use behaviours.

Centrality measures identify the most influential or connected points in the network, highlighting which variables play a key role in the system as a whole.

Specifically, the aim was to identify the most influential node within the network, which includes common psychological symptoms/substance use, and perceived and objective urban characteristics. Additionally, identifying the primary bridge node within this network provides insight into how psychological health measures are interconnected with the surrounding environment, potentially highlighting key pathways. Each variable of interest represents a specific node within the network, and the edges in-between represent pairwise conditional associations similar to partial correlation coefficients. We estimated a mixed-graphical-model as our data consists of scale and categorical variables (Haslbeck & Waldorp, 2020). We excluded 12 individuals with missing values on some urban-neighbourhood measures (perceived *social contact*, *safety*, and *sleep problems* and objective *urbanization*, *poverty*, and *SES*) leaving an analytical sample of $N = 1670$. Preceding network estimation, we defined and excluded redundant nodes using the *goldbricker*-function (PHQ-*slow/restless* and GAD-*worry different things*). The network-models were estimated with the *bootnet*-package and visualized with the *qgraph*-package (Epskamp et al., 2018). To assess the accuracy and stability of the model, we performed non-parametric bootstrapping and case-dropping bootstraps accordingly.

To quantify the influence of each node, we analysed centrality metrics, including a measure of node *strength centrality*. This metric computes the weighted number and strength of all edges of specific nodes. Additionally, we examined *bridge centrality* (Jones et al., 2021) and explored clusters of closely connected nodes to determine which aspects of urban living potentially relate to symptom activation and substance use. We employed two main networks, an urban-affective symptom network (37 nodes) and an urban-substance use network (30 nodes), to focus on unique domain connections and ensure sufficient power, as a combined network would have too many nodes for the given observations. Covariates were included as nodes in the networks to adjust for their relative contribution.

Subsequently, we assessed whether the two networks differed between participants still living in Amsterdam and those living outside Amsterdam. We performed a permutation test using the *NetworkComparisonTest*-package (van Borkulo et al., 2023) to assess potential differences in global strength, network structure, and edge strength between the two groups. The global strength invariance hypothesis implies that the total sum of edge weights, describing the total connectivity within a network, is identical across subgroups. The network structure invariance hypothesis infers similarity across subgroups in connectivity patterns, such as the extent of clustering. With the edge strength statistic, the invariance of a specific edge in the network can be tested.

Results

Sample Demographics

Participants were on average 17.44 years old ($SD = 0.36$), of which 952 girls (56.6%) and 730 boys (43.4%). The majority attained a pre-university or (applied) scientific educational program ($n = 1072$; 63.7%), followed by 17.8% in senior general, 13.3% in vocational/further education, and 5.1% not enrolled in any educational program at the time. Over a quarter of participants (27.5%) indicated poor sleep quality in the prior month, and 29.3% expressed considerable worry about their mental health due

to COVID-19 measures. Nearly a quarter of participants (23.8%) reported moderate to severe depressive symptoms (PHQ-9 score ≥ 10), and 20.9% reported moderate to severe anxiety symptoms (GAD-7 score ≥ 10). Most participants indicated to have contact with at least one to three people from their neighbourhood (79.5%) and felt safe in their neighbourhood (91.4%). Nonetheless, objective social cohesion and safety as well as sense of security were significantly lower in Amsterdam than in other regions ($p < 0.001$). Experiences of urban hassles were on average more prevalent in Amsterdam than in other areas ($p < 0.001$). See Table 1 for sample details.

Table 1 Descriptives of urban characteristics, mental health, and substance use

	Amsterdam ($N = 840$)	Outside ($N = 842$)	Total ($N = 1682$)
	Mean (*SD*)	Mean (*SD*)	Mean (*SD*)
Population density (no. residents 500 m)	107.14 (54.02)**	47.63 (27.02)	77.34 (52.03)
Urbanization (no. addresses 1 km)	5331.28 (3266.19)**	1966.89 (1296.10)	3645.08 (2998.5)
Green (%)	30.50 (13.03)*	45.63 (16.07)	38.07 (16.47)
Noise (dB)	56.49 (4.93)**	53.62 (5.70)	55.06 (5.52)
Distance CS (m)	1127.34 (1118.18)*	3236,55 (2924.46)	2183.2 (2452.69)
Distance AS (m)	212.44 (198.02)*	382.88 (343.42)	297.76 (292.99)
Poverty (%)	9.53 (5.07)**	4.50 (2.72)	7.01(4.78)
SES (*z*)	0.08 (0.30)*	0.23 (0.24)	0.16 (0.29
Total liveability (≤ 3.67 to ≥ 4.27)	4.08 (0.79)	4.08 (0.77)	4.08(0.78)
Safety (*z*)	− 0.06 (0.07)*	0.03 (0.06)	− 0.015 (0.08)
Social cohesion (*z*)	− 0.06 (0.05)*	0.01 (0.04)	− 0.022(0.06)
UHI (0–45)	5.23 (3.56)**	4.07 (3.11)	4.65 (3.39)
PHQ-9 (0–27)	6.68 (5.59)	6.48 (5.54)	6.58 (5.56)
GAD-7 (0–21)	6.20 (4.81)	6.09 (4.59)	6.14 (4.70)
(Last 3 months)	*N* (%)	*N* (%)	*N* (%)
Alcohol use ≥ 1 time	565 (67.3)	617 (73.3)	1182 (70.3)
Drunkenness ≥ 1 time	386 (46.0)	388 (46.1)	774 (46.0)
Tobacco use ≥ 1 time	320 (38.1)	294 (34.9)	614 (36.5)
Cannabis use ≥ 1 time	293 (34.9)**	256 (30.4)	549 (32.6)
Illicit drug use ≥ 1 time	60 (7.1)	48 (5.7)	108 (6.4)

