BMJ Open

Urban environment and mental health: the NAMED project, a mixed method approach

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-031963
Article Type:	Protocol
Date Submitted by the Author:	28-May-2019
Complete List of Authors:	Lauwers, Laura; University of Antwerp Faculty of Medicine and Health Sciences, Department of Primary and Interdisciplinary Care Trabelsi, Sonia; Université catholique de Louvain, Center for Operations Research and Econometrics Pelgrims, Ingrid; Sciensano, Department of Risk and Health Impact Assessment Bastiaens, Hilde; University of Antwerp Faculty of Medicine and Health Sciences, Department of Primary and Interdisciplinary Care De Clercq, Eva ; Sciensano, Department of Risk and Health Impact Assessment Guilbert, Ariane ; Sciensano, Department of Risk and Health Impact Assessment Guyot, Madeleine; Université catholique de Louvain, Center for Operations Research and Econometrics Leone, Michael; Research Institute for Nature and Forest, Nature and Society Team Mortelmans, Dieter; Research Institute for Nature and Forest, Nature and Society Team Nawrot, Tim; Hasselt University, Centre for Environmental Sciences; Catholic University College Leuven, Department of Public Health and Primary Care Van Nieuwenhuyse, An; Laboratoire National de Santé, Department of Health Protection Remmen, Roy; University of Antwerp, Faculty of Medicine and Health Sciences, Department of Primary and Interdisciplinary Care Saenen, Nelly; Hasselt University, Centre for Environmental Sciences Thomas, Isabelle; Université catholique de Louvain, Center for Operations Research and Econometrics Keune, Hans; University of Antwerp Faculty of Medicine and Health Sciences, Department of Primary and Interdisciplinary Care; Research Institute for Nature and Forest, Belgian Biodiversity Platform, Nature and Society Team
Keywords:	urban environment, MENTAL HEALTH, mixed method, built and non-built environment, air and noise pollution

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Urban environment and mental health: the NAMED project, a mixed method approach

Laura Lauwers, Sonia Trabelsi, Ingrid Pelgrims, Hilde Bastiaens, Eva M De Clercq, Ariane Guilbert, Madeleine Guyot, Michael Leone, Dieter Mortelmans, Tim Nawrot, An Van Nieuwenhuyse, Roy Remmen, Nelly Saenen, Isabelle Thomas, Hans Keune

Corresponding author:

Laura Lauwers
Department of Primary and Interdisciplinary Care
Faculty of Medicine and Health Sciences
University of Antwerp
Gouverneur Kinsbergencentrum 00.58.
Doornstraat 331
Wilrijk, 2610
Belgium
Phone: 32 489097822
Email: laura.lauwers@uantwerpen

First authors and associations:

Laura Lauwers
laura.lauwers@uantwerpen.be
Department of Primary and Interdisciplinary Care, Faculty of Medicine and Health Sciences, University of Antwerp, Antwerp, Belgium

Sonia Trabelsi
s.trabelsi@uclouvain.be
Center for Operations Research and Econometrics, Université catholique de Louvain, Louvain-la-Neuve, Belgium

Ingrid Pelgrims
Ingrid.Pelgrims@sciensano.be
Department of Risk and Health Impact Assessment, Sciensano, Brussels, Belgium

Co-authors

Hilde Bastiaens
hilde.bastiaens@uantwerpen.be
Department of Primary and Interdisciplinary Care, Faculty of Medicine and Health Sciences, University of Antwerp, Antwerp, Belgium

Eva M De Clercq
Eva.DeClercq@sciensano.be
Department of Risk and Health Impact Assessment, Sciensano, Brussels, Belgium

Ariane Guilbert
aguilbert.prof@laposte.net
Department of Risk and Health Impact Assessment, Sciensano, Brussels, Belgium

Madeleine Guyot
madeleine.guyot@uclouvain.be
Center for Operations Research and Econometrics, Université catholique de Louvain, Louvain-la-Neuve, Belgium

Michael Leone
michael.leone@inbo.be
Nature and Society Team, Research Institute for Nature and Forest (INBO), Brussels, Belgium

Dieter Mortelmans
dieter.mortelmans@inbo.be
Nature and Society Team, Research Institute for Nature and Forest (INBO), Brussels, Belgium

Tim Nawrot
tim.nawrot@uhasselt.be
Centre for Environmental Sciences, Hasselt University, Hasselt, Belgium
Department of Public Health and Primary Care, Leuven University, Leuven, Belgium

An Van Nieuwenhuyse
An.vanNieuwenhuyse@lns.etat.lu
Laboratoire National de Santé, Department of Health Protection, Dudelange, Luxembourg

Roy Remmen
roy.remmen@uantwerpen.be
Department of Primary and Interdisciplinary Care, Faculty of Medicine and Health Sciences, University of Antwerp, Antwerp, Belgium

Nelly Saenen
nelly.saenen@uhasselt.be
Centre for Environmental Sciences, Hasselt University, Hasselt, Belgium

Isabelle Thomas
isabelle.thomas@uclouvain.be
Center for Operations Research and Econometrics, Université catholique de Louvain, Louvain-la-Neuve, Belgium

Hans Keune
hans.keune@inbo.be
Belgian Biodiversity Platform, Nature and Society Team, Research Institute for Nature and Forest (INBO), Brussels, Belgium
Chair Care and the Natural Living Environment, Department of Primary and Interdisciplinary Care, Faculty of Medicine and Health Sciences, University of Antwerp, Antwerp, Belgium

Word count: 3850

ABSTRACT

Introduction: Mental health issues appear as a growing problem in modern societies and tend to be more frequent in big cities. Where increased evidence exists for positive links between nature and mental health, associations between urban environment characteristics and mental health are still not well understood. These associations are highly complex and require an interdisciplinary and integrated research approach to cover the broad range of mitigating factors. This article presents the study protocol of a project called NAMED that aims to generate a more complete understanding of associations between mental health and the urban environment.

Methods and analysis: Following a mixed method approach, this project combines quantitative and qualitative research. In the quantitative part, data on Brussels' (non)-built environment, air and noise pollution are coupled to data of the national health interview survey. Linkage is done at individual level. We analyze relationships between mental health and urban environment indicators using multivariate regression models, taking respondents' socio-economic status, lifestyle, age, and gender into account. We assess the mediating role of physical activity, social life, noise and air pollution in associations between mental health and (non-)built environment using structural equation modelling. In the qualitative part, we conduct interviews with Brussels residents to record individual perceptions on associations between urban environment and mental health. We apply a thematic analysis on transcripts of the audio-recorded interviews. In the validation part, results from these two approaches are triangulated and evaluated through interviews and focus groups with stakeholders of healthcare and urban planning sectors.

Ethics and dissemination: The Privacy Commission of Belgium and ethical committee from University Hospital of Antwerp respectively approved quantitative database merging and qualitative interviewing. We will share project results with a wide audience including the scientific community, policy authorities and civil society through scientific and non-expert communication.

Keywords: urban environment; mental health; mixed method; built and non-built environment; air pollution; noise pollution

ARTICLE SUMMARY

Strengths and limitations of this study

- The NAMED project mixes quantitative and qualitative methods to obtain a more comprehensive understanding of the association between urban environment and mental health.
- The NAMED project applies and combines a variety of indicators for mental health and the urban environment to investigate various components of mental health with differences in severity and various aspects of the urban environment to create a more detailed description of the surroundings of urban dwellers, closer to individual perceptions.
- The NAMED project couples urban environment indicators and mental health indicators at individual level to capture the complexity of this relationship influenced by very local environmental factors and individual attributes.
- The NAMED project includes a validation phase in which key stakeholders and experts can evaluate the quality of the project and direct outcomes relevant from a societal practice perspective.
- The NAMED project intends to draw general conclusions and recommendations, but due to limitation in time and space, some outcomes are expected to be context-specific and not applicable in the long-term.

INTRODUCTION

According to the World Health Organisation (WHO) depression alone affects around 300 million people worldwide.[1] In Belgium, the Health Interview Survey (HIS) underlined a deterioration of the psycho-emotional health of the population: the proportion of respondents presenting psychological difficulties increased from 25% to 32% between 2008 and 2013. These included anxiety, depressive disorder, or sleep disorders. Strikingly, these are more prevalent in the Brussels-Capital Region (40%) than in the two other Regions Wallonia (35%) and Flanders (29%).[2]

It is now well-established that the nature, prevalence, and age of onset of mental disorders vary according to demographic, socioeconomic, and cultural factors.[2-6] Several international studies analyzed links between the urban environment and mental health from different research angles by looking at the urban social or physical environment.[7] The occurrence of psychosocial difficulties in Belgium is generally higher in cities.[7-10]
Concentrations of low socio-economic status, low social capital, or social segregation have been studied as social risk factors for mental health in cities.[7,8] Associations between the physical environment and mental health have been investigated in terms of noise pollution, air pollution, and urban design.[11-13] Regarding the latter, several studies highlighted positive associations between urban green and blue spaces and psychological, emotional, mental health, or stress reduction.[14] Others studied associations between mental health and the built environment in terms of walkability, access to care, and housing quality.[15-17] For instance, increased walkability has been associated with a decreased incidence of depression and enhanced physical activity.[15,16]

Conclusions tend however to differ or to be contradictory across studies as most studies relating the urban environment to mental health rely on a limited and different set of indicators. Most of the studies use a single indicator such as the “General Health Questionnaire 12” (GHQ-12 items) to describe mental health which makes it difficult to grasp diverse degrees of severity and to compare across studies.[7,14] Studies tend to investigate only one aspect of the urban environment, such as urban green space, overlooking the complexity of the urban landscape.[18] Studies relating urban green spaces to health issues often rely on a “standard” set of measures (proximity and access to green) and vegetation data (i.e. Normalized Difference Vegetation Index) with the risk of oversimplifying the perceptions of urban dwellers of their environment.[14] Many studies only look at SES as a potential determinant for associations between urban environment and mental health and risk to miss other key factors.[7,17] Finally, little is known on how citizens themselves experience the urban environment in relation to their mental health. Considering the increasing urbanization worldwide, it becomes clear that further research on which characteristics of the urban environment may be beneficial or detrimental for mental health, on pathways involved, and on the impact of social, economic, and cultural factors is needed.[19] In addition, there is a growing need to evaluate the quality and relevance of research results for practice.

