




BMJ Open ECO-MIND: enhancing pro-environmental behaviours and mental health through nature contact for urban youth – a research protocol for a multi-country study using geographic ecological momentary assessment and mental models

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To cite: Bubalo M, van den Broek K, Helbich M, *et al.* ECO-MIND: enhancing pro-environmental behaviours and mental health through nature contact for urban youth – a research protocol for a multi-country study using geographic ecological momentary assessment and mental models. *BMJ Open* 2024;**14**:e083578. doi:10.1136/bmjopen-2023-083578

► Prepublication history for this paper is available online. To view these files, please visit the journal online (<https://doi.org/10.1136/bmjopen-2023-083578>).

Received 22 December 2023
Accepted 03 September 2024



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ABSTRACT

Introduction Urban youth are experiencing increasing mental health problems due to diverse personal, social and environmental concerns. Youths' detachment from natural environments, including green and blue spaces, may intensify such issues further. Contact with nature can benefit mental health and promote pro-environmental behaviour (PEB). Yet, only a few studies assess these relationships among the youth usually ignoring effects of living in diverse urban contexts, and everyday nature experiences. ECO-MIND will investigate whether urban youth's dynamic greenspace exposure and their mental models about nature connectedness explain the associations between greenspace exposure, mental health and PEB in multiple urban contexts.

Methods and analysis We will collect data from university students from the Global South (ie, Dhaka, Kampala) and Global North cities (ie, Utrecht). Participants aged 18–24 will be recruited through stratified random sampling. We will use geographic ecological momentary assessment to assess respondents' everyday experiences and exposure to greenspaces. Our definition of greenspace exposure will be based on the availability, accessibility and visibility of greenspaces extracted from satellite and street view images. We will administer a baseline questionnaire to participants about mental health, nature connectedness and PEB characteristics. Further, we will ask participants to build mental models to show their perception of nature connectedness. Finally, we will fit partial least square structural equation models and multi-level models to our longitudinal geographic momentary assessment data.

Ethics and dissemination The study was approved by the Ethical Review Board of the Utrecht University (Geo S-23221). Informed consent must be given freely, without coercion and based on a clear understanding of the participation in the study. Findings will be disseminated in peer-reviewed journals and at conferences. Furthermore, we will implement public engagement activities (eg, panel

STRENGTHS AND LIMITATIONS OF THIS STUDY

- ⇒ A comparative approach will be used to unpack geographic differences in greenspace exposure, mental health and pro-environmental behaviour among youth in the Global South and North.
- ⇒ Innovative geotechnologies and data-driven methods, including global positioning system-based tracking, geographic ecological momentary assessment and computer vision modelling, will be employed to collect and analyse diverse data.
- ⇒ Repeated measures throughout each day for two consecutive weeks will enable us to capture the dynamic greenspace exposure and day-to-day experiences. We will unpack youth's perceptions of nature connectedness using mental models.
- ⇒ Due to the study's observational nature, causal relations will not be inferable.

discussion) to share results among local stakeholders and policymakers and cocreate policy briefs.

INTRODUCTION

Today, more than 54% of the global population lives in urban areas, and the United Nations estimates suggest that by 2050 the number will increase to 68%. According to the World Youth Report (2020), youth accounts for 16% of the global population, and there are currently 1.2 billion young people aged 15–24.¹ Due to diverse social, environmental and personal concerns, urban youth are experiencing increasing mental health problems such as anxiety or depression.^{2–4}

Young people are living increasingly urban, sedentary and technologically centred lives,

which leads to less time spent in nature.⁵ This detachment from natural environments, including green (eg, parks, forests) and blue spaces (eg, water bodies), can intensify mental health problems. On the other hand, greenspace contact can lead to various health benefits,^{6,7} and there are theoretical grounds explaining pathways linking greenspace to health. Markevych *et al*⁸ suggest three pathways for how exposure to greenspace benefits health, including reducing harm (eg, filtering air pollutants and noise, mitigating heat), restoring capacities (eg, attention restoration and physiological stress recovery) and building capacities (eg, encouraging physical activity and facilitating social cohesion). Focusing on the mental health benefits, Bratman *et al*⁹ propose a conceptual model for the mental health effects derived from nature experience that comprises a four-step assessment: gathering information regarding the natural features (step 1), calculating nature exposure (step 2), accounting for the experiential characteristics of nature exposure (step 3) and finally characterising potential mental health impacts that follow from nature experience (step 4).