Note: Descriptive statistics for main variables of interest including merged objective urban data. Values with "**" are significantly higher in Amsterdam than outside, and values with "*" are significantly lower in Amsterdam ($p < 0.001$). "≥ 1 time" refers to having used the substance at least once or more often in the prior 3 months. Range number of times alcohol use and drunkenness (0 = never; 1 = not in last 3 months; 2 = once; 3 = twice; 4 = 1–2 times per month; 5 = once per week; 6 = twice per week; 7 = 3 times per week; 8 = 4–5 times per week; 9 = daily); range number of times cannabis use (0 = never; 1 = not in last 3 months; 2 = once; 3 = 2–3 times; 4 = 4–10 times; 5 = 11–19 times; 6 = more than 19 times); range number of times tobacco use (0 = never; 1 = once in last 3 months; 2 = once per month; 3 = multiple times per month; 4 = once per week; 5 = multiple times per week; 6 = daily); range number of times illicit drug use (0 = never; 1 = not in last 3 months; 2 = yes, once; 3 = yes, multiple times)

Abbreviations: *UHI* urban hassles index, *PHQ-9* Patient Health Questionnaire 9-items, GAD-7 general anxiety disorder 7-items, *m* meters, *dB* decibels (prolonged noise around 70 dB can be critical; Yoshida et al., 1997), *CS* coffeeshops, *AS* alcohol suppliers, *z* positive/negative *z*-score means higher/lower than national average

Urban-Symptom Network

The estimated urban-symptom network is visualized in Fig. 1. Results revealed clustering between depressive/anxiety symptoms, between neighbourhood perceptions, and between objective urban characteristics. Self-reported sense of security, safety concerns, environmental nuisance, and drug-related nuisance act as bridge nodes connecting objective urban characteristics to mental health. Fear and COVID-19-related worry about one's own mental health are directly associated with safety concerns. After adjusting for sex and COVID-19-related worry, depressive symptoms such as anhedonia, sadness, guilt, and suicidal thoughts were found to be linked to urban hassles. Higher objective safety, connecting negatively to poverty and positively to social cohesion scores, bridges the city cluster to a higher sense of security. The strongest environmental nodes in the network were objective safety, SES, and social cohesion. The strongest symptoms in the network were fatigue and sadness (Fig. 2). Bridge centrality measures reveal that self-reported safety concerns, sense of security, and drug-related nuisance act as top three strongest bridge nodes (Figure S1). These bridge nodes represent key variables that connect the environmental and symptom

