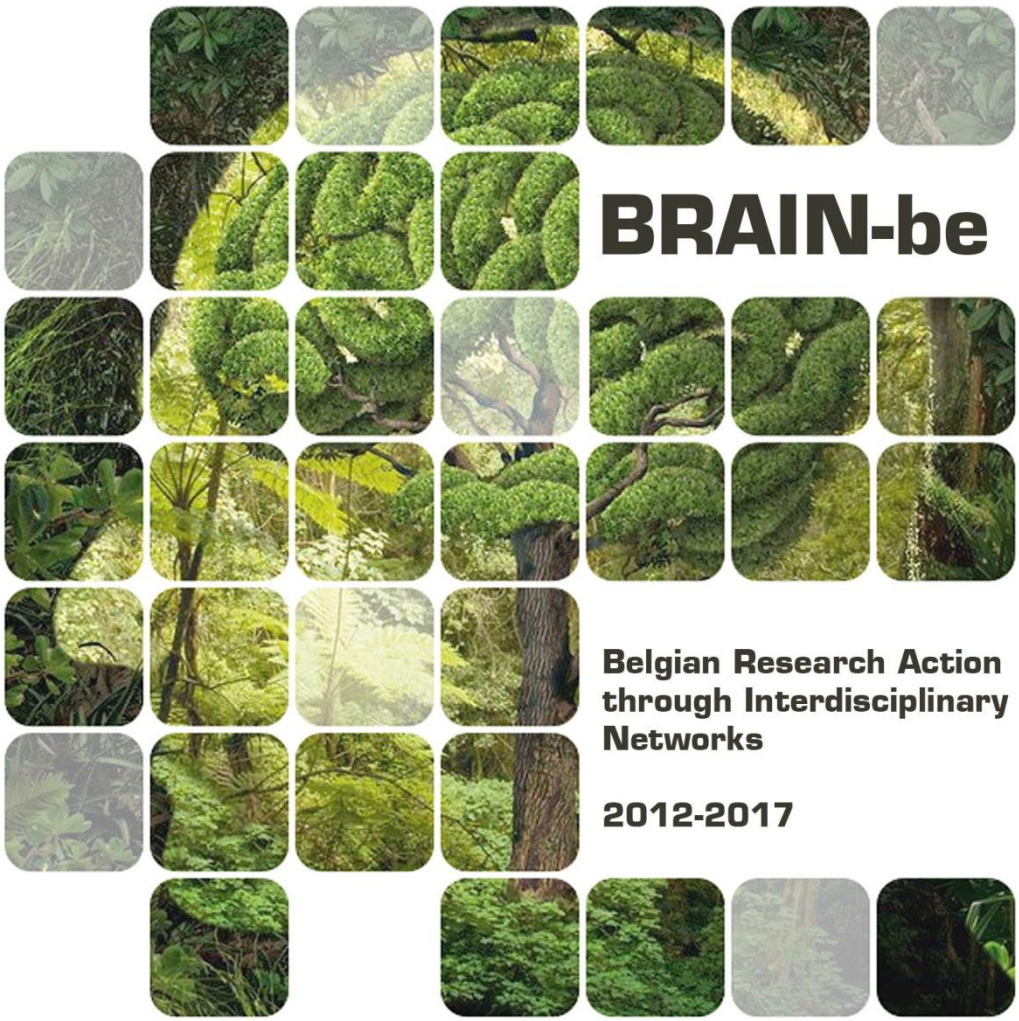

NAMED

Nature Impact on Mental Health Distribution

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NETWORK PROJECT

NAMED

Nature Impact on Mental Health Distribution

Contract - BR/175/A3/NAMED

FINAL REPORT

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READING GUIDE

A big part of this report includes literal citations of the scientific articles that already have been published in the scope of the NAMED project. **We marked the literally cited text in color in accordance to the reference of the publication**:

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Lauwers L, Leone M, Guyot M, Pelgrims I, Remmen R, Van den Broeck K, Keune H, Bastiaens H. Exploring how the urban neighborhood environment influences mental well-being using walking interviews. Health and Place. 2021 Jan 1;67:102497. https://doi.org/10.1016/j.healthplace.2020.102497

Pelgrims, Ingrid, Brecht Devleesschauwer, Madeleine Guyot, Hans Keune, Tim S. Nawrot, Roy Remmen, Nelly D. Saenen, e.a. "Association between urban environment and mental health in Brussels, Belgium". BMC Public Health 21, nr. 1 (1 april 2021): 635. https://doi.org/10.1186/s12889-021-10557-7

Guyot M, Araldi A, Fusco G, Thomas I. The urban form of Brussels from the street perspective: The role of vegetation in the definition of the urban fabric. Landscape and Urban Planning. 2021 Jan 1;205:103947. https://doi.org/10.1016/j.landurbplan.2020.103947

ABSTRACT

Context

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.

Objectives

This report presents the project Nature Impact on Mental Health Distribution (NAMED) that aimed to generate a more comprehensive understanding of associations between mental health and the urban residential environment. Following a mixed method approach, the project combined quantitative and qualitative research. In the quantitative part, we analyzed among the Brussels urban population associations between the urban residential environment and mental health, taking respondents' socioeconomic status and lifestyle factors 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 objective indicators for buildings, network infrastructure, noise pollution, air pollution, and the green environment developed for the purpose of this project. We assessed the mediating role of lifestyle factors, such as physical activity and social support. In the qualitative part, we conducted walking interviews with Brussels residents to record their subjective well-being in association with their neighborhood. In the validation part, results from these two approaches were triangulated and evaluated through a citizen workshop, and interviews with stakeholders of healthcare and urban planning sectors to develop recommendations for their practices, policies, and the HIS. At last, an internal validation with the research team resulted in methodological recommendations for future research.