The Nature Impact on Mental Health Distribution (NAMED) is a Belgian four-year project (2017 – 2021) that aims to further investigate the associations and underlying mechanisms between mental health and urban environment. To overcome the weaknesses of conducting only qualitative research, where the results cannot be

generalized, or only quantitative research, where individual understanding of these associations is limited, the project applies a mixed method approach, integrating qualitative and quantitative approaches. The qualitative research involves interviews with urban dwellers with the goal to analyze how they describe and experience the urban environment in relation to mental health. The quantitative research relies on data collected within the HIS and investigates how the (non-)built environment, air and noise pollution intertwine and relate to mental health, taking socioeconomic and lifestyle factors into account. To do so, we adapt, develop and combine a broad set of indicators to overcome the limitations of previous research. Eventually, in a validation stage, we discuss and evaluate together with experts and stakeholders the qualitative and quantitative results. The mixed method approach presented in this paper is conducted by a multidisciplinary team, including epidemiologists, geographers, general practitioners, and environmental and social scientists. The integration of both research parts will result in a comprehensive understanding of urban determinants of mental health, from individual to community scales.

Based on the research results, NAMED intends to draw recommendations for urban planning, health management, and policy. As representatives of the medical community are involved throughout the project, we expect the conclusions of NAMED to guide health practices in understanding better the role of the environment among factors affecting mental health. Additionally, NAMED will make suggestions for extension of the HIS (new approaches derived from the qualitative methods, new wordings or new questions relating to urban environment and mental health). Besides, the involvement of representatives of the urban planning sectors will guide a better integration of mental health issues in new urban development projects in order to elaborate more health-promoting cities.

METHODOLOGY

Study area

The study area is the Brussels-Capital Region (BCR). The BCR is one of the three administrative Regions of Belgium (besides Wallonia and Flanders) and comprises 19 municipalities. The BCR is 161.38 km² large and counts 1 198 726 inhabitants (01/01/2018) which means an average density of 7 428 inhabitants/km².[20] The BCR is the headquarter of several Belgian and European institutions as well as international companies. It can be considered as a green urban region as 54% of its surface area is covered by vegetation (forest, public green spaces, urban trees, private gardens, green boulevards, etc.).[21] However, a clear contrast in vegetation cover exists between the center and the outer parts of the Region. Besides difference in access to green, the neighborhoods are highly diverse in population density, median income, household composition, etc. BCR is also characterized by a high cultural diversity (40% non-belgian nationality and a mixed use of language (most spoken: French, English, Flemish and Arabic).[20,22]

Mixed method approach

The NAMED project is structured into two parts in a convergent parallel design:

The quantitative research part uses the data collected within the Belgian HIS in 2008 and 2013. It consists in (1) retrieving HIS respondents' home address, (2) developing relevant indicators characterizing each home addresses in terms of (non-)built environment, air and noise pollution using Geographical Information Systems (GIS) and (3) coupling these environmental indicators with HIS data. Based on this enriched database, this part investigates then associations between mental health and urban environment in a cross-sectional way, taking into account demographic, socioeconomic and lifestyle factors. The qualitative research part interviews Brussels inhabitants from different neighborhoods on how they experience their living environment in relation to what they express as their mental health.

This mixed method approach is conducted by combining disciplines and requires a constant interaction between the different researchers in order to adapt their investigations to others' findings. The main level of interaction between the quantitative and qualitative research part occurs at the results interpretation step which allows to investigate if the citizen's perceptions on the association between urban environment and mental health converge or diverge from quantitative findings. Following research questions are addressed:

- How does the urban environment associate to mental health according to objective indicators?
- How does the urban environment associate to mental health according to subjective experiences?
- How do the outcomes of both approaches diverge or converge?

The quantitative research part

1. Study population

The study population for the quantitative part consists of the inhabitants of the BCR aged 15 and older who participated in the HIS in 2008 (n = 2831) or in 2013 (n = 2532). The HIS is a re-occurring national cross-sectional epidemiological survey carried out by the Belgian research institute for health (Sciensano) in partnership with the Belgian statistical office (Statbel). It has been organized every five years since 1997. For each survey, approximately 10 000 individuals are selected from the National Register based on a random sampling scheme stratified by Region (including 3000 individuals from the BCR) and province, ensuring representativity for the Belgian population. Any person officially living in Belgium is likely to be selected.

2. Data collection and indicators selection

Mental health, socioeconomic, lifestyle and perceived environmental data

During each survey, detailed information is collected through face-to-face and self-administered questionnaires. The face-to-face questionnaire collects information on general health status, reduced mobility, use of health care services, socio-economic status, nutrition, and perception on environmental characteristics, such as air pollution and noise disturbance. The self-administered questionnaire is used to collect data on mental health and on sensitive topics, such as alcohol and drug use. Both questionnaires include questions adapted from validated screening tools. A description of the questionnaires can be found online.[23] The HIS is rich in terms of population

coverage, representativity, and information provision. Mental health, socioeconomic information, lifestyle, and perceived environmental data are retrieved from the Belgian HIS. The selection of relevant indicators for the NAMED project, is based on a literature review, on the variables distribution and on a factor analysis of mixed data (FAMD) on all mental health variables. Thus, the mental health status of each HIS respondent is described by following indicators:

- The prevalence of psychological distress across the population. This categorical indicator is based on the "General Health Questionnaire 12" for general well-being.
- The respondents' energy level is based on the "Vitality scale (VT-4 items) for positive mental health" from the Short-Form Health Survey (SF-36). This index containing four items measures the respondents' vital energy level and is used to assess the positive dimension of mental health. This score is recommended by the EUROHIS2 (European project on developing common instruments for health surveys).
- The prevalence of anxiety disorders, the prevalence of depressive disorders, and the prevalence of sleeping disorders. These dichotomized indicators are based on the SCL-90-R subscales (42 items) for depression, anxiety, and sleeping problems.
- The subjective health, the reported depression in the past 12 months and the reported suicidal ideation in the past 12 months based on isolated variables.
- Indicators on risky behaviours are also considered through variables related to addictive substances consumption ("Problematic alcohol consumption" and "Lifetime prevalence of cannabis use").

This rich data set allows to consider various components of mental health and diverse degrees of severity. The use of these standardized variables facilitates comparisons across studies.

To describe respondents' socio-economic status, six indicators are selected: age, gender, country of birth, household composition, highest educational level within the household, professional activity, employment status, and reported household income. Regarding respondents' lifestyle, five indicators are selected: appreciation of social life, level of health enhancing physical activity, BMI, reported problems in mobility, and presence of one or more long standing illnesses, chronic conditions, or handicaps. These data allow to investigate the underlying mechanisms by which the urban environment associates with mental health.

Respondents' perception of environmental problems at their residence is approached through 18 indicators in three different domains.

- Nuisance in the neighborhood is described by: traffic volume, traffic speed, accumulation of rubbish, vandalism, graffiti or deliberate damage of property, and lack of access to parks or other green or recreational public places;
- Nuisance at home is characterized by: air pollution, bad smell from industry, bad smell from others sources (sewer, waste, etc.), vibrations from road, metro, tram, train, or air traffic, noise from road, train, tram, metro, air traffic, or factories, and neighborhood noise;
- Problems linked to the dwelling are approached by: unable to keep the home warm enough in the winter, problem of humidity or mould in the dwelling, smoke inside the dwelling every day or almost every day, and overcrowded household.

These indicators potentially contain information on environmental degradations not captured by GIS data and provide a good opportunity to assess the level of environmental stress felt by the respondents.

Built and non-built environment data

The NAMED project focuses on the health impact of outdoor environment including buildings, infrastructures, and green environment. We study the built environment in terms of building structures (their 2D footprint, spatial organization, height, type, etc.). We describe the non-built environment by two separate elements: the street network supporting daily mobility and the green environment including urban trees, open green public spaces, and private gardens.

We make use of two datasets available for the BCR: an open database, called UrbIS (CIRB-CIBG 2016) provides a set of cartographic data specific to the Region, and Brussels-Environment (the local environment and energy administration) provides vegetation data, as adapted in Van de Voorde et al. (2010).[21,24] We process these data using GIS to provide indicators on (non-)built environment to describe the surrounding environment of each HIS respondent. We develop indicators at three different scales in order to capture a variety of spatial characteristics that can influence the HIS respondents' perception of their environment and their wellbeing:

- At the scale of the building of the respondent: view of green and garden coverage;
- At the scale of the street in which the respondent lives: canyon or street corridor effect, linear density of urban trees, and visible street vegetation coverage;
- At the scale of the neighborhood of the respondent (600m and 1000m): typology of urban fabric, green coverage, accessibility and quality of green coverage, and sidewalk coverage.

Air quality data

Data on HIS respondents' exposure to air pollution are obtained through the national monitoring system supervised by the Belgian interregional environment agency (IRCEL - CELINE). Measurements rely on a dense network of stations distributed all over the country. They assess on a daily basis concentrations of various pollutants which are then interpolated to estimate very local exposure (taking into account land cover data in combination with a dispersion model).[25,26] Saenen et al (2017) demonstrated the accuracy of the model to estimate a person's real exposure by showing that modelled particulate matter ($PM_{2.5}$) and black carbon (BC) at the residence correlates with internal exposure to nanosized BC particles measured in urine.[27] We use annual averages of PM_{10}, $PM_{2.5}$, BC, ozone (O_3) and nitrogen dioxide (NO_2) exposure levels (µg/m³) at HIS respondents' home address as indicators for air quality.

Noise data

Noise information is derived from the European NOISE database, a system supervised by the European Commission (directive 2002/49/EC, 2002). It aims at identifying and mapping noise and allows an assessment of population exposure across Europe according to standardized procedures, including harmonized noise indicators: day–evening–night noise level (Lden) and night noise level (Lnight). Since 2002, measures are done for urban areas counting more than 200 000 inhabitants, every five years, at the most exposed façades of buildings. We adapt Lden and Lnight as indicators to estimate traffic noise levels in 5 dB(A)-intervals.