Some (but not all) studies demonstrate that exposure to nature positively affects mood and mental health and is associated with pro-environmental behaviours (PEBs).^{10–14} For example, higher exposure to greenness is inversely related to reporting stress at school, university or workplace among young adults.¹⁵ Yet, it is suggested that nature exposure alone is not always sufficient for these benefits to become apparent, as an individual also needs to feel psychologically connected to nature (ie, nature connectedness).¹⁶ Moreover, existing studies recognise that nature connectedness is positively associated with mental health and PEB.¹⁷ However, only a few studies assess these relationships among the youth.^{18,19}

To our knowledge, we are the first to use mental models in greenspace research. In our context, mental models refer to internal representations constructed by individual's cognition to structure and interpret external environments.^{20,21} Mental models can help us increase our understanding of a particular system and demonstrate similarities and difference in system perception between different participants.²² We will explore how people's mental models, including the perceived causes and consequences of nature connectedness, might influence the relations between greenspace contact, mental health and PEB.

Another aspect that still needs to be addressed is a more comprehensive geographical coverage. Several reviews stress the need for more cross-cultural studies.^{23–25} These studies should include multiple locations with different population sizes, urban densities, and demographic and socioeconomic population groups. Further, the reviews advise assessing the frequency and duration of exposure to greenspace and subsequent attitudes towards nature.^{23–25} However, these calls for research in diverse urban contexts remain unaddressed.

There is a limited evidence base with regards to longitudinal studies assessing the access and exposure to green

and blue spaces and their beneficial impacts on humans.²⁶ Therefore, a need is recognised in the current literature for more longitudinal research to assess the duration and frequency of time spent in nature and how this is associated with nature connectedness, mental health and PEB.²⁴ DeVille *et al*²⁴ have suggested that future studies use geographic ecological momentary assessment (GEMA), which involves the repeated sampling of participants' current behaviours, emotions and experiences in real-time as they move through (natural) environments. In contrast to cross-sectional studies, GEMA allows real-time tracking of experiences in the real world, reducing retrospective bias.²⁷ To summarise, there have not yet been studies among the youth that focus on the link between nature exposure, nature connectedness, mental health and PEB in a cross-cultural context.

Our research will fill these critical knowledge gaps by investigating whether urban youth's perceptions of nature connectedness affect the impact of nature exposure on mental health and PEB in multiple cities in varying geographical contexts. Figure 1 shows the research design flow. To accomplish the research aim, we will answer the following research questions:

1. Do urban youth who spend more time in greenspace self-report better mood, lower stress and higher well-being compared with the youth who spend less time in greenspace?
2. Does an individual experience lower stress levels, better mood and higher well-being when they are in greenspace compared with when they are in a built environment?
3. How are various greenspace exposure types (ie, availability, accessibility and visibility) related to mental health and PEB among urban youth?
4. Do nature connectedness and mental models mediate these associations?

In relation to the research questions, we have developed the following hypotheses:

H1: We expect youth who spend more time in greenspace to report better mood, less stress and higher well-being compared with youth who spends less time in greenspace.

H2: We hypothesise that an individual's mood will be better, they will be less stressed, and they will report higher well-being when exposed to greenspace instead of a built environment.

H3: We hypothesise that (a) greater greenspace exposure will be positively associated with better mental health and (b) greater greenspace exposure will be positively associated with PEBs.

H4: We anticipate that (a) greenspace exposure will be positively associated with nature connectedness (ie, as greenspace exposure increases, nature connectedness is expected to increase), (b) nature connectedness will be positively associated with PEBs and better mental health (ie, as nature connectedness increases, PEBs are expected to increase and mental health is expected to improve) and (c) mental model of nature connectedness

