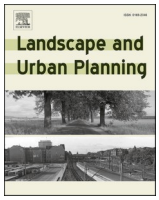
Landscape and Urban Planning 264 (2025) 105487

Contents lists available at ScienceDirect

Landscape and Urban Planning

journal homepage: www.elsevier.com/locate/landurbplan



A systematic review of geographically informed ecological momentary assessment studies on the place-based correlates of mental health, substance use and wellbeing

Ronja Christensen [a,b,*], Charlotte Constable Fernandez [a,c,1], Noémie Topalian [d,1], Laura Vaughan [e], Kimon Krenz [e], Alexandra Pitman [f,g], Anne-Kathrin Fett [a,h]

[a] Department of Psychology and Neuroscience, City St George's, University of London, School of Health and Medical Sciences, London, UK
[b] Queen Square Multiple Sclerosis Centre, Department of Neuroinflammation, UCL Queen Square Institute of Neurology, University College London, London, UK
[c] UCL Division of Psychology and Language Sciences, University College London, UK
[d] Luxembourg Institute of Socio-Economic Research, Esch-sur-Alzette, Luxembourg
[e] Space Syntax Lab, The Bartlett School of Architecture, UCL, London, UK
[f] UCL Division of Psychiatry, University College London, London, UK
[g] North London NHS Foundation Trust, London, UK
[h] King's College London, Institute of Psychiatry, Psychology and Neuroscience, Department of Psychosis Studies, De Crespigny Park, London, UK

HIGHLIGHTS

- The 33 reviewed studies were highly heterogenous in design.
- Place characteristics were associated with mental health, substance use, and wellbeing.
- Geographically informed EMA analyses of temporal associations remain scarce.

ARTICLE INFO

Keywords:
Geographically-Explicit Ecological Momentary Assessment (GEMA)
Real-time data collection
Mental health
Wellbeing
Built environment
Nature Exposure

ABSTRACT

Place characteristics are associated with mental health and wellbeing, yet mechanisms and pathways are not well understood. Geographically explicit ecological momentary assessment (GEMA) is a real-time data collection method that captures individuals' experiences and behaviours in their natural environments, minimising recall bias and enhancing ecological validity. Previous reviews have underscored the feasibility of GEMA studies to deliver important insights on relationships between mental health and wellbeing and place. This systematic review provides a narrative synthesis of the existing GEMA literature on place-based correlates of mental health and wellbeing in daily life. We searched PubMed, PsycINFO and Embase, using a systematic search strategy to identify relevant English-language studies that used EMA and geographical information to assess place and mental health, wellbeing and/or substance use and their relationship. Studies were included if either the exposure (place) or outcome (mental health, substance use or wellbeing) was assessed in the moment. We identified 33 eligible studies. Eleven focused on nature exposure, 19 on built environment characteristics, and three studies on ambient characteristics. Place-based factors were assessed through various objective and subjective indicators (e.g. Global Positioning System signal, descriptions of nature sounds or noise levels). Regardless of study methodology, exposure to nature was consistently associated with better mental health and higher wellbeing, with small to moderate effect sizes. Specific urban characteristics were linked to poorer mental health and increased substance use. Despite much heterogeneity in study methodologies, our results suggest that EMA in conjunction with geographical information can advance the understanding of the place-mental health and wellbeing nexus. Although these findings reinforce well-established associations, relatively few GEMA studies have examined how place-based exposures influence mental health over time, limiting the ability to infer

* Corresponding author at: Queen Square MS Centre, Department of Neuroinflammation, UCL Queen Square Institute of Neurology, Faculty of Brain Sciences, University College London, London, UK.
E-mail address: ronja.christensen@ucl.ac.uk (R. Christensen).
[1] Contributed equally.

https://doi.org/10.1016/j.landurbplan.2025.105487
Received 5 November 2024; Received in revised form 21 July 2025; Accepted 2 September 2025
Available online 16 September 2025

causal mechanisms. We discuss implications for urban planning, policy making and mental health and wellbeing support through place-based interventions.

1. Introduction

The importance of places and environmental factors for mental health and wellbeing is now widely recognised. Several reviews, largely of epidemiological studies, have reported associations between natural and built characteristics and mental health and wellbeing (Collins et al., 2020; Gascon et al., 2015; Gruebner et al., 2017; Kondo et al., 2018; Krabbendam et al., 2021; Núñez-González et al., 2020). Intrinsic qualities of natural spaces may contribute to restoration of mental health. It has been proposed that this may be due to our evolutionary affinity for natural environments, stress reduction or attention restoration (Kaplan & Kaplan, 1989; Kellert & Wilson, 1995; Ulrich et al., 1991). However, greater exposure to natural spaces may reduce harm through decreased pollution, better air quality and fewer space restrictions (Kuo, 2015; Li et al., 2018). In addition, positive effects may also be indirect through health promoting behaviours, such as physical activity or increased social connection (Kuo, 2015; Li, van Vugt, & Colarelli, 2018), which can increase mental health and wellbeing. Importantly, amidst continuous urbanisation, built characteristics play an important role in the everyday physical environments of a large proportion of the global population (World Health Organization, 2022). While urbanised areas may offer access to resources, such as career opportunities or easy transportation, and opportunities for social encounters, they also have negative characteristics, such as restricted living space, increased social neighbourhood disorder, noise and air pollution (Gruebner et al., 2017; Krabbendam et al., 2021; Núñez-González et al., 2020). Furthermore, poorly designed built environments may restrict walkability, so disconnecting individuals from both physical and social resources and ultimately influencing mental health (Boniface et al., 2015).

Many studies have linked urban living to a higher risk of mental illness, including psychosis, depression, and drug use (Galea, 2005; Galea et al., 2005; Sui et al., 2022; Vassos et al., 2012). Importantly, the risks and benefits from exposure to specific environments vary with individual characteristics such as age, gender, ethnicity, genetic liability and socio-demographic factors (Astell-Burt et al., 2014; Krabbendam et al., 2021; Lachowycz & Jones, 2013). Research has generated important evidence on associations between mental health, wellbeing and place. Yet, it has relied mostly on cross-sectional designs, retrospective self-reports or static measures, such as residential green space density and neighbourhood socio-economic status, or experimental designs that do not capture the dynamic and individualised nature of human experiences in their daily environmental context (Collins et al., 2020; Núñez-González et al., 2020).

Ecological Momentary Assessment (EMA) has emerged as a powerful and highly valid tool for the study of mental health and wellbeing in individuals' natural environments and can be used to shed light on dynamic interactions between places and mental health and wellbeing (de Vries, Baselmans, & Bartels, 2021; Shiffman, Stone, & Hufford, 2008). EMA involves the real-time collection of data on individuals' behaviours, experiences, and environmental contexts as they occur in natural settings, traditionally using beepers or diaries, and more recently through the use of smartphones. The EMA approach minimises recall bias and provides ecological insights into the contexts of health and wellbeing. A recent systematic review highlighted the effective application in understanding health within its natural context and reported feasibility of smartphone-based EMA (Zhang et al., 2024). While recent developments in wearable technologies, mobile sensing, and physiological monitoring have expanded possibilities for real-time, *in situ* data collection, these approaches do not typically include repeated subjective self-reports and are often structured as field experiments (Torku et al., 2021, 2022; Xiang et al., 2021). As such, they are methodologically distinct from classic EMA, which centres on capturing subjective experience as it naturally unfolds over time. Geographically informed (G-) EMA studies have started to explore the links between place, mental health and wellbeing by using objective and subjective place-related measures (e.g., global positioning systems (GPS), mobile sensing, geographic information systems (GIS), or questions about place-based characteristics) in conjunction with longitudinal momentary assessments of individuals' psychological states (de Vries, Baselmans, & Bartels, 2021; Kirchner & Shiffman, 2016). One recent review by Zhang et al. (2024) identified several key challenges and recommendations, including participant compliance rates, the importance of protecting privacy when using location data, and the need for improved measurement validity, particularly when adapting mental health assessments for daily or momentary repetition. Similarly, in another recent review, referring to EMA studies in general, de Vries, Baselmans, & Bartels, 2021 emphasised the limitations of passive data collection methods, potential biases related to participant demographics in terms of mobile phone usage, and critically, the need for rigorous pre-testing of applications to ensure participant retention. Importantly, both reviews noted a lack of focus on the spatiotemporal associations that GEMA is uniquely positioned to investigate.

Together these previous reviews highlight the feasibility but also the methodological complexities of GEMA research. However, they did not specifically address the relationships between place-based factors and mental health outcomes. GEMA research has the potential to improve our understanding of causal relationships between mental health and wellbeing and place and to inform policymaking and implementation across various sectors (Gromatsky et al., 2020). Notably, the number of studies has increased substantially over the past decade (Kingsbury et al., 2024; Zhang et al., 2024). Yet, the existing evidence has not been systematically reviewed. Here we aimed to review and summarise the available literature to address the following research question: What is the current evidence in GEMA studies on the associations between place, mental health and wellbeing?

2. Methods

2.1. Search strategy

We sought to include all EMA studies on the association between place-based factors and mental health (including substance use) and/or wellbeing. We pre-registered our protocol on PROSPERO (CRD42023432842). We followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) reporting guidelines (Page et al., 2021).

The initial literature search was performed on 19/07/2023 using PubMed, PsycINFO and Embase databases for any relevant studies from database inception and updated on 10/09/2024. Databases were selected for their relevance to mental health, psychology, and medicine, using an expansive search strategy to maximise sensitivity. To complement these searches, we used snowballing of reference lists of included studies to ensure comprehensive coverage. All authors participated in the development of the search strategy, which comprised three concepts; 1) place-based factors, such as neighbourhood or pollution, 2) mental health, such as psychiatric symptoms or eating disorders, psychological distress and substance use, and wellbeing, and 3) EMA, covering all terms related to such methodologies (Table 1). Search items within a concept were linked with the Boolean operator "OR", and subsequently concepts were linked with "AND" (Table 1). R.C. performed the search using the final Boolean search query, which was restricted to English language and human participants. We also conducted systematic

Table 1
Database search terms.

Category	Keywords
Place characteristics	neighbo?rhood OR residency OR community? OR park OR restaurant OR pub OR café OR high street OR public space OR neighbo?rhood perception OR neighbo?rhood crime OR neighbo?rhood safety OR population density OR ethnic homogeneity OR ethnic density OR nature OR * pollution OR street light* OR spill OR environmental * OR exposure OR density OR *space OR spatial* OR transport OR public transport OR mobility OR commute OR street network OR walkab* OR digital connectivity OR broadband connectivity OR mobile networks OR urban* OR suburban OR built* OR public amenities OR *planning OR land?use OR locality characteristics OR geographical* OR access to OR accessib* OR connectivity OR *environment OR environment* OR street OR streetscapes OR road OR infrastructure OR playgrounds OR skate park* OR recreational facilit* OR youth cent* OR librar* OR housing OR museum OR theatre OR cinema OR social club* OR art club* OR religious place* OR religious space* OR church OR mosque OR synagogue OR temple OR sacred space* OR place* of worship
Mental health	mental* health* OR mental disorder* OR mental ill OR psychological distress OR stress OR post?traumatic stress OR sadness OR depress* OR affective OR mood disorder* OR psychiatry* OR psychosis OR schizo* OR bipolar* OR eating disorder OR anorexi* OR bulimi* OR binge eating OR obsessive compulsive OR anxi* OR panic OR substance?use OR adhd
Ecological assessment methodology	ecological momentary assessment OR EMA OR geographic* momentary assessment OR GEMA OR experience sampling methodology OR ESM OR time sampling OR daily diary OR beeper OR ambulatory assessment OR real?time OR digital phenotyping OR mobile* OR electronic diary OR sensor*

snowballing, examining the reference lists of the included studies.

2.2. Inclusion and exclusion criteria

Studies were included if they were quantitative or mixed methods research articles, written in English and published in a peer-reviewed journal that assessed a combination of mental health (including substance use) or wellbeing measures and place-based factors where at least one aspect was assessed by EMA. Mental health outcomes were broadly defined to include for example psychological distress, substance use, loneliness and wellbeing, given their established links to mental health (Krabbendam et al., 2021). Similarly, place-based measures were conceptualised broadly to reflect the heterogeneity in study designs (e.g. including objective and subjective measures) and environmental characteristics of interest. Studies that only included mobility (i.e. distance travelled, or time spent walking) were excluded, as we aimed to focus specifically on characteristics of places.

2.3. Screening

Abstracts and titles were screened by R.C and a randomly selected 10 % were double screened by a blinded second author (C.C.F.). Full-text screening was then independently conducted by R.C. and C.C.F. The reference lists of the included articles were screened, and further eligible articles underwent full-text screening by R.C., L.V. and C.C.F. Any disagreements were discussed and resolved among all authors.

2.4. Data extraction

Data on study characteristics, including author, publication year, country/setting, sample characteristics, place-based measure, mental health/wellbeing related measure, EMA methods and key results, were extracted by R.C. and N.T. (Table 2).

2.5. Study quality

R.C. and C.C.F. assessed the quality of all included papers using the Mixed Methods Appraisal Tool (MMAT) version 18 (Hong et al., 2018) that distinguishes between five types of study designs: qualitative, quantitative randomised controlled trials, quantitative non-randomised, quantitative descriptive, and mixed methods. Each design type includes a list of criteria that are scored as met "1" or unmet "0". We did not exclude studies based on quality assessment but present the research in the context of quality ratings (see Supplementary Tables 1.1, 1.2 and 1.3).

2.6. Review approach

The retrieved studies were characterised by substantial heterogeneity in research designs and methods (e.g. using objective and subjective assessments of place-related factors, ambient characteristics, context, momentary and questionnaire-based assessments of various aspects of mental health and wellbeing, and cross-sectional or longitudinal analytic approaches). We created an initial classification of findings based on key parameters: 1) methodological approach (qualitative/quantitative), 2) country, 3) sample characteristics, 4) place-based categories (1. natural/ 2. built environment characteristics) and 5) outcomes. After data extraction and quality appraisal the multi-disciplinary research team discussed whether meta-analysis was possible and concluded that a narrative synthesis would be the most appropriate approach for summarising findings (Popay et al., 2006). Our final agreed classification was based on three key categories of exposure (1. natural, 2. built environment/neighbourhood and 3. ambient characteristics), aligned to key policy themes, which we further sub-classified by type as headings for summaries of study findings. We further synthesized and contextualised these findings in our Discussion section, considering the limitations of this narrative synthesis.

3. Results

The first search yielded 5,166 records (2023). The updated search (2024) yielded 428 additional records. We removed 1682 duplicates and deemed 3,385 records ineligible based on abstract and title screening. Of the 112 articles screened at full-text stage, one could not be accessed, and 97 were excluded for ineligibility, identifying 14 eligible for inclusion. Snowballing yielded 32 additional eligible articles that were full-text screened, yielding 19 eligible. A total of 33 studies were included (see Fig. 1 for PRISMA flowchart).

The earliest included article was published in 2007, with one in 2008 and one in 2010, then a marked rise was observed from 2013 (Fig. 2).

The 33 included studies are summarized in Table 2. Only one study used a mixed methods design (McQuoid et al., 2018), all other included studies were quantitative. Studies used a mix of subjective (i.e. self-reported) and objective measures of place-based factors, as outlined below (Section 3.3 and Table 2). Seventeen studies were conducted in the US, four in the UK, three in the Netherlands, one each in Germany, Austria, and China, and one included a global population sample comprising participants from the UK, US, European Union, China and Australia. In terms of exposure to place-based factors, three broad categories were identified: i) exposure to natural environments (n = 11) and ii) exposure to built environment characteristics (n = 19), and iii) exposure to ambient characteristics (n = 3). In terms of mental health outcomes, thirteen studies investigated mental wellbeing in adults in the general population, three investigated specific mental health conditions, 11 investigated various aspects of substance use. Thirteen studies included samples of adolescents or young adults; 20 studies included adult samples. Most of the included papers reported some data on EMA compliance (87.8 %). Specifically, compliance with EMA sampling

Table 2
Key characteristics and findings of studies included in review (N = 33).