3. Data analysis

In a first step, we take full advantage of the HIS dataset itself by investigating the associations between indicators describing the respondents' mental health and indicators describing the respondents' perceived environment, socio-economic and lifestyle data through bivariate analyses. Additionally, we describe the distribution of socioeconomic status across environmental indicators in order to assess potential "environmental inequalities". These descriptive analyses permit to identify potential vulnerable groups (likely and among others: socially deprived, isolated persons, teenagers) that should receive a greater attention. The first step results in crude distribution patterns to be further investigated with more complex statistical techniques in the second step.

In a second step, we merge the database with environmental indicators as previously described with individual data of HIS respondents. Linkage is done at the individual level and implies to temporarily geo-locate the home address of all respondents ("x,y" coordinates) at the time they participated in the survey. Based on the merged dataset and mental health indicators as previously described, we analyze relationships between mental health and urban environment characteristics using multivariate regression models adjusted for respondents' socio-economic status, lifestyle and stratified by age and gender. We use structural equation modelling which provides a flexible framework for performing mediation analysis to assess the potential mediating role of physical activity, social life, and noise and air pollution in the associations between mental health and (non-)built environment.[28] We check results for robustness with sensitivity analyses.

In a third step, we compare differences between respondents' perception and objective environmental indicators (related to air and noise pollution and lack of access to parks) of their environment through a Test de Student for comparison of means to assess the share of subjectivity in respondents' answers.

4. Data protection

All institutions handling data ensure their protection against leak, theft, misuse or degradation. In addition to current protection measures already implemented to protect HIS data, we consider and discuss additional controls such as specific encryption and special back up with the ICT team and Data Safety Advisor.

The qualitative research part

Grounded theory methodology, as originally developed by Glaser and Strauss (1967) informed the plan of the qualitative research part for this study.[29] This part involves a generic qualitative approach from a constructivist perspective.[30]

1. Study population

We conduct interviews with urban dwellers in various areas of the BCR representing a diversity in typology of urban fabric, access to green, median income, and population density. We recruit participants through several local organizations and initiatives which have often established familiar relationships with their members. This

recruitment strategy intends to reach a varied sample in terms of gender, age, cultural and socioeconomic backgrounds. Only participants with skills in Dutch, French or English and a minimum age of 18 years can participate. Based on sample size recommendations for grounded theory, the sample is estimated to consist of 30 participants.[31]

2. Data collection

We invite the participants for semi-structured interviews, which consist in an open discussion following a framework of topics to be explored.[32] Although we developed this framework in advance, the open method allows to add new ideas brought in by the interviewees. These discussions take the form of a walking interview. This approach, also called go-along or walk-along interview, provides detailed insights into the meanings and practices people associate with their living environment.[33] Furthermore, it helps to reduce steering the conversation by the interviewer and the typical power dynamics that exist between the interviewer and interviewee.[34]

3. Data analysis

We apply a thematic analysis on transcripts of the audio-recorded interviews, involving a three-stage coding process: descriptive coding, interpretative coding, and finally coming to overarching themes and their relationships. We check the themes appearing in interviews from the same area and across different areas (in terms of typology of urban fabric, access to green, median income and population density) for similarities and differences in the perception and experiences of urban environment in relation to mental health.

4. Data protection

We pseudonymize the transcripts so the identity of the interviewed participants is not disclosed during the presentation of the research results.

The validation part

1. Data triangulation

Data triangulation is defined as “a process of validating research conclusions by examining a relationship from different methodological angles”.[35] Quantitative results are triangulated with qualitative results to get a better understanding of the associations between urban environment and mental health. The qualitative results can support a better understanding of mechanisms that underlie associations identified in the quantitative part. If both results provide at some points mutual confirmation, we can consider the results more valid.[36] In the case that results diverge from each other, new research questions and hypotheses can emerge.

2. Extended peer evaluation

Throughout the project, we consult key stakeholders from local, regional, and national health and environment authorities and institutions and experts from the international research community. This allows to evaluate the quality of the project and produce

outcomes relevant not only from a scientific perspective but also from a societal practice perspective. We consult these actors through individual interviews and focus groups. Involvement of experts and stakeholders through participatory processes is a well-established practice for environmental management and policy making.[37-40] Modern views on governance underline that managing the living environment is no longer solely seen as the sole responsibility of governmental institutions.[38] It is perceived more as an interplay of different societal actors, including governmental institutions, local communities, and professional and stakeholder groups.[41] When conducting and assessing research findings in the perspective of urban planning, health management, and policy recommendations, the involvement of a diversity of actors seems vital in order to have an encompassing and well-informed view.

ETHICS AND DISSEMINATION

Approval for the data merging in the quantitative research part has been given by the Privacy Commission of Belgium (19/01/2018, reference number 02/2018). The walking interview with Brussels residents in the qualitative research part has been approved by the ethical committee from the University Hospital of Antwerp (Alternative Ethical Review board of the University of Antwerp) (26/11/2018, reference number 18/44/503). We will present and discuss research results in the form of maps, explanatory models, and storytelling and share them with a wide audience including the scientific community, policy authorities, and the civil society through international peer-reviewed publications, scientific conferences, and non-expert communication. We will also make specific efforts to translate and communicate research results to the general public through media, non-profit organizations and specific events. The NAMED website https://www.uantwerpen.be/en/projects/named/ will provide an overview of the project, progress, actualities and publications.

ACKNOWLEDGEMENTS

We express our gratitude to all members of the follow up committee who provide relevant input throughout the project. We acknowledge the full HIS team of Sciensano and the Belgian statistical office, Statbel, for their technical support during the process of database merging and linking.

AUTHOR CONTRIBUTIONS

All authors contributed to the conception of the mixed method. LL, ST and IP contributed equally to the draft of the manuscript with critical revisions and appraisal from the other authors. All authors have read and approved the final version of the manuscript.

FUNDING

This work was supported by the Belgian Federal Science Policy Office (BELSPO), grant number BR/175/A3/NAMED.

DATA STATEMENT

No data are available.

PATIENT AND PUBLIC STATEMENT

For the qualitative part, local organizations and experts are involved to reflect on the interview design. The local organizations support participant recruitment by promoting the project to their members or visitors. The interviews involve a diverse sample of inhabitants of the Brussels Capital Region.

For the validation part, stakeholders and experts are invited for focus groups to discuss research results. Their inputs will support final reporting of the project results and implications.

REFERENCES

1. World Health Organization. Mental disorders. WHO. 2018 Apr 9. https://www.who.int/en/news-room/fact-sheets/detail/mental-disorders
2. Drieskens S, Charafeddine R, Demarest S, Gisle L, Tafforeau J, Van der Heyden J. Health Interview Survey, Belgium, 1997 - 2001 - 2004 - 2008 - 2013: Health Interview Survey Interactive Analysis. Brussels: WIV-ISP. https://hisia.wiv-isp.be/
3. Regier DA, Farmer ME, Rae DS, et al. One-month prevalence of mental disorders in the United States and sociodemographic characteristics: the Epidemiologic Catchment Area study. *Acta Psychiatr Scand* 1993;88:35–47.
4. Alonso J, Angermeyer MC, Bernert S, et al. Prevalence of mental disorders in Europe: results from the European Study of the Epidemiology of Mental Disorders (ESEMeD) project. *Acta Psychiatr Scand* 2004;109:21–7.
5. Merikangas KR, He J, Burstein M, et al. Lifetime Prevalence of Mental Disorders in U.S. Adolescents: Results from the National Comorbidity Survey Replication–Adolescent Supplement (NCS-A). *J Am Acad Child Adolesc Psychiatry* 2010;49:980–9.
6. Bijl RV, Ravelli A, van Zessen G. Prevalence of psychiatric disorder in the general population: results of the Netherlands Mental Health Survey and Incidence Study (NEMESIS). *Soc Psychiatry Psychiatr Epidemiol* 1998;33:587–95.
7. Gruebner O, Rapp MA, Adli M, Kluge U, Galea S, Heinz A. Cities and Mental Health. *Dtsch Arztebl Int* 2017; 114: 121-7.
8. Desjarlais R, editor. World mental health: Problems and priorities in low-income countries. Oxford University Press, USA; 1995.
9. Patel V. Poverty, inequality and mental health in developing countries. In: Leon D, Walt G, editors. Poverty, inequality and health. Oxford: Oxford University Press; 2001. p. 247-62.
10. Vassos E, Pedersen CB, Murray RM, Collier DA, Lewis CM. Meta-analysis of the association of urbanicity with schizophrenia. *Schizophr Bull* 2012;38:1118-23
11. Ma J, Li C, Kwan MP, Chai Y. A Multilevel Analysis of Perceived Noise Pollution, Geographic Contexts and Mental Health in Beijing. *International journal of environmental research and public health* 2018;15:1479.
12. Buoli M, Grassi S, Caldiroli A et al. Is there a link between air pollution and mental disorders? *Environment international* 2018;118:154-68.