Conclusions

Based on the results of the NAMED project, we conclude that concerning the outdoor urban environment, mental health benefits from a natural, social, and physically active environment. In contrast, motorized traffic harms mental health through the related air pollution, traffic noise, and lack of traffic safety. Both positive (presence of nature) and negative (motorized traffic) environmental factors are unequally distributed in the Brussels-Capital Region (BCR), with Brussels' dwellers with a lower socioeconomic status affected most by the environmental negatives and least by the environmental positives. We conclude that cities are complex systems, with urban mental health outcomes depending on many interactions between personal, social, physical, and institutional factors. Investigating urban mental health is further challenged by the low availability of fine-scaled mental health data. The use of the HIS data was challenged by a great amount of missing data on mental health and income, implying potential underestimations or biases in the current findings. We finalize this report with recommendations for practice, policy, research, and the HIS based on the involvement of experts from the environmental and (mental) health sector.

Keywords

Mental health; Urban environment; Mixed method; Interdisciplinary approach; Brussels.

SAMENVATTING

Context

Mentale gezondheidsproblemen blijken een groeiend probleem in moderne samenlevingen en komen vaker voor in grote steden. Hoewel er steeds meer bewijs is voor positieve verbanden tussen natuur en de mentale gezondheid, zijn verbanden tussen stedelijke omgevingskenmerken en de mentale gezondheid nog steeds niet goed gekend. Deze verbanden zijn uiterst complex en vereisen een interdisciplinaire en geïntegreerde aanpak om het brede scala aan mogelijk beïnvloedende factoren te onderzoeken.

Doelstellingen

Dit rapport presenteert het project Nature Impact on Mental Health Distribution (NAMED) met het doel om de kennis over de associaties tussen de mentale gezondheid en de stedelijke woonomgeving te verruimen. Het project hanteerde een gemixte methode, waarbij kwantitatief en kwalitatief onderzoek gecombineerd werden. In het kwantitatieve deel analyseerden we bij de Brusselse bevolking associaties tussen de stedelijke woonomgeving en de mentale gezondheid, rekening houdend met de socio-economische status en levensstijlfactoren van de respondenten. Inzake de mentale gezondheid werden indicatoren uit de nationale gezondheidsenquête gebruikt. De stedelijke woonomgeving werd beschreven door objectieve indicatoren voor de bebouwde omgeving, de netwerkinfrastructuur, de geluidsoverlast, de luchtvervuiling en de groene omgeving. We evalueerden de mogelijke rol die leefstijlfactoren, zoals fysieke activiteit en sociale steun, spelen in de onderzochte associaties. In het kwalitatieve luik voerden we wandelinterviews uit met Brusselaars om hun subjectief welzijn in relatie tot hun buurt vast te leggen. In het validatiegedeelte werden de resultaten van deze twee benaderingen samengebracht en geëvalueerd via een workshop voor inwoners en interviews met belanghebbenden uit de gezondheidszorg en de stedenbouwkundige sector om aanbevelingen te ontwikkelen voor hun praktijken, beleid en de nationale gezondheidsenquête. Ten slotte resulteerde een interne validatie met het onderzoeksteam in methodologische aanbevelingen voor toekomstig onderzoek.

Conclusies

Op basis van de resultaten van het NAMED project concluderen we dat wat betreft de stedelijke buitenomgeving, de mentale gezondheid baat heeft bij een natuurlijke, sociale en fysiek actieve omgeving. Gemotoriseerd verkeer daarentegen schaadt de mentale gezondheid door de luchtvervuiling, het verkeerslawaai en het gebrek aan verkeersveiligheid die ermee gepaard gaan. Zowel de positieve (aanwezigheid van natuur) als de negatieve (gemotoriseerd verkeer) milieufactoren zijn ongelijk verdeeld in het Brussels Hoofdstedelijk Gewest, waarbij Brusselaars met een lagere socio-economische status het meest getroffen worden door de negatieve milieufactoren en het minst door de positieve milieufactoren. We concluderen dat steden complexe systemen zijn, waarbij de resultaten op het gebied van stedelijke mentale gezondheid afhankelijk zijn van vele interacties tussen persoonlijke, sociale, fysieke en institutionele factoren. Het onderzoek naar de mentale gezondheid in steden wordt verder bemoeilijkt door de geringe beschikbaarheid van gedetailleerde gegevens over mentale gezondheid. Het gebruik van de gegevens uit de nationale

gezondheidsenquête werd bemoeilijkt door een grote hoeveelheid ontbrekende gegevens over de mentale gezondheid en het inkomen, waardoor de huidige bevindingen mogelijk een onderschatting of vertekening van de realiteit tonen. We sluiten dit rapport af met aanbevelingen voor praktijk, beleid, onderzoek en de nationale gezondheidsenquête, gebaseerd op de betrokkenheid van experts uit de milieu- en (mentale) gezondheidssector.

Trefwoorden

Mentale gezondheid; Stedelijk leefomgeving; Gemixte methode; Interdisciplinaire aanpak; Brussel.