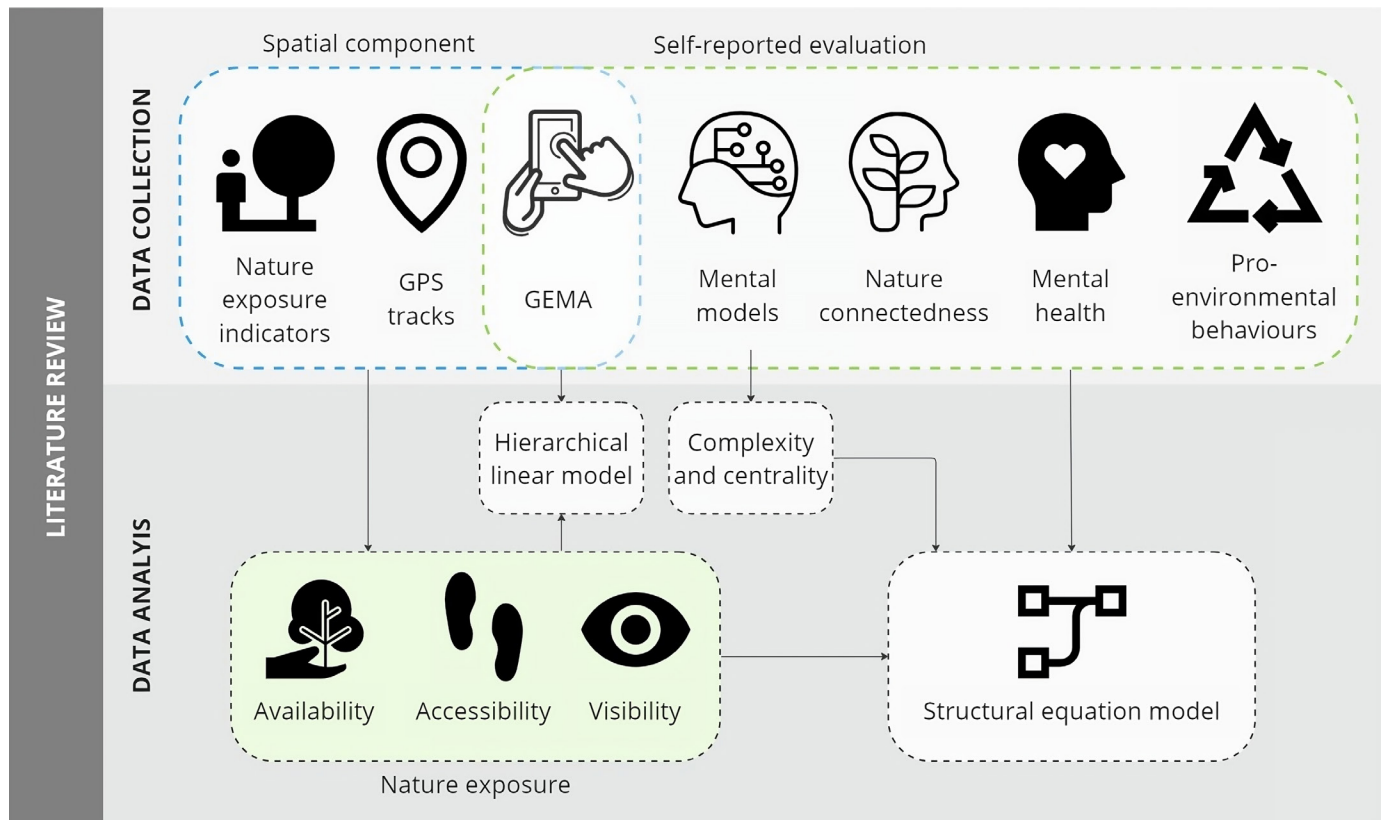


Figure 1 Research design flow. GEMA, geographic ecological momentary assessment.

will mediate the relationships between greenspace exposure and outcome variables (PEB and mental health).

The findings from this study should aid the creation and implementation of policies and urban planning practices to improve mental health and stimulate PEB among urban youth using nature-based solutions and interventions.