13. McCay L, Bremer I, Endale T, Jannati M, Yi J. Urban design and mental health. *Mental Health and Illness in the City* 2017:1-24.
14. Gascon M, Triguero-Mas M, Martínez D. Mental health benefits of long-term exposure to residential green and blue spaces: a systematic review. *International journal of environmental research and public health* 2015;12:4354-79.
15. Nutsford D, Pearson AL, Kingham S. An ecological study investigating the association between access to urban green space and mental health. *Public Health* 2013;127:1005–11.
16. Cohen-Cline H, Turkheimer E, Duncan GE. Access to green space, physical activity and mental health: a twin study. *J Epidemiol Community Health* 2015;69:523–9.
17. Evans GW. The built environment and mental health. *Journal of urban health* 2003;80:536-55.
18. Rautio N, Filatova S, Lehtiniemi H, Miettunen J. Living environment and its relationship to depressive mood: A systematic review. *International Journal of Social Psychiatry* 2018;64:92-103.
19. Hartig T, Mitchell R, de Vries S, et al. Nature and health. *Annu Rev Public Health 2014*;35:207–28.
20. statbel.fgov.be [Internet]. Brussels: Statbel, the Belgian statistical office; c2018. Available from: statbel.fgov.be/en
21. Van de Voorde T, Canters F, Chan JC. Mapping update and analysis of the evolution of non-built (green) spaces in the Brussels Capital Region. Final Report. Brussels: Cartography and GIS Research Group, Department of Geography, Vrije Universiteit Brussel; Dec 2010. Report No.: ActuaEvol/09
22. Hermia JP, Sierens A. Belges et étrangers en Région bruxelloise, de la naissance à aujourd'hui. IBSA Brussels. 2017 Aug 20. http://ibsa.brussels/fichiers/publications/focus-de-libsa/focus_20_aout_2017
23. his.wiv-isp.be [Internet]. Brussels: Sciensano; c2019. Available from: https://his.wiv-isp.be/SitePages/Questionnaires.aspx
24. UrbIS data [Internet]. Brussels: CIRB-CIBG. c2019 - [cited 2019 May 6]. Available from: https://cirb.brussels/fr/nos-solutions/urbis-solutions/urbis-data
25. Janssen S, Dumont G, Fierens F, et al. Spatial interpolation of air pollution measurements using CORINE land cover data. *Atmos Environ* 2008;42:4884–903.
26. Lefebvre W, Degrawe B, Beckx C, et al. Presentation and evaluation of an integrated model chain to respond to traffic- and health-related policy questions. *Environ Model Softw* 2013;40:160–70.
27. Saenen ND, Bové H, Steuwe C et al. Children's urinary environmental carbon load. A novel marker reflecting residential ambient air pollution exposure? *American journal of respiratory and critical care medicine* 2017;196:873-81.
28. Gunzler D, Chen T, Wu P, et al. Introduction to mediation analysis with structural equation modeling. *Shanghai Arch Psychiatry* 2013;25:390–4.
29. Glaser BG, Strauss AL. Discovery of grounded theory: Strategies for qualitative research. Chicago: Aldine; 1967.
30. Kahlke RM. Generic qualitative approaches: Pitfalls and benefits of methodological mixology. *International Journal of Qualitative Methods* 2014;13:37-52.

31. Marshall B, Cardon P, Poddar A, Fontenot R. Does sample size matter in qualitative research?: A review of qualitative interviews in IS research. *Journal of Computer Information Systems* 2013;54:11-22.
32. Green J, Thorogood N. Qualitative methods for health research. London: Sage; 2018.
33. O'Brien L, Morris J, Stewart A. Engaging with peri-urban woodlands in England: the contribution to people's health and well-being and implications for future management. *International journal of environmental research and public health* 2014;11:6171-92.
34. Carpiano RM. Come take a walk with me: The "Go-Along" interview as a novel method for studying the implications of place for health and well-being. *Health & Place* 2009;15:263-272.
35. Molina-Azorin, J. F., Bergh, D. D., Corley, K. G., & Ketchen, D. J. (2017). Mixed Methods in the Organizational Sciences: Taking Stock and Moving Forward. Organizational Research Methods, 20(2), 179–192.
36. Molina-Azorin JF, Bergh DD, Corley KG, Ketchen DJ. Mixed methods in the Organizational Sciences: Taking Stock and Moving Forward. *Organizational Research Methods* 2017;20:179–192.
37. Renn O. Participatory processes for designing environmental policies. *Land Use Policy* 2006;23:34–43.
38. Jordan A. The Governance of Sustainable Development: Taking Stock and Looking Forwards. *Environ Plan C Gov Policy* 2008;26:17–33.
39. Reed MS. Stakeholder participation for environmental management: A literature review. *Biol Conserv* 2008;141:2417–31.
40. Brown G, de Bie K, Weber D. Identifying public land stakeholder perspectives for implementing place-based land management. *Landsc Urban Plan* 2015;139:1–15.
41. Hooghe L, Marks G. Unraveling the Central State, but How? Types of Multi-Level Governance. *Am Polit Sci Rev* 2003;97:233–43.

BMJ Open

Urban environment and mental health: the NAMED project, protocol for a mixed method study

Journal:	*BMJ Open*
Manuscript ID	bmjopen-2019-031963.R1
Article Type:	Protocol
Date Submitted by the Author:	15-Jan-2020
Complete List of Authors:	Lauwers, Laura; University of Antwerp Faculty of Medicine and Health Sciences, Department of Primary and Interdisciplinary Care Trabelsi, Sonia; Université catholique de Louvain, Center for Operations Research and Econometrics Pelgrims, Ingrid; Sciensano, Department of Risk and Health Impact Assessment Bastiaens, Hilde; University of Antwerp Faculty of Medicine and Health Sciences, Department of Primary and Interdisciplinary Care De Clercq, Eva ; Sciensano, Department of Risk and Health Impact Assessment Guilbert, Ariane ; Sciensano, Department of Risk and Health Impact Assessment Guyot, Madeleine; Université catholique de Louvain, Center for Operations Research and Econometrics Leone, Michael; Research Institute for Nature and Forest, Nature and Society Team Nawrot, Tim; Hasselt University, Centre for Environmental Sciences; Catholic University College Leuven, Department of Public Health and Primary Care Van Nieuwenhuyse, An; Laboratoire National de Santé, Department of Health Protection; Catholic University College Leuven, Department of Public Health and Primary Care Remmen, Roy; University of Antwerp, Faculty of Medicine and Health Sciences, Department of Primary and Interdisciplinary Care Saenen, Nelly; Hasselt University, Centre for Environmental Sciences Thomas, Isabelle; Université catholique de Louvain, Center for Operations Research and Econometrics Keune, Hans; University of Antwerp Faculty of Medicine and Health Sciences, Department of Primary and Interdisciplinary Care; Research Institute for Nature and Forest, Belgian Biodiversity Platform, Nature and Society Team
Primary Subject Heading:	Mental health
Secondary Subject Heading:	Research methods
Keywords:	urban environment, MENTAL HEALTH, mixed method

I, the Submitting Author has the right to grant and does grant on behalf of all authors of the Work (as defined in the below author licence), an exclusive licence and/or a non-exclusive licence for contributions from authors who are: i) UK Crown employees; ii) where BMJ has agreed a CC-BY licence shall apply, and/or iii) in accordance with the terms applicable for US Federal Government officers or employees acting as part of their official duties; on a worldwide, perpetual, irrevocable, royalty-free basis to BMJ Publishing Group Ltd ("BMJ") its licensees and where the relevant Journal is co-owned by BMJ to the co-owners of the Journal, to publish the Work in this journal and any other BMJ products and to exploit all rights, as set out in our licence.

The Submitting Author accepts and understands that any supply made under these terms is made by BMJ to the Submitting Author unless you are acting as an employee on behalf of your employer or a postgraduate student of an affiliated institution which is paying any applicable article publishing charge ("APC") for Open Access articles. Where the Submitting Author wishes to make the Work available on an Open Access basis (and intends to pay the relevant APC), the terms of reuse of such Open Access shall be governed by a Creative Commons licence – details of these licences and which Creative Commons licence will apply to this Work are set out in our licence referred to above.

Other than as permitted in any relevant BMJ Author's Self Archiving Policies, I confirm this Work has not been accepted for publication elsewhere, is not being considered for publication elsewhere and does not duplicate material already published. I confirm all authors consent to publication of this Work and authorise the granting of this licence.

Urban environment and mental health: the NAMED project, protocol for a mixed method study

Laura Lauwers, Sonia Trabelsi, Ingrid Pelgrims, Hilde Bastiaens, Eva M De Clercq, Ariane Guilbert, Madeleine Guyot, Michael Leone, Tim Nawrot, An Van Nieuwenhuyse, Roy Remmen, Nelly Saenen, Isabelle Thomas, Hans Keune

Corresponding author:

Laura Lauwers
Department of Primary and Interdisciplinary Care
Faculty of Medicine and Health Sciences
University of Antwerp
Gouverneur Kinsbergencentrum 00.58.
Doornstraat 331
Wilrijk, 2610
Belgium
Phone: 32 489097822
Email: laura.lauwers@uantwerpen

First authors and affiliations:

Laura Lauwers
laura.lauwers@uantwerpen.be
Department of Primary and Interdisciplinary Care, Faculty of Medicine and Health Sciences, University of Antwerp, Antwerp, Belgium

Sonia Trabelsi
s.trabelsi@uclouvain.be
Center for Operations Research and Econometrics, Université catholique de Louvain, Louvain-la-Neuve, Belgium

Ingrid Pelgrims
Ingrid.Pelgrims@sciensano.be
Department of Risk and Health Impact Assessment, Sciensano, Brussels, Belgium

Co-authors

Hilde Bastiaens
hilde.bastiaens@uantwerpen.be
Department of Primary and Interdisciplinary Care, Faculty of Medicine and Health Sciences, University of Antwerp, Antwerp, Belgium

Eva M De Clercq
Eva.DeClercq@sciensano.be
Department of Risk and Health Impact Assessment, Sciensano, Brussels, Belgium

Ariane Guilbert
aguilbert.prof@laposte.net
Department of Risk and Health Impact Assessment, Sciensano, Brussels, Belgium

Madeleine Guyot
madeleine.guyot@uclouvain.be
Center for Operations Research and Econometrics, Université catholique de Louvain, Louvain-la-Neuve, Belgium

Michael Leone
michael.leone@inbo.be
Nature and Society Team, Research Institute for Nature and Forest (INBO), Brussels, Belgium

Tim Nawrot
tim.nawrot@uhasselt.be
Centre for Environmental Sciences, Hasselt University, Hasselt, Belgium
Department of Public Health and Primary Care, Leuven University, Leuven, Belgium

An Van Nieuwenhuyse
An.vanNieuwenhuyse@lns.etat.lu
Laboratoire National de Santé, Department of Health Protection, Dudelange, Luxembourg
Department of Public Health and Primary Care, University of Leuven, Belgium

Roy Remmen
roy.remmen@uantwerpen.be
Department of Primary and Interdisciplinary Care, Faculty of Medicine and Health Sciences, University of Antwerp, Antwerp, Belgium

Nelly Saenen
nelly.saenen@uhasselt.be
Centre for Environmental Sciences, Hasselt University, Hasselt, Belgium

Isabelle Thomas
isabelle.thomas@uclouvain.be
Center for Operations Research and Econometrics, Université catholique de Louvain, Louvain-la-Neuve, Belgium

Hans Keune
hans.keune@inbo.be
Belgian Biodiversity Platform, Nature and Society Team, Research Institute for Nature and Forest (INBO), Brussels, Belgium
Chair Care and the Natural Living Environment, Department of Primary and Interdisciplinary Care, Faculty of Medicine and Health Sciences, University of Antwerp, Antwerp, Belgium

Word count: 4515

ABSTRACT

Introduction: Mental health issues appear as a growing problem in modern societies and tend to be more frequent in big cities. Where increased evidence exists for positive links between nature and mental health, associations between urban environment characteristics and mental health are still not well understood. These associations are highly complex and require an interdisciplinary and integrated research approach to cover the broad range of mitigating factors. This article presents the study protocol of a project called NAMED that aims to generate a comprehensive understanding of associations between mental health and the urban residential environment.