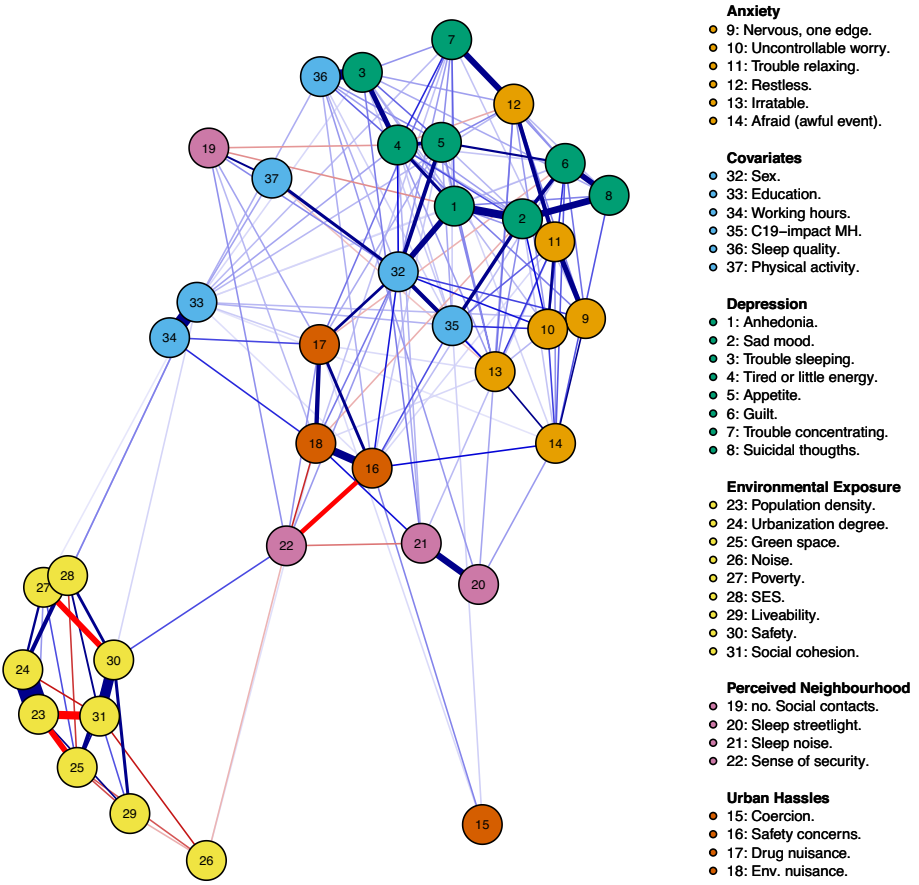

Fig. 1 Urban-symptom network

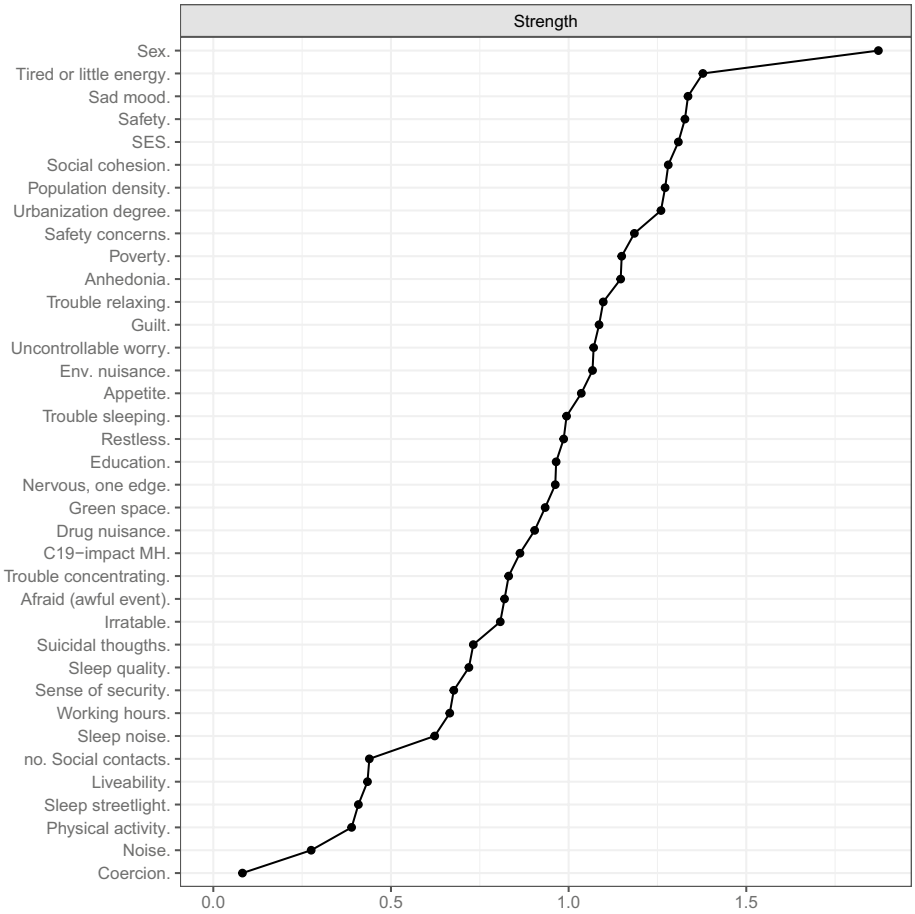

Fig. 2 Strength centrality (urban-symptom)

domains, highlighting possible pathways through which perceptions of safety and social nuisance may impact mental health outcomes. Model estimates, that were found to be stable through bootstrapping, emphasize mental health intertwining with perceptions of city life and overall social safety (Figure S2). Case-dropping analysis showed a case stability coefficient of 0.87, indicating preserved stability of strength centrality when only 10% of the sample was left (Figure S3).

Urban-Substance Network

Figure 3 visualizes the network structure of substance use, neighbourhood perceptions, and objective urban characteristics. Objective safety bridges the strongly connected city cluster to self-reported sense of security and urban hassles indicating safety concerns, and drug-related as well as environmental nuisance. Cannabis use, positively linked to illicit drug and tobacco use, connects to these urban hassles. Experienced urban stressors and the level of social safety may enhance problematic substance use and simultaneously contribute to overall city life, increasing distress in the social living environment (e.g. increased

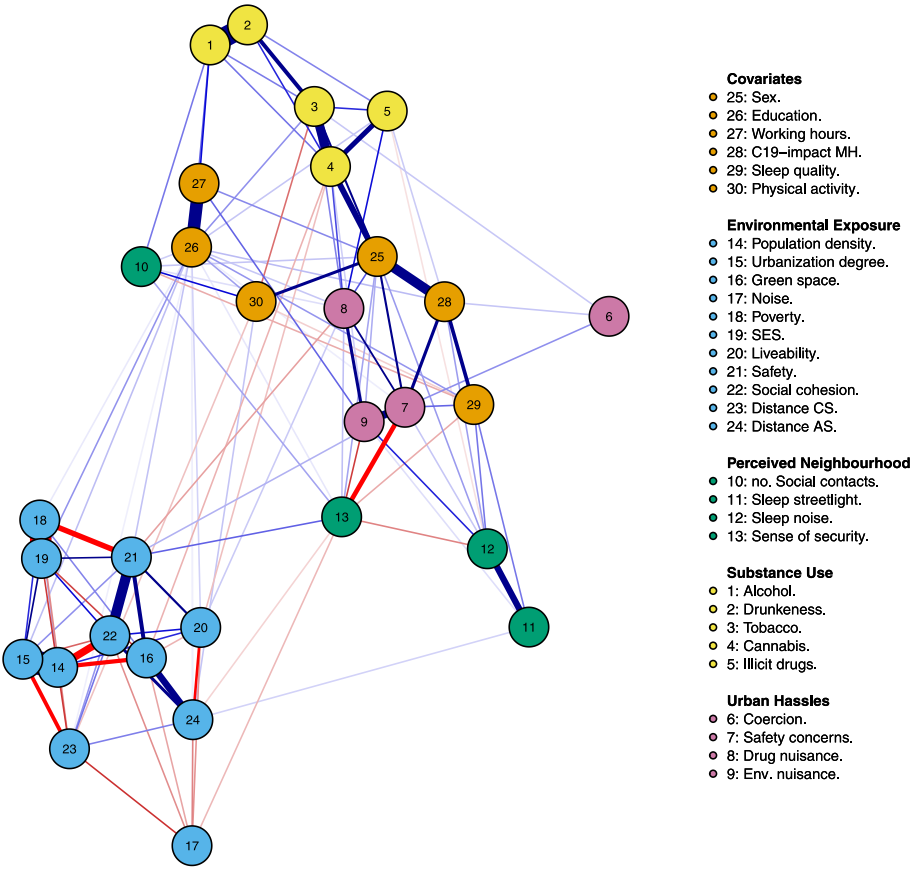

Fig. 3 Urban-substance network

nuisance). The strongest environmental nodes in the substance-network were objectively measured safety, social cohesion, urbanization, and SES. The strongest substance-node was cannabis use, followed by tobacco and alcohol use (Fig. 4). The three strongest bridge nodes were self-reported drug-related nuisance, alcohol use, and sense of security (Figure S4). Bootstrapping and case-dropping results reveal good model stability estimates with a CS coefficient of 0.83 (Figure S5-S6).