RÉSUMÉ

Contexte

Les problématiques de santé mentale constituent un enjeu croissant dans les sociétés modernes et ont tendance à être plus fréquentes dans les grandes villes. Alors qu'il existe de plus en plus de preuves de relations bénéfiques entre la nature et la santé mentale, les associations entre les caractéristiques de l'environnement urbain et la santé mentale ne sont pas encore bien comprises. Ces associations sont très complexes et nécessitent une approche interdisciplinaire et intégrée pour couvrir le large éventail de facteurs de mitigation.

Objectifs

Ce rapport présente relate les résultats issus du projet « Nature Impact on Mental Health Distribution » (NAMED) qui vise à développer une compréhension plus complète des associations entre la santé mentale et l'environnement urbain résidentiel. Suivant une approche de méthode mixte, le projet a combiné recherche quantitative et qualitative. Dans la partie quantitative, nous avons analysé parmi la population urbaine bruxelloise les associations entre l'environnement résidentiel urbain et la santé mentale, en tenant compte du statut socioéconomique et des facteurs liés au mode de vie des répondants. La santé mentale est déterminée par les indicateurs de santé mentale de l'Enquête nationale de Santé (Health Interview Survey, HIS). L'environnement résidentiel urbain est décrit par des indicateurs objectifs relatifs au bâti, aux infrastructures de réseau, à la pollution sonore, à la pollution de l'air et à la végétation, développés dans le cadre de ce projet. Nous avons évalué le rôle médiateur des facteurs liés au mode de vie, tels que l'activité physique et le soutien social. Dans la partie qualitative, nous avons mené des entretiens en marchant avec des habitants de Bruxelles pour enregistrer leur bienêtre subjectif dans le contexte de leur quartier. Dans la partie validation, les résultats de ces deux approches ont été triangulés et évalués par le biais d'un atelier citoyen, et par le biais d'entretiens avec des acteurs des secteurs de la santé et de l'urbanisme afin de développer des recommandations pour leurs pratiques, leurs politiques et l'Enquête de Santé. Enfin, une validation interne avec l'équipe de recherche a abouti à des recommandations méthodologiques pour les recherches futures.

Conclusions

Sur base des résultats du projet NAMED, nous concluons que la santé mentale est favorisée par la présence de nature, de support social et d'un environnement favorisant le fait d'être physiquement actif. En revanche, le trafic motorisé nuit à la santé mentale en raison de la pollution de l'air, du bruit et du manque de sécurité routière. Les facteurs environnementaux positifs (présence de la nature) et négatifs (trafic motorisé) sont inégalement répartis dans la Région de Bruxelles-Capitale (RCB), les Bruxellois de statut socioéconomique faible étant les plus touchés par les facteurs environnementaux négatifs et les moins touchés par les facteurs environnementaux positifs. Nous concluons que les villes sont des systèmes complexes, la modélisation de la santé mentale urbaine dépend de nombreuses interactions entre les facteurs personnels, sociaux, physiques et institutionnels. L'étude de la santé mentale en milieu urbain est rendue encore plus difficile par la faible disponibilité de données sur la santé mentale à une échelle fine. L'utilisation des données de

l'Enquête de Santé a été rendue difficile par un grand nombre de données manquantes sur la santé mentale et le revenu, ce qui implique des sous-estimations ou des biais potentiels dans les résultats actuels. Nous terminons ce rapport avec des recommandations pour la pratique, la politique, la recherche et l'Enquête de Santé, basées sur l'implication d'experts du secteur de l'environnement et de la santé (mentale).

Mots-clés

Santé mentale ; Environnement urbain ; Méthode mixte ; Approche interdisciplinaire ; Bruxelles.

1. INTRODUCTION

Mental health disorders appear to be a growing problem in modern societies, specifically in urban areas (Peen et al., 2010). According to the World Health Organization (WHO), depression affects around 264 million people and is one of the main causes of disability worldwide (WHO, 2020). Nearly the same amount of people suffer from anxiety disorders and many people experience both conditions simultaneously (WHO, 2017). 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%) (Gisle, 2013). It is now well-established that the nature, prevalence, and age of onset of mental disorders vary according to demographic, socioeconomic, and cultural factors (Regier et al., 1993; Bijl et al., 1998; Merikangas et al., 2010; Gisle et al., 2013; Alonso et al., 2017). Growing evidence indicates a higher prevalence of mental illnesses in urban environments in comparison to rural environments (Gruebner et al., 2017; Okkels et al., 2018; Solmi et al., 2017). Also in Belgium, the occurrence of psychosocial difficulties is generally higher in cities (Gisle, 2013). With growing urbanization, more and more people are exposed to environmental stressors, potentially contributing to increased stress and impairing mental health (Gruebner et al. , 2017; Rautio et al., 2018). It is therefore important to identify specific features of the urban environment that might affect the health of the city dwellers.

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 (Evans, 2003; Galea et al., 2005; Rao et al., 2007; Halpern, 2014). Hypothesized explanations include social risk factors, such as concentrations of low socio-economic status, low social capital, and social segregation (Gruebner et al., 2017; Okkels et al., 2018), and physical risk factors such as noise pollution, air , 2005; pollution, and poor urban design (Buoli et al., 2018; Gruebner et al., 2017; Ma et al., 2018; Mccay et al., 2019; Rautio et al., 2018). Recently, a growing body of evidence has corroborated positive effects of urban green-blue spaces on mental health (Beyer et al., 2014; Cox et al., 2017; Kabisch, 2019; Nutsford et al., 2013; South et al., 2018; Stigsdotter et al., 2010).