Reference	Country	Sample	Place, ambient characteristics and context	Mental health, wellbeing and substance use related factors	Methods and baseline assessment	Results
Section 1. Nature						
Section 1.1. Objectively Measured Exposure to Nature						
S. de Vries et al. (2021)	Netherlands	4,318 participants, 44 % aged 30–50, 67 % females	Land cover assessed using national topographic map TOP10NL, dominant land type within 125 m of GPS location EMA: characteristics of environment: beauty, peacefulness and "fascinatingness"	EMA: Self-reported happiness (1 item; scale 0–10)	30-day EMA period with 2 daily random prompts EMA compliance not reported Multi-level models with random intercepts were used to explore the association between happiness and types and characteristics of the environment Baseline: background characteristics (e.g. gender, age, level of education) used as controls	• Overall, participants reported greater happiness in all subtypes of natural environments compared to built environments (all $p < 0.001$) • Participants reported greatest happiness in areas of natural coasts ($B = 0.44$, $p < 0.001$) or low-lying natural vegetation ($B = 0.43$, $p < 0.001$), while arable land showed the lowest happiness scores ($B = 0.09$, $p < 0.001$) • Participants reported greater happiness when outdoors compared to indoors ($B = 0.31$, $p < 0.001$), however in natural coast environments, happiness was equally great indoors and outdoors
Henson et al. (2020)	United States	37 participants diagnosed with schizophrenia (age 37.75 ± 14.05, 51.4 % male) and 26 healthy controls (age 30.04 ± 13.41, 50 % male)	Geolocation via smartphone GPS used to derive exposure to vegetation (green space proxy) Geographic exposure estimated using GPS 3 h prior to EMA Population density and income per capita as geographic confounders	EMA: Self-reported symptoms of anxiety, depression, psychosis and sleep and sociability (scale 0–3)	3-month study with three weekly EMA questionnaires Overall EMA compliance not reported, 70 % of participants with ≥ 1 EMA + GPS ≤ 50 m were included T-tests were used to compare group means, and Pearson correlations were used to explore within-group correlations with symptom severity Baseline: demographics, analyses controlled for age, sex, income, population density and neighbourhood income	• Participants with schizophrenia had lower green space exposure than healthy controls, mean NDVI (0.16 ± 0.03 vs 0.19 ± 0.02, $p < 0.001$) • More green space exposure associated with better symptom scores in all 5 domains (coefficients between 0.007–0.18, all $p < 0.001$) • In patients, high green space exposure was related to significantly lower symptoms of anxiety ($d = -0.70$, $p < 0.001$), depression ($d = -0.97$, $p < 0.001$), psychosis ($d = -0.94$, $p < 0.001$) and better sleep ($d = -0.54$, $p < 0.001$), but worse sociability levels ($d = 0.55$, $p < 0.001$) • In controls, anxiety was significantly lower in the high green space exposure compared to low green space exposure ($d = -0.38$, $p < 0.001$)
Li et al. (2018)	United States	155 participants; adolescents aged 13-19, 15.72 ± 0.50, 58% female, 60% white	Concentration of nature assessed through GPS coordinates and subsequent analysis of pixels in Google Street View images to indicate vegetation/non-vegetation For paths of more frequent visits, a higher weight was applied in the final nature	EMA: Mood assessed using the Profile of Mood States questionnaire (20 items; scale 0–5) Five subscales included: tension-anxiety, depression-dejection, anger-hostility, fatigue-inertia, vigour-activity	4-day EMA study with 1 daily evening prompt EMA compliance or valid GPS data not reported, participants with ≥ 1 EMA + GPS included Correlation analyses used to explore relationships between nature concentration and mood. t-tests used to explore	• Higher concentration of nature in daily environment was associated with better mood regardless of sociodemographic status • Specifically, greater concentrations of nature were associated with lower depression ($r = -0.09$, $p < 0.05$), anger ($r = -0.16$, $p < 0.01$), fatigue ($r = -0.12$, $p < 0.01$) and

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Table 2 (*continued*)

Reference	Country	Sample	Place, ambient characteristics and context	Mental health, wellbeing and substance use related factors	Methods and baseline assessment	Results
			concentration index. Place-based measurements collected continuously		whether density of vegetation in environment differs between socio-economic groups Baseline: Socioeconomic status (parental income, parental education attainment and parental occupation) used as controls	better mood (n = -0.13, $p < 0.01$), while proportion of time spent in outdoor activities also predicted better mood (B = −0.02, $p < 0.05$) • Adolescents from low-income households were exposed to lower nature concentrations (16 %) compared with those from medium and high-income households (20 %), (r = 0.31, p < 0.0001)
MacKerron & Mourato (2013)	United Kingdom	21,947 participants, 55 % male, 95 % aged under 50	Land cover (green and blue space types) assessed using UK Land Cover Map 2000 GIS Weather conditions using data from weather sensors across the UK Daylight exposure calculated by sunrise/ sunset	EMA: Self-reported happiness (1 item; scale 0–100)	EMA across ~ 6 months with 2 daily random prompts Range 1–737 EMA responses per participant, outdoor responses with GPS accuracy > 250 m and > 60 min delay excluded (48 % of EMA had valid GPS), overall EMA compliance not reported Fixed effect model allowing for participant specific intercepts was used to explore the association between happiness and environment characteristics	• Participants were happier outdoors than indoors (B = 2.32, $p < 0.001$, and every outdoor habitat type was associated with increased happiness (B = 0.88 to 6.02, all $p < 0.01$), except for inland bare ground (B = 0.37) • Marine and coastal environments were the happiest locations, scoring 6 points higher than urban environments • All other natural environment types, such as mountains, freshwater, woodlands, etc., were between 2.7 and 1.8 points happier than urban environments. • Suburban and rural environments were just under 1 point happier than urban environments • Older people benefitted more from being outdoors and were also the only group to be happier in mountainous regions, but age or gender did not significantly affect other associations
Mennis et al. (2018)	United States	179 participants aged 13–16, 89 % African American, 58 % female	GPS linked green space exposure assessed using Normalised Difference Vegetation Index Index of neighbourhood disadvantage based on the US Census Bureau	EMA: Self-reported stress (1 item; scale 1–9) Baseline assessment: Emotional dysregulation (15 items, self-report questionnaire)	2-year study period, 4 days EMA with 3–6 daily prompts every other month 50 % EMA response rate 41 % of GPS data for beeps outside home Ordinal logistic Generalised estimating equation to explore effect of green space on stress Baseline: demographics (age, sex, race) used as controls	• Green space exposure was associated with lower stress in places away from home, but not when the participant was at home (OR = 1.98, $p < 0.05$). This association was not affected by gender, neighbourhood disadvantage or season
Sabatelli, Osmani, Mayora, Gruenerbl, & Lukowicz, 2015	Austria	12 patients with bipolar disorder; 11 female, aged 18–65 (7 included in final analysis)	Continuous locations tracking derived from Wi-Fi traces to identify significant places (home, outside home, clinic)	EMA: Clinical questionnaire assessing patients' subjective state of depression (scale 0–3)	12-week trial period, 1 daily EMA prompt Average EMA compliance 7 of 10 participants; participants with both WI-FI and EMA included	• Most patients reported worse psychological states when spending time in the clinic, compared to outside • Conversely, a positive correlation was seen

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Table 2 (*continued*)

Reference	Country	Sample	Place, ambient characteristics and context	Mental health, wellbeing and substance use related factors	Methods and baseline assessment	Results
					Pearson's correlation was used to explore the relationship between patients' psychological state and time spent in significant locations	between self-reported psychological wellbeing and time spent outside the clinic or home • There was a lack of statistical power to explore the association between state and spending time at home
Section 1.2. Self-reported Exposure to Natural Environments						
Bakolis et al. (2018)	United Kingdom	108 participants, 27 % male, age 31.1 ± 11.1 years	EMA: Individual perception of surrounding environment (presence of blue space/green space elements) Geographical location through GPS	EMA: Momentary well-being assessed at EMA using adapted version of Warwick-Edinburgh Mental Well-Being scale (14 items; scale 1–5) Baseline assessment: Trait impulsivity (Trait impulsivity scale) and mental wellbeing (Warwick-Edinburgh Mental Well-Being Scale) measured with questionnaires at baseline	7-day EMA with 7 daily pseudo-random prompts Average EMA compliance not reported; 59 % completed ≥ 50 %; individuals with < 33 % excluded Random intercept multilevel regression models were used to explore longitudinal associations between seeing and hearing birds and mental wellbeing Participants with > 50 % response rate were included in the main analysis (n = 64), while reliability assessments were run on samples of > 33 % (n = 108) and > 66 % (n = 25) response rate thresholds as well	• Being outdoors, seeing trees, hearing birdsong, seeing the sky and feeling in contact with nature was associated with increased mental wellbeing at all response thresholds (effect sizes ranging from 1.31 to 3.82, all $p < 0.001$) • This association was time-lasting, so the positive effect of nature on wellbeing persisted to the subsequent EMA assessment (effect sizes ranging from 1.46 to 1.70) • Seeing or hearing water was associated with increased mental wellbeing only at the 66 % threshold • The effect of green space exposure on momentary wellbeing was higher in people with high compared with low trait impulsivity (all $p < 0.04$)
Bergou et al. (2022)	United Kingdom	299 participants, 67 % female, aged 30.16 ± 17.25 years	EMA: Current visits to canals and rivers (canal/river/lake/pond/sea/rain) or green spaces (park/garden/woodland) and place characteristics (e.g., beautiful/historic/ugly etc.) EMA asking for past visits or canals in the previous 24 h	EMA: Mental wellbeing scale comprising assessing positive and negative emotions (10 questions; scale 0–5) Baseline assessment: mental health condition	14-day EMA with 3 pseudo-random daily prompts Multilevel regression models used to explore association between visits to canals/rivers/green spaces and mental health Participants with > 50 % response rate were included in the main analysis, while reliability assessments were run on samples of > 25 % and > 75 % response rate thresholds as well; overall EMA compliance 78.4 % Baseline assessment: sociodemographic characteristics	• Canal and river visits showed a significant positive effect on mental wellbeing compared to being anywhere else at all thresholds • Visiting canals and rivers were associated with higher levels of wellbeing than visiting green spaces at both 25 % (MD = 1.82, [0–83-2.82], $p < 0.05$) and 50 % threshold (MD = 1.54, [0.39–2.68], $p < 0.05$), but not at 75 % • Having visited a canal or river in the past 24 h was associated with higher rates of wellbeing at all thresholds (effect sizes ranging from 0.86 to 1.35) • Having a mental disorder did not interact with the association between canal/river visits and mental wellbeing • Feelings of safety and social inclusion were more likely during visits to canals and rivers, compared to being elsewhere. • Participants were more likely to use positive place characteristics (beautiful,

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Table 2 (*continued*)

Reference	Country	Sample	Place, ambient characteristics and context	Mental health, wellbeing and substance use related factors	Methods and baseline assessment	Results
						peaceful) compared to negative (ugly, uninspiring) (all $p < 0.05$)
Beute & de Kort (2018)	Netherlands	59 participants aged 20–60 Two groups; 27 clinical (BDI-II > 14) and 32 healthy controls (BDI-II < 14).	EMA: Semi-objective momentary assessment of nature and daylight (30 items; 19 naturalness, 11 daylight, 1 filler (food), participants rate yes/no to presence of item in their current location)	EMA: mood (hedonic tone, tension, energy), and stress (12 items; scale 1–7) Baseline assessment: Dutch version of Becks Depression Inventory (BDI-II); depression and anxiety subscales of Dutch version of the Symptom Checklist (SLC-90-R) questionnaires	6-day EMA with 8 daily random prompts Average EMA compliance 80 %; participants with ≥ 40 % EMA included A three-level Hierarchical Linear Model was used to explore the effect of nature and daylight exposure on mood and stress in participants with varying degrees of affective states	• Exposure to nature and daylight was associated with higher hedonic tone (nature B = 0.025, p = 0.007; daylight (B = 0.027, p = 0.003) and energy (nature B = 0.053, p < 0.001; daylight B = 0.025, p = 0.024) and lowered tension (nature B = −0.009, p = 0.35; daylight = -0.21, p = 0.035) in all individuals • The positive effect of nature was stronger in individuals who scored higher on depression, and those with higher levels of tension. No differences were seen for daylight, which appeared to positively influence all individuals, irrespective of their affective states. • Increased daylight exposure was associated with lowered stress (B = −0.036, p = 0.005), but no significant positive effects were seen for nature or daylight exposure on rumination, psychosomatic complaints or momentary health
Hammoud et al. (2022)	Global; United Kingdom (46 %), the European Union (16 %), United States (8 %), China (4 %), Australia (2 %)	1292 participants; aged 36.7 ± 15, 69.2 % females	EMA: Encounters with birds (Can you see/hear birds right now?")	EMA: Mental wellbeing scale comprising assessing positive and negative emotions (10 questions; scale 0–5) Baseline assessment: mental health condition	14-day EMA with 3 pseudo-random daily prompts Participants with > 50 % response rate (46 %) were included in the main analysis, while reliability assessments were run on samples of > 25 % and > 75 % response rate thresholds as well; all EMA compliance not reported Random intercept multilevel regression models were used to explore longitudinal associations between seeing and hearing birds and mental wellbeing Baseline assessment: sociodemographic characteristics	• Seeing or hearing birds was positively associated with mental wellbeing at all thresholds (MDs ranging from 1.53 to 1.72) • This association was time-lasting, such that seeing/hearing birds positively affected mental wellbeing at the subsequent assessment, albeit with a lower effect size than during time of bird exposure (MD = 0.69 [0.42–0.96] • Having a mental disorder or depression did not interact with the association between bird encounters and mental wellbeing (p > 0.05)
Ryan et al. (2010)	United States*	5 studies; 2 EMA Study 4: 138 students (97 female; aged 18–24; 73 % Caucasian) Study 5: 51 students (43 female; aged	Study 4: EMA: Time spent outside, characteristics about the place of activity (natural vs artificial setting). Study 5: EMA: Outdoors vs	Study 4: EMA: Daily subjective vitality and Trait subjective vitality (2–3 items; Subjective Vitality brief scale 0–7), daily exercise, daily social interaction (evening)	Study 4: 14-day EMA study with 3 random daily prompts EMA compliance not reported Hierarchical linear modelling was used to	Study 4: • Being outdoors at the time of assessment predicted greater subjective vitality (B = 0.58, $p < 0.05$). This effect was substantially smaller when nature was controlled for (B = 0.25, $p < 0.07$)

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Table 2 (*continued*)

Reference	Country	Sample	Place, ambient characteristics and context	Mental health, wellbeing and substance use related factors	Methods and baseline assessment	Results
		18–26; 82.4 % Caucasian)	indoors, nature experience measures (natural vs non-natural elements in the immediate surrounding environment).	Study 5: Subjective Vitality Scale; 0–7, "in the present moment" Trait subjective vitality, presence of others, physical activity (EMA) Baseline assessment: Trait subjective vitality (Subjective Vitality Scale)	predict vitality from being outside. Study 5: 4-day EMA study with 6 random daily prompts EMA compliance not reported Hierarchical linear modelling was used to predict vitality, while mediation analyses were used to explore whether presence of natural elements mediated association between time spent outdoors and vitality	Study 5: • Being outdoors predicted higher subjective vitality ($b = 0.34$, $p < 0.05$). However, this was mediated by exposure to nature experience measures
Section 2: Built Environment/Neighbourhood Characteristics **Section 2.1. Neighbourhood Characteristics and Social Contexts**						
Browning et al. (2023)	United States	690 youth, 61.5 % White, 44 % male, aged 11–17	EMA: Safety of current location (1 item; scale 1–5)	Hair cortisol concentration (estimated hair sample for the week of EMA)	7-day EMA with 5 pseudo-random daily prompts EMA compliance: 53.8 %, participants with ≥ 1 EMA at non-home + valid hair sample included Bivariate associations explored between race and average unsafety perceptions, and OLS regression used to model race differences Baseline: early life financial difficulty	• Black youth reported greater levels of perceived unsafety compared to White youth (−0.67 vs −0.93, $p < 0.05$) • White youth had a lower hair cortisol concentration compared to Black youth ($B = -0.608$, $p < 0.001$). Hair cortisol concentration was associated with higher perceived unsafety in Black ($B = 0.09$, $p < 0.05$), but not White youth ($p = 0.50$)
Browning et al. (2024)	United States	658 youth, 363 White, aged 11–17	GPS tracked location Exposure to White-dominated spaces (Census data) Area-level information: Block group socioeconomic status (mean of poverty rate, unemployment rate, percentage of female-headed households, percentage of households with annual income exceeding $50,000, percentage of adults 25 + with a college degree, and percentage of adults with professional occupation) Violent crime (recent violent crime rate of location) Individual-level activity space % White	EMA: Perceived safety of current location (1 item: 1–5)	7-day EMA with 5 pseudo-random daily prompts EMA compliance: 53.8 %, participants with ≥ 1 EMA + GPS included Regression models with fixed effects used to test relationship between within-person activity space exposure and probability of reporting "strongly agree" to a current location being safe	• For both races, 100 % increase in violent crime rate was associated with an 18 % decrease in probability of strongly agreeing to feel safe ($B = -0.018$, $p < 0.05$) • Black youth were exposed to an averaged 70 % of White-dominated neighbourhoods, compared to 85 % in White youth • Being in a White-dominated neighbourhood was associated with a 13 % decrease in probability of strongly agreeing that they feel safe in Black youth but increase in probability of feeling safe in White youth
Li et al. (2007)	United States	263 African American youth from grade 5–8	Questionnaire: positive neighbourhood	EMA: Confidence, helpfulness of family	7-day EMA with 7 daily pseudo-random prompts	• Both externalising and internalising symptoms