Living in Amsterdam vs. Outside

The urban-symptom network comparison between participants living in Amsterdam versus outside reveal significant differences in overall network structure ($p = 0.005$) but not in global strength ($p = 0.315$), indicating that the density of the connections for both groups is equal (Figure S7). Similarly, the structure of the urban-substance network differed significantly between the groups ($p = 0.028$) but not the global strength ($p = 0.686$) (Figure S8). Although the network comparison revealed some structural differences, concerning particularly urban characteristics, the overall strength of connections remained similar (see Table S1-S2 for edge-differences).

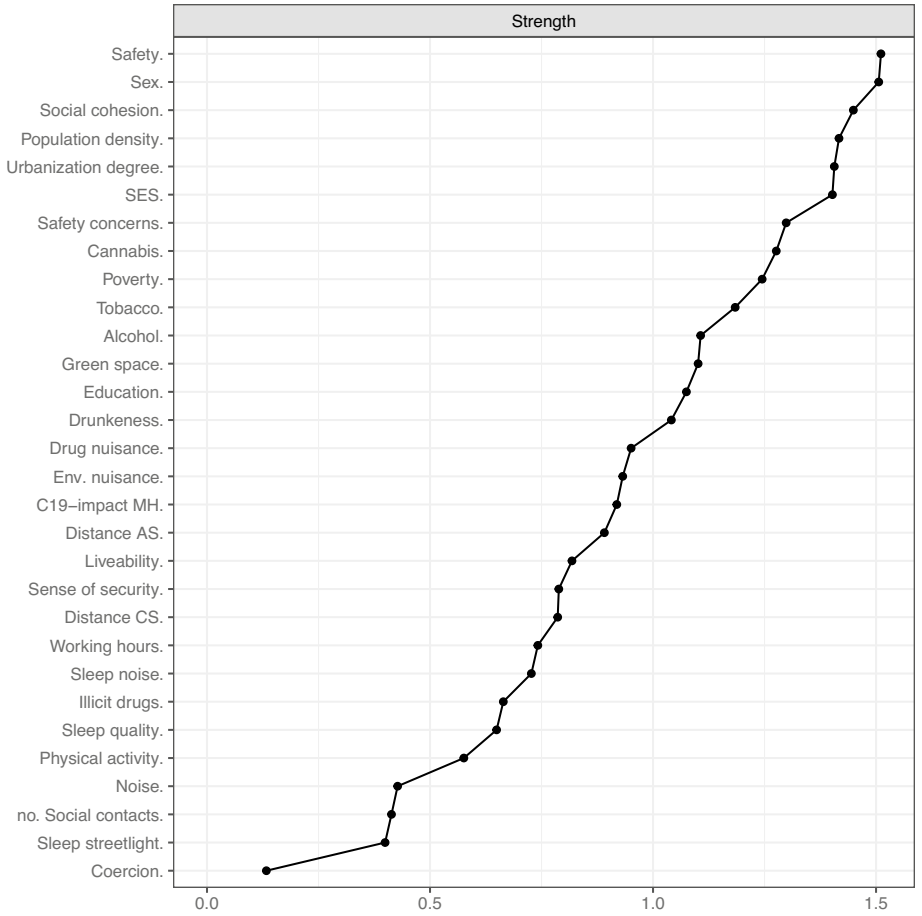

Fig. 4 Strength centrality (urban-substance)

Discussion

This study's purpose was to elucidate reciprocal connections between mental health, substance use, perceptions of urban life, and neighbourhood characteristics. Findings revealed strong clustering among affective symptoms, among various substance use behaviours, and among urban characteristics. The bridge nodes connecting these clusters seem to converge around self-reported urban life characteristics, particularly self-reported experiences with safety and overall nuisance in daily living circumstances. Objective measures of safety and social cohesion support this connection between experiences with urban hassles and older adolescents' mental health and substance use.

The results of our study align with existing research showing that anxiety and depression symptoms often cluster together (Cai et al., 2022; Mullarkey et al., 2019), especially in (older) adolescents. This clustering is well-documented and reflects the close relationship between these affective symptoms. However, our findings also highlight some less commonly explored connections, such as the clustering of both affective symptoms and substance use behaviours with level of social contact and self-reported urban hassles. This

suggests that perceptions of urban life, including safety, social connection, and environmental nuisance, play a significant role in shaping mental health and substance use among older adolescents (Pykett et al., 2023).

The network comparison revealed some significant structural differences between Amsterdam and non-Amsterdam groups, but the overall strength of connections remained similar. The nuanced edge-differences suggest that while mental health symptoms and substance use prevalence do not vary much between these city-groups, specific urban characteristics may influence symptom connections differently depending on the location (i.e. neighbourhood). This is particularly relevant in the Dutch context, where the distinction between urban and rural areas is less pronounced than in many other countries. Nevertheless, recent national findings from the NEMESIS-3 study (Ten Have et al., 2023) showed that higher levels of urbanization are associated with a higher prevalence of mental disorders—particularly among young urban residents. This underscores that even within a relatively suburbanized national context, urban-specific stressors and neighbourhood characteristics may play a vital role in adolescent mental health and substance use.