Current evidence implies that the urban environment influences both mental illness (mental health disorder) and mental well-being (mental health). Mental well-being has been conceptualized as more than the absence of mental illness (Doré and Caron 2017), and encompasses hedonic (happiness, life satisfaction, and affect) and eudaimonic (positive functioning, sense of purpose, and self-acceptance) wellbeing (Huppert 2005, Tennant et al 2007). While mental illness and mental well-being may be related, they are not necessarily distinct ends of a continuum, but rather two separate continua: one continuum indicates the presence or absence of mental health, the other the presence or absence of mental illness (Westerhof and Keyes, 2010).

This final report presents the methods and results of the Nature Impact on Mental Health Distribution (NAMED) project. The NAMED project is a Belgian 4-year project (2017–2021) that investigated associations between urban environment characteristics and mental illness and well-being in the Brussels-Capital Region (BCR) (Lauwers et al., 2020).

The Healthy Cities Commission, a collaboration between the University College London and the Lancet, stated clearly that “cities are complex systems, so urban health outcomes are dependent on many interactions” (Rydin et al., 2012, p. 2079). To be relevant, research should attempt to unravel this complexity and embrace different realities explaining this complexity (Westhues et al., 2008). In the NAMED project, this effort translated into a mixed method approach conducted by a multidisciplinary research team, including epidemiologists, geographers, general practitioners, and

environmental and social scientists. The quantitative research relied on mental health and environmental data collected within the HIS, and environmental indicators describing the urban residential environment developed for the purpose of this project. Based on these environmental indicators, an urban typology was developed that guided the neighborhood selection for the qualitative research. The qualitative research involved walking interviews with Brussels dwellers in their neighborhood environment. The combination of both study parts aimed at exploring and understanding associations between the urban residential environment and mental health. In a validation stage the project results were discussed with experts from the health and environmental sector of the BCR to develop recommendations for their practices, policies, and the HIS (Figure 1). At last, an internal validation with the research team resulted in methodological recommendations for future research. We like to emphasize that our findings apply to the urban context of the BCR, and might differ for other living contexts.

The combined approach allowed to answer following research questions:

- What morphological typology describes the urban environment of the BCR as perceived by pedestrians freely moving on the street network? (Typology part)
- Is there an association between the urban residential environment and mental health in the BCR using objective and subjective environmental indicators? (Quantitative part)
- How do people living in the BCR perceive and experience their urban residential environment in association with their mental health? (Qualitative part)
- How can the project results guide future practice, policy and research? (Validation part)

2. STATE OF THE ART AND OBJECTIVES

While mental health disorders are generally linked to demographic and socioeconomic factors, little quantitative data is available on the interaction between mental health and the urban environment. When studying the impact of the urban environment on mental health, the main focus goes to air pollution, urban greenness, noise and urban morphology.

Air pollution, largely attributed to traffic volume, has been associated with mental disorders in several studies (Power et al., 2015; Gong et al., 2016; Kim et al., 2016; Zijlema et al., 2016; Sass et al., 2017; Kioumourtzoglou et al., 2017; Pun et al., 2017). In the light of their toxicity on the central nervous system, air pollutants may have a possible role in the onset or worsening of mental conditions (Anisman and Hayley, 2012; Buoli et al., 2018). Air pollution exposure may lead to oxidative stress, neuro-inflammation, cerebrovascular damage, and neurodegenerative pathology (Block and Calderón-Garcidueñas, 2009). Air pollution has also been associated with behavioral determinants of mental health such as spending less time outdoors, reduced physical activity (von Lindern et al., 2016; An et al., 2018) and contact with nature, limited exposure to sunlight and vitamin D deficiency (Wilkins et al., 2006). Among the common indices of air pollution, fine particulate matter (PM2.5) appears to play an influential role on depression and on psychotic disorders (Attademo et al., 2017; Zeng et al., 2019). Also, nitrogen oxides (NOx), particularly nitrogen dioxide (NO2), seem to have a significant place among the risks factors of psychotic disorders. Regarding ambient ozone exposure (O3), current evidence for an association with mental health remains inconclusive (Zhao et al., 2018). While there has been an increasing number of studies investigating the association between PM and mental health, few studies have examined the potential impact of black carbon (BC). According to toxicological studies, BC may operate as an universal carrier of a large variety of toxic chemicals in the human body and could be a more suitable air quality indicator to evaluate the health risks of traffic-related air pollution (Janssen et al., 2012).

Noise is another prominent feature within the urban environment. Recent reviews have revealed that transportation noise such as road, aircraft or rail traffic noise leads to sleep disturbance (Clark and Paunovic, 2018). Increasing exposure to road traffic noise has also been associated with depression and anxiety in recent systematic reviews and meta-analyses, yet quality of evidence was considered as “very low” (Dzhambov and Lercher, 2019; Clark et al., 2020). However, poor quality of evidence does not mean that noise should not be considered as a risk factor for mental disorders (Clark and Paunovic, 2018), as the relationship between noise and mental health is biologically plausible (van den Bosch and Meyer-Lindenberg, 2019). Several studies support the hypothesis that noise is associated with neurocognitive functions, mood disorders and neurodegenerative disease (Tzivian et al., 2015; van den Bosch and Meyer-Lindenberg, 2019).