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Table 2 (*continued*)

Reference	Country	Sample	Place, ambient characteristics and context	Mental health, wellbeing and substance use related factors	Methods and baseline assessment	Results
		(aged 10–15) Recruited from 8 schools representing neighbourhoods of different economic range; 2 poor, 3 middle-class, 1 working/middle-class	(parental self-report questionnaire)	Questionnaire: Externalising symptoms (combination of the externalising subscale of the Child Behaviour Checklist-parent form and the Juvenile Delinquency Scale) Internalising symptoms (combination of Children's Depression Inventory, the Child Behaviour Checklist-parent form and the How I Feel child report)	EMA compliance: 70.36 %; participants with at ≥ 1 EMA included Correlation to explore individual associations between risk and protective factors and internalising and externalising symptoms Hierarchical multiple regression used to explore effect of cumulative risk and protective factors on internalising and externalising symptoms Baseline assessment: Hassles (Hassles Scale for Children), exposure to violence (Experience to Violence scale), family income, poverty level (Census), confidence (self-reported), family support (Social Support Survey), helpfulness of family (self-report)	were predicted by hassles ($B = 0.18$, $p < 0.01$ and $B = 0.32$, $p < 0.01$), exposure to violence ($B = 0.41$, $p < 0.01$ and $B = 0.27$, $p < 0.01$) • Increased confidence predicted fewer internalising symptoms ($B = -0.21$, $p < 0.01$), greater family support predicted both lower externalising ($B = -0.17$, $p < 0.01$) and internalising symptoms ($B = -0.30$, $p < 0.01$) • Cumulative risk explained 33 % variance in externalising and 24 % in internalising symptoms. Family income did not contribute unique explanatory value, but poverty level of the community did • Cumulative protection explained 7 % variance in externalising and 13 % in internalising symptoms • Confidence and helpfulness of family contributed 5 % and 8 % variance respectively in internalising symptoms, while helpfulness of family added 3 % to externalising symptoms
Ortega-Williams et al. (2022)	United States	75 Black youths aged 13–18, 81 % females	EMA: Routine activity locations, perception of surroundings	EMA: Momentary positive/negative emotions, (1 item; scale 1–5) racism (3 items; scale 1–5, social support (4 items; scale 1–5) At the end of each day questionnaire: perceived stress (1 item; scale 1–5) and safety (1 item; scale 1–5)	1-month EMA with 3 pseudo-random prompts plus end of day survey EMA compliance: 29 % (62 % end-of-day survey); participants with ≥ 1 EMA included. Multilevel models were used to explore associations between routine activity locations and momentary mental wellbeing	• Reports of racism and social support differed between location types with more perceived racism ($M = 2.29$, $SD = 0.90$) and less perceived social support ($M = 3.85$, $SD = 1.00$) on the bus, at school, walking on the street compared to when at home • Youths felt safe at family members houses ($B = 0.43$, $p < 0.001$), community centres ($B = 0.34$, $p < 0.01$) and at the library ($B = 0.81$, $p < 0.01$) • Reports of racism ($B = 0.16$, $p < 0.05$) and the possibility for racism ($B = 0.10$, $p < 0.001$) was associated with more momentary negative emotion, while reports of social support were associated with less momentary negative emotion ($B = -0.16$, $p < 0.01$)
Pinchak et al. (2022)	United States	1,180 youth, aged 14.30 ± 1.86, 48 % Black	Youth activity spaces, measured by GPS Area level information: Concentrated disadvantage (averaged	Baseline: Collective efficacy (caregiver self-reports on trust (1 item: scale 1–5), monitoring (1 item: scale 1–5),	7-day EMA period with GPS tracking, sampling schedule not reported Overall EMA compliance not reported; participants	• Black adolescents had a greater concentrated disadvantage in their non-home activity space, lower exposure to collective efficacy, higher levels of

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Table 2 (*continued*)

Reference	Country	Sample	Place, ambient characteristics and context	Mental health, wellbeing and substance use related factors	Methods and baseline assessment	Results
			poverty rate, unemployment rate, percentage of female-headed households, percentage of households receiving cash assistance) proportion of Black residents (Census data), exposure to violent crime (reported crime incidents)	intervention in location spaces (1 item; scale 1–5) such as grocery stores, workplace)	with ≥ 1 EMA + GPS at non-home included Multilevel regression models were used to investigate Black-White differences in momentary nonhome exposure to disadvantaged and segregated contexts	racial segregation, violent crime and socioeconomic disadvantage compared to their White peers (all $p < 0.05$)
Rivenbark et al. (2019)	United States	2,104 adolescents aged 10–16, 395 participated in EMA	Baseline: neighbourhood income (Census data), school-level economic disadvantage (percentage of children eligible for free/reduced lunch), local area income inequality (Census data)	EMA: depression (3 items; scale 1–100), anxiety (1 item; 1–100), inattention and hyperactivity (2 items; scale 1–3), conduct and substance abuse. (7 items; yes/no) Baseline assessment: Subjective social status (1 item; scale 1–5), adolescent mental health; psychological distress (Psychological Distress scale; 2 items; scale 0–4), conduct problems (25 items; 0–5), early substance use (4 items, yes/no)	14-days EMA with 3 daily fixed prompts EMA compliance: 80 %; participants with ≥ 1 EMA included Multiple regression models used to test whether Subjective Social Status (SSS) associated with adolescent's reports of mental health and whether local area economic inequality measures were associated with adolescents SSS and mental health above Baseline assessment: objective social status, family economic disadvantage	• Adolescents from economically disadvantaged families ($r = -0.26$, $p < 0.001$), in higher poverty schools ($r = -0.12$, $p = 0.028$) and lower income neighbourhoods ($r = 0.29$, $p < 0.001$) reported lower SSS • Living in an area with higher income inequality was associated with lower SSS ($r = -0.07$, $p = 0.034$) • Lower SSS was associated with poorer mental health, particularly after the age of 14 ($B = -0.28$, $p < 0.001$)
Section 2.2. Alcohol Cravings and Use						
Byrnes et al. (2017)	United States	170 adolescents, aged 14.8 ± 0.84, 54.7 % female	EMA: Observed contextual risks: social disorganisation (5 items of vandalism, litter, drug activity, groups of young people) and alcohol outlet (presence of an alcohol outlet) Objectively measured with GPS linkage: social disorganisation (low socio-economic status), and alcohol outlets (alcohol outlet within 50-, 100- and 200-meter buffers of participants location)	EMA: Alcohol use (yes/no), problem behaviours (yes/no – are you doing something that could get you in trouble with the law)	4-week EMA period, with 2 daily scheduled prompts and GPS tracking Average EMA compliance 68.4 %; participants with ≥ 1 EMA included Zero-inflated Poisson models were used to explore relationships between observed and objectively measured social disorganisation, alcohol use and problem behaviours. Zero-inflated Poisson models (IRR, 95 % CI)	• Observed disorganisation was associated with problem behaviour (IRR 2.87, $p < 0.001$)Alcohol consumption was associated with observed disorganisation (IRR = 2.42, $p < 0.001$), objective indicators of disorganisation (IRR = 1.25, $p = 0.001$), alcohol outlets within 100 m (IRR = 3.45, $p < 0.001$) and 200 m (IRR = 2.56, $p < 0.001$)
Fischer et al. (2023)	United States	61 young adults (aged 21–29), 57 % male Inclusion criteria: heavy drinkers (≥14/≥7 drinks per week for males/females) for at least a year. Exclusion criteria: severe Alcohol Use Disorder, tobacco use disorder or major psychiatric disorders.	EMA: Location (self-reported categorical) Social context (alone, with others)	EMA: Subjective responses to alcohol: sedation, stimulation, feeling, liking, wanting more (scale 0–10) Computed estimated blood alcohol concentration (eBAC) levels based on self-reported responses to the Drug Effects Questionnaire (scale 0–100), and Brief	2 EMAs for 2 drinking episodes with minimum 24 h interval Self-initiated EMA survey pre, during and post drink Generalised Estimating Equations were used to explore the effects of social contexts, and locations on subjective alcohol responses	• eBAC increased more in the presence of others ($B = 0.01$, $p = 0.006$) as well as in bars/restaurants ($B = 0.006$, $p = 0.04$) • Drinking with others was associated with higher ratings of stimulation, liking and wanting more later in the drinking session (all $p < 0.01$), and a lower rating of sedation compared to drinking alone ($B = -2.87$, $p < 0.001$)

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Table 2 (*continued*)

Reference	Country	Sample	Place, ambient characteristics and context	Mental health, wellbeing and substance use related factors	Methods and baseline assessment	Results
				Biphasic Alcohol Effects Scale (scale 0–10)		
Trela et al. (2018)	United States	403 participants; current drinkers (>=4 drinking occasions in past 30 days), aged 23.3 ± 7.2. 50 % female	EMA: Locations (bar, home…), time of the day, presence of people	EMA: Drink craving (scale 1–5). Recent cigarette use Craving for cigarette positive and negative affect (scale 1–5) Baseline assessment: Alcohol sensitivity assessed using the Self-Rating of the Effects of Alcohol (SRE)	21-day EMA; 1 EMA in the morning and up to 5 daily prompts randomly. EMA compliance not reported Additional cigarette reports, drink reports had to be reported by participants and drinking-follow-up were automatically sent Multilevel mixed regression models used to investigate contextual and individual predictors of alcohol cravings	• At baseline, LS were heavier drinkers ($r = 0.52$, $p < 0.001$) • Higher alcohol cravings were associated with being in a bar/restaurant ($B = 0.14$), being with a friend ($B = 0.08$), cigarette craving ($B = 0.16$), the time of day, weekend ($B = 0.16$), elevated positive ($B = 0.15$), and negative affect ($B = 0.19$), (all $p < 0.001$) • On the contrary, recent smoking was inversely associated with drinking ($B = -0.048$, $p < 0.001$) • Alcohol sensitivity moderated cravings, suggesting that low sensitivity drinkers were more likely to be affected by the contextual factors of drinking or being prone to anticipatory cravings
Treloar & Miranda (2017)	United States	86 youth, aged 20.7 ± 2.21, 49 % female Inclusion criterion was to have reported drinking at least twice weekly in the past 30 days	EMA: Social context, current location, time of day Weekend	EMA: Alcohol craving (1 item; scale 1–5), positive affect (3 items; scale 1–5), negative affect (2 items; scale 1–5), cigarette craving stimulation (2 items; scale 0–10) and sedation (2 items; scale 0–10) Baseline assessment: Alcohol Use Disorders (AUD) diagnosed based on the Kiddie Schedule for Affective Disorders for School-Age Children Estimated blood alcohol content (eBAC) based on the participants' EMA drink reports	7-day EMA with 6 daily random prompts, and self-initiated EMA at begin and end of drink reports Average EMA compliance 79.3 %; participants with ≥ 1 EMA included Multilevel mixed models used to investigate contextual and individual predictors of alcohol cravings, stimulation and sedation	• Cravings increased just before drinking ($B = 4.05$, $p < 0.001$), and while drinking ($B = 2.62$, $p < 0.001$) compared to non-drinking times • Tension decreased while drinking ($B = -0.68$, $p < 0.001$), while sedation increased after drinking ($B = 0.50$, $p = 0.01$) • Each additional AUD symptom was associated with decrease in craving ($B = -0.19$, $p = 0.003$) and increase in stimulation ($B = 0.17$, $p = 0.003$) while drinking, suggesting a greater craving relief and higher stimulatory effect of alcohol in those with more AUD severity • Drinking cravings were associated with being in a public place ($B = 0.41$, $p < 0.05$) or at a party ($B = 1.05$, $p < 0.05$), and with peers present ($B = (0.42$, $p < 0.001$)
Section 2.3. Tobacco Use						
Kirchner et al. (2013)	United States	475 smokers trying to quit, 1st month of cessation, aged 44 ± 11.05, 66 % male	GPS tracking linked to a database of 1060 Tobacco outlets) within 30 m of participant	EMA: Craving (1 item; scale 0–10), Behavioural outcomes (abstinence/lapse/relapse)	27-day EMA period, 3 daily prompts and continuous GPS tracking Average EMA compliance 79 %; participants with ≥ 1 EMA included Log-linear models were used to investigate relationship between point of tobacco sale outlets and risk of lapsing	• Lapsing was significantly more likely on days with any POST contact (OR = 1.19), and increasingly likely as the number of daily POST contacts increased (OR = 1.07) • Overall, daily tobacco outlet exposure was significantly associated with lapsing when craving was low (OR = 1.22)

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Table 2 (*continued*)

Reference	Country	Sample	Place, ambient characteristics and context	Mental health, wellbeing and substance use related factors	Methods and baseline assessment	Results
McQuoid et al. (2018)	United States	17* young adult bisexual smokers, ages 18–26 71 % female *Data from 3 participants reported; female 1, mid-20 s, female 2, late-teens, male 1, early 20 s	Locations (e.g., home, car) Contexts (interview)	Interview based on EMA patterns	30-day EMA period with GPS tracking plus self-initiated reports when smoking, followed by a 1-hour interview to discuss the spatial and temporal contexts of smoking behaviours EMA compliance not reported; participants with > 50 % of EMA included Mixed methods were used to capture EMA quantitative data which was used to guide subsequent qualitative interview	• Interviews identified more in-depth information on common smoking places and the roles of smoking in these locations, underlining important shortcomings of GEMA methodology
Watkins et al. (2014)	United States	47 smokers in cessation, aged 52.29 ± 7.42, 59.6 % female	Proximity to tobacco outlets assessed using GPS location at EMA time linked to Tobacco Retail Outlets from the Texas Comptroller of Public Accounts Distance from home	Baseline: Pre-quit tobacco dependence assessed using the Heaviness of Smoking Index 1 week prior to quitting EMA: Real-time smoking urge (1 item; scale 1–5), number of cigarettes smoked the previous day Participants verified biochemically abstinent or non-abstinent after EMA period	1 week EMA period with four daily random prompts, GPS locations at EMA Average EMA compliance 84.2 %; of which 29.9 % had valid GPS data; participants responding ≥ 1 EMA + GPS included Linear mixed models were used to investigate associations between tobacco retail outlet density and proximity and urge to smoke Baseline assessment: Sociodemographic (age, gender, partner, education)	• The effect of tobacco retail outlet proximity on real-time smoking urges was not significant (B = −0.31, p = 0.16) • Distance between home and tobacco outlets was significantly associated (B = − 1.83, p = 0.001) and smoking urges were stronger around tobacco outlets less than 1 mile away from home (B = 0.49, p = 0.03)
Section 2.4. Substance Use						
Epstein et al. (2014)	United States	27 outpatients admitted for methadone maintenance at a research clinic, aged 41.2 ± 7.7	Social disorganisation: assessed using the Neighbourhood Inventory for Environmental Typology (NIfETy); social, physical disorder and drug activity linked with GPS	EMA: Drug craving (1 item; scale 1–5), stress (1 item; scale 1–5) Positive and negative affect was measured with composite variables based on the answers on items	16-week EMA, 3 daily random prompts Average EMA compliance 79 %; participants with ≥ 1 EMA included Generalised linear mixed models used to explore associations between substance use cravings and NIfETy characteristics	• Cocaine craving was associated with all the NIfETy characteristics: social disorder (B = −0.06, p = 0.008), physical disorder (B = −0.04, p = 0.002) and drug activity (B = −0.05, p = 0.0009) • Heroin craving was associated with physical disorder (B = −0.08, p < 0.0001) and drug activity (B = −0.09, p = 0.0003)
Linden-Carmichael et al. (2021)	United States	148 participants, aged 20.3 ± 1.45, 57.4 % female, reporting binge drinking (4+/5 + drinks in one day in women/men)	EMA: Location self-reported Social context (alone, with others) Risky drinking activities (pre-gaming, playing drinking games)	EMA: Alcohol and Marijuana use (yes/no) reported once daily	14-day EMA study, one prompt daily to complete about the previous day EMA compliance: 95.36 %; participants with ≥ 1 EMA included Multilevel models were used to investigate physical location, risky drinking activities and social contexts as predictors of simultaneous alcohol and marijuana use	• For under 21-year-olds, only substance use at the home location was associated with odds of simultaneous alcohol and marijuana (SAM) use relative to alcohol-only use (B = 2.92, p < 0.05) • For those over 21 years old, using at a friend's house (B = 2.35, p < 0.05), or outdoors (B = 2.43, p < 0.05), was associated with higher odds of SAM use, while using at a bar/club was