METHODS AND ANALYSIS

Data collection

Study area

This observational study will be conducted in multiple countries with data collection occurring from September 2024 to July 2025. We will study the urban youth population in two cities in the Global South (ie, Dhaka, Bangladesh, and Kampala, Uganda) and one in the Global North (ie, Utrecht, The Netherlands). We selected cities from three different continents because we wanted to expand our study's geographical representation outside the WEIRD (ie, Western, Educated, Industrialised, Rich and Democratic) societies.²⁸ By ensuring variations in culture and contexts, we will be able to assess if youth's connectedness with nature varies under diverse conditions.²⁹ Nature connectedness scholarship is needed across various cultures to understand possible differences in how multiple populations understand the concept.²³

Recruiting of participants

Participants will be eligible when they are aged 15–24 as per the United Nation's definition of youth.³⁰ We will focus on university students who are 18 years or older due to concerns regarding the recruitment, consent procedures and accessibility of this population. We will collect primary data over a period of 6 months. We chose to study university students because they often face stressful circumstances. For example, students must bear the brunt of university level education,³¹ as well as confront anxiety about climate change.³² With this in mind, we consider the student population particularly vulnerable to mental health issues, especially in recent years. To illustrate, the National Institute for Public Health and the Environment in the Netherlands found that 51% of students struggle with psychological issues.³³ We will recruit 660 participants (220 per study location). We based the sample size on the recommended sample size for a partial least square structural equation model (PLS-SEM).³⁴ As PLS-SEM will be the final modelling approach in this study (details in the Data analysis section), we determine the sample size based on the guideline for PLS-SEM. We are interested in nine paths in the model. We will use a significance level of 1% and expect the model to explain at least 10% of the variance ($R^2=0.10$). Based on these criteria, the recommended sample size is 204. In order to recruit students in Utrecht, we will publicise the study through newsletters and leaflets distributed on the campus and we will make announcements in various courses across

study programmes. We will recruit students in Dhaka and Kampala with the help of our local project partners and research assistants from the Bangladesh University of Engineering and Technology in Dhaka and the Kyambogo University in Kampala. The research assistants will undergo a 3-day training course. Teams of research assistants will actively recruit students on campus by distributing leaflets. As the study requires a certain level of dedication from the participants, we will offer them incentives to keep them motivated throughout the data collection period. We will offer participants vouchers for gift cards or mobile data. This will be done in all three study locations and the types of vouchers will be adjusted to the local context. To be eligible for the vouchers, participants must complete all parts of the study (ie, mental models, survey, GEMA).

Literature review

We will start the study by conducting an umbrella review of systematic literature reviews. Such an umbrella review provides a comprehensive summary of the evidence by synthesising the existing review articles published on a specific topic.³⁵ We will carry out an umbrella review to summarise existing research syntheses on the outcomes of greenspace exposure and nature connectedness on mental health and PEB. The literature search and data extraction will follow Preferred Reporting Items for Systematic Reviews and Meta-Analyses guidelines. The study synthesis will serve as a basis for further operationalisation of variables for subsequent project stages. The findings from the umbrella literature review will be reported in a separate publication. This comprehensive umbrella review will highlight gaps in the current literature and provide recommendations for future research. Additionally, it will help identify the most significant factors that influence mental health and PEB, guiding subsequent empirical studies.

Baseline survey

We will conduct a baseline survey before the GEMA/GPS tracking. We will use the Kessler Psychological Distress Scale (K10) to measure baseline mental health. This instrument consists of 10 questions about emotional states over the last 4 weeks with a 5-point Likert response scale. The answers range from 'none of the time' to 'all of the time'. The maximum score is 50, indicating severe distress, and the minimum score is 10, indicating no distress.³⁶ K10 has shown good reliability in Dutch³⁷ and Ugandan adults.³⁸ The shorter version of the scale (K6) has been validated among the student population in Dhaka.³⁹ It proved to be an acceptable instrument to assess the psychological distress of Bangla-speaking young people.

Additionally, we will use the WHO Well-Being Index (WHO-5) to measure psychological well-being over the last 14 days. The WHO-5 consists of five positively phrased items, for example, 'I have felt cheerful and in good spirits' and 'I have felt calm and relaxed'. Each item is

scored from 5 ('all of the time') to 0 ('none of the time'). The score ranges from 0 ('absence of well-being') to 25 ('maximal well-being').⁴⁰

We will use the six question Nature Relatedness Scale (NRS) to measure affective and experiential aspects of an individual's nature connection.⁴¹ This scale has recently been validated as reliable in a cross-cultural context across four countries: Canada, Hungary, India and South Korea.⁴² To rate the levels of agreement, answers are on a 5-point Likert scale (1=strongly disagree, 5=strongly agree). Examples of items included in the NRS are 'My ideal vacation spot would be a remote wilderness area' and 'I always think about how my actions affect the environment'.

We will rate PEB on the General Ecological Behaviour (GEB) scale—adolescent version.⁴³ The instrument was developed for cross-cultural applications, and it is considered to be the best-established measure based on its frequency of use and thoroughness of psychometric evaluation according to Lange and Dewitte.⁴⁴ It captures behaviour-based environmental attitude as a composite score of 40 items. The behaviours can be grouped into energy conservation, mobility and transportation, waste avoidance, recycling, consumerism and vicarious behaviours toward conservation.⁴³ A study with secondary school students in Tanzania adapts 16 items of the GEB scale to measure self-reported PEBs. It considers four behavioural types: recycling, environmental pollution management, environmental activism and biodiversity protection.⁴⁵

GEMA and GPS data collection

GEMA is increasingly used to capture human-environment interactions by assessing psychological stress in relation to urban greenspace.^{46 47} We will use a time-contingent, semi-random experience sampling design where prompts will be geocoded. We opted for a semi-random sampling as it has higher ecological validity than a fixed sampling scheme,²⁷ a relatively low participant burden leading to a higher chance of good compliance, and is appropriate when the concept of interest may fluctuate dynamically over the day⁴⁸ (eg, mood and stress levels⁴⁹). Besides that, we will track people's day-to-day mobility using the smartphone-embedded GPS with a locational sampling interval of 20s when the subject is in motion. Such intervals have been used previously⁵⁰ and are a compromise between battery consumption and tracking accuracy. The GEMA and the location tracking will be integrated into a mobile app, which participants will use for two consecutive weeks. Using an app running on smartphones is advantageous as each participant is likely to carry it throughout the day and makes it possible to obtain larger samples.⁵¹ However, we are aware that requiring participants to carry and use a smartphone throughout the day can introduce some biases. For example, those young adults who do not own a smartphone or are not comfortable using it (eg, individuals from lower socioeconomic backgrounds or with certain disabilities), might be excluded from the

study. This may skew the results towards a more affluent and tech-savvy young population. As we will assess the participants' socioeconomic status through the survey, we should be able to control for the potential discrepancies. We will use mobile phone application (eg, MovisensXS), available on the Android operating system and used elsewhere.^{52–54} In Uganda and Bangladesh, Android is the main smartphone operating system used, as it dominates the market due to the availability of more affordable Android devices compared with iOS devices.⁵⁵ However, in the Netherlands there is a larger proportion of people using iOS devices which may introduce a selection bias in our study.⁵⁵

GEMA design

The GEMA app will prompt participants' experiences throughout the day. Prompts will be sent between 08:00 and 20:00 using semi-random sampling. The period will be divided into six intervals of 2 hours, and a prompt will appear randomly within each interval. In total, participants will receive six prompts per day, each at least 30 min apart from each other. Once the prompt appears, participants will have 30 min to answer the questions; otherwise, the prompt will be skipped. We will use an 80% compliance threshold as recommended by Stone and Schiffman,⁵⁶ meaning that participants who answer to less than 80% of the prompts will be excluded from the analysis. Participants will be asked to complete questions related to their stress levels (Do you feel stressed right now?), mood (What is your current mood?) and well-being (How happy do you feel right now?). The answers will be given on a 7-point Likert scale. To better understand how social context contributes to an individual's experience variability, we will also ask participants if they are alone or in company. The total time for completing the questionnaire is no longer than 1 min. We will conduct a pilot study among students in Utrecht to assess the EMA design, including the questions' length, phrasing and order.

Greenspace exposure assessment

To assess participant's greenspace exposure, we need to know their whereabouts captured through GPS tracking. The GPS tracks will capture distinct types of greenspace contact and the duration and frequency of greenspace exposure. We will use multiple greenspace exposure types.⁵⁷ The data on the *availability*, *accessibility* and *visibility* of nature will be derived from several data sources:

1. *Availability* will be measured as the physical amount of greenspaces (eg, percentage of canopy) along people's daily mobility routes. These measures will be derived from satellite imagery (ie, Sentinel data with a 10 m spatial resolution) and expressed as Normalised Difference Vegetation Index.⁵⁸
2. *Accessibility* will be measured as spatial proximity between greenspaces and the locations of interest (eg, home, university).⁵⁹ Using spatial network analysis, we will determine the distances to the nearest greenspace

from the addresses of interest (eg, home, campus, employment location). Greenspace data, such as publicly accessible green open spaces, will be collected from national or city authorities or OpenStreetMap.