A green environment has been associated with improved mental health in several reviews and epidemiological studies (van den Berg et al., 2010; Lee and Maheswaran, 2011; Triguero-Mas et al., 2015; de Vries et al., 2016; Gascon et al., 2018; Vanaken and Danckaerts, 2018). 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 (Sugiyama et al., 2008; Stigsdotter et al., 2010; Nutsford et al., 2013; Beyer et al., 2014;

Cox et al., 2017; South et al., 2018). Different theories were suggested based on three benefits attributed to green spaces: (i) reducing exposure to environmental stressors such as noise, heat, and air pollution, (ii) facilitating social cohesion and physical activities, and (iii) reducing stress levels (Markevych et al., 2017). The mechanism for stress reduction requires visual perception of green space. However, measures of green exposure are commonly assessed at the neighborhood level and do not capture street-level exposures (Larkin and Hystad, 2019). Green exposure is often assessed through a "standard" set of measures (i.e. greenness, quantified by the Normalized Difference Vegetation Index) that does not incorporate information on specific features of urban greenness that might drive health outcomes and present a risk of oversimplifying the perceptions of urban dwellers of their environment (Gascon et al., 2015; Fong et al., 2017). For instance, it has been shown that tree density, assessed on the ground and not by remote sensing, had a significant influence on reducing oppressiveness (Asgarzadeh et al., 2012; Helbich et al., 2019).

The urban building morphology may also have a potential impact on mental health (Evans, 2003). The street canyon effect, where narrow streets are flanked by high buildings on both sides, may reduce light penetration and increase noise volume at street level Echevarria et al., 2016; Mohajeri et al., 2019). Also the shape of high-rise buildings may have an oppressive impact on dwellers (Zarghami et al., 2019). Urban canyons contribute to the urban heat island effect and poor air quality by reducing the capacity for pollutants released by traffic to dissipate (Vardoulakis et al., 2003; Memon et al., 2010). All this may impact the mental health of city dwellers. The street corridor effect is another common characteristic of the building structure of urban streets and is determined by the ratio between the distance between parallel facades and street length. To our knowledge, no study has yet assessed the potential impact of the street canyon and corridor effect on mental health.

When focusing on analysis of the urban form – the spatial organization of urban physical elements such as buildings, streets and parcels – several methods have been developed, such as: street-network configurational analyses (Hillier, 1996; Porta et al., 2006), fractal-based approaches (De Keersmaecker et al., 2003; Thomas et al., 2008), multivariate analysis of morphometric descriptors of built-up density (Berghauser Pont and Haupt, 2010), or a combination of geoprocessing and spatial statistic procedures (Caruso et al., 2017). Data can be very simple, such as the centroid of each building (Caruso et al., 2017; Thomas et al., 2008) or the building footprint (Hamaina et al., 2014), or include several morphological indicators (Araldi and Fusco, 2019; Gil et al., 2012; Vanderhaegen and Canters, 2017). While these studies allow quantitative description of the urbanform, two aspects are traditionally overlooked. Firstly, the pedestrian point of view: when analyzing socio-economic phenomena occurring in the public space, the pedestrian perspective assumes crucial importance and should be preferred to the more aerial point of view traditionally favored in urban studies (Araldi and Fusco, 2019). Secondly, public and private green spaces feature in the definition of urban morphology indicators and, consequently, in the urban fabric. The importance of the urban form from the street perspective has already been recognized by several authors. From the urban design field of research, Purciel et al. (2009); Vialard (2013); and Harvey et al. (2017) provide innovative protocols for quantitative analysis of the distribution of urban features along the edges of streets, i.e. the skeletal streetscape. Araldi and Fusco (2019) extended the analysis of the urban form of individual streetscapes to the analysis of urban fabrics and morphological regions using the Multiple Fabric Assessment (MFA) protocol. MFA allows both the characterization of individual morphometrics at street level and the identification of urban fabrics as perceived by pedestrians within large urban areas. This approach differs strongly from the aerial approach traditionally

adopted by urban planners, geographers and morphologists: urban morphological features are described quantitatively from the pedestrian point of view and their spatial distribution is statistically evaluated in order to identify significant local patterns in the street-network layout. Lastly, patterns of morphological indicators are combined using Naïf Bayesian Classification approaches, allowing a probabilistic description of urban fabric profiles. While the importance of vegetation distribution in urban public spaces has been widely investigated in quantitative analyses (e.g. Harvey et al., 2017; Li et al., 2015), urban form studies have focused on built-up rather than green spaces. There are some exceptions such as Hermosilla et al. (2014), who included vegetation cover data obtained from high-resolution satellite imagery and LiDAR to define urban typologies. Vegetation indicators such as these require specific data, either pre-processed or from high-resolution satellite imagery, in order to have a fine-grained definition of vegetation. There is also a rising interest among streetscape researchers in vegetation and built-up indicators based on street images (e.g. Google Street View), which provide realistic 3-D representations of urban streets from a pedestrian's perspective (Gong et al., 2018; Li et al., 2015; Richards and Edwards, 2017). The problem with all these vegetation data is that the choice of database significantly affects the modelling results (Texier et al., 2018; Trabelsi, 2020). **The aim of the typology part of the NAMED project was to develop accurate indicators to describe the urban residential environment from a pedestrian point of view and to guide a diverse neighborhood selection for the qualitative interviews.**