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Table 2 (*continued*)

Reference	Country	Sample	Place, ambient characteristics and context	Mental health, wellbeing and substance use related factors	Methods and baseline assessment	Results
					Analyses were conducted in subsamples of those aged > 21 and < 21	associated with lower odds (B = 0.44, p < 0.05) • Engaging in risky drinking activities was not associated with SAM use
Mennis et al. (2016)	United States	139 adolescents, aged 13–14, 59 % female, 89 % African American	Neighbourhood disadvantage from Census data GPS tracking Relative neighbourhood disadvantage calculated by conditioning the neighbourhood disadvantage at EMA response relative to participants' home neighbourhood	Baseline: Substance use was assessed with the Adolescent Alcohol and Drug Involvement Scale EMA: Stress and safety (1 item each; scales 1–9)	4-day EMA with 3–6 prompts per day On average 52 EMA responses per participant, participants with ≥ 1 EMA + GPS included (50 % of EMA had valid GPS); overall EMA compliance not reported Generalised estimating equations were used to explore effects of relative neighbourhood disadvantage on substance use, perceived stress and safety	• Relative neighbourhood disadvantage was associated with greater substance use involvement (B = 0.30, p < 0.005), higher stress (B = 0.030, p < 0.005), and lower perceived safety (B = −0.01, p < 0.05)
Rhew et al. (2022)	United States	14 marijuana users, aged 21.6 ± 2.3, 51 % male	Marijuana outlet exposure measured as a 100-meter buffer around each outlet, linked with participants GPS location Area-level poverty based on Census data	Morning survey: Number of marijuana uses since getting up and on the previous day EMA: Desire to use marijuana (1 item; scale 0–8)	14-day EMA study with GPS tracking, 4 fixed daily prompts Average EMA compliance 80.1 %; participants responding ≥ 1 EMA + GPS included Spearman's correlations used to investigate relationship between marijuana outlet exposure, the number of uses and the desire to use	• Cumulative exposure to outlets was associated with total number of marijuana use occasions (rho = 0.62) and desire to use (rho = 0.37) • Neighbourhood poverty was associated with total number of use occasions (rho = 0.45) and with desire to use (rho = 0.19)
Section 2.5. Social and Physical Contexts of Wellbeing						
Dunton et al. (2015)	United States	116 participants, 72 % females, aged 27–73, 61 % overweight or obese	EMA: Activity (physical activity/not physical activity) Social context (alone/with others) Physical context (outdoors/indoors)	EMA: Positive (3 items; scale 1–5) and negative affect (4 items; scale 1–5)	Three waves of data collection, separated by 6 months: each wave 4 days with 8 pseudo-random prompts per day EMA compliance: 83 %; participants with ≥ 1 EMA + valid accelerometer data Multilevel models used to assess whether momentary activity level moderates the association of being alone/with others and being indoors/outdoors with the concurrent affective states Baseline: sociodemographic, BMI	• Lower positive affect during physical activity with alone when compared with being with other people (B = −0.30, p = 0.24). • Enhanced positive affect (B = 0.26, p < 0.001) and attenuated negative affect (B = −0.20, p = 0.03) when physical activity was performed outdoors compared to indoors.
van Roekel et al. (2015)	Netherlands	268 adolescents, 59 % females, aged 13–16	EMA: Location; home, school, other EMA: Social contexts; alone, with others (parents/siblings, friends, classmates, or others)	EMA: Loneliness on four items; lonely, isolated, left out and abandoned (4 items; scale 1–7)	6-day EMA with 9 pseudo-random daily prompts Average EMA compliance 69 %; participants responding ≥ 18 of prompts included Multilevel regression analyses used to explore	• Being with company was associated with lower levels of state loneliness (B = −0.09, p < 0.001) in both genders. • When in company, adolescents reported lower loneliness when with family (B = −0.13, p < 0.001), with friends (B = −0.11, p < 0.001),

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Table 2 (*continued*)

Reference	Country	Sample	Place, ambient characteristics and context	Mental health, wellbeing and substance use related factors	Methods and baseline assessment	Results
					whether loneliness differed between contexts. Chi Squares were used to examine gender differences. Baseline: age, sex, education	compared to when with classmates (B = −0.05, p < 0.05). • Being alone at the current assessment had the strongest association with state loneliness, independently of the presence of company at the previous assessments. • Solitude at two consecutive assessments did not increase loneliness at the second assessment time (all p < 0.001). Being in the company of friends following solitude led to significantly lower loneliness levels compared with two consecutive assessments in solitude (−0.08, p < 0.02). However, being in the company of family following solitude did not show this effect (0.04, p < 0.05), and loneliness levels were not significantly changed
Section 3. Ambient Characteristics and Mental Wellbeing						
(Bundo et al., 2023)	Switzerland	906 participants living in 10 km radius of NABLAU weather station 54.7 % female; 68 % aged under 65, 10 % MDD, 5.1 % anxiety, bipolar or schizophrenia < 3 %	Hourly average ambient temperature, relative humidity, sunshine duration, rainfall, barometric pressure taken from weather station data	EMA: Mood (1 item; scale 1–7) Sleep quality collected as EMA morning questionnaire every morning Baseline assessment: Trait neuroticism assessed by Eysenck Personality Questionnaire and diagnostic criteria for lifetime and current disorders	7-day EMA with 4 daily fixed prompts EMA compliance (83 %); participants with ≥ 1 EMA included Multilevel random-effects linear regression models used to explore association between maximum temperature and mood level	• Odds of reporting a bad mood decreased by 7 % (OR: 0.93) for each 5°Celsius increase in maximum temperature; 3 % (OR: 0.97) when controlling for sunshine duration • Effect was stronger in elderly (−10 %, OR: 0.90) than young (−5%, OR: 0.95); in single (−11 %, OR 0.89) than married (−1%, OR: 0.99); in those with low education (−10 %, OR: 0.90) than high (−5%, OR: 0.95) • In mental health disorders, people with bipolar disorders had a 23 % decreased chance of bad mood for each 5° increase (OR: 0.77), but a reversed association was seen for anxiety (20 %, OR: 1.20), depression (18 %, OR:1.18) and schizophrenia (18 %, OR: 2.93) • People with high trait neuroticism had decreased probability of reporting bad mood (−13 %, OR: 0.87), but the reverse was true for people with low trait neuroticism (8 %, OR: 1.08)
(Denissen et al., 2008)	Germany	1233 participants aged 13–68, 88.6 % female	Objective weather data was retrieved from German weather stations matched to participants using ZIP codes	EMA: Positive affect, negative affect, tiredness (Positive and negative affect subscales; 10 items	30-day EMA period, with 1 daily random prompt Average EMA compliance not reported; 13.75 ±	• There were no significant effects of any daily weather parameters on positive affect

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Table 2 (*continued*)

Reference	Country	Sample	Place, ambient characteristics and context	Mental health, wellbeing and substance use related factors	Methods and baseline assessment	Results
				each, scale 1–5)	10.30 responses on average Multivariate linear mixed model used to explore main effects of weather on mood Subsequent univariate linear mixed models were used to explore inter-individual differences Baseline assessment: Personality traits were assessed at baseline using the Five Factor Model	• For negative affect, a positive effect of temperature (B = 0.035, p < 0.01) and a negative effect of sunlight (B = −0.023, p < 0.01) and wind power (B = −0.023, p < 0.01) was seen • Similarly, a significant negative effect of sunlight on tiredness was found (B = −0.063, p < 0.01) • A great deal of inter-individual variance was seen across all analyses; but this was not explained by differences in personality traits, age, or gender • A significant negative interaction was seen between season and wind power on positive affect, indicating that increased wind power had a stronger negative impact on mood in summer and spring than winter and autumn
			Six weather variables: temperature, sunlight, wind power, precipitation, air pressure, photoperiod (sunrise to sunset) weather station data retrieved once daily			
MacKerron & Mourato (2013)	United Kingdom	21,947 participants, 55 % male, 95 % aged under 50	Land cover (green and blue space types) assessed using UK Land Cover Map 2000 GIS Weather conditions using data from weather sensors across the UK Daylight exposure calculated by sunrise/sunset	EMA: Self-reported happiness (1 item; scale 0–100)	EMA across ~ 6 months with 2 daily random prompts Range 1–737 EMA responses per participant, outdoor responses with GPS accuracy > 250 m and > 60 min delay excluded (48 % of EMA had valid GPS), overall EMA compliance not reported Fixed effect model allowing for participant specific intercepts was used to explore the association between happiness and environment characteristics	• Greater happiness was linked to higher temperatures, lower wind speeds, increased sunshine, decreased rain and fog.
Kou et al. (2020)	China	101 participants, 52.5 % female, aged 30–49	Momentary measured noise collected though portable noise sensor Momentary perceived noise (1 item; scale 0–4) EMA: Location and nature of activities (travel/activity diary)	EMA: Psychological stress (1 item; scale 0–4)	2-day EMA study period; a weekday and a weekend day, four daily scheduled prompts Average EMA compliance 84 %; participants responding ≤ 1hr of prompt included Structural equation modelling used to examine relationships between momentary measured noise, perceived noise, and psychological stress among different contexts	• Momentary measured noise differed between contexts and its effect on psychological stress was mediated by perceived noise • For example, during out-of-home recreational activities, the momentary measured noise was higher compared to when working (B = 2.22, p < 0.05), however participants experienced a decrease in momentary psychological stress (B = −0.188, p < 0.05)

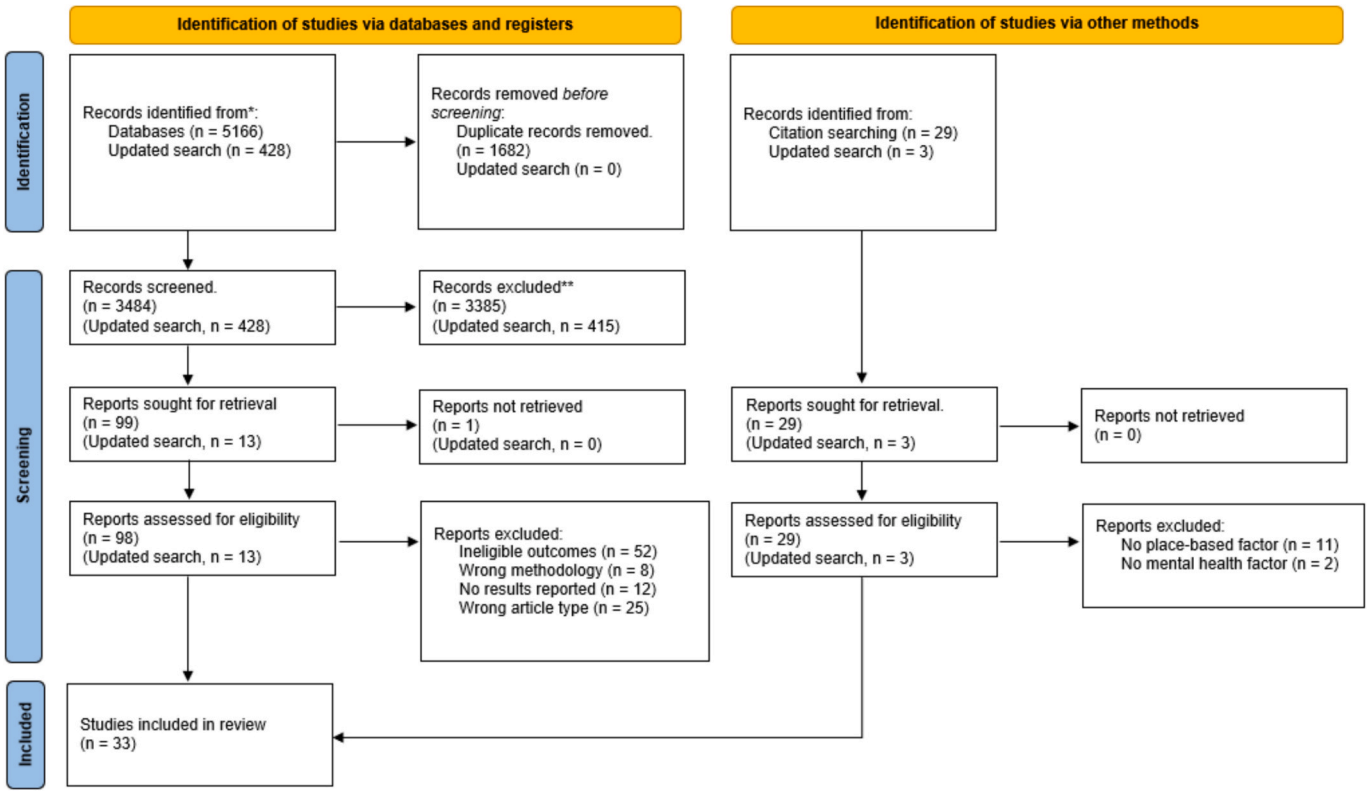

Fig. 1. PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) flow diagram of the review and final inclusion of literature.

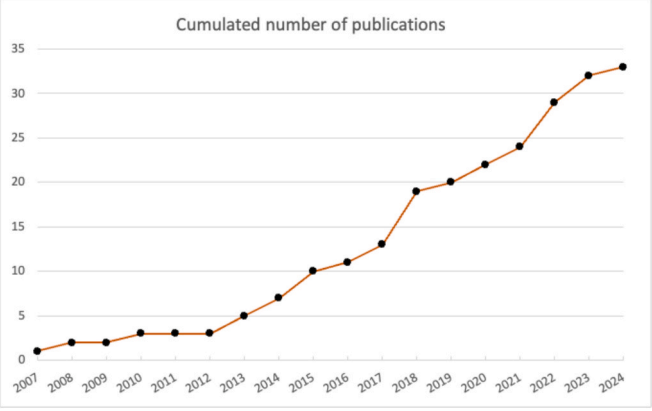

Fig. 2. Number of relevant publications.

schedules ranged from 29 %-95 %. Four of 14 papers that used GPS explicitly reported on missingness of valid GPS signals (MacKerron & Mourato, 2013; Mennis et al., 2016, 2018; Watkins et al., 2014).

3.1. Study quality

We judged the overall quality of included studies as good; 22 studies scored 100 %, 7 scored 80 % and 4 scored 60 % on MMAT criteria with detailed scoring tabulated (Supplementary Table 1.1, Table 1.1 for exposure to natural environments, Table 1.2 for exposure to built Environments/neighbourhood characteristics and Table 1.3 for ambient characteristics).

3.2. Results of the included studies

3.2.1. Exposure to natural environments

Eleven studies explored the effect of exposure to natural environments on wellbeing (Table 2, section 1). Six used passively collected objective measures of exposures to natural environments and five used self-reported assessment of participants' surroundings during EMA.