Previously, it was not well understood which specific aspects of urban life were intertwined with older adolescents' mental health and substance use (van der Wal et al., 2021). Urban living is often viewed as a single component, but our study reveals that it is much more varied, with distinct characteristics at the neighbourhood level within a city such as social safety and drug-related nuisance. This aligns with Bronfenbrenner's ecological model (Bronfenbrenner & Morris, 2007), which conceptualizes adolescent development as embedded in multi-layered environmental systems, from neighbourhood settings to broader urban infrastructure. Our findings echo this layered view by showing how urban characteristics stemming from different ecological layers—ranging from individual-level social contact to broader structural indicators like neighbourhood poverty and safety—relate to various mental health symptoms and behaviours. In line with urban health frameworks (Kim et al., 2022; Pykett et al., 2023; van der Wal et al., 2021), our results demonstrate how neighbourhood-level stressors can reflect broader systemic issues like spatial inequality, social cohesion, and infrastructural design. This study thus contributes to our understanding of the heterogeneous nature and clinical phenotype of common mental disorders by showing that various urban characteristics relate to unique symptoms. Granular network connections capture heterogeneity better than correlations between sum scores, highlighting the complexity of urban mental health.

Interestingly, our study emphasizes the importance of both subjective and objective social aspects in these networks. This finding aligns with Lazarus' transactional model of stress (Lazarus & Folkman, 1984), which conceptualizes stress not as a fixed outcome, but as the result of how individuals appraise and cope with environmental demands. From this perspective, it is not merely the objective presence of urban stressors that matters, but how adolescents interpret these urban surroundings—such as feelings of unsafety or social disconnection—which may shape their psychological responses and related behaviours.

Objective safety and social cohesion in the daily living circumstances appear to be critical elements connecting self-reported feelings of security, social interaction, mental health, and substance use among older adolescents. Enhancing neighbourhood social cohesion and safety could be valuable targets for future (intervention) studies to explore their impact on older adolescents' well-being and substance use, highlighting the link between social environments and individual health outcomes (Breedvelt et al., 2022).

On the one hand, existing studies have shown that social insecurity in the living environment can act as a significant stressor for older adolescents. Exposure to unsafe neighbourhoods has been linked to increased anxiety, depression, and behavioural problems

(Baranyi et al., 2021; Visser et al., 2021). When older adolescents feel unsafe, they are more likely to experience chronic stress, which can exacerbate mental health issues and comorbid substance use (Baranyi et al., 2021; Midouhas et al., 2021). Also, individuals who use substances excessively may more often encounter stressful and threatening situations (Amaro et al., 2021; Carter et al., 2020), which can further intensify feelings of insecurity.

On the other hand, neighbourhood social cohesion plays a critical role in promoting the well-being and mental health of older adolescents. High levels of social cohesion, where community members support and trust each other, are associated with lower levels of stress and better mental health outcomes (Breedvelt et al., 2022). Older adolescents who grow up in cohesive neighbourhoods tend to have stronger social networks and a greater sense of belonging, which can buffer against the negative effects of stress and enhance overall well-being (Kingsbury et al., 2020).

Furthermore, older adolescents' mental health and substance use can reflect back on the safety and social atmosphere of their neighbourhoods. Individuals who experience mental health issues or engage in excessive substance use can contribute to a sense of instability and insecurity within their communities. Conversely, when older adolescents are mentally healthy and engage positively with their surroundings, they can enhance the social atmosphere and safety of their neighbourhoods (Midouhas et al., 2021). This reciprocal relationship highlights the importance of addressing both individual and community features to foster healthier urban environments for older adolescents.

Future studies should continue to explore the multifaceted nature of urban living and its impacts on older adolescents' mental health. While safety and social cohesion are important across geographic areas, urban environments often present more intense and layered challenges—ranging from environmental nuisances to reduced trust between residents. Researchers could examine which specific design elements and policy interventions might most effectively strengthen social safety and cohesion in urban neighbourhoods. Building on our findings, longitudinal or time-series network studies could help uncover how symptoms and urban stressors influence each other over time—revealing, for instance, whether certain symptoms trigger others within changing neighbourhood conditions. Such studies can clarify how adolescents move from a healthy to a more vulnerable mental state and how substance use becomes entangled in that process (Borsboom, 2017). The current network structure offers a foundation to formulate and test specific predictions. For example, future research might examine whether improving perceptions of safety can weaken the observed link between anxiety and cannabis use. In this way, our approach contributes to hypothesis generation and can inform the development of precision-targeted interventions tailored to urban youth contexts.

Although preliminary and based on a cross-sectional design, our findings may help identify potential directions for urban design and municipal policy. Urban planners and policymakers might consider prioritizing the creation of safe and cohesive neighbourhoods as a potential strategy to support young residents' well-being. This can include increasing public spaces that encourage community interaction, enhancing surveillance to improve safety, and implementing programs that foster community engagement and trust. Schools, community centres, and local organizations can also play vital roles in promoting social cohesion by organizing activities and initiatives that bring residents together. Furthermore, municipal policies could address environmental nuisances and safety concerns proactively. This might involve stricter regulations on drug-related activities, better maintenance of public spaces, and targeted interventions in areas with high levels of social disorganization. Overall, by understanding and addressing the social and environmental factors that

associate with older adolescents' mental health, we can create urban spaces that not only support their wellbeing but also foster healthier, more resilient communities.

With the rising mental health challenges faced by adolescents in urban settings, our findings offer initial insights into the interplay between urban social safety and common mental health problems in older adolescents. However, replication in other countries or urban settings is a crucial next step to validate these results. Establishing causal relationships will further strengthen the foundation for providing evidence-based recommendations to urban planners.

Strengths and Limitations

One of the strengths of this study is the comprehensive approach we took in examining the interplay between urban characteristics, mental health, and substance use among older adolescents. By utilizing network analysis, we were able to capture the complex relationships between these domains, providing a more holistic understanding of the urban environment's impact on older adolescents' well-being. Additionally, our study incorporated both self-report and objective measures of urban characteristics, allowing for a more comprehensive and valid understanding of urban living experiences. Also, subjective measures ensure that the concerns of the community are included in the assessments, making the findings inclusive and socially just.