The exposures to air pollution, noise, surrounding green, and characteristics of the built environment are generally spatially correlated (Markevych et al., 2017). However, most of the epidemiological studies assessing the relation between the built environment and mental health are single exposure models (Gascon et al., 2015; Rautio et al., 2018). Evaluating these environmental exposures separately ignores the potential confounding effects between them (Gascon et al., 2015; Rautio et al., 2018). It remains thus unclear to what extent associations between urban greenness and mental health are attributable to air pollution, and vice versa. Lifestyle factors, such as physical activity and social support can also mediate or confound the relation between environment and mental health (de Vries et al., 2013). Another shortcoming of existing studies is that mental health is often approached by a single indicator making it difficult to grasp the different dimensions of mental health and to compare results across studies (Gruebner et al., 2017; Gascon et al., 2015). **The aim of the quantitative part of the NAMED project was to define associations of combined long-term exposure to air pollution, surrounding green at different scales, noise from multiple sources, and urban building morphology with several dimensions of mental health in Brussels.**

A recent review underlines that these mental health risk and protective factors also operate at the neighborhood level (Rautio et al., 2018). 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 (Chu et al., 2004; Clark et al., 2007; Dalgard and Tambs, 1997; Guite et al., 2006; Mair et al., 2008; Paczkowski and Galea, 2010; Toma et al., 2015). Neighborhood aesthetics and green space were shown to significantly associate with lower depression, where the opposite effects were detected for neighborhood noise and deterioration (Rautio et al., 2018). Qualitative evidence has indicated the importance of access to and quality of neighborhood services, neighborhood aesthetics, public meeting places, sense of security, neighborhood cohesion, neighborhood affordability and access to natural environments to improve mental well-being (Bornioli et al., 2018; Francis et al., 2015; O'campo et al., 2009). Contrary, neighborhood insecurity caused by crime, vandalism, and violence and neighborhood abandonment in terms of trash

accumulation, vacant lands, poor maintenance of houses and sidewalks are shown to negatively affect well-being (O'campo et al., 2009; Garvin et al., 2013; Mehdipanah et al., 2013).

Although, current studies already pay attention to both social and physical effects, in-depth knowledge on interactions among those factors and the underlying mechanisms in their associations with mental well-being remain scarce (Cattell et al., 2008; Dinnie et al., 2013; O'campo et al., 2009). A socioecological approach, originally stemming from Bronfenbrenner's ecological model of human development, offers a way to simultaneously investigate individual and environmental factors and the dynamic interplay between both factors in determining their influence on mental well-being (Eriksson et al., 2018; Sreetheran and Van Den Bosch, 2014). Several studies rely on socio-ecological frameworks to detect and recognize complex relationships, for example to describe personal, social, and physical attributes to fear of crime in urban green spaces (Sreetheran and Van Den Bosch, 2014) or to explain associations between public space and mental health (Francis, 2010).

Existing concepts and theories from environmental psychology already help to understand how environments can contribute to mental well-being. The concept of 'sense of place' refers to the feelings evoked among people as a result of the experiences and memories they associate with a place and the symbolism they attach to that place (Shamai, 2018). Associated concepts are place attachment (bonding that occurs between individuals and their meaningful environments, containing emotional components, cognitive elements and practices), place dependence (how a place can be important because of its functional value), and place identity (part of our identity that relates to place) (Wartmann et al., 2018). Environments can also be restorative by offering opportunities for self-regulation (self-altering its own responses or inner states) through environmental (involve the use of places), physical (involve physical activity), or social strategies (involve contacting others) (Baumeister et al., 2007; Korpela et al., 2001). Both sense of place and higher capacities of self-regulation were shown to improve mental well-being (Baumeister et al., 2007; Cattell et al., 2008; Kienast et al., 2018; Scannell and Gifford, 2017). Both concepts also imply an inherent connection between personal, physical, and social factors. Regarding nature's restorative benefits to mental well-being, two leading theories are Ulrich's Stress Recovery Theory (SRT) and Kaplan and Kaplan's Attention Restoration Theory (ART) (Kaplan and Kaplan, 1989). SRT states that natural environments can reduce stress due to the innate inclination of humans towards nature, which is their evolutionary habitat (Bornioli et al., 2018; Ulrich, 1983). According to ART, natural environments can support recovery from mental fatigue in presence of several restorative properties, including being away (being mentally away from routine or demanding activities), soft fascination (a necessary but not sufficient condition for restoration: being engaged without attentional effort), compatibility (providing a good fit with one's activities or inclinations), and extent (an environment that is coherent, ordered, and of substantial scope) (Kaplan and Kaplan, 1989; Bornioli et al., 2018).

Considering the increasing urbanisation 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 (Hartig et al., 2014). **The aim of the qualitative interview part of the NAMED project was to apply a socioecological approach to investigate the factors that play a role in how the neighborhood environment influences mental well-being and to understand the interplay between those factors. Additionally, by linking the qualitative results to existing concepts and theories, the qualitative part aimed to better understand underlying mechanisms explaining links between the neighborhood environment and mental well-being.**

In addition, there is a growing need to evaluate the quality and relevance of research results for practice. Throughout the project, we consulted key stakeholders from local, regional, and national health and environment authorities as well as institutions and experts from the international

research community (Keune et al., 2014). 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 (Renn, 2006; Jordan, 2008; Reed, 2008; Brown et al., 2015). Modern views on governance underline that managing the living environment is no longer exclusively seen as the sole responsibility of governmental institutions (Jordan, 2008). It is perceived more as an interplay of different societal actors, including governmental institutions, local communities, and professional and stakeholder groups (Hooghe and Marks, 2003). 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. **Finally, the aim of the validation part was to validate the project results for practice, policy, and research through the consultation of citizens, experts from the health and environmental sector, and an internal validation with the research team.**

3. METHODOLOGY

3.1. 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, digitised 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 geographical 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 (1 January 2018) which means an average density of 7428 inhabitants/km² (Statbel, 2018). 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, etc) (Van de Voorde et al., 2010). However, a clear contrast in vegetation cover exists between the centre 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. BCR is characterised by a high cultural diversity (40% non-Belgian nationality) and a mixed use of language (most spoken: French, English and Flemish) (Statbel, 2018; Hermia and Sierens, 2017).