3.2.2. Objectively measured exposure to natural environments

Five of six studies that used objective measures of nature exposure used GPS coordinates from participants' mobile phones one used the WiFi network to identify participants' time spent outside (Table 2, section 1.1). All but one study (Sabatelli, Osmani, Mayora, Gruenerbl, & Lukowicz, 2015) achieved 100 % MMAT ratings. The largest UK-based study included 21,947 individuals who used the iPhone "Mappiness" application (app). For a 6-month period, GPS locations were recorded during EMA of happiness and linked to a land cover map to specify exposure to different natural environments (MacKerron & Mourato, 2013). Happiness ratings were higher when participants were outdoors than indoors, with a particularly pronounced increase in happiness when being in marine and coastal as opposed to other natural environments. De Vries and colleagues used a similar GPS-based approach and the smartphone app "HappyHier" to study the association between different environments and happiness in 4,318 Dutch participants over 30 days (S. de Vries et al., 2021). In line with the UK study, happiness was increased in natural environments, particularly coastal areas and areas with low-lying vegetation. Furthermore, participants' ratings of the beauty, peacefulness and "fascinatingness" predicted higher happiness ratings, with particular importance of the latter two. Notably, some indoor environments were associated with increased happiness. While the authors speculated that watching natural scenery through windows may account for this effect, this was not measured.

Exposure to vegetation, captured through satellite images and Normalised Difference Vegetation Index (NDVI), and EMA of daily stress

were studied in 179 adolescents in Richmond, VA, US over a 2-year period (Mennis et al., 2018). Higher green space exposure was associated with lower stress when adolescents were away from home. This association did not differ between genders, by degrees of neighbourhood disadvantage, or season. This suggests that the positive effects of place on stress levels were related to being away from the stress dynamics at home and in natural environments, but not necessarily driven by the 'greenness' of the surrounding vegetation *per se*. A study by Li et al. (2018) set out to address possible limitations of NDVI that captures a 'Birds-eye view' which differs from the eye-level view people have as they navigate their environments. They adapted a novel vegetation calculation composed of pixel-by-pixel analysis of Google Street View images taken from GPS coordinates to study place-related variations in mood in a sample of 155 adolescents in metropolitan areas, IL, US, over four days. Greater concentrations of nature were associated with lower depression, anger, fatigue, and better overall mood. The associations were independent of most demographic characteristics. However, adolescents from higher socio-economic backgrounds were exposed to greater concentrations of nature compared to those from lower ones (Li et al., 2018).

Two studies specifically focused on the association between nature and diagnosed mental health disorders. An American study followed 37 outpatients with a diagnosis of schizophrenia and 26 controls for three months, taking three weekly measurements of self-reported symptoms alongside geolocation (Henson et al., 2020). Vegetation exposure, measured with NDVI, was significantly lower for patients than controls, irrespective of neighbourhood factors. Across groups a higher exposure to green space correlated with reduced symptoms of distress on a variety of measures. However, some of the associations were notably stronger in patients than in controls. Patients with high vegetation exposure reported better sleep, lower anxiety, depression, psychotic symptoms, and diminished sociability. These points towards a restorative hypothesis in which patients with mental health problems get larger benefits from green space exposure, thus underscoring the potential therapeutic value (Henson et al., 2020).

The second study from Tirol, Austria, investigated place-related fluctuations in mood symptoms in a small sample of seven inpatients with a diagnosis of bipolar disorder over a 12-week period, using Wi-Fi to determine the location (Sabatelli, Osmani, Mayora, Gruenerbl, & Lukowicz, 2015). Participants showed poorer mood when they were in a psychiatric clinic compared to elsewhere. Importantly, the patients with lower mood may spend more time in the psychiatric clinic, rather than their mood being influenced by spending time in the clinic. This study received 60 % MMAT due to the small sample, and a systematic lack of data from the home location (due to lack of WiFi).

3.2.3. Self-reported Exposure to Natural Environments

Five studies assessed nature exposure through self-reports. Three used the Urban Mind app, which provides daily EMA prompts to collect data on mental wellbeing and characteristics of the surrounding environment. The other two asked participants to complete a checklist to assess effects of nature and daylight on mental health. The three Urban Mind studies received 80 % MMAT ratings, due to an overrepresentation of highly educated females. The first included 108 participants who used the app for 7 days. Participants reported higher wellbeing when being outdoors, seeing trees or the sky, hearing birdsong, or feeling in contact with nature. Importantly, the beneficial nature effects on momentary wellbeing persisted to the subsequent assessment, suggesting a sustained positive effect over several hours. The results showed no such association for blue space exposure, i.e. seeing or hearing water (Bakolis et al., 2018). The second Urban Mind study examined blue space exposure, specifically to canals and rivers and other outdoor environments (e.g. green spaces) and indoor spaces, in relation to mental wellbeing in 299 participants over 14 days (Bergou et al., 2022). In contrast to earlier findings, canal and river exposure was associated with higher momentary wellbeing as well as higher wellbeing over a longer time span of 24 h, as compared to green space exposure alone. The authors noted that blue space and green space exposure may be confounded due to canals and rivers being surrounded by plant life, which may account for the positive effect. They speculated that blue space environments are home to wildlife, which could further improve momentary wellbeing. This theory was indeed supported by the third Urban Mind study (Hammoud et al., 2022), which assessed birdlife exposure and momentary wellbeing in 1,292 participants over 14 days. The results showed a strong and time-lasting effect of hearing birdsong on wellbeing at the next measurement. The authors argued that bird encounters might have been a proxy for being in green- and blue space environments. However, even after controlling for these factors, the effect of bird-exposure on wellbeing remained. Finally, the Urban Mind studies investigated personality-related modulators of the association between nature and wellbeing. Bakolis et al. (2018) found that positive nature effects were particularly pronounced in individuals with high trait impulsivity, pointing to an enhanced benefit. However, Bergou et al. (2022) and Hammoud et al. (2022) could not replicate this finding, suggesting general benefits of nature exposure.

The two US-based studies with semi-objective checklists of nature exposure (Beute & de Kort, 2018; Ryan et al., 2010) received 80 % MMAT ratings; the former due to not having a clear research question and the latter due to suboptimal representativeness of the study population. Ryan et al. (2010) examined how spending time outdoors related to vitality, defined as physical and mental energy, in 97 participants who completed 14 EMA days. Individuals who spent more than 20 min daily outdoors engaged in activities requiring physical exercise and social interactions reported higher vitality. Importantly, all outside activities were associated with higher vitality ratings, irrespective of their physical and social nature. The association between being outdoors and vitality ratings was largely explained by exposure to natural characteristics, that is vitalising effects of outside activity might be driven by nature exposure. A second study by Ryan et al. (2010) explored the mediating effect of place-based characteristics in the association between time spent outside and vitality, using four days of EMA in 51 participants. Place-based characteristics were dichotomised into natural (e.g. a tree) or non-natural (e.g. a TV). Again, being outdoors was related to greater vitality, but this association was no longer apparent when controlling for natural characteristics, underlining the specificity of exposure to nature on vitality rather than spending time outside *per se*.

Lastly, Beute & de Kort (2018) conducted a 6-day EMA study to explore the effects of nature and daylight exposure in 59 participants with clinical depression, categorized into a low and a high depression group. Participants completed a checklist on nature (e.g. presence of grass or trees) and daylight exposure and questions about their mood and stress levels. Nature exposure was associated with better mood, higher energy levels, and lower tension in all individuals, but it appeared particularly beneficial for those with more affective problems, in line with findings from Urban Mind (Bakolis et al., 2018). Interestingly, this differential effect was not seen for daylight, which was equally beneficial for all participants.

3.2.4. Exposure to built environment and neighbourhood characteristics

Nineteen studies explored associations between built environment and neighbourhood characteristics and wellbeing (Table 2, section 2). Specifically, six investigated social determinants in the neighbourhood context (Table 2, section 2.1), eleven studies investigated exposure to built environment characteristics (e.g. nearby alcohol outlets, neighbourhood disorder) in relation to alcohol (Table 2, section 2.2), tobacco (Table 2, section 2.3), and substance consumption more broadly (Table 2, section 2.4). Finally, two investigated associations between physical and social contexts and mental wellbeing (Table 2, section 2.5).

3.2.5. Neighbourhood characteristics and social contexts

Two US-based studies with 100 % MMAT ratings investigated

patterns of neighbourhood characteristics and wellbeing (Li et al., 2007; Ortega-Williams et al., 2022). Li et al. (2007) investigated risk and protective factors for externalising and internalising symptoms in 263 young African Americans attending urban Chicago middle schools using a 7-day EMA design. The presence of family support, family helpfulness and a perception of a positive neighbourhood appeared to protect against externalising symptoms, even when other risk factors, such as exposure to violence, were present. This highlights the importance of neighbourhood characteristics in attenuating the impact of other risk factors. However, individual confidence was also associated with lower internalising and externalising symptoms, underscoring the role of individual characteristics.

Ortega-Williams et al. (2022) assessed 4 weeks of EMA of negative and positive emotions, perceptions of racism and social support across everyday locations in 75 Black youths in the US. The young people experienced more racism and less social support in certain locations, such as on the bus, at school, or walking along the street, than when at home. However, they felt more socially supported and safer at extended families' houses and at community centres than at home. Being subjected to racism or anticipating the possibility of racism was associated with more momentary negative emotion, while feeling socially supported was associated with less negative emotion. These findings highlight the impact of different locations on Black youths' feelings of safety, exposure to racism, and mental wellbeing.

A third 100 % MMAT study from the US by Rivenbark et al. (2019) used 14 days of EMA to investigate how perceptions of social status and exposure to local area income inequality relate to mental health in 2,100 adolescents from North Carolina Public Schools. Living in an area with higher income inequality was associated with lower subjective social status across all ages. Moreover, lower subjective social status was associated with poorer mental health. Importantly, lower subjective social status was associated with more psychological distress, conduct problems, early substance abuse and overall poorer mental health (Rivenbark et al., 2019). Together the three studies highlight how place and social and person factors interact in impacting young people's wellbeing and mental health.

Three further 100 % MMAT studies came from the US Adolescent Health and Development in Context (AHDC) study, which followed a cohort of adolescents aged 11–17 years residing in Columbus (Browning et al., 2023, 2024; Pinchak et al., 2022).

The first examined racial differences in exposure to disadvantaged activity spaces and wellbeing among 1,180 Black and White adolescents who completed 7 EMA days with GPS tracking (Pinchak et al., 2022). Black adolescents were exposed to higher levels of racial segregation, violent crime, and socioeconomic disadvantage in their non-home activity spaces compared to White adolescents and reported lower levels of collective efficacy (i.e. neighbourhood evaluations related to social cohesion and trust). These disparities remained significant after controlling for key confounders. In sum, Black adolescents experienced greater disadvantages in their day-to-day leisure or school commute spaces relative to their White peers, potentially contributing to broader racial disparities in health and wellbeing.

A subsample of 690 adolescents had given hair samples for measures of cortisol concentration (HCC). Browning et al. (2023) linked perceptions of safety across the 7-day EMA period to HCC indices of chronic stress. Black adolescents reported lower levels of perceived safety than White adolescents, and a relationship between perceived safety and HCC was observed in Black adolescents. The authors suggested that Black youth might experience greater physiological stress responses, potentially due to repeated distressing experiences like racial discrimination. A third analysis of this dataset by Browning et al. (2024) explored how exposure to neighbourhood poverty, violence and "Whiteness" of areas shaped perceived safety. Being near home increased feelings of safety, but a higher violent crime rate in the surrounding block was associated with significantly decreased perceptions of safety in all adolescents. Black adolescents who spent time in predominantly White neighbourhoods were less likely to feel safe, whereas White adolescents reported increased feelings of safety. The authors suggested that Black adolescents may experience a lack of safety in predominantly White neighbourhoods due to increased exposure to race-based discrimination. This finding challenges the hypothesis that familiarity with an environment would reduce perceived threat, particularly for Black adolescents in racially segregated spaces.

3.2.6. Place, alcohol cravings and alcohol use

Four US-based studies that were rated 100 % MMAT, investigated the geographical contexts of alcohol use and cravings (Byrnes et al., 2017; Fischer et al., 2023; Trela et al., 2018; Treloar & Miranda, 2017).

Trela et al. (2018) investigated the contextual factors associated with cravings in 403 young adults in Missouri over a 21-day EMA period by measuring occurrences of alcohol consumption and smoking, in addition to mood, locations, social context, and sensitivity to alcohol (i.e. the number of drinks required to experience alcohol effects). Higher alcohol craving was significantly associated with contextual factors, such as being at a bar or restaurant, being with a friend, craving a cigarette, and the time of the day (3pm to 3am). Recent smoking reduced the likelihood that a young person consumed alcohol. Alcohol sensitivity had a moderating effect on cravings in response to context. The authors suggested that low sensitivity drinkers are more likely affected by context and anticipatory cravings considering future drinking occasions.

Another US study examined alcohol consumption and craving in relation to environmental context among 86 youth with early signs of Alcohol Use Disorders (AUD). Participants responded to EMA prompts and provided self-initiated reports on starting and finishing alcoholic beverages, cravings and affective states, including feeling energized, excited, sedate, sluggish, tense and stressed, over a 1-week period (Treloar & Miranda (2017). Again, alcohol cravings were found to be significantly and positively associated with the time of the day (6pm to midnight being the period with the greatest cravings), and to be stronger on weekends, in public places, at parties, and when peers were present. At non-drinking times AUD symptom severity was unrelated to cravings, stimulation (energy, excitement) or tension (feeling tense). However, during alcohol consumption, those with greater AUD symptom severity experienced a stronger positive effect of alcohol (i.e. feeling more energized and excited), and less craving compared to those with lower AUD symptomology.

Byrnes et al. (2017) asked 170 adolescents in San Francisco to report their alcohol use, risk factors for drinking and problem behaviours (e.g. shoplifting, selling drugs) and the perceived social disorganisation of their environment (e.g. vandalism, drug use and littering) over four weeks with three weekly EMA days. The authors also gathered objective measures of social disorganization from Census data and the GPS-determined distance to alcohol outlets. Alcohol consumption was significantly correlated with risk factors for drinking, perceived and objective measures of social disorganisation, and proximity to alcohol outlets. Only perceived social disorganisation was related to problem behaviour. The authors stressed the importance of individual perceptions of the environment when evaluating contextual risk factors for drinking and problem behaviours in adolescents.

Lastly, Fischer et al. (2023) studied alcohol use in 61 young adults in Chicago for two drinking episodes with a minimum of 24-hour interval. Drinking frequency, stimulation (e.g. energy, excitement), reward and sedation were measured at EMA in relation to current location and presence of other people. Alcohol consumption was higher when participants were drinking with others compared to alone, and when drinking in bars and restaurants compared to other locations. Interestingly, the stimulating and rewarding effects of alcohol were higher and sedative effects lower when drinking occurred with others rather than alone. The enhanced positive (and attenuated negative) effects of alcohol when consumed socially highlights the importance for the understanding and prevention of the development of AUD (Fischer et al., 2023).

3.2.7. Tobacco use

Three US studies with 100 % MMAT ratings investigated tobacco use in relation to the proximity to outlets (Kirchner et al., 2013; McQuoid et al., 2018; Watkins et al., 2014).

Kirchner et al. (2013) studied the exposure to point-of-sale of tobacco (POST) and the desire to smoke and smoking relapses in 475 smokers in their first month after cessation in Washington DC. Vicinity to POST was assessed through GPS position or Wi-Fi and linked to a database of tobacco outlets, while cravings and self-reported smoking relapses were recorded through EMA surveys. Smoking relapses were more likely on days that participants were exposed to a POST and increasingly likely as the daily POST exposure increased. The association between POST exposure and relapse was stronger when cravings were high. This raises the question of reverse causation, in that participants may have been more likely to be near POSTs when intending to relapse, but authors argued that the frequency and duration of the data collection enabled them to capture both intended and unintended POST exposure, in environments with both high and low exposure to POSTs, thereby capturing the true effects of exposure on relapse.