Methods and analysis: Following a mixed method approach, this project combines quantitative and qualitative research. In the quantitative part, we analyze among the Brussels urban population associations between the urban residential environment and mental health, taking respondents' socio-economic status and physical health into account. Mental health is determined by the mental health indicators in the national Health Interview Survey (HIS). The urban residential environment is described by subjective indicators for the participant's dwelling and neighborhood present in the HIS and objective indicators for buildings, network infrastructure, and green environment developed for the purpose of this project. We assess the mediating role of physical activity, social life, noise and air pollution. In the qualitative part, we conduct walking interviews with Brussels residents to record their subjective wellbeing in association with their neighborhood. In the validation part, results from these two approaches are triangulated and evaluated through interviews and focus groups with stakeholders of healthcare and urban planning sectors.

Ethics and dissemination: The Privacy Commission of Belgium and ethical committee from University Hospital of Antwerp respectively approved quantitative database merging and qualitative interviewing. We will share project results with a wide audience including the scientific community, policy authorities and civil society through scientific and non-expert communication.

Keywords: urban environment; mental health; mixed method; air pollution; noise pollution

ARTICLE SUMMARY

Strengths and limitations of this study

- The NAMED project mixes quantitative and qualitative methods to obtain a comprehensive understanding of the association between urban residential environment and mental health.
- The NAMED project investigates various components of mental health and of the urban residential environment using complementary indicators. However, only indicators describing the physical and not the social residential environment (such as neighborhood cohesion, neighborhood criminality) are considered.
- The NAMED project combines subjective and objective environmental indicators. However, the cross-sectional study design does not allow ruling out reverse causation for associations found between the subjective environmental and mental health measures.
- The NAMED project couples urban environment indicators and mental health indicators at individual level to capture the complexity of this relationship influenced by very local environmental factors and individual attributes. However, available data do not allow investigating other relevant environmental exposures than the one to the residential environment.
- The NAMED project includes a validation phase in which key stakeholders and experts can evaluate the methodological approach of the project and direct recommendations relevant from a societal practice perspective.

INTRODUCTION

According to the World Health Organization (WHO) depression alone affects around 300 million people worldwide.[1] In Belgium, the Health Interview Survey (HIS) underlined a deterioration of the psycho-emotional health of the population: the proportion of respondents presenting psychological difficulties increased from 25% to 32% between 2008 and 2013. These included anxiety, depressive disorder, or sleep disorders. Strikingly, these are more prevalent in the Brussels-Capital Region (40%) than in the two other Regions Wallonia (35%) and Flanders (29%).[2]

It is now well-established that the nature, prevalence, and age of onset of mental disorders vary according to demographic, socioeconomic, and cultural factors.[2-6] Several international studies analyzed links between the urban environment and mental health from different research angles by looking at the urban social or physical environment.[7] With respect to the urban social environment, concentrations of low socio-economic status (SES), low social capital, or social segregation have been studied as social risk factors for mental health in cities.[7-9] Feelings of community attachment and social cohesion are shown to improve mental health, where neighborhood disorder, such as crime and violence, is associated with poor mental health.[9-15] In Belgium, the occurrence of psychosocial difficulties is generally higher in cities.[2]
Associations between the urban physical environment and mental health have been investigated in terms of urban design, noise pollution, and air pollution.[16-18] Regarding the urban design, evidence has increased on the positive impact of urban green and blue spaces on mental health.[16,19,20] After controlling for confounding factors, significant associations were found between (1) depression, anxiety, visits to mental health specialists, and stress and access to green space (2) between depression and park size (3) between depression, anxiety, perceived risk for poor mental health, and visits to mental health specialists and surrounding greenness and (4) between perceived mental health and perceived greenness. [21-26] Besides the natural environment, several studies investigated associations between mental health and the built environment in terms of walkability, access to care, and housing quality.[23,27,28] For instance, increased walkability has been associated with a decreased incidence of depression and enhanced physical activity.[23,27] Indoor and outdoor noise are found to be significantly associated with self-reported mental health problems or mental disorders.[13,16,29] Also air pollution has been found to be associated with depressive symptoms. However, many studies did not take into account confounding factors.[17,29]

Although a broad range of research has found some trends in associations between mental health and urban environment, conclusions still tend to differ or to be contradictory across studies.[12,20,29-31] This may be explained by different research limitations. First, most studies rely on a single indicator such as the “General Health Questionnaire 12” (GHQ-12 items) to describe mental health or focus on a single aspect such as depression.[7,9,14,20,29,32,33] This makes it difficult to grasp diverse degrees of severity and to compare across studies. Second, the strict use of subjective environmental measures in some studies make it difficult to conclude on whether participants with mental health issues are more likely to report negatively on their environment or that negative environmental aspects contribute to mental illnesses

(reverse causation).[10,12,14,15] Studies including objective environmental measures make often use of a limited set of indicators developed at census area unit level, which makes it difficult to compare results across different study contexts and reflect lived experiences of the residential urban environment.[14,16,20,32] Exposures to surrounding green, air pollution and other factors of the urban environment are generally spatially correlated.[34] However, most of the epidemiological studies assessing the relation between the urban environment and mental health have evaluated only one of these environmental exposures, ignoring the potential confounding or interaction effects between noise, air pollution and green space. Finally, a general restriction to quantitative methods limits the development of a comprehensive understanding of mechanisms underlying associations between the urban environment and mental health.[12,15,20] Considering the increasing urbanization worldwide, it becomes clear that further research on which characteristics of the urban environment may be beneficial or detrimental for mental health, on pathways involved, and on the impact of social, economic, and cultural factors is needed.[35] In addition, there is a growing need to evaluate the quality and relevance of research results for practice.

The Nature Impact on Mental Health Distribution (NAMED) is a Belgian four-year project (2017 – 2021) that aims to further investigate the associations and underlying mechanisms between mental health and urban residential environment in the Brussels Capital Region (BCR). To overcome the weaknesses of conducting only quantitative research, where individual understanding of these associations is limited, or only qualitative research, where the results cannot be generalized, the project applies a mixed method approach. In NAMED, the quantitative research relies on data collected within the HIS and analyzes associations between the urban residential environment and mental health, taking SES and physical health into account. To do so, we adapt, develop and combine a broad set of both subjective and objective indicators to overcome the limitations of previous research. We assess the mediating role of physical activity, social life, noise and air pollution in associations with mental health and urban environment. The qualitative research involves interviews with Brussels dwellers with the goal to analyze how they perceive and experience the urban environment in relation to mental health. The combined approach allows a better understanding of the underlying mechanisms, including direct effects (stress buffer, recovery, etc.), indirect effects (physical activity, social life, noise and air pollution) and impacts of individuals' perceptions and experiences.

Eventually, in a validation stage, we discuss and evaluate together with experts and stakeholders the quantitative and qualitative results. The mixed method approach presented in this paper is conducted by a multidisciplinary team, including epidemiologists, geographers, general practitioners, and environmental and social scientists. The integration of both research parts will result in a comprehensive understanding of urban determinants of mental health, from individual to community scales. Based on the research results, NAMED intends to draw practice and policy recommendations for urban planning and health management. NAMED will make suggestions for extension of the HIS (new approaches derived from the qualitative methods, new wordings or new questions relating to urban environment and mental health). Besides, the involvement of representatives of the urban planning sectors will

guide a better integration of mental health issues in new health-promoting urban development projects. The following research questions are addressed:

- Is there an association between the urban residential environment and mental health in the BCR using objective and subjective indicators? (Quantitative research part)
- How do people living in the BCR perceive and experience their urban residential environment in association with their mental health? (Qualitative research part)
- How can the project results contribute to practice and policy? (Validation part)

METHODOLOGY

Study area

The study area is the Brussels-Capital Region (BCR). The BCR is one of the three administrative Regions of Belgium (besides Wallonia and Flanders) and comprises 19 municipalities. The restriction to the BCR is motivated by the high prevalence of mental health problems, but also by the large representativeness and distribution of the HIS participants for 2008 and 2013. The large cities in Flanders and Wallonia have much less HIS-participants than the BCR. Since we include qualitative interviews, it is not realistic to propose an investigation in the large cities of every region in Belgium. The focus on the BCR was also motivated by the available geographic data. Very detailed spatial information has been collected, digitized and made available to the general public for the BCR, which is not the case for the other regions of Belgium, Flanders and Wallonia. The existence of a rich dataset, both in HIS participation and geographic detail, was a strong argument for choosing BCR as our study region. The BCR is 161.38 km² large and counts 1 198 726 inhabitants (01/01/2018) which means an average density of 7 428 inhabitants/km².[36] It can be considered a green urban region as 54% of its surface area is covered by vegetation (forest, public green spaces, urban trees, private gardens, etc.).[37] However, a clear contrast in vegetation cover exists between the center and the outer parts of the Region. Besides difference in access to green, the neighborhoods are highly diverse in population density, median income, household composition, etc. BCR is characterized by a high cultural diversity (40% non-Belgian nationality) and a mixed use of language (most spoken: French, English, Flemish).[36,38]

Mixed method approach

The NAMED project applies a mixed method approach, combining quantitative and qualitative research structured into a convergent parallel design. This mixed method approach is conducted by combining disciplines and requires a constant interaction between the different researchers in order to adapt their investigations to others' findings. The main level of interaction between the quantitative and qualitative research part occurs at the results interpretation step, which allows to understand if qualitative findings converge or diverge from quantitative ones. Besides this data triangulation, the validation part also involves key stakeholders and experts to reflect throughout the project on scientific and practice relevance. The three research parts are explained in detail in following sections (Fig. 1).

Fig. 1 Schematic overview of the working plan of NAMED with the main characteristics of each research part.