However, there are also limitations to consider. Firstly, the cross-sectional nature of our study means that we cannot establish causality or infer the direction of relationships between variables. Longitudinal studies are needed to elucidate the temporal dynamics of these associations over time. Additionally, our sample was drawn from a specific geographic area with participants with relatively high educational level limiting the generalizability of our findings to other populations or contexts. The Netherlands does not have a significant distinction between urban and rural areas, as the country is largely characterized by suburban regions. Although we compared Amsterdam residents with those living in other parts of the Netherlands, the generalizability of our findings to other contexts with clearer urban–rural divides may be limited.

Additionally, while we explored a wide range of urban characteristics, there may be other phenomena not accounted for in our analysis that could impact the overall well-being of older adolescents, such as access to healthcare, socio-cultural influences, impact of parenting, and the COVID period.

Conclusion

In conclusion, the presented networks suggest a complex interplay between urban environmental characteristics and individual health outcomes, with objective safety and social cohesion serving as key connectors between urban characteristics and mental health symptoms and substance use. Depressive symptoms and substance use are notably linked to urban hassles and sense of safety, highlighting the importance of addressing both objective and subjective urban stressors to mitigate mental health risks and substance use in older adolescents. By building upon these findings, we can further advance our understanding of how urban environments shape older adolescents' well-being and inform interventions to promote healthier outcomes.

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Data Availability The data that support the findings of this study are not publicly available due to privacy and ethical restrictions, specifically participant confidentiality and data protection regulations.

Declarations

Informed consent All procedures followed were in accordance with the ethical standards of the responsible committee on human experimentation (institutional and national) and with the Helsinki Declaration of 1975, as revised in 2000 (5). Informed consent was obtained from all patients for being included in the study.

Conflict of interest The authors declare no competing interests.

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References

Amaro, H., Sanchez, M., Bautista, T., & Cox, R. (2021). Social vulnerabilities for substance use: Stressors, socially toxic environments, and discrimination and racism. *Neuropharmacology, 188*, 108518. https://doi.org/10.1016/j.neuropharm.2021.108518

Arnett, J. J. (2024). Emerging Adulthood: The Winding Road from the Late Teens Through the Twenties. *Oxford University Press*. https://doi.org/10.1093/oso/9780197695937.001.0001

Baranyi, G., Di Marco, M. H., Russ, T. C., Dibben, C., & Pearce, J. (2021). The impact of neighbourhood crime on mental health: A systematic review and meta-analysis. *Social Science and Medicine, 282*, 114106. https://doi.org/10.1016/j.socscimed.2021.114106

Borsboom, D. (2017). A network theory of mental disorders. *World Psychiatry, 16*(1), 5–13. https://doi.org/10.1002/wps.20375

Breedvelt, J. J. F., Tiemeier, H., Sharples, E., Galea, S., Niedzwiedz, C., Elliott, I., & Bockting, C. L. (2022). The effects of neighbourhood social cohesion on preventing depression and anxiety among adolescents and young adults: Rapid review. *Bjpsych Open, 8*(4), e97. https://doi.org/10.1192/bjo.2022.57

Bronfenbrenner, U., & Morris, P. A. (2007). The bioecological model of human development. In Damon, W., & Lerner, R. M. (Eds.), *Handbook of Child Psychology* (1ste dr.). Wiley. https://doi.org/10.1002/9780470147658.chpsy0114

Buysse, D. J., Reynolds, C. F., Monk, T. H., Berman, S. R., & Kupfer, D. J. (1989). The Pittsburgh sleep quality index—a new instrument for psychiatric practice and research. *Psychiatry Research, 28*(2), 193–213. https://doi.org/10.1016/0165-1781(89)90047-4

Cai, H., Bai, W., Liu, H., Chen, X., Qi, H., Liu, R., Cheung, T., Su, Z., Lin, J., Tang, Y. L., Jackson, T., Zhang, Q., & Xiang, Y. T. (2022). Network analysis of depressive and anxiety symptoms in adolescents during the later stage of the COVID-19 pandemic. *Translational Psychiatry, 12*(1), 98. https://doi.org/10.1038/s41398-022-01838-9

Carter, P. M., Cranford, J. A., Buu, A., Walton, M. A., Zimmerman, M. A., Goldstick, J., Ngo, Q., & Cunningham, R. M. (2020). Daily patterns of substance use and violence among a high-risk urban emerging adult sample: Results from the Flint Youth Injury Study. *Addictive Behaviors, 101*, 106127. https://doi.org/10.1016/j.addbeh.2019.106127

Crielaard, L., Nicolaou, M., Sawyer, A., Quax, R., & Stronks, K. (2021). Understanding the impact of exposure to adverse socioeconomic conditions on chronic stress from a complexity science perspective. *BMC Medicine, 19*(1), 242. https://doi.org/10.1186/s12916-021-02106-1

Epskamp, S., Borsboom, D., & Fried, E. I. (2018). Estimating psychological networks and their accuracy: A tutorial paper. *Behavior Research Methods, 50*(1), 195–212. https://doi.org/10.3758/s13428-017-0862-1

Finnemann, A., Huth, K., Borsboom, D., Epskamp, S., & van der Maas, H. (2024). The urban desirability paradox: U.K. urban-rural differences in well-being, social satisfaction, and economic satisfaction. *Science Advances*, *10*(29), eadn1636. https://doi.org/10.1126/sciadv.adn1636

Gouin, J. P., de la Torre-Luque, A., Sanchez-Carro, Y., Geoffroy, M. C., & Essau, C. (2023). Heterogeneity in the trajectories of psychological distress among late adolescents during the COVID-19 pandemic. *JCPP Advances, 3*(4), e12195. https://doi.org/10.1002/jcv2.12195