3.2. 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 (figure 1).

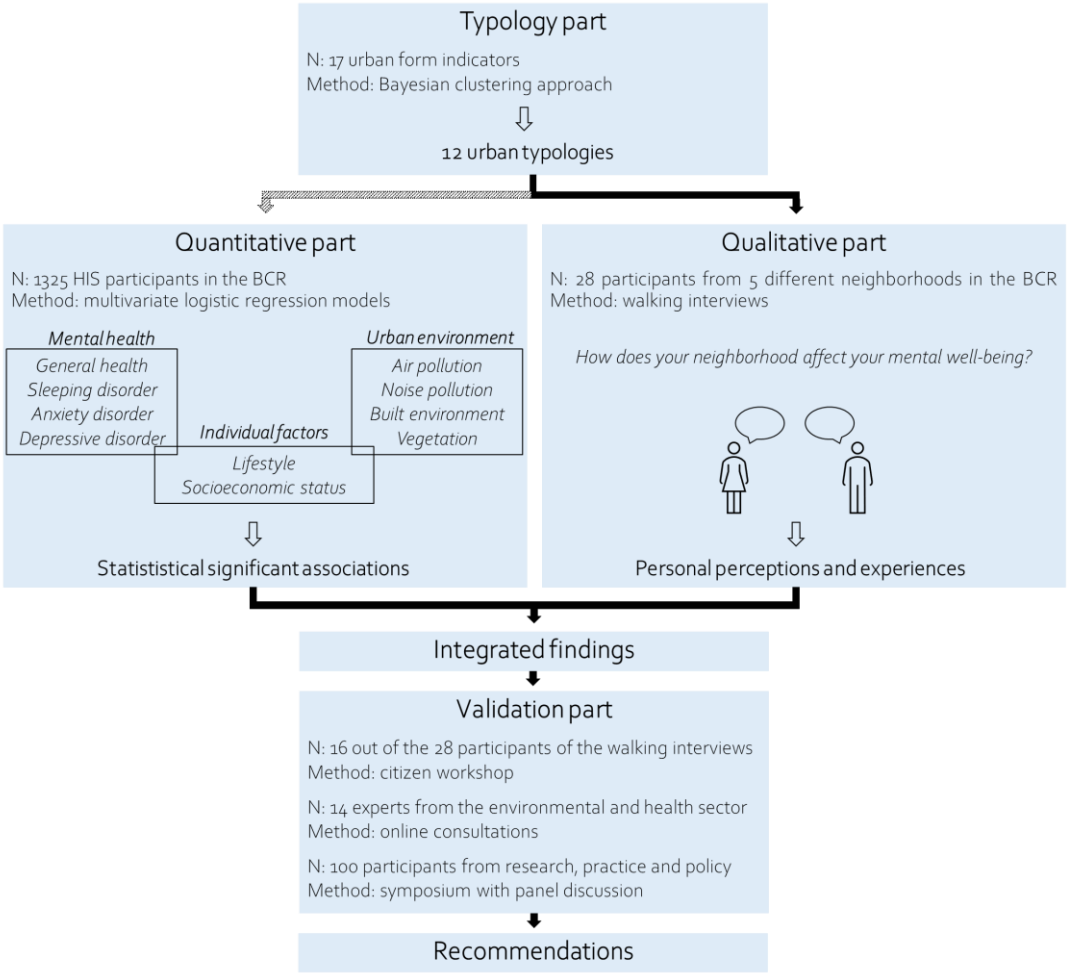


Fig. 1. Overview of the three main study parts of the NAMED project: the quantitative research, the qualitative research and the validation of the integrated findings to develop integrated recommendations.

3.3. Typology part

Araldi and Fusco (2019) developed the Multiple Fabric Assessment (MFA) protocol for the identification and characterization of urban fabrics. This is a data-driven bottom-up procedure which could be summarized in four steps (figure 2). After definition of a street-based spatial unit partition – the Proximity Band (PB) (3.3.1), urban form indicators are computed via geoprocessing protocols which capture different aspects of the skeletal streetscape (3.3.2). Spatial patterns of morphological indicators are identified in a network constrained environment (3.3.3). Finally, local patterns are clustered using a Naïf Bayesian classification approach (3.3.4). The MFA allows the urban landscape to be described at both the individual level (streetscape) and the meso-scale level (urban fabric). This method has proved successful in the analysis of several case studies with different geographic extent and data sources: the French Riviera conurbation (Araldi and Fusco, 2019), the metropolitan region of Osaka-Kobe, Japan (Perez et al., 2019) and the Karşıyaka district, Turkey. It is applied here to the intra-urban environment of Brussels.