Mental health and the urban residential environment are approached in a complementary manner in both research parts. In the quantitative research part, mental health is determined by the mental health indicators for psychological distress, energy level, anxiety, depression, sleeping problems, suicidal ideation, addictive substance consumption present in the HIS. The urban residential environment is described by (1) self-reported assessment of participant's dwelling (such as humidity) and neighborhood (such as accumulation of rubbish) present in the HIS; (2) objective indicators for buildings, network infrastructure, and green environment developed for the purpose of this project. In the qualitative research part, mental health is assessed using the subjective wellbeing of the participants in association with their urban residential environment. The urban residential environment is covered by the subjective description of characteristics and places in the neighborhood that play an important role in the participant's wellbeing.

The quantitative research part

The quantitative research part uses the data collected within the Belgian HIS in 2008 and 2013. It consists in (1) retrieving HIS respondents' home address, (2) developing relevant indicators characterizing each home address in terms of urban environment, air and noise pollution using Geographical Information Systems (GIS) and (3) coupling these environmental indicators with HIS data. Based on this enriched database, this part investigates then the associations between mental health and urban environment in a cross-sectional way, taking into account socioeconomic and lifestyle factors.

1. Study population

The study population for the quantitative part includes the inhabitants of the BCR aged 15 and older who participated in the HIS in 2008 (n = 2 831) or in 2013 (n = 2 532). The HIS is a re-occurring national cross-sectional epidemiological survey carried out by the Belgian research institute for health (Sciensano) in partnership with the Belgian statistical office (Statbel). It has been organized every five years since 1997. For each survey, approximately 10 000 individuals are selected from the National Register based on a random sampling scheme stratified by Region (including 3 000 individuals from the BCR) and by Province, ensuring representativity of the Belgian population. Any person officially residing in Belgium is likely to be selected.

2. Data collection and indicators selection

Mental health, socioeconomic, lifestyle and perceived environmental data

During each survey, detailed information is collected through face-to-face and self-administered questionnaires. The face-to-face questionnaire collects information on general health status, reduced mobility, use of health care services, SES, nutrition, and perception on environmental characteristics, such as air pollution and noise disturbance. The self-administered questionnaire is used to collect data on mental health and on sensitive topics, such as alcohol and drug use. Both questionnaires include questions adapted from validated screening tools. A description of the

questionnaires can be found online.[39] Mental health, SES, lifestyle, and perceived environmental data are retrieved from the Belgian HIS. The selection of relevant indicators for the NAMED project, is based on a literature review, on the variables distribution and on a factor analysis of mixed data (FAMD) on all mental health variables. We selected all the mental health indicators available in the HIS database that were based on internationally validated scales. We only excluded the eating disorders since it is a very specific disorder for which we did not find anything in the literature review. The indicator on suicidal attempts in the past 12 months was also excluded given the too few cases reported. Thus, the mental health status of each HIS respondent is described by following indicators:

- The prevalence of psychological distress across the population. This categorical indicator is based on the "General Health Questionnaire 12" for general well-being.
- The respondents' energy level. This indicator is based on the "Vitality scale (VT-4 items) for positive mental health" from the Short-Form Health Survey (SF-36). This index contains four items measuring the respondents' vital energy level and is used to assess the positive dimension of mental health. This score is recommended by the EUROHIS2 (European project on developing common instruments for health surveys).
- The prevalence of anxiety disorders, the prevalence of depressive disorders, and the prevalence of sleeping disorders. These dichotomized indicators are based on the SCL-90-R subscales (42 items) for depression, anxiety, and sleeping problems.
- The subjective health, the reported depression in the past 12 months and the reported suicidal ideation in the past 12 months based on isolated variables.
- Indicators on risky behaviors are also considered through variables related to addictive substances consumption ("Problematic alcohol consumption" and "Lifetime prevalence of cannabis use").

Based on the results of the FAMD, all the indicators were kept in order to cover both positive and negative dimensions of mental health and diverse degrees of severity. The use of these standardized variables facilitates comparisons across studies.

To describe respondents' SES, eight indicators are selected: age, gender, country of birth, household composition, highest educational level within the household, professional activity, employment status, and reported household income. From the lifestyle data, indicators are further selected to describe physical health, social life and physical activity. Regarding respondents' physical health, three indicators are identified: BMI, reported problems in mobility, and presence of one or more long standing illnesses, chronic conditions, or handicaps. SES and physical health are included as confounders. The indicators 'appreciation of social life' and 'level of health enhancing physical activity' are included as potential mediators.

Respondents' perception of environmental problems at their residence is approached through 18 indicators in three different domains.

- Nuisance in the neighborhood is described by: traffic volume; traffic speed; accumulation of rubbish; vandalism; graffiti or deliberate damage of property; and lack of access to parks or other green or recreational public places;
- Nuisance at home is characterized by: air pollution; bad smell from industry; bad smell from others sources (sewer, waste, etc.); vibrations from road, metro, tram, train, or air traffic; noise from road, train, tram, metro, air traffic, factories, and neighbors;

- Problems linked to the dwelling are approached by: unable to keep the home warm enough in the winter; problem of humidity or mold in the dwelling; smoke inside the dwelling every day or almost every day; and overcrowded household.

These indicators potentially contain information on environmental degradations not captured by GIS data and provide a good opportunity to assess the level of environmental stress felt by the respondents.

Indicators of urban environment

The urban environment indicators include buildings, network infrastructure, and green environment. The building structure is described in terms of 2D footprint, spatial organization, height, etc. The network infrastructure is described by the street network supporting daily mobility. And the green environment is described in terms of urban trees, open green public spaces, and private gardens.

We make use of two datasets available for the BCR: an open database, called UrbIS (CIRB-CIBG 2016) providing a set of cartographic data specific to the Region, and Brussels-Environment (the local environment and energy administration) providing vegetation data.[37,40] The vegetation data was computed by Van de Voorde et al. (2010) with high resolution remote sensing data using an NDVI threshold value of 0.275.[37]

We process these data using GIS to develop indicators describing the residential environment of each HIS respondent. We provide indicators at three different scales to represent the individual's experience at home, on the street, or in the neighborhood:

- At the scale of the building of the respondent: view of green and garden coverage;
- At the scale of the street in which the respondent lives: canyon effect (height/width ratio); street corridor effect; linear density of urban trees; and visible street vegetation coverage;
- At the scale of the neighborhood of the respondent (1 000m): typology of urban fabric and green coverage.

As specified above, a typology of 12 urban fabrics (combination of 21 indicators of urban environment) has been created to highlight the urban environment as perceived by pedestrians freely moving on the street network.[41] This typology and other indicators enable us to approach the concept of walkability by taking into account the presence of sidewalks, urban street trees, design of the street (canyon and street corridor effect), visible street vegetation coverage, etc.[42]

Air quality data

Data on HIS respondents' exposure to air pollution are obtained from the national monitoring system supervised by the Belgian interregional environment agency (IRCEL - CELINE). Regional background levels of particular manner (PM) PM10, PM2.5, black carbon (BC), ozone (O3) and nitrogen dioxide (NO2) exposure (µg/m3) are determined for each HIS respondent based on their home address. A land use regression model is used for background concentrations taking into account land cover data obtained from satellite images (CORINE Land Cover data set) and daily pollution data from fixed monitoring stations. Then, this model is superimposed with a dispersion model to account for point and line sources (industrial smokestacks, road traffic). This

results in daily exposure values with a high spatial and temporal resolution.[43-45] Saenen et al (2017) demonstrated the accuracy of the model to estimate a person's real exposure by showing that modelled PM2.5 and BC at the residence correlates with internal exposure to BC particles measured in urine.[45] Using the daily estimates, we calculate annual averages of PM10, PM2.5, BC, O3 and NO2 exposure levels (µg/m³) at HIS respondents' home address as indicators for air quality.

Noise data

Noise information is derived from the European NOISE database, a system supervised by the European Commission (directive 2002/49/EC, 2002). It aims at identifying and mapping noise from road, rail and air traffic and allows an assessment of population exposure across Europe according to standardized procedures, including harmonized noise indicators: day–evening–night noise level (Lden) and night noise level (Lnight). The Lden indicator is an average sound pressure level over all days (12 hours), evenings (four hours) and nights (eight hours) in a year. Lnight is the A-weighted long-term average sound level determined over all the night periods (eight hours) of a year. As associations between mental health and noise pollution are expected to occur as a result of long-term exposure, it is generally accepted that the most relevant parts of the whole day or night, which especially account for the time when a person is at home, are correctly attributed when using average indicators like Lden or Lnight.[46] Since 2002, measures are done for urban areas counting more than 200 000 inhabitants, every five years, at the most exposed façades of buildings. We will combine noise maps available for the years 2006 and 2011 with the geographical coordinates of the participants' residence to estimate Lden and Lnight noise values in 5 dB(A)-intervals. Since the evolution in noise pollution between 2006 and 2011 was very weak, we can assume that average noise levels in 2008 and 2013 will not differentiate significantly on a two-years difference from the collected noise data.[47]

3. Data analysis

In a first step, we take full advantage of the HIS dataset itself by investigating the associations between indicators describing the respondents' mental health and indicators describing the respondents' perceived environment through bivariate analyses. Additionally, we describe the distribution of SES across environmental indicators in order to assess potential "environmental inequalities". These descriptive analyses permit to identify potential vulnerable groups (likely and among others: socially deprived, isolated persons, teenagers) that should receive a greater attention. This first step results in crude distribution patterns to be further investigated with more complex statistical techniques.

In a second step, we merge the database on environmental indicators previously described with individual data of HIS respondents. Linkage is done at the individual level and implies to temporarily geo-locate the home address of all respondents ("x,y" coordinates) at the time they participated in the survey. The relations between all the environmental variables are assessed through a Principal Component Analysis. Based on the merged dataset and mental health indicators as previously described, we analyze relationships between mental health and urban environment characteristics using multivariate logistic regression models. In order to take into account the complex relationships between all the environmental variables, single exposure and multi

exposure models are performed. Models will be fitted with increasing adjustments for covariates: respondents' SES, physical health and lifestyle factors. We use structural equation modelling which provides a flexible framework to assess the potential mediating role of physical activity, social life, and noise and air pollution in the associations between mental health and urban environment.[48] We check results for robustness with sensitivity analyses by for example including only participants living at the same address for more than one year, and using the environmental factors as continuous and categorical variables in the analysis.