Guite, H. F., Clark, C., & Ackrill, G. (2006). The impact of the physical and urban environment on mental well-being. *Public Health, 120*(12), 1117–1126. https://doi.org/10.1016/j.puhe.2006.10.005

Haslbeck, J. M. B., & Waldorp, L. J. (2020). mgm: Estimating time-varying mixed graphical models in high-dimensional data. *Journal of Statistical Software*, *93*(8). https://doi.org/10.18637/jss.v093.i08

Jones, P. J., Ma, R., & McNally, R. J. (2021). Bridge centrality: A network approach to understanding comorbidity. *Multivariate Behavioral Research, 56*(2), 353–367. https://doi.org/10.1080/00273171.2019.1614898

Kanner, A. D., Coyne, J. C., Schaefer, C., & Lazarus, R. S. (1981). Comparison of two modes of stress measurement: Daily hassles and uplifts versus major life events. *Journal of Behavioral Medicine, 4*(1), 1–39. https://doi.org/10.1007/BF00844845

Kim, J., de Leeuw, E., Harris-Roxas, B., & Sainsbury, P. (2022). Four urban health paradigms: The search for coherence. *Cities*, *128*. https://doi.org/10.1016/j.cities.2022.103806

Kingsbury, M., Clayborne, Z., Colman, I., & Kirkbride, J. B. (2020). The protective effect of neighbourhood social cohesion on adolescent mental health following stressful life events. *Psychological Medicine, 50*(8), 1292–1299. https://doi.org/10.1017/S0033291719001235

Krabbendam, L., van Vugt, M., Conus, P., Soderstrom, O., Abrahamyan Empson, L., van Os, J., & Fett, A. J. (2021). Understanding urbanicity: How interdisciplinary methods help to unravel the effects of the city on mental health. *Psychological Medicine, 51*(7), 1099–1110. https://doi.org/10.1017/S0033291720000355

Kroenke, K., & Spitzer, R. L. (2002). The PHQ-9: A new depression diagnostic and severity measure. *Psychiatric Annals, 32*(9), 509–515. https://doi.org/10.3928/0048-5713-20020901-06

Lakerveld, J., Wagtendonk, A., Vaartjes, I., Karssenberg, D., Consortium G. (2020). Deep phenotyping meets big data: The Geoscience and hEalth Cohort COnsortium (GECCO) data to enable exposome studies in The Netherlands. *International Journal of Health Geographics, 19*(1), 49. https://doi.org/10.1186/s12942-020-00235-z

Lazarus, R. S., & Folkman, S. (1984). *Stress, appraisal, and coping*. Springer publishing company.

Leifheit, K. M., Parekh, J., Matson, P. A., Moulton, L. H., Ellen, J. M., & Jennings, J. M. (2015). Is the association between neighborhood drug prevalence and marijuana use independent of peer drug and alcohol norms? Results from a household survey of urban youth. *Journal of Urban Health, 92*(4), 773–783. https://doi.org/10.1007/s11524-015-9962-3

Magee, K. E., & Connell, A. M. (2021). The role of substance use coping in linking depression and alcohol use from late adolescence through early adulthood. *Experimental and Clinical Psychopharmacology, 29*(6), 659–669. https://doi.org/10.1037/pha0000436

Midouhas, E., Sifaki, M., Lai, H. L., & Flouri, E. (2021). Reciprocal associations of adolescent perceptions of neighbourhood safety and problem behaviour. *Wellbeing Space and Society*, *2*. https://doi.org/10.1016/j.wss.2021.100036

Miller, D. B., & Bennett, M. D. (2016). Continued development of the urban hassles index: Evolving examination of urban adolescent stressors. *Child and Adolescent Social Work Journal, 33*(4), 327–335. https://doi.org/10.1007/s10560-015-0430-4

Min, M. O., Kim, J. Y., Olgac, T., Francis, M., Shon, E. J., & Yoon, D. (2018). Factor structure of the urban hassles index. *Research on Social Work Practice, 28*(6), 741–750. https://doi.org/10.1177/1049731516674815

Mize, J. L., & Kliewer, W. (2017). Domain-specific daily hassles, anxiety, and delinquent behaviors among low-income, urban youth. *Journal of Applied Developmental Psychology, 53*, 31–39. https://doi.org/10.1016/j.appdev.2017.09.003

Mullarkey, M. C., Marchetti, I., & Beevers, C. G. (2019). Using network analysis to identify central symptoms of adolescent depression. *Journal of Clinical Child and Adolescent Psychology, 48*(4), 656–668. https://doi.org/10.1080/15374416.2018.1437735

Nuijen, J., Verweij, A., Dopmeijer, J., van Wamel, A., Schouten, F., Buijs, M., van der Horst, M., & van der Brink, C. (2023). *Monitor mentale gezondheid en middelengebruik studenten hoger onderwijs 2023*. Trimbos-instituut, RIVM, & GGD GHOR Nederland. https://doi.org/10.21945/rivm-2023-0214

Pettit, J. W., Lewinsohn, P. M., Seeley, J. R., Roberts, R. E., & Yaroslavsky, I. (2010). Developmental relations between depressive symptoms, minor hassles, and major events from adolescence through age 30 years. *Journal of Abnormal Psychology, 119*(4), 811–824. https://doi.org/10.1037/a0020980

Pykett, J., Campbell, N., Fenton, S. J., Gagen, E., Lavis, A., Newbigging, K., Parkin, V., Williams, J., Members of the Institute for Mental Health Youth Advisory G. (2023). Urban precarity and youth mental health: An interpretive scoping review of emerging approaches. *Social Science and Medicine, 320*, 115619. https://doi.org/10.1016/j.socscimed.2022.115619