A second study with 55 participants from a smoking cessation clinic in Dallas, Texas, followed participants for a week from the day of tobacco cessation, measuring their smoking urges (EMA) and POST exposure using geo-location data (Watkins et al. (2014). Closer proximity to POSTs was associated with stronger urges to smoke, but only within 1 mile of home. Residential POSTs may represent a larger relapse risk because people are more likely to smoke at home than when at work or in public. Moreover, people may not be aware of their proximity to POSTs when outside their residential areas (or of POST density in general), and therefore this may not elicit the same triggering effect on urges.

Lastly, McQuoid et al. (2018) used GEMA in conjunction with interviews to understand the relationship between cigarette cravings and internal and external factors (e.g. location type, seeing others smoking) in 17 bisexual young adults in California. Interview data of three individuals was linked to data from a 30-day GEMA study. One person's GEMA showed they most frequently smoked at home, in her car, and in restaurants/bars and primarily alone. While the GEMA data was not presented in the paper, the interview clarified that smoking in the vehicle frequently occurred while parked at school, a setting linked to emotional stress, where they felt smoking helped coping with negative experiences. Another person smoked mostly at others' homes, while walking, and at work. Smoking was socially driven and triggered by tobacco paraphernalia. Smoking helped to suppress hunger and provided structure in a hectic day. For a third participant GEMA reflected morning smoking at home, while the interview highlighted a wider range of locations, including LGBTQ+ bars. They viewed smoking as a coping mechanism for identity management and stress. Taken together, the study demonstrated how GEMA data can be enriched with qualitative information, revealing emotional and situational patterns that might have been missed by GEMA alone.

3.2.8. Substance Use

Substance use in relation to place was investigated by four US studies with MMAT ratings from 60-100 % due to problems with sample representativeness and confounders not accounted for in analyses (Epstein et al., 2014; Linden-Carmichael et al., 2021; Mennis et al., 2016; Rhew et al., 2022).

Epstein et al. (2014) assessed drug cravings, stress, and mood in 27 adults with clinically diagnosed drug use in Baltimore, US. Participants completed a 16-week EMA of positive and negative mood, stress and drug cravings. The Neighborhood Inventory for Environmental Typology scale was used to assess social (e.g. people yelling, intoxicated people) and physical disorder (e.g. unmaintained property, graffiti), and drug activity (e.g. drug paraphernalia, alcohol bottles) in the neighbourhood. Greater neighbourhood social disorder was associated with lower momentary cocaine craving; greater neighbourhood physical disorder was associated with lower cocaine and heroin cravings, as well as lower negative mood and stress ratings. More neighbourhood drug activity was associated with lower cocaine and heroin craving and lower stress reports. The findings were contradictory to the study hypotheses, that more neighbourhood problems would be associated with increased cravings, underscoring the complexity of the relationship (Epstein et al., 2014).

Mennis et al. (2016) studied the mediating role of substance use on stress and perceived safety in disadvantaged neighbourhoods in 139 adolescents in Richmond, US. A relative neighbourhood disadvantage index was computed for adolescents' current location relative to their home neighbourhood, using GPS and Census data. The study period spanned a year, with 4 days of EMA every other month. Participants reported on momentary psychological stress and perceived safety, while the Adolescent Alcohol and Drug Involvement Scale was used to measure alcohol and substance use. Relative neighbourhood disadvantage was associated with higher substance use. Further, the association between relative neighbourhood disadvantage and stress was moderated by substance use. The authors speculated that the moderating effect of substance use on feeling unsafe in relatively disadvantaged neighbourhoods may reflect that adolescents who are visiting more disadvantaged neighbourhoods with the intent to acquire drugs may feel less safe than those who are visiting for other reasons, such as visiting a relative.

Linden-Carmichael et al. (2021) examined associations between physical and social contexts of alcohol and simultaneous alcohol and marijuana use (SAM) across 14 EMA days in 148 young adults in the Northeastern US. Participants reported on alcohol and marijuana use, location and risky drinking activities (e.g. playing drinking games), and social context. Those aged under 21 were more likely to report SAM at home, whilst those over 21 were more likely to report SAM when outdoors or at a friend's house. For both age groups, SAM occurred more often in private settings or outdoors than in public spaces such as bars or clubs, which is understandable given the illegal nature of marijuana consumption.

Lastly, a small pilot study by Rhew et al. (2022) followed 14 young adults in Seattle for 14 days to assess their use and desire to use marijuana in conjunction to their GPS-determined exposure to marijuana outlets. As found for other substances, marijuana use and desire to use were associated with exposure to outlets. The authors discuss the possibility of a reverse causal relationship in which individuals who intend to use may approach such outlets (Rhew et al., 2022).

3.2.9. Social and physical contexts of wellbeing

Two studies rated 100 % MMAT investigated the social and physical environmental contexts of loneliness (van Roekel et al., 2015) and affective states (Dunton et al., 2015).

The first by van Roekel et al. (2015) investigated loneliness in relation to social company (in company or alone) and physical locations (e.g. home/school/other place), using six EMA days in a sample of 268 Dutch adolescents. Adolescents reported feeling lonelier when alone, compared with all types of company. However, loneliness was lower in company of friends and family compared to being with peers at school. The authors propose that classmates do not necessarily form intimate relationships (compared to friends and family) and that they may represent a social threat. Interestingly, being alone at two consecutive assessments did not lead to higher feelings of loneliness, suggestive of a habituation effect. Moreover, adolescents reported lower loneliness when spending time with friends following a period of being alone, as compared to when being in social company for two consecutive assessments. In other words, the effect of social company on loneliness was more pronounced following time spent alone. Importantly, this effect did not occur when spending time with family following a period of being alone, suggestive of a particular importance of spending time with friends.

Beneficial effects of social company for physical activity were suggested by a study from suburban California in which 116 participants

completed three 4-day EMA waves (Dunton et al., 2015). Positive affect was higher during physical activity in the company of others, compared to when engaging in physical activity alone. Moreover, participants reported greater positive and lower negative affect when physical activities were performed outdoors versus indoors. This result highlights the importance of both social connectedness and outdoor environments for affective wellbeing.

3.2.10. Ambient characteristics and wellbeing

Three studies investigated associations between ambient characteristics and mental wellbeing (Table 2, section 3). Two studies investigated weather/temperature, and one investigated the association between noise and momentary stress.

3.2.11. Weather and temperature

Three studies, one of which was also included in the 'exposure to natural characteristics' section, investigated associations between weather, temperature and mental wellbeing (Bundo et al., 2023; Denissen et al., 2008; MacKerron & Mourato, 2013), rated 100 %, 80 % and 100 % MMAT, respectively. One 100 % MMAT study investigated the association between noise exposure and mental wellbeing (Kou et al., 2020).

Bundo et al. (2023) collected seven days of EMA data from 906 individuals in Lausanne, Switzerland, and combined this with weather station data to study ambient temperature and daily mood variations. A 5° Celsius increase in maximum daily temperature corresponded to a 7 % decrease in negative mood, but this effect reduced to 3 % when considering daily sunshine duration. Subgroup analyses revealed that people who were elderly, single, or had low education showed stronger temperature-mood associations. Individuals with bipolar disorder experienced a more marked positive effect of temperature increases, while those with schizophrenia, depression, and anxiety showed the opposite, where temperature increases correlated with lower mood ratings. Warmer and sunnier weather also correlated with more positive mood in those with high neuroticism, but with more negative mood in those with low neuroticism.

The second study used data from German weather stations, matched to participants' ZIP codes and linked it to personality traits and 30-day EMA records of tiredness, positive and negative affect (Denissen et al., 2008). This study received 80 % on the MMAT due to suboptimal representativeness of the sample. Weather conditions were weakly associated with positive affect but were more strongly associated with negative affect. Specifically, higher temperature was linked to higher negative affect, while sunlight and wind power were associated with lower negative affect. A higher number of sunlight hours correlated with decreased tiredness. A notable interaction emerged between season and wind power, indicating a stronger negative association between wind and mood during warmer seasons compared to colder ones. The difference in findings might be explained by differences between samples and/or operationalisation in affect/mood between studies.

Finally, MacKerron & Mourato (2013) (discussed in 3.3.1 and Table 2, section 2.1) also found that greater happiness was linked to higher temperatures, lower wind speeds, increased sunshine and decreased rain and fog (MacKerron & Mourato, 2013). Together, the three studies highlight the possible influence of weather and temperature on mood, yet the associations suggest complex patterns that need further investigation, while considering person and place-based factors.

Noise. Only one study, rated 100 % on the MMAT, investigated the association between exposure to noise and mental wellbeing in 101 participants who carried a portable sound sensor for two days and reported on momentary perceived noise and psychological stress (Kou et al., 2020). Objective measures of noise, defined as the A-weighted (i.e. filtered to reflect sound perceivable to the human ear) equivalent continuous sound level averaged over the five minutes preceding each self-report and calculated from one-minute noise recordings using logarithmic averaging, were associated with momentary psychological distress, but this association was mediated by how the noise was subjectively perceived in that moment. This suggests that noise can be tolerated well when it is expected or part of a chosen environment, e.g. spending time with friends in a busy public area. The authors speculated that habituation to certain types of noise may occur with repeated exposure, e.g., when using public transportation, so that people were not particularly bothered by the noise level. This highlights the importance of considering subjective and contextual factors when evaluating noise pollution (Kou et al., 2020).

4. Discussion

4.1. Main findings

This systematic, narrative review summarised the results of 33 studies that used some form of geographically informed EMA (GEMA) methodology to study the association between place-related factors and mental health and wellbeing, including substance use. We found a substantial heterogeneity in study designs, conceptualisation and measurement of built and natural place-related characteristics. This makes it difficult to assert precise associations across studies (Ortegon-Sanchez et al., 2021). This heterogeneity in GEMA studies has also been observed in prior systematic reviews (Kingsbury et al., 2024; Zhang et al., 2024), and highlights a critical need for standardised reporting, as per the STROBE GEMA guidelines proposed by Kingsbury and colleagues (2024). Despite these methodological challenges, we found evidence to support associations between characteristics of the built and natural environment with aspects of mental health and wellbeing and substance use, as an indicator thereof, in both clinical and non-clinical populations. The eleven studies that investigated associations between exposure to natural environments and mental health and wellbeing (Table 2, section 1) consistently found that being in nature is associated with higher wellbeing, happiness, vitality, and mood (higher positive and lower negative affect), and lower stress. Importantly, the findings suggest unique beneficial effects of different natural characteristics, such as blue space, green space, and presence of wildlife, albeit with some variation between studies. It appears that natural characteristics rather than the frequency of being outside influence mental wellbeing. This is an important distinction, as some people have easier and therefore possibly more frequent access to outdoor spaces where green and blue space characteristics are present, while others may reside in heavily populated areas, where buildings and facilities take up most of the space and restrict easy access to natural environments. However, future studies with systematic measurements of both frequency and time-spent metrics are needed to assess the relative contributions of exposure duration versus frequency of exposure. Importantly, some evidence showed that nature exposure was related to age (MacKerron & Mourato, 2013), higher socio-economic status (Li et al., 2018), and having a diagnosis of schizophrenia (Henson et al., 2020), highlighting that some of the potential beneficial effects are less accessible for those who may benefit most. Some studies identified particularly beneficial effects of nature exposure for participants with specific personality traits, such as impulsivity or neuroticism or clinical characteristics, such as depression or anxiety, in support of a restorative hypothesis. Individuals with higher baseline negative emotions or distress, or generally poorer mental health may benefit particularly from natural environments, which can alleviate stress and provide positive downstream effects on mental health.

Despite the longitudinal nature of the studies the directionality of effects remained uncertain from most of the included studies. This is because included studies generally employed cross-sectional analyses to GEMA data or assessed place-related or mental health related characteristics at only one time point. Thus, it remained possible that people with specific traits or mental health problems choose to spend time outside less frequently, for example due to low energy, reduced motivation, or fears about negative events and social encounters.

Furthermore, people with certain demographic characteristics may have more restricted access to natural environments, and the quality and conditions of available natural and built environments may differ markedly between areas. Nonetheless, three of the included studies that probed temporal associations (Bakolis et al., 2018; Bergou et al., 2022; Hammoud et al., 2022) support the importance of improving access to natural environments and the need for further research into the nature exposure as a preventative and therapeutic avenue for mental health.

Sixteen studies provided consistent evidence to support cross-sectional associations between neighbourhood characteristics and social context and mental health and wellbeing (Table 2, section 2). Specifically, neighbourhood income inequality, lack of neighbourhood support and social company were linked to poorer mental health and wellbeing (i.e. stress, positive and negative affect, internalising and externalising symptoms, perceived social support, loneliness, perceptions of safety), lowered physical activity, and conduct problems in urban environments. Positive neighbourhood characteristics, such as neighbourhood support or perceived safety, in turn, appeared protective against mental distress. This effect differed between ethnicities, with some evidence indicating that Black adolescents perceive neighbourhoods as less safe compared to their White peers. This could be due to racial segregation or more negative experiences leading to lower expectations of safety. The findings highlight the potential beneficial effects of local initiatives that increase social support and safety.

Substance use, including of tobacco, alcohol and illicit drugs, was consistently linked to exposure to the proximity to point-of-sale outlets (POSTs). Whilst this suggests that such outlets may act as cues or triggers for substance use, other explanations are possible. For example, individuals may approach these locations in response to craving and after having decided to use, rather than being triggered by the presence of those locations. It is also plausible that businesses selling alcohol, tobacco and other substances may situate their business in a location where a substantial number of residents are known users. Additionally, participants may intentionally choose destinations where social norms are more conducive to substance consumption, such as nightlife districts, where craving might increase through co-presence with other consumers and nearby POSTs. Overall, our findings provide evidence to support the impact of natural and built characteristics on mental health and wellbeing and substance use. They underscore the importance of considering these factors in understanding and improving mental health and wellbeing. Our findings also suggest that specific social context (e.g. neighbourhood support) can moderate those associations.

Finally, a smaller subset of studies examined how ambient environmental characteristics, particularly weather, temperature, and noise, influence mental wellbeing. This subcategory was created to reflect the fact that such characteristics inherently exist across natural and urban settings and thus may influence mental wellbeing in either environment. Three studies provided evidence that warmer temperatures, more sunshine, and lower wind speeds are associated with better mood and reduced negative affect, although results varied based on personality traits and clinical status (e.g., bipolar disorder, schizophrenia) (Bundo et al., 2023; Denissen et al., 2008; MacKerron & Mourato, 2013). For example, Bundo et al. (2023) found that the positive effects of temperature were more pronounced among individuals with bipolar disorder, while people with schizophrenia, depression, and anxiety experienced the opposite. Denissen et al. (2008) reported complex interactions between weather variables and affect, including a stronger effect of wind power during warmer seasons. Furthermore, one study investigating noise exposure (Kou et al., 2020), showed that the impact of ambient sound on psychological distress was mediated by subjective perception, suggesting that noise is more tolerable when expected or contextually appropriate, such as during social interactions in public spaces. These findings highlight the nuanced ways in which ambient characteristics interact with personal and contextual factors in shaping mental wellbeing and support the need for further research in this area.

We included studies if at least one aspect (exposure or outcomes) was assessed by EMA. Importantly, EMA only allows for dynamic (i.e. temporal) analyses that provide an understanding of how place-based characteristics shape mental health or wellbeing, and how such outcomes impact on the choice or perception of places when all aspects are measured in the moment. That is, this type of understanding cannot be generated from studies that used cross-sectional designs, constituting the majority of included studies (n = 29, 87.9 %), neglecting investigation of temporality. Despite our review highlighting a growing interest in GEMA applications to mental health research from 2013, only 4 studies attempted temporal analyses to study the directionality between exposure to place, social context and mental wellbeing. These included the Urban Mind studies (Bakolis et al., 2018; Bergou et al., 2022; Hammoud et al., 2022), which all found a sustained positive effect of different aspects of nature exposure (e.g. blue space, birdsong exposure) on wellbeing 2 to 24 h later. Van Roekel et al. (2015) further reported a greater relief from loneliness in participants who had been in solitude at a previous assessment compared to those who were in social company.