In a third step, we look at the interrelations between the perceived and the objective exposure (lack of access to parks, air and noise pollution) using general linear models and classification and regression trees (CART). This allows to assess the share of subjectivity in respondents' answers.

4. Data protection

All institutions handling data ensure their protection against leak, theft, misuse or degradation. In addition to current protection measures already implemented to protect HIS data, we consider and discuss additional controls such as specific encryption and special back up with the ICT team and Data Safety Advisor.

The qualitative research part

We apply a qualitative descriptive approach and undertake research within a relativist ontology and subjectivist epistemology. This approach holds the view that reality is subjective and stresses the active role and contribution the researcher plays in the research process. The use of a qualitative description approach is most appropriate for this study as we seek to discover and understand a phenomenon, time and resources are limited, and this study is part of a mixed method project.[49] In this project, walking semi-structured interviews are employed as data-collection method. This method allows to better understand and perceive respondents' daily interactions in local contexts.[50]

1. Study population

To capture a diversity of inhabitants in the BCR, we aim for a maximum variation sample size in the recruitment of the participants. To do so, we apply a purposeful sampling frame where we aim to reach a diverse sample by selecting diverse study areas, local organizations, and participants. Five study areas representing a diversity in urban fabric, population density, access to green and median income are defined. In each area, we contact a diversity of local organizations involved in either environmental, socio-cultural, or health-related activities. In each organization, the project is communicated to the inhabitants through an oral introduction, posters, and folders. This recruitment strategy intends to reach a varied sample in terms of age, gender, education level, employment status and cultural background. Only participants skilled in Dutch, French, or English and a minimum age of 18 years can participate. Based on sample size recommendations to reach theoretical saturation when using a semi-structured interview approach, the sample size is estimated to consist of 30 participants.[51] Regarding the complexity of the project theme and the aimed heterogeneity of respondents, this sample size seems appropriate because of the

exploratory nature of this research and the focus on identifying underlying ideas about the topic.

2. Data collection

We invite the participants for semi-structured interviews, which consist in an open discussion following a guide of topics to be explored.[52] Topics tackled within the NAMED project include: residential street; neighborhood places, characteristics, and changes; reasons to walk in neighborhood; future vision on neighborhood. All topics are questioned in relation to participant's wellbeing. This list serves the interviewer to keep the flow of the conversation and to remind the participant of the interview purpose. However, the participants are stimulated to lead the conversation as much as possible to minimize steering by the interviewer. These discussions take the form of a walking interview. This approach, also called go-along or walk-along interview, provides detailed insights into the meanings and practices people associate with their living environment.[53] Furthermore, it helps to reduce steering the conversation by the interviewer and the typical power dynamics that exist between the interviewer and interviewee.[54] At the beginning of the interview the participants are asked to guide the walk along a route in the neighborhood that allows to discover the places and characteristics that play an important role in their wellbeing. The interviews are audio-recorded and GPS-tracked (with consent). The interviews are estimated to take maximally two hours, including an introduction, the walk and a discussion.

3. Data analysis

We apply a thematic analysis on transcripts of the audio-recorded interviews, involving a three-stage coding process: descriptive coding, interpretative coding, and finally coming to overarching themes and their relationships.[55,56] We check the themes appearing in interviews from the same area and across different areas for similarities and differences in the perception and experiences of the urban residential environment in relation to subjective wellbeing.

4. Data protection

We pseudonymize the transcripts so the identity of the interviewed participants is not disclosed during the presentation of the research results.

The validation part

1. Data triangulation

Data triangulation is defined as "a process of validating research conclusions by examining a relationship from different methodological angles".[57] Quantitative results are triangulated with qualitative ones to get a better understanding of the associations between the urban residential environment and mental health. The qualitative results can support a better understanding of mechanisms that underlie associations identified in the quantitative part. If both results provide at some points mutual confirmation, we can consider the results more valid.[57] In the case that results diverge from each other, new research questions and hypotheses can emerge.

2. Extended peer evaluation

Throughout the project, we consult key stakeholders from local, regional, and national health and environment authorities as well as institutions and experts from the international research community.[58] This allows to evaluate the quality of the project and to produce outcomes relevant not only from a scientific perspective but also from a societal practice perspective. We consult these actors through individual interviews and focus groups. Involvement of experts and stakeholders through participatory processes is a well-established practice for environmental management and policy making.[59-62] Modern views on governance underline that managing the living environment is no longer exclusively seen as the sole responsibility of governmental institutions.[60] It is perceived more as an interplay of different societal actors, including governmental institutions, local communities, and professional and stakeholder groups.[63] When conducting and assessing research findings in the perspective of urban planning, health management, and policy recommendations, the involvement of a diversity of actors seems vital in order to have an encompassing and well-informed view.

ETHICS AND DISSEMINATION

Approval for the data merging in the quantitative research part has been given by the Privacy Commission of Belgium (19/01/2018, reference number 02/2018). The walking interviews with Brussels residents in the qualitative research part has been approved by the ethical committee from the University Hospital of Antwerp (Alternative Ethical Review board of the University of Antwerp) (26/11/2018, reference number 18/44/503). A written informed consent is obtained from the participants.
The team will present and discuss research results in the form of maps, explanatory models, and storytelling and share them with a wide audience including the scientific community, policy authorities, and the civil society through international peer-reviewed publications, scientific conferences, and non-expert communication. We will also make specific efforts to translate and communicate research results to the general public through media, non-profit organizations and specific events (including media, non-profit organizations and specific events). The NAMED website (https://www.uantwerpen.be/en/projects/named/) provides an overview of the project, progress, actualities and publications.

ACKNOWLEDGEMENTS

We express our gratitude to all members of the follow up committee who provide relevant input throughout the project. We acknowledge the full HIS team of Sciensano and the Belgian statistical office, Statbel, for their technical support during the process of database merging and linking.

COMPETING INTERESTS

None declared.

CONTRIBUTORSHIP STATEMENT

All authors contributed to the conception of the mixed method study protocol. LL, ML, RR, HB, and HK are responsible for the development and implementation of the qualitative research part and evaluation part in consultation with IP, ST, MG, NS, EDC, IT, and TN. IP, ST, MG, NS, EDC, IT, and TN are responsible for the development and implementation of the quantitative research part in consultation with LL, ML, RR, HB, and HK. AG and AVN are no longer active on the project but contributed greatly to the study design and gave their reflections on the manuscript. LL provided a first draft and adapted the manuscript to the comments from all other authors and reviewers. IP and ST were responsible for the adjustments to the quantitative research part in the manuscript. LL and ST proofread the manuscript and made final adjustments. All authors have read and approved the final version of the manuscript.

FUNDING

This work was supported by the Belgian Federal Science Policy Office (BELSPO), grant number BR/175/A3/NAMED.

DATA STATEMENT

No data are available. Due to privacy legislation, we cannot share the data obtained and analyzed for the purpose of the NAMED project. More details on data availability are included in the manuscript.

PATIENT AND PUBLIC STATEMENT

For the qualitative part, local organizations and experts are involved to reflect on the interview design. The local organizations support participants recruitment by promoting the project to their members or visitors. The interviews involve a diverse sample of inhabitants of the BCR.

For the validation part, stakeholders and experts are invited for focus groups to discuss research results. Their inputs will support final reporting of the project results and implications.

REFERENCES

1. World Health Organization [Internet]. Mental disorders. WHO; 2018 Apr 9 [cited 2019 Nov 18]. Available from: https://www.who.int/en/news-room/fact-sheets/detail/mental-disorders
2. Drieskens S, Charafeddine R, Demarest S, et al. HISIA: Belgian Health Interview Survey - Interactive Analysis. Brussels: Sciensano [cited 2019 Nov 18]. Available from: https://hisia.wiv-isp.be/
3. Regier DA, Farmer ME, Rae DS, et al. One-month prevalence of mental disorders in the United States and sociodemographic characteristics: the Epidemiologic Catchment Area study. *Acta Psychiatr Scand* 1993;88:35-47.
4. Alonso J, Angermeyer MC, Bernert S, et al. Prevalence of mental disorders in Europe: results from the European Study of the Epidemiology of Mental Disorders (ESEMeD) project. *Acta Psychiatr Scand* 2004;109:21-7.
5. Merikangas KR, He J, Burstein M, et al. Lifetime Prevalence of Mental Disorders in U.S. Adolescents: Results from the National Comorbidity Survey Replication–

Adolescent Supplement (NCS-A). *J Am Acad Child Adolesc Psychiatry* 2010;49:980-9.
6. Bijl RV, Ravelli A, van Zessen G. Prevalence of psychiatric disorder in the general population: results of the Netherlands Mental Health Survey and Incidence Study (NEMESIS). *Soc Psychiatry Psychiatr Epidemiol* 1998;33:587–95.
7. Gruebner O, Rapp MA, Adli M, et al. Cities and Mental Health. *Dtsch Arztebl Int* 2017;114:121-7.
8. Desjarlais R, Eisenberg L, Good B, Kleinman A . World mental health: Problems and priorities in low-income countries. USA: Oxford University Press 1995.
9. Paczkowski MM, Galea S. Sociodemographic characteristics of the neighborhood and depressive symptoms. *Curr Opin Psychiatry* 2010;23:337-41.
10. Dalgard OS, Tambs K. Urban environment and mental health: a longitudinal study. *BJPsych* 1997;171:530-6.
11. Chu A, Thorne A, Guite H. The impact on mental well-being of the urban and physical environment: an assessment of the evidence. *J Public Ment Health* 2004;3:17-32.
12. Clark C, Myron R, Stansfeld S, et al. A systematic review of the evidence on the effect of the built and physical environment on mental health. *J Public Ment Health* 2007;6:14-27.
13. Guite HF, Clark C, Ackrill G. The impact of the physical and urban environment on mental well-being. *Public health* 2006;120:1117-26.
14. Mair C, Roux AD, Galea S. Are neighbourhood characteristics associated with depressive symptoms? A review of evidence. *Journal of Epidemiology & Community Health* 2008;62:940-6.
15. Toma A, Hamer M, Shankar A. Associations between neighborhood perceptions and mental well-being among older adults. *Health & Place* 2015;34:46-53.
16. Ma J, Li C, Kwan MP, Chai Y. A Multilevel Analysis of Perceived Noise Pollution, Geographic Contexts and Mental Health in Beijing. *Int J Environ Res Public Health* 2018;15:1479.
17. Buoli M, Grassi S, Caldiroli A, et al. Is there a link between air pollution and mental disorders? *Environment international* 2018;118:154-68.
18. McCay L, Bremer I, Endale T, et al. Urban design and mental health. *Mental Health and Illness in the City* 2017:1-24.
19. Lorenc T, Clayton S, Neary D, et al. Crime, fear of crime, environment, and mental health and wellbeing: mapping review of theories and causal pathways. *Health & Place* 2012;18:757-65.
20. Gascon M, Triguero-Mas M, Martínez D. Mental health benefits of long-term exposure to residential green and blue spaces: a systematic review. *Int J Environ Res Public Health* 2015;12:4354-79.
21. Sugiyama T, Leslie E, Giles-Corti B, et al. Associations of neighbourhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships? *Journal of Epidemiology & Community Health* 2008;62:e9.
22. Stigsdotter UK, Ekholm O, Schipperijn J, et al. Health promoting outdoor environments - Associations between green space, and health, health-related quality of life and stress based on a Danish national representative survey. *Scand J Public Health* 2010;38:411-7.
23. Nutsford D, Pearson AL, Kingham S. An ecological study investigating the association between access to urban green space and mental health. *Public Health* 2013;127:1005-11.