Quednow, B. B., Steinhoff, A., Bechtiger, L., Ribeaud, D., Eisner, M., & Shanahan, L. (2022). High prevalence and early onsets: Legal and illegal substance use in an urban cohort of young adults in Switzerland. *European Addiction Research, 28*(3), 186–198. https://doi.org/10.1159/000520178

Racine, N., McArthur, B. A., Cooke, J. E., Eirich, R., Zhu, J., & Madigan, S. (2021). Global prevalence of depressive and anxiety symptoms in children and adolescents during COVID-19: A meta-analysis. *JAMA Pediatrics, 175*(11), 1142–1150. https://doi.org/10.1001/jamapediatrics.2021.2482

Rudolph, K. E., Stuart, E. A., Glass, T. A., & Merikangas, K. R. (2014). Neighborhood disadvantage in context: The influence of urbanicity on the association between neighborhood disadvantage and adolescent emotional disorders. *Social Psychiatry and Psychiatric Epidemiology, 49*(3), 467–475. https://doi.org/10.1007/s00127-013-0725-8

Schwinn, T. M., Schinke, S. P., & Trent, D. N. (2010). Substance use among late adolescent urban youths: Mental health and gender influences. *Addictive Behaviors, 35*(1), 30–34. https://doi.org/10.1016/j.addbeh.2009.08.005

Sharifi, A., & Khavarian-Garmsir, A. R. (2020). The COVID-19 pandemic: Impacts on cities and major lessons for urban planning, design, and management. *Science of the Total Environment, 749*, 142391. https://doi.org/10.1016/j.scitotenv.2020.142391

Spitzer, R. L., Kroenke, K., Williams, J. B., & Lowe, B. (2006). A brief measure for assessing generalized anxiety disorder: The GAD-7. *Archives of Internal Medicine, 166*(10), 1092–1097. https://doi.org/10.1001/archinte.166.10.1092

Ten Have, M., Tuithof, M., van Dorsselaer, S., Schouten, F., Luik, A. I., & de Graaf, R. (2023). Prevalence and trends of common mental disorders from 2007–2009 to 2019–2022: Results from the Netherlands Mental Health Survey and Incidence Studies (NEMESIS), including comparison of prevalence rates before vs. during the COVID-19 pandemic. *World Psychiatry*, *22*(2), 275–285. https://doi.org/10.1002/wps.21087

Timmermans, E. J., Lakerveld, J., Beulens, J. W. J., Boomsma, D. I., Kramer, S. E., Oosterman, M., Willemsen, G., Stam, M., Nijpels, G., Schuengel, C., Smit, J. H., Brunekreef, B., Dekkers, J. E. C., Deeg, D. J. H., Penninx, B., & Huisman, M. (2018). Cohort profile: The Geoscience and Health Cohort Consortium (GECCO) in the Netherlands. *British Medical Journal Open, 8*(6), e021597. https://doi.org/10.1136/bmjopen-2018-021597

United Nations, Department of Economic and Social Affairs, Population Division. (2019). *World Urbanization Prospects 2018: Highlights* (ST/ESA/SER.A/421). Retrieved September 2, 2024, from https://population.un.org/wup/publications

van Borkulo, C. D., van Bork, R., Boschloo, L., Kossakowski, J. J., Tio, P., Schoevers, R. A., Borsboom, D., & Waldorp, L. J. (2023). Comparing network structures on three aspects: A permutation test. *Psychological Methods, 28*(6), 1273–1285. https://doi.org/10.1037/met0000476

van der Wal, J. M., van Borkulo, C. D., Deserno, M. K., Breedvelt, J. J. F., Lees, M., Lokman, J. C., Borsboom, D., Denys, D., van Holst, R. J., Smidt, M. P., Stronks, K., Lucassen, P. J., van Weert, J. C. M., Sloot, P. M. A., Bockting, C. L., & Wiers, R. W. (2021). Advancing urban mental health research: From complexity science to actionable targets for intervention. *Lancet Psychiatry, 8*(11), 991–1000. https://doi.org/10.1016/S2215-0366(21)00047-X

van Eijsden, M., Vrijkotte, T. G. M., Gemke, R. J. B. J., & van der Wal, M. F. (2011). Cohort profile: The Amsterdam born children and their development (ABCD) study. *International Journal of Epidemiology, 40*(5), 1176–1186. https://doi.org/10.1093/ije/dyq128

Vassos, E., Agerbo, E., Mors, O., & Pedersen, C. B. (2016). Urban-rural differences in incidence rates of psychiatric disorders in Denmark. *British Journal of Psychiatry, 208*(5), 435–440. https://doi.org/10.1192/bjp.bp.114.161091

Visser, K., Bolt, G., Finkenauer, C., Jonker, M., Weinberg, D., & Stevens, G. (2021). Neighbourhood deprivation effects on young people's mental health and well-being: A systematic review of the literature. *Social Science and Medicine, 270*, 113542. https://doi.org/10.1016/j.socscimed.2020.113542

Wiers, R. W., El Marroun, H., Bockting, C., Krugers, H., & Urban Mental Health Researchers. (2025). Debate: Urban versus rural environments—Which is better for mental health? *The one good thing about a small town.… Child and Adolescent Mental Health*, camh.12771. https://doi.org/10.1111/camh.12771

J., Xu, X., Liu, Q., Li, R., Goldblatt, W., Qin, F., Liu, C., Chu, Q., Luo, A., Ing, L., … Consortia. (2022). Global urbanicity is associated with brain and behaviour in young people. *Nature Human Behaviour, 6*(2), 279–293. https://doi.org/10.1038/s41562-021-01204-7

Yoshida, T., Osada, Y., Kawaguchi, T., Hoshiyama, Y., Yoshida, K., & Yamamoto, K. (1997). Effects of road traffic noise on inhabitants of Tokyo. *Journal of Sound and Vibration, 205*(4), 517–522. https://doi.org/10.1006/jsvi.1997.1020

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