The directionality of effects also remained speculative for studies investigating substance use. For example, it is possible that people approach POSTs with the intent to purchase substances, or that people of poorer mental health chose to spend less time inside. Studies with longer follow-up periods, which may cover both the intentional and non-intentional activity patterns of individuals, may help to overcome this limitation. A more proactive approach might be to use georeferenced prompts such as *"When did you decide to go to this location?"*, which could help distinguish between environmental trigger-points and locations reached due to prior intent. In summary, we noted an overall lack of designs investigating longer-term or lagged effects of place exposure on subsequent mental health, substance use or wellbeing (and vice versa). Thus, future research should focus more on investigating temporal relationships to generate better insights into possible causality.

Similarly, as highlighted by the sole mixed methods study in this review, McQuoid et al. (2018) found that complementary qualitative information may aid the interpretation of patterns observed through geographically informed EMA reports. This highlights the need for further mixed methods GEMA research using this approach. Furthermore, while some studies used objective measures of place and its characteristics, such as weather station data or GPS tracking, others relied on self-reports of participants to gauge place-related characteristics, e.g. whether they could see natural features or hear birdsong. Both methods have strengths; while the former allows for a homogenous and objective report of the environment (albeit with large inter-study variation in how this is quantified) that is not biased by individual perception, self-reported measures may provide a more valid exposure measure due to the subjective nature of an individual's experience of environmental features and characteristics of places. This is particularly illustrated by an included study finding that noise pollution effects are mediated by subjective perceptions of noise (Kou et al., 2020). For example, a noisy environment may be more tolerable while on public transport or when spending time outside with friends. Similarly, the beneficial effects of a nearby forest may not be experienced by an individual if a skyscraper is blocking the view, whilst a nearby alcohol outlet may not be something that someone who uses alcohol is aware of and therefore it may not trigger a craving despite its proximity.

The breadth of methods used in the included studies could be considered both a strength and a limitation of the wider GEMA methodology. Study durations varied from 2 days to 2 years with continuous or intermitted sampling, and single or multiple assessment waves, and EMA prompts ranging from one to eight per day. We found that most studies (87.8 %) reported on EMA compliance rates, which ranged from about 29 % to 95 %. In terms of study designs, some used time-invariant assessments of mental health and wellbeing made with standard, validated questionnaires, whilst others were time-variant using various EMA items. EMA protocols often lacked validation and employed differing questions, with differing scales to measure specific concepts. Efforts to further the development, transparency and reproducibility of

EMA research are under way (Kirtley et al., 2018). Data on place-related characteristics were assessed objectively or subjectively, again with much variability in terms of methods, utilised questions and sampling frequencies. In addition, there were differences in the apps used to collect (G)EMA data, as reviewed in detail by Zhang et al. (2024). While prior recommendations for GEMA research methods (Kingsbury et al. (2024) will help to address some of these issues, it is important that the generally consistent findings from studies using a broad range of methods would appear to provide some triangulation, pointing towards an important influence of nature exposure on mental wellbeing.

4.2. Strengths and limitations

Our study is the first systematic review and synthesis of the geographically informed EMA literature on mental health, wellbeing and substance use in the context of place-based characteristics. While two recent reviews have addressed related topics (Kingsbury et al., 2024; Zhang et al., 2024), they were mainly concerned with methodological considerations (de Vries, Baselmans, & Bartels, 2021; Zhang, Li, Li, Zhou, & Newman, 2024) and guidelines for conducting GEMA studies (Kingsbury et al., 2024). Our search strategy allowed for the inclusion of all aspects of place-based characteristics and thus provides an overview of the impact of both natural and built and social characteristics on momentary and general mental health and wellbeing. Our rigour in pre-registering our protocol, following PRISMA guidelines, and using an established quality rating tool increases the validity of our findings. Given the interdisciplinary nature of the topic, a particular strength was the composition of our research team, comprising researchers from social psychiatry, psychology, neuroscience, built environment and socio-economic research. A limitation of our review was that we were unable to *meta*-analyse the data due to the heterogenous nature of the study designs, outcome variables, and reported effects. Publication of further studies using similar effect measures will facilitate *meta*-analysis to convey the overall strength of effects. Another limitation is the scope of our database selection. While PubMed, PsychINFO, and Embase are highly relevant to research in the domains of health and psychology, the addition of broader interdisciplinary databases, such as Scopus and Web of Science could have resulted in retrieval of additional relevant studies. The articles captured by us only partially overlapped with recent similar reviews (de Vries, Baselmans, & Bartels, 2021; Kingsbury et al., 2024; Zhang, Li, Li, Zhou, & Newman, 2024). The articles captured by us only partially overlapped with recent similar reviews (de Vries, Baselmans, & Bartels, 2021; Kingsbury et al., 2024; Zhang, Li, Li, Zhou, & Newman, 2024). For example, two studies (Tao et al., 2020; Tao et al., 2021) appearing in recent similar reviews (de Vries, Baselmans, & Bartels, 2021; Kingsbury et al., 2024; Zhang, Li, Li, Zhou, & Newman, 2024) fell outside our preregistered inclusion window, yet their findings are consistent with the present conclusions. Thus, future reviews would benefit from a broader search strategy and the inclusion of more data bases to more fully capture the interdisciplinary landscape of this research field.

We utilised MMAT to establish study quality ratings. We found that most studies scored high on the methodological quality criteria assessed by the tool despite some misgivings we had about EMA study quality that were not captured in the MMAT criteria (e.g., intermittent missingness of prompt responses or GPS accuracy). As the MMAT rating criteria are broad and not specific to GEMA research designs (e.g. no inclusion of assessment of temporal associations), methodological differences between studies may not have been captured (Kwasnicka et al., 2021).

4.3. Future directions for research and policy

Using real-time assessment, GEMA can capture the nuances of spatio-temporal influences on mental health and related factors in daily life contexts. Despite this potential, the majority of included studies did not investigate temporal relationships, and such studies are needed to improve our understanding of the dynamic interactions between natural and built characteristics and mental health, substance use and well-being. This methodological approach will bring important cross-disciplinary advantages. For clinicians and patients, the ability to monitor and understand symptoms and psychological distress in real-world contexts may help to develop coping strategies (e.g. seeking pockets of tranquillity in busy urban environments, working out least stressful commutes between places). Furthermore, pinpointing areas linked to higher stress levels or psychological symptoms can support intelligent urban planning that considers ambient characteristics (e.g. light, temperature, noise pollution), walkability, safety, protection of green space and wildlife, serving as an important tool for improving mental health and wellbeing. Such approaches may also help to identify which groups of individuals fail to use available opportunities optimally and why.

GEMA is still a relatively new approach for studying the links between place-based factors and mental health and wellbeing, and methodological approaches vary, as previously noted (de Vries, Baselmans, & Bartels, 2021; Kingsbury et al., 2024; Zhang, Li, Li, Zhou, & Newman, 2024). Specific smartphone EMA apps have increased the convenience to participants and researchers of conducting such studies, as have utilisations of pre-installed software, such as GPS systems and text-messaging. This way, EMA offers flexibility in research recruitment and retention, as participants are no longer required to travel to research facilities and adhere to specific data-collection timeslots. Nevertheless, there are several challenges and considerations that warrant attention. Important issues related to privacy and data security must be carefully addressed, given the collection of sensitive personal information, including location data, psychological states, and for some purposes even voice recognition and biostatistics. The inconvenience to participants of being disturbed by prompts should also be considered, including appropriate remuneration. Ensuring that data collection methods are ethical and compliant with relevant regulations is paramount to protecting the rights and interests of participants. Recent guidance, issued as an extension to the Strengthening the Reporting of Observational Studies in Epidemiology for GEMA studies (STROBE-GEMA), provides a 70-item checklist that will help to address issues of heterogeneity in GEMA methodologies and reporting, as observed in our systematic review and others (de Vries, Baselmans, & Bartels, 2021; Kingsbury et al., 2024; Zhang, Li, Li, Zhou, & Newman, 2024).

Finally, the findings from this review have tentative implications for policy and planning. First, in line with green equity theory (Nesbitt et al., 2019; Nesbitt et al., 2023), findings point to inequalities in accessibility of nature spaces related to sex, age, ethnicity, socio-economic status, and the presence of mental health diagnoses, highlighting that provision of nature spaces and opportunities must be shaped in a way that makes them accessible for all. Second, our findings suggest that the quality of outdoor experiences, such as perceptions of safety, natural characteristics and neighbourhood support, matters more for mental health and wellbeing than the amount of time spent outside. They are both important factors that determine how places are experienced and used, highlighting the importance of safe, high quality outdoor spaces and neighbourhood initiatives that enhance belonging and community. Third, our findings regarding substance use suggest that regulation of outlets may help to reduce cravings and use. However, as pointed out by others, there is little evidence on causal direction, i.e. whether demand leads to more supply or increased availability increases alcohol use and harm (Gmel et al., 2016), highlighting the need for research. Fourth, and most broadly, the scarcity of GEMA studies in this area suggests important missed opportunities for collaborations between policy makers, urban planners and researchers. Specifically, collaborative investigations may help to identify high-risk environments where individuals are more vulnerable to poor mental health and reduced wellbeing.

In conclusion, this review highlights that geographically informed

EMA studies hold great promise for advancing the understanding of the place, mental health and wellbeing nexus within the context of cross-disciplinary collaborations, involving urban planners, clinicians, and policymakers, to translate these findings into practical solutions at individual and community levels. Ultimately, increasing equitable access to natural environments and improving urban design may provide meaningful ways to support mental health and wellbeing in diverse populations.

6. Disclosures

Noémie Topalian is funded by the European Union (ERC-2021-STG, FragMent, 101040492). Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or the European Research Council Executive Agency. Neither the European Union nor the granting authority can be held responsible for them.

CRediT authorship contribution statement

Ronja Christensen: Writing – original draft, Methodology. **Charlotte Constable Fernandez:** Writing – review & editing, Validation. **Noémie Topalian:** Writing – original draft. **Laura Vaughan:** Writing – review & editing, Funding acquisition, Conceptualization. **Kimon Krenz:** Writing – review & editing, Funding acquisition, Conceptualization. **Alexandra Pitman:** Writing – review & editing, Funding acquisition, Conceptualization. **Anne-Kathrin Fett:** Writing – review & editing, Supervision, Project administration, Methodology, Funding acquisition, Conceptualization.

Funding

This work was supported by City, University of London Collaborative Grant Application Booster (CGAB) funding. CCF is supported by the award of an MRC PhD studentship. AP is supported, as co-lead of the Loneliness and Social Isolation in Mental Health research network, by the NIHR University College Hospitals London (UCLH) Biomedical Research Centre. This research was partly funded by the ActEarly UK Prevention Research Partnership Consortium, grant number MR/S037527/1 (authors L.V., K.K.).

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2025.105487.

Data availability

No data was used for the research described in the article.

References

Astell-Burt, T., Mitchell, R., & Hartig, T. (2014). The association between green space and mental health varies across the lifecourse. A longitudinal study. *Journal of Epidemiology and Community Health, 68*(6), 578–583. https://doi.org/10.1136/jech-2013-203767

Bakolis, I., Hammoud, R., Smythe, M., Gibbons, J., Davidson, N., Tognin, S., & Mechelli, A. (2018). Urban mind: Using smartphone technologies to investigate the impact of nature on mental well-being in real time. *Bioscience, 68*(2), 134–145. https://doi.org/10.1093/biosci/bix149

Bergou, N., Hammoud, R., Smythe, M., Gibbons, J., Davidson, N., Tognin, S., Reeves, G., Shepherd, J., & Mechelli, A. (2022). The mental health benefits of visiting canals and rivers: An ecological momentary assessment study. *PLoS ONE, 17*(8 August). Doi: 10.1371/journal.pone.0271306.

Beute, F., & de Kort, Y. A. W. (2018). The natural context of wellbeing: Ecological momentary assessment of the influence of nature and daylight on affect and stress for individuals with depression levels varying from none to clinical. *Health and Place, 49*, 7–18. https://doi.org/10.1016/j.healthplace.2017.11.005

Boniface, S., Scantlebury, R., Watkins, S. J., & Mindell, J. S. (2015). Health implications of transport: Evidence of effects of transport on social interactions. *Journal of Transport & Health, 2*(3), 441–446. https://doi.org/10.1016/j.jth.2015.05.005

Browning, C. R., Ford, J. L., Tarrence, J., Kertes, D. A., Pickler, R. H., Way, B. M., & Calder, C. A. (2023). Everyday perceptions of safety and racial disparities in hair cortisol concentration. *Psychoneuroendocrinology, 153*. https://doi.org/10.1016/j.psyneuen.2023.106088

Browning, C. R., Pinchak, N. P., Calder, C. A., & Boettner, B. (2024). Racial differences in activity space exposures and everyday perceptions of safety among urban youth. *Journal of Adolescent Health, 74*(6), 1156–1163. https://doi.org/10.1016/j.jadohealth.2024.01.022

Bundo, M., Preisig, M., Merikangas, K., Glaus, J., Vaucher, J., Waeber, G., Marques-Vidal, P., Strippoli, M. P. F., Müller, T., Franco, O., & Vicedo-Cabrera, A. M. (2023). How ambient temperature affects mood: An ecological momentary assessment study in Switzerland. *Environmental Health: A Global Access Science Source, 22*(1). https://doi.org/10.1186/s12940-023-01003-9

Byrnes, H. F., Miller, B. A., Morrison, C. N., Wiebe, D. J., Woychik, M., & Wiehe, S. E. (2017). Association of environmental indicators with teen alcohol use and problem behavior: Teens' observations vs. objectively-measured indicators. *Health and Place, 43*, 151–157. https://doi.org/10.1016/j.healthplace.2016.12.004

Collins, R. M., Spake, R., Brown, K. A., Ogutu, B. O., Smith, D., & Eigenbrod, F. (2020). A systematic map of research exploring the effect of greenspace on mental health. *Landscape and Urban Planning, 201*, Article 103823. https://doi.org/10.1016/j.landurbplan.2020.103823

de Vries, L. P., Baselmans, B. M. L., & Bartels, M. (2021). Smartphone-based ecological momentary assessment of well-being: A systematic review and recommendations for future studies. *Journal of Happiness Studies, 22*(5), 2361–2408. https://doi.org/10.1007/s10902-020-00324-7

de Vries, S., Nieuwenhuizen, W., Farjon, H., van Hinsberg, A., & Dirkx, J. (2021). In which natural environments are people happiest? Large-scale experience sampling in the Netherlands. *Landscape and Urban Planning, 205*, Article 103972. https://doi.org/10.1016/j.landurbplan.2020.103972

Denissen, J. J. A., Butalid, L., Penke, L., & van Aken, M. A. G. (2008). The effects of weather on daily mood: A multilevel approach. *Emotion, 8*(5), 662–667. https://doi.org/10.1037/a0013497

Dunton, G. F., Liao, Y., Intille, S., Huh, J., & Leventhal, A. (2015). Momentary assessment of contextual influences on affective response during physical activity. *Health Psychology, 34*(12), 1145–1153. https://doi.org/10.1037/hea0000223

Epstein, D. H., Tyburski, M., Craig, I. M., Phillips, K. A., Jobes, M. L., Vahabzadeh, M., Mezghanni, M., Lin, J. L., Furr-Holden, C. D. M., & Preston, K. L. (2014). Real-time tracking of neighborhood surroundings and mood in urban drug misusers: Application of a new method to study behavior in its geographical context. *Drug and Alcohol Dependence, 134*(1), 22–29. https://doi.org/10.1016/j.drugalcdep.2013.09.007

Fischer, A. M., King, A. C., Cao, D., & Fridberg, D. J. (2023). Drinking context, alcohol use, and subjective responses during binge drinking episodes measured by high-resolution ecological momentary assessment (HR-EMA). *Psychology of Addictive Behaviors, 37*(2), 258–266. https://doi.org/10.1037/adb0000887

Galea, S. (2005). Urban built environment and depression: A multilevel analysis. *Journal of Epidemiology & Community Health, 59*(10), 822–827. https://doi.org/10.1136/jech.2005.033084

Galea, S., Rudenstine, S., & Vlahov, D. (2005). Drug use, misuse, and the urban environment. *Drug and Alcohol Review, 24*(2), 127–136. https://doi.org/10.1080/09595230500102509

Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Forns, J., Plasència, A., & Nieuwenhuijsen, M. (2015). Mental health benefits of long-term exposure to residential green and blue spaces: A systematic review. *International Journal of Environmental Research and Public Health, 12*(4), 4354–4379. https://doi.org/10.3390/ijerph120404354

Gmel, G., Holmes, J., & Studer, J. (2016). Are alcohol outlet densities strongly associated with alcohol-related outcomes? a critical review of recent evidence. *Drug and Alcohol Review, 35*(1), 40–54. https://doi.org/10.1111/dar.12304

Gromatsky, M., Sullivan, S. R., Spears, A. P., Mitchell, E., Walsh, S., Kimbrel, N. A., & Goodman, M. (2020). Ecological momentary assessment (EMA) of mental health outcomes in veterans and servicemembers: A scoping review. *Psychiatry Research, 292*, Article 113359. https://doi.org/10.1016/j.psychres.2020.113359

Gruebner, O., Rapp, M. A., Adli, M., Kluge, U., Galea, S., & Heinz, A. (2017). Cities and Mental Health. *Deutsches Ärzteblatt International*. https://doi.org/10.3238/arztebl.2017.0121

Hammoud, R., Tognin, S., Burgess, L., Bergou, N., Smythe, M., Gibbons, J., Davidson, N., Afifi, A., Bakolis, I., & Mechelli, A. (2022). Smartphone-based ecological momentary assessment reveals mental health benefits of birdlife. *Scientific Reports, 12*(1). https://doi.org/10.1038/s41598-022-20207-6

Henson, P., Pearson, J. F., Keshavan, M., & Torous, J. (2020). Impact of dynamic greenspace exposure on symptomatology in individuals with schizophrenia. *PLoS ONE, 15*(9 September 2020). Doi: 10.1371/journal.pone.0238498.