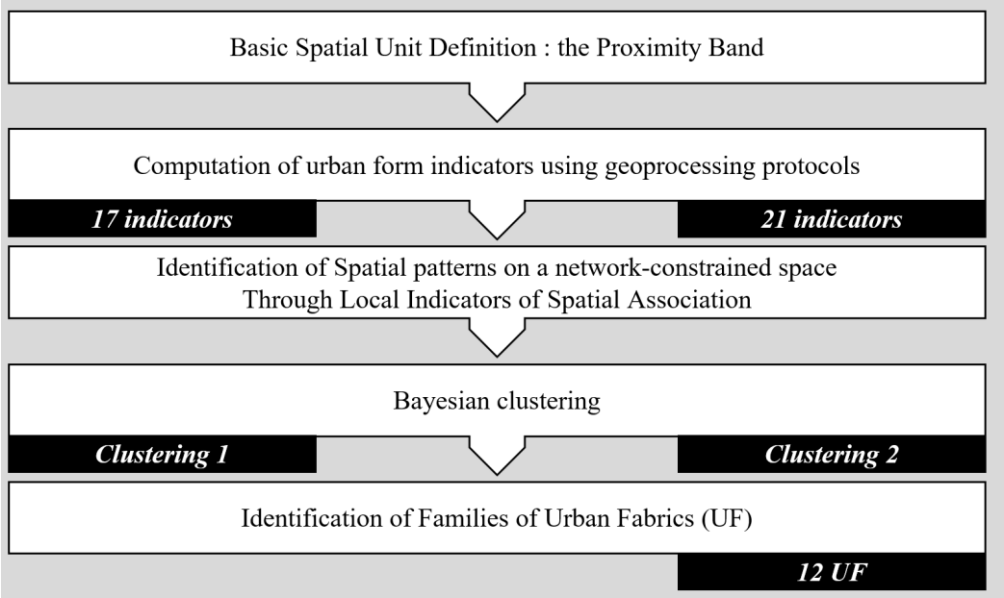


Fig. 2. Flowchart of the MFA protocol.

3.3.1. Basic spatial Unit: The Proximity Band

Finding the spatial unit of the right scale for analyzing urban form has always been a challenge for geographers. Administrative divisions often do not match with urban landscapes: each spatial unit is hence heterogeneous in terms of built-up and non-built-up surfaces. The Proximity Band (PB) proposed in Araldi and Fusco (2019) provides a good means of analyzing the urban form from the pedestrian point of view. It is a street-based partition that satisfies, on the one hand, the need to reduce the MAUP (modifiable areal unit problem) by minimizing spatial unit size variability (the size variability of PB partition is lower than that of the administrative unit), on the other, the need for a behaviorally based partition in which both the street point of view and street-network contiguity are incorporated. Finally, the street constitutes the bridging element that enables cross-analysis with different urban morphometric approaches or socio-economic events along the network (distribution of occurrences, movement, perception, etc.), thus avoiding possible spatial unit inconsistencies.

The implementation of the Proximity Band (PB) was adapted to the data available for Brussels (Urbis dataset) (figure 3A). Street surface data were simplified – notably by removing intersections – to give street segments (figure 3B). A street segment is the part of a street located between two intersections. Around each street segment, Generalized Thiessen Polygons were defined, allocating to each segment the nearest space (figure 3C). Then buffers (10 m, 20 m or 50 m) were computed from the street edges (figure 3D). Three different Proximity Band widths were used, depending on the indicator being considered. Thus 12,457 Proximity bands were identified for the BCR. The longest is 3 km, but 90% of the dataset lies between 20 m and 260 m.

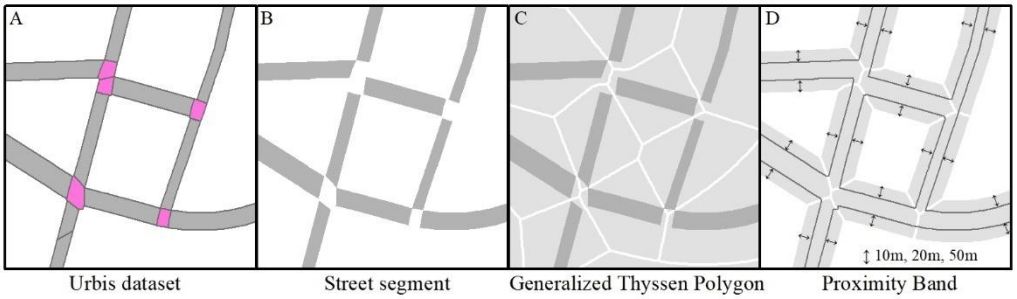


Fig. 3. Computation of the basic spatial units: from the original data (A) to Proximity Band (D).

3.3.2. Computation of urban form indicators using geoprocessing protocols

In the original implementation of MFA, twenty-one indicators were computed for each street segment, each of which described a different morphological aspect of the streetscape. As discussed in Araldi and Fusco (2019), MFA protocol is a flexible procedure which can be easily adapted to each case study by modifying and introducing specific morphometric indicators to capture particular features of the area being studied.

Of the indicators developed in the original MFA applied to the French Riviera, three were not included: (i) Land ownership fragmentation along the street network for its high similarity to Building frequency, (ii) Surface slope and (iii) Street acclivity, given the smoother site morphology in Brussels than in the original case study of the French Riviera.

The five indicators called Prevalence of building types are based on a classification of the surface of the building footprint adapted to the Brussels case study. Starting from a threshold of 25 sq. m, which allows small structures such as separate garages and garden sheds to be overlooked, we are able to identify: (i) detached or small contiguous houses between 25 and 125 sq. m, mainly found in suburban residential areas and representing the most prevalent building type in Brussels (numerically); (ii) large villas and contiguous houses between 125 and 400 sq. m, encompassing the traditional 'Brussels townhouses'; (iii) blocks of flats and offices between 400 and 2000 sq. m; (iv) large blocks of commercial, industrial or service buildings 2000–4000 sq. m; and (