3. *Visibility* will be measured as the amount of greenness (ie, trees, parks) that can be seen from a particular location (eg, home). We will use street network data from OpenStreetMap and street view images from Mapillary to measure greenspace visibility. We will apply image segmentation techniques to derive the amount of visible greenspace.⁶⁰ We will test and compare the accuracy of multiple deep learning image segmentation models, such as Xception-71 CNN and Mask2Former.⁶¹

Models to measure these indicators of greenness are already available. Using buffer analysis, we will measure greenspaces along the geotracked travel routes and activity locations participants visit throughout the day.⁶² We will use buffers of 50 m to determine the presence or absence of greenspaces and estimate visible greenery. The 50-metre buffer is selected as it includes a person's immediate surroundings.⁵⁹ Further, we will test 300-metre buffers, commonly used in mental health studies.⁵⁹

Mental models data collection

Mental models will be used to map the perceived causes and consequences of nature connectedness. We will use the M-tool.⁶³ The M-tool was designed to have a standardised format and it can successfully capture mental models among diverse participants.⁶⁴ We will implement a two-step approach in which the mental model concepts will first be generated through a short pilot survey carried out in all three study sites, and a literature review. We will aim for a sample size of 20–50 participants per study location, totalling 60–150 participants as done elsewhere.^{65 66}

The survey will consist of two open-ended questions. We will ask the participants to list their perceived causes and consequences of nature connectedness. Thereafter, we will present participants with a list of relevant concepts derived from the literature and ask participants to select 5–10 most important concepts. The answers to open-ended questions will be coded and compared with the predefined list. A set of 10–15 most often stated concepts will be derived from the answers. If there is an overlap in the listed concepts between the three study locations, we will use the same fixed set of concepts in all three countries. If the concepts significantly differ per study location, we will use region-specific settings with the same number of concepts (10–15) across all three study locations.

In the second step, the final set of concepts will be included in the M-tool and depicted as pictograms as illustrated in figure 2. The pictograms will be accompanied with an audio explanation. Our total sample of 660 participants will be asked to decide for each concept if it influences or is influenced by nature connectedness. Consequently, participants will be asked to connect the selected pictograms to the nature connectedness pictogram using weighted arrows. There are three sizes of the

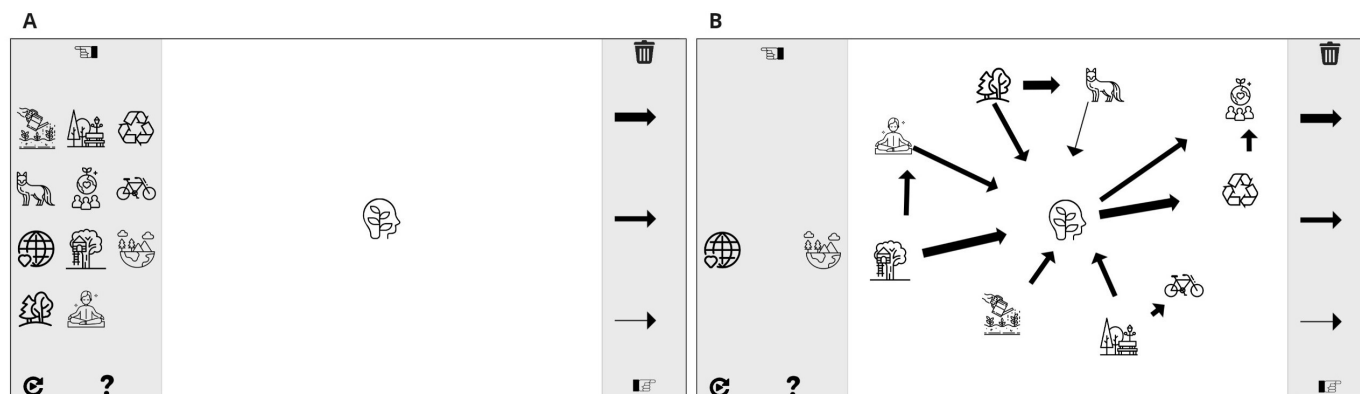


Figure 2 Screenshots of M-tool: (A) mental model mapping screen, (B) example of a cognitive map. Icons are placeholders.

arrows, each corresponding to the strength of the influence (ie, weak, moderate and strong).

Data analysis

Geographic, ecological momentary assessment

To assess associations, as stated in the first and second research question, between short-term greenspace exposure, stress levels, mood and happiness, we will develop hierarchical linear models (HLM). Such models are necessary because GEMA data is nested within persons. We will investigate within-person and between-person associations.²⁷ Time-varying exposures and covariates will be divided into person-specific means (ie, between-person component) and deviations from the means (ie, within-person component), to separate the level-specific estimation.⁶⁷ Further, the number of measures for each person or group can vary in HLM. Given that some individuals may only complete a small number portion of GEMA surveys, whereas some individuals may complete nearly all GEMA surveys, HLM has multiple benefits (eg, it has higher power in finding effects and contrasts in the data and it is robust against missing data).⁶⁸ We will adjust for the covariates, including time spent in nature, sex, age, university level, income, employment and accommodation. The analysis will be conducted in R⁶⁹ using the lme4 package.⁷⁰

Mental models

We will analyse mental models using network analysis.⁶⁶ The M-tool data will be imported into R, where it will be analysed by computing model complexity and the centrality of variables.⁶⁶ Model complexity comprises the number of concepts included in the model and the number of connections between the concepts.⁶³ We will calculate four node-specific measures for each participant's mental model: (a) a binary variable indicating node selection, (b) the in-strength of the node, (c) the out-strength of the node and (d) the betweenness of the node. The latter three measures comprise centrality measures that capture the location and importance of a variable within the network.⁷¹ We will create groups of participants based on their responses to the nature connectedness survey using the percentile method. The

cut-off points will be determined based on the answers given using the NR-6 scale. The scale consists of six statements on a 5-point Likert scale. The maximum score is 30 (ie, highest nature connectedness), while the minimum score is 6 (ie, lowest nature connectedness). We will group the responses into low, medium and high (tertiles). Further, we will group participants based on their self-reported PEB into those engaging in PEB rarely, sometimes and often. Correspondingly, we will compare the content and the complexity of mental models between the relevant subsets.

Structural equation modelling

The three objective greenspace exposure measures will relate to the subjective responses captured through GEMA, mental models and self-reported questionnaires to answer the third and fourth research question. **Figure 3** illustrates the pathways included in the model. As the collected data will be temporal, we will conduct PLS-SEM to test the relations between greenspace exposure, nature connectedness, mental models, mental health and PEB. Mental models will be included in the structural equation model by computing several network metrics applied to each participant. We will measure the degree of connectedness in the system by dividing the number of connections by the number of concepts.⁷² Further, we will include the complexity of mental models measured as the number of concepts included in the model and the number of connections per concept.⁶³ Following recommendations,³⁴ we will examine several fit statistics (eg, standardised root mean square residual and root mean square residual covariance) to validate the model.³⁴

Patient and public involvement

None.

Ethics, data management and dissemination

Ethics

The legal basis for processing personal data within this study will be the General Data Protection Act of the European Union. As we will collect privacy-sensitive data, special care will be taken to ensure the confidentiality and anonymity of the data. Personal data will be protected

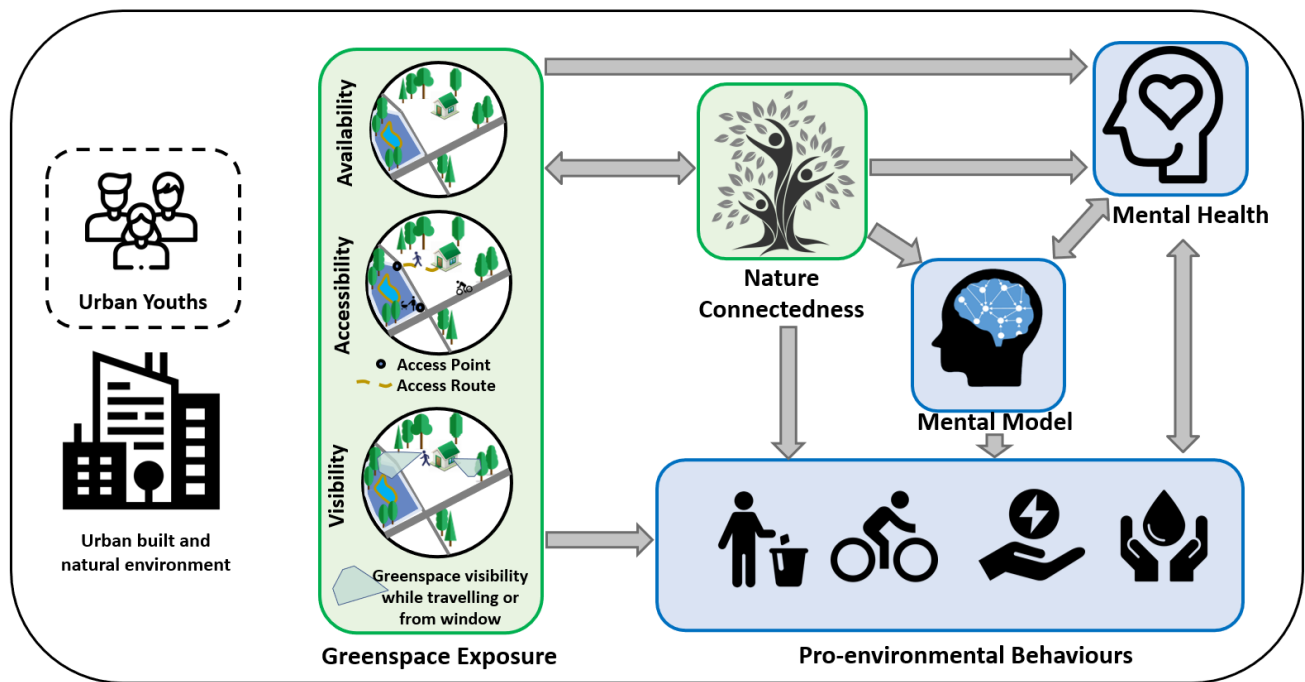


Figure 3 Conceptual model.

per design throughout the research cycle using technical (eg, secure workstations) and organisation measures (eg, documenting the operating procedures). We will only collect and process personal data that is strictly necessary to achieve our research objectives. Informed consent of participants will be given in written. Informed consent is vital to respect participant's rights to free choice and data privacy. Compliance must be given freely, without coercion and based on a clear understanding of participation before study inclusion. The Ethics Review Board of Utrecht University granted ethical approval for the entire study (Geo S-23221).

Data management

Data processing will be conducted within the secure information technology environment of Utrecht University. In compliance with Dutch law and European regulations, the data security and data protection strategies were approved through a privacy impact assessment at Utrecht University. We have set up a data management plan, which will be kept up to date.

Dissemination

We will ensure the data is re-usable and verifiable by adhering to the FAIR principles. To make sure the data is findable, data will be indexed through digital object identifiers. Data and programming code (eg, R-scripts) will be open and usable via GitHub. We will ensure the data is interoperable by using data formats and standards approved by the Open Geospatial Consortium to ease data exchange and platform-independent use. Finally, the data will be reusable

as we publish the collected data and models on the Open Science Framework, ensuring transparency and reproducibility.

We will disseminate the study findings through five peer-reviewed open-access journal papers. Researchers in Dhaka and Kampala will be invited to contribute to the analysis, interpretation and writing of the manuscript, and as per the CRediT taxonomy (<https://credit.niso.org/>) outlined contribution level, they will be listed as coauthors of the paper. Additionally, results will also be disseminated through conference presentations. Furthermore, we will distribute the study findings among local stakeholders and policymakers through public engagement activities such as panel discussions, community forums and online webinars. We will also leverage our network of local researchers and research assistants to ensure a broad dissemination and to encourage a public dialogue. Finally, we will add regular updates to our project website.

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Funding This work was supported by Dean's Policy Resources 2023, Geoscience Faculty Utrecht University grant number [3.4FB221220]. The project runs from 2023 to 2027.

Disclaimer The funders had no role concerning the study design or the data collection, analysis, interpretation or dissemination.

Competing interests None declared.

Patient and public involvement Patients and/or the public were not involved in the design, or conduct, or reporting, or dissemination plans of this research.

Patient consent for publication Not applicable.

Provenance and peer review Not commissioned; externally peer reviewed.

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