Hong, Q. N., Fàbregues, S., Bartlett, G., Boardman, F., Cargo, M., Dagenais, P., Gagnon, M.-P., Griffiths, F., Nicolau, B., O'Cathain, A., Rousseau, M.-C., Vedel, I., & Pluye, P. (2018). The mixed Methods Appraisal Tool (MMAT) version 2018 for

information professionals and researchers. *Education for Information, 34*(4), 285–291. https://doi.org/10.3233/EFI-180221
Kaplan, R., & Kaplan, S. (1989). *The experience of nature: A psychological perspective*. Cambridge University Press.
Kellert, S. R., & Wilson, E. O. (1995). *The Biophilia Hypothesis* (Vol. 4, Issue 2). Island Press.
Kingsbury, C., Buzzi, M., Chaix, B., Kanning, M., Khezri, S., Kiani, B., Kirchner, T. R., Maurel, A., Thierry, B., & Kestens, Y. (2024). STROBE-GEMA: A STROBE extension for reporting of geographically explicit ecological momentary assessment studies. *Archives of Public Health, 82*(1), 84. https://doi.org/10.1186/s13690-024-01310-8
Kirchner, T. R., Cantrell, J., Anesetti-Rothermel, A., Ganz, O., Vallone, D. M., & Abrams, D. B. (2013). Geospatial exposure to point-of-sale tobacco: Real-time craving and smoking-cessation outcomes. *American Journal of Preventive Medicine, 45*(4), 379–385. https://doi.org/10.1016/j.amepre.2013.05.016
Kirchner, T. R., & Shiffman, S. (2016). Spatio-temporal determinants of mental health and well-being: Advances in geographically-explicit ecological momentary assessment (GEMA). *Social Psychiatry and Psychiatric Epidemiology, 51*(9), 1211–1223. https://doi.org/10.1007/s00127-016-1277-5
Kondo, M., Fluehr, J., McKeon, T., & Branas, C. (2018). Urban green space and its impact on human health. *International Journal of Environmental Research and Public Health, 15*(3), 445. https://doi.org/10.3390/ijerph15030445
Kou, L., Tao, Y., Kwan, M. P., & Chai, Y. (2020). Understanding the relationships among individual-based momentary measured noise, perceived noise, and psychological stress: A geographic ecological momentary assessment (GEMA) approach. *Health and Place, 64*. https://doi.org/10.1016/j.healthplace.2020.102285
Krabbendam, L., van Vugt, M., Conus, P., Söderström, O., Abrahamyan Empson, L., van Os, J., & Fett, A.-K.-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
Kuo, M. (2015). How might contact with nature promote human health? Promising mechanisms and a possible central pathway. *Frontiers in Psychology, 6*. https://doi.org/10.3389/fpsyg.2015.01093
Kwasnicka, D., Kale, D., Schneider, V., Keller, J., Yeboah-Asiamah Asare, B., Powell, D., Naughton, F., ten Hoor, G. A., Verboon, P., & Perski, O. (2021). Systematic review of ecological momentary assessment (EMA) studies of five public health-related behaviours: Review protocol. *BMJ Open, 11*(7), Article e046435. https://doi.org/10.1136/bmjopen-2020-046435
Lachowycz, K., & Jones, A. P. (2013). Towards a better understanding of the relationship between greenspace and health: Development of a theoretical framework. *Landscape and Urban Planning, 118*, 62–69. https://doi.org/10.1016/j.landurbplan.2012.10.012
Li, D., Deal, B., Zhou, X., Slavenas, M., & Sullivan, W. C. (2018). Moving beyond the neighborhood: Daily exposure to nature and adolescents' mood. *Landscape and Urban Planning, 173*, 33–43. https://doi.org/10.1016/j.landurbplan.2018.01.009
Li, N. P., van Vugt, M., & Colarelli, S. M. (2018). The evolutionary mismatch hypothesis: implications for psychological science. *Current directions in psychological science, 27*(1), 38–44. https://doi.org/10.1177/0963721417731378
Li, S. T., Nussbaum, K. M., & Richards, M. H. (2007). Risk and protective factors for urban African-American youth. *American Journal of Community Psychology, 39*(1–2), 21–35. https://doi.org/10.1007/s10464-007-9088-1
Linden-Carmichael, A. N., Allen, H. K., & Lanza, S. T. (2021). The socio-environmental context of simultaneous alcohol and marijuana use among young adults: Examining day-level associations. *Drug and Alcohol Review, 40*(4), 647–657. https://doi.org/10.1111/dar.13213
MacKerron, G., & Mourato, S. (2013). Happiness is greater in natural environments. *Global Environmental Change, 23*(5), 992–1000. https://doi.org/10.1016/j.gloenvcha.2013.03.010
McQuoid, J., Thrul, J., & Ling, P. (2018). A geographically explicit ecological momentary assessment (GEMA) mixed method for understanding substance use. *Social Science and Medicine, 202*, 89–98. https://doi.org/10.1016/j.socscimed.2018.02.014
Mennis, J., Mason, M., & Ambrus, A. (2018). Urban greenspace is associated with reduced psychological stress among adolescents: A Geographic Ecological Momentary Assessment (GEMA) analysis of activity space. *Landscape and Urban Planning, 174*, 1–9. https://doi.org/10.1016/j.landurbplan.2018.02.008
Mennis, J., Mason, M., Light, J., Rusby, J., Westling, E., Way, T., Zahakaris, N., & Flay, B. (2016). Does substance use moderate the association of neighborhood disadvantage with perceived stress and safety in the activity spaces of urban youth? *Drug and Alcohol Dependence, 165*, 288–292. https://doi.org/10.1016/j.drugalcdep.2016.06.019
Nesbitt, L., Meitner, M. J., Girling, C., Sheppard, S. R. J., & Lu, Y. (2019). Who has access to urban vegetation? a spatial analysis of distributional green equity in 10 US cities. *Landscape and Urban Planning, 181*, 51–79. https://doi.org/10.1016/j.landurbplan.2018.08.007
Nesbitt, L., Sax, D. L., Quinton, J., Harris, L. M., Ordóñez Barona, C., & Konijnendijk, C. (2023). Greening practitioners worry about green gentrification but many don't address it in their work. *Ecology and Society, 28*(4). https://doi.org/10.5751/ES-14579-280429
Núñez-González, S., Delgado-Ron, J. A., Gault, C., Lara-Vinueza, A., Calle-Celi, D., Porreca, R., & Simancas-Racines, D. (2020). Overview of "systematic reviews" of the built environment's effects on mental health. *Journal of Environmental and Public Health, 2020*, 1–10. https://doi.org/10.1155/2020/9523127
Ortega-Williams, A., Booth, J. M., Fussell-Ware, D. J., Lawrence, Y. J., Pearl, D., Chapman, N., … Overby, Z. (2022). Using Ecological Momentary Assessments to understand Black youths' experiences of racism, stress, and safety. *Journal of Research on Adolescence, 32*(1), 270–289. https://doi.org/10.1111/jora.12733
Ortegon-Sanchez, A., McEachan, R. R. C., Albert, A., Cartwright, C., Christie, N., Dhanani, A., … Vaughan, L. (2021). Measuring the built environment in studies of child health—A meta-narrative review of associations. *International Journal of Environmental Research and Public Health, 18*(20), 10741. https://doi.org/10.3390/ijerph182010741
Page, M. J., McKenzie, J. E., Bossuyt, P. M., Boutron, I., Hoffmann, T. C., Mulrow, C. D., Shamseer, L., Tetzlaff, J. M., Akl, E. A., Brennan, S. E., Chou, R., Glanville, J., Grimshaw, J. M., Hróbjartsson, A., Lalu, M. M., Li, T., Loder, E. W., Mayo-Wilson, E., McDonald, S., & Moher, D. (2021). The PRISMA 2020 statement: An updated guideline for reporting systematic reviews. *BMJ, n71*. https://doi.org/10.1136/bmj.n71
Pinchak, N. P., Browning, C. R., Calder, C. A., & Boettner, B. (2022). Racial inequalities in adolescents' exposure to racial and socioeconomic segregation, collective efficacy, and violence. *Demography, 59*(5), 1763–1789. https://doi.org/10.1215/00703370-10210688
Kirtley, O., Kunkels, Y. K., Van, Heck. L., & Vermaelen, N. (2018). *The Experience Sampling Method (ESM) Item Repository*. *Myin-Germeys*. https://doi.org/10.17605/OSF.IO/KG376
Popay, J., Roberts, H., Sowden, A., Petticrew, M., Arai, L., Rodgers, M., Britten, N., Roen, K., & Duffy, S. (2006). *Guidance on the conduct of narrative synthesis in systematic reviews: A product from the ESRC Methods Programme*. https://doi.org/10.13140/2.1.1018.4643.
Rhew, I. C., Hurvitz, P. M., Lyles-Riebli, R., & Lee, C. M. (2022). Geographic ecological momentary assessment methods to examine spatio-temporal exposures associated with marijuana use among young adults: A pilot study. *Spatial and Spatio-Temporal Epidemiology, 41*. https://doi.org/10.1016/j.sste.2022.100479
Rivenbark, J. G., Copeland, W. E., Davisson, E. K., Gassman-Pines, A., Hoyle, R. H., Piontak, J. R., Russell, M. A., Skinner, A. T., & Odgers, C. L. (2019). Perceived social status and mental health among young adolescents: Evidence from census data to cellphones. *Developmental Psychology, 55*(3), 574–585. https://doi.org/10.1037/dev0000551
Ryan, R. M., Weinstein, N., Bernstein, J., Brown, K. W., Mistretta, L., & Gagné, M. (2010). Vitalizing effects of being outdoors and in nature. *Journal of Environmental Psychology, 30*(2), 159–168. https://doi.org/10.1016/j.jenvp.2009.10.009
Shiffman, S., Stone, A. A., & Hufford, M. R. (2008). Ecological Momentary Assessment. *Annual Review of Clinical Psychology, 4*(1), 1–32. https://doi.org/10.1146/annurev.clinpsy.3.022806.091415
Sui, Y., Ettema, D., & Helbich, M. (2022). Longitudinal associations between the neighborhood social, natural, and built environment and mental health: A systematic review with meta-analyses. *Health & Place, 77*, Article 102893. https://doi.org/10.1016/j.healthplace.2022.102893
Tao, Y., Chai, Y., Kou, L., & Kwan, M.-P. (2020). Understanding noise exposure, noise annoyance, and psychological stress: Incorporating individual mobility and the temporality of the exposure-effect relationship. *Applied Geography, 125*, Article 102283. https://doi.org/10.1016/j.apgeog.2020.102283
Tao, Y., Kou, L., Chai, Y., & Kwan, M.-P. (2021). Associations of co-exposures to air pollution and noise with psychological stress in space and time: A case study in Beijing, China. *Environmental Research, 196*, Article 110399. https://doi.org/10.1016/j.envres.2020.110399
Torku, A., Chan, A. P. C., Yung, E. H. K., & Seo, J. (2021). The influence of urban visuospatial configuration on older adults' stress: A wearable physiological-perceived stress sensing and data mining based-approach. *Building and Environment, 206*, Article 108298. https://doi.org/10.1016/j.buildenv.2021.108298
Torku, A., Chan, A. P. C., Yung, E. H. K., & Seo, J. (2022). Detecting stressful older adults-environment interactions to improve neighbourhood mobility: A multimodal physiological sensing, machine learning, and risk hotspot analysis-based approach. *Building and Environment, 224*, Article 109533. https://doi.org/10.1016/j.buildenv.2022.109533
Trela, C. J., Hayes, A. W., Bartholow, B. D., Sher, K. J., Heath, A. C., & Piasecki, T. M. (2018). Moderation of alcohol craving reactivity to drinking-related contexts by individual differences in alcohol sensitivity: An ecological investigation. *Experimental and Clinical Psychopharmacology, 26*(4), 354–365. https://doi.org/10.1037/pha0000206
Treloar, H., & Miranda, R. (2017). Craving and acute effects of alcohol in youths' daily lives: Associations with alcohol use disorder severity. *Experimental and Clinical Psychopharmacology, 25*(4), 303–313. https://doi.org/10.1037/pha0000133
Ulrich, R. S., Simons, R. F., Losito, B. D., Fiorito, E., Miles, M. A., & Zelson, M. (1991). Stress recovery during exposure to natural and urban environments. *Journal of Environmental Psychology, 11*(3), 201–230. https://doi.org/10.1016/S0272-4944(05)80184-7
van Roekel, E., Scholte, R. H. J., Engels, R. C. M. E., Goossens, L., & Verhagen, M. (2015). Loneliness in the faily lives of adolescents: An Experience Sampling study examining the effects of social contexts. *Journal of Early Adolescence, 35*(7), 905–930. https://doi.org/10.1177/0272431614547049
Vassos, E., Pedersen, C. B., Murray, R. M., Collier, D. A., & Lewis, C. M. (2012). Meta-analysis of the association of urbanicity with schizophrenia. *Schizophrenia Bulletin, 38*(6), 1118–1123. https://doi.org/10.1093/schbul/sbs096
Watkins, K. L., Regan, S. D., Nguyen, N., Businelle, M. S., Kendzor, D. E., Lam, C., Balis, D., Cuevas, A. G., Cao, Y., & Reitzel, L. R. (2014). Advancing cessation research by integrating EMA and geospatial methodologies: Associations between tobacco retail outlets and real-time smoking urges during a quit attempt. *Nicotine and Tobacco Research, 16*(SUPPL2). https://doi.org/10.1093/ntr/ntt135
Sabatelli, M., Osmani, V., Mayora, O., Gruenerbl, A., & Lukowicz, P. (2015). Correlation of significant places with self-reported state of bipolar disorder patients. *Proceedings of the 2014 4th International Conference on Wireless Mobile Communication and Healthcare - "Transforming Healthcare Through Innovations in Mobile and Wireless*

Technologies", MOBIHEALTH 2014, 116–119. doi: 10.1109/MOBIHEALTH.2014.7015923.

World Health Organization. (2022). *Urban Health Repository*. https://Urbanhealth-Repository.Who.Int/.

Xiang, L., Cai, M., Ren, C., & Ng, E. (2021). Modeling pedestrian emotion in high-density cities using visual exposure and machine learning: Tracking real-time physiology and psychology in Hong Kong. *Building and Environment, 205*, Article 108273. https://doi.org/10.1016/j.buildenv.2021.108273

Zhang, Y., Li, D., Li, X., Zhou, X., & Newman, G. (2024). The integration of geographic methods and ecological momentary assessment in public health research: A systematic review of methods and applications. *Social Science & Medicine, 354*, Article 117075. https://doi.org/10.1016/j.socscimed.2024.117075