24. Beyer K, Kaltenbach A, Szabo A, et al. Exposure to neighborhood green space and mental health: evidence from the survey of the health of Wisconsin. *Int J Environ Res Public Health* 2014;11:3453-72.
25. Cox DT, Shanahan DF, Hudson HL, et al. Doses of neighborhood nature: the benefits for mental health of living with nature. *BioScience* 2017;67:147-55.
26. South EC, Hohl BC, Kondo MC, et al. Effect of greening vacant land on mental health of community-dwelling adults: a cluster randomized trial. *JAMA network open* 2018;1:e180298.
27. Cohen-Cline H, Turkheimer E, Duncan GE. Access to green space, physical activity and mental health: a twin study. *J Epidemiol Community Health* 2015;69:523–9.
28. Evans GW. The built environment and mental health. *Journal of urban health* 2003;80:536-55.
29. Rautio N, Filatova S, Lehtiniemi H, et al. Living environment and its relationship to depressive mood: A systematic review. *International Journal of Social Psychiatry* 2018;64:92-103.
30. Moore TH, Kesten JM, López-López JA, et al. The effects of changes to the built environment on the mental health and well-being of adults: Systematic review. *Health & Place* 2018;53:237-57.
31. Benita F, Bansal G, Tunçer B. Public spaces and happiness: Evidence from a large-scale field experiment. *Health & Place* 2019;56:9-18.
32. Melis G, Gelormino E, Marra G, et al. The effects of the urban built environment on mental health: A cohort study in a large northern Italian city. *Int J Environ Res Public Health* 2015 12:14898-915.
33. Gong Y, Palmer S, Gallacher J, et al. A systematic review of the relationship between objective measurements of the urban environment and psychological distress. *Environment international* 2016;96:48-57.
34. Markevych I, Schoierer J, Hartig T, et al. Exploring pathways linking greenspace to health: Theoretical and methodological guidance. *Environmental Research* 2017;158:301-17.
35. Hartig T, Mitchell R, de Vries S, et al. Nature and health. *Annu Rev Public Health* 2014;35:207–28.
36. statbel.fgov.be [Internet]. Brussels: Statbel, the Belgian statistical office; 2018 [cited 2019 Nov 18]. Available from: statbel.fgov.be/en
37. Van de Voorde T, Canters F, Chan JC. Mapping update and analysis of the evolution of non-built (green) spaces in the Brussels Capital Region. Final Report. Brussels: Cartography and GIS Research Group, Department of Geography, Vrije Universiteit Brussel; Dec 2010. Report No.: ActuaEvol/09
38. Hermia JP, Sierens A. Belges et étrangers en Région bruxelloise, de la naissance à aujourd'hui. IBSA Brussels. 2017 Aug 20.
39. his.wiv-isp.be [Internet]. Brussels: Sciensano; 2019 [cited 2019 Nov 18]. Available from: https://his.wiv-isp.be/SitePages/Questionnaires.aspx
40. UrbIS data [Internet]. Brussels: CIRB-CIBG; 2019 [cited 2019 May 6]. Available from: https://cirb.brussels/fr/nos-solutions/urbis-solutions/urbis-data
41. Araldi A, Fusco G. From the street to the metropolitan region: Pedestrian perspective in urban fabric analysis. *Environment and Planning B: Urban Analytics and City Science* 2019;46:1243-63.
42. Maghelal PK, Capp CJ. Walkability: A Review of Existing Pedestrian Indices. *Journal of the Urban & Regional Information Systems Association* 2011;23.
43. Janssen S, Dumont G, Fierens F, et al. Spatial interpolation of air pollution measurements using CORINE land cover data. *Atmos Environ* 2008;42:4884–903.

44. Lefebvre W, Degrawe B, Beckx C, et al. Presentation and evaluation of an integrated model chain to respond to traffic- and health-related policy questions. *Environ Model Softw* 2013;40:160–70.
45. Saenen ND, Bové H, Steuwe C, et al. Children's urinary environmental carbon load. A novel marker reflecting residential ambient air pollution exposure? *Am J Respir Crit Care Med* 2017;196:873-81.
46. World Health Organization. Environmental Noise Guidelines for the European Region. Copenhagen: WHO Regional Office for Europe: Copenhagen; 2018.
47. Styns. Evaluatie van de gezondheids- en economische gevolgen van het globale verkeersgeluid in het Brussels Hoofdstedelijk Gewest. BIM, collectie factsheets, thema geluid. Brussels: Leefmilieu Brussel; 2016.
48. Gunzler D, Chen T, Wu P, et al. Introduction to mediation analysis with structural equation modeling. *Shanghai Arch Psychiatry* 2013;25:390–4.
49. Bradshaw C, Atkinson S, Doody O. Employing a qualitative description approach in health care research. *Glob Qual Nurs Res* 2017;4:2333393617742282.
50. Kusenbach M. Street phenomenology: The go-along as ethnographic research tool. *Ethnography* 2003;4:455-485.
51. Morse JM. Determining sample size. *Qual Health Res* 2000;10:3–5.
52. Green J, Thorogood N. Qualitative methods for health research. London: Sage; 2018.
53. O'Brien L, Morris J, Stewart A. Engaging with peri-urban woodlands in England: the contribution to people's health and well-being and implications for future management. *Int J Environ Res Public Health* 2014;11:6171-92.
54. Carpiano RM. Come take a walk with me: The "Go-Along" interview as a novel method for studying the implications of place for health and well-being. *Health & Place* 2009;15:263-272.
55. Braun V, Clarke V. Using thematic analysis in psychology. *Qual Res Psychol* 2006;3:77-101.
56. Maguire M, Delahunt B. Doing a thematic analysis: A practical, step-by-step guide for learning and teaching scholars. *AISHE-J* 2017;9.
57. Molina-Azorin JF, Bergh DD, Corley KG, et al. Mixed Methods in the Organizational Sciences: Taking Stock and Moving Forward. *Organ Res Methods* 2017;20:179-192.
58. Keune H, Gudrun Koppen, Bert Morrens, et al. Extended Peer Evaluation of an Analytical Deliberative Decision Support Procedure in Environmental Health Practice. *Eur J Risk Regul* 2014;1:25-35
59. Renn O. Participatory processes for designing environmental policies. *Land Use Policy* 2006;23:34–43.
60. Jordan A. The Governance of Sustainable Development: Taking Stock and Looking Forwards. *Environ Plan C Gov Policy* 2008;26:17–33.
61. Reed MS. Stakeholder participation for environmental management: A literature review. *Biol Conserv* 2008;141:2417–31.
62. Brown G, de Bie K, Weber D. Identifying public land stakeholder perspectives for implementing place-based land management. *Landsc Urban Plan* 2015;139:1–15.
63. Hooghe L, Marks G. Unraveling the Central State, but How? Types of Multi-Level Governance. *Am Polit Sci Rev* 2003;97:233–43.

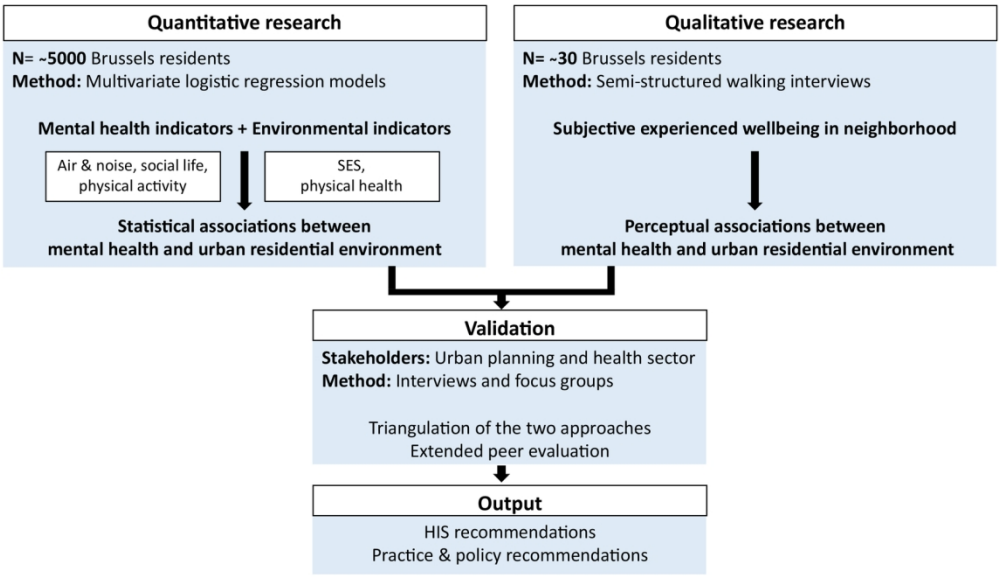

Fig. 1 Schematic overview of the working plan of NAMED with the main characteristics of each research part.

149x90mm (300 x 300 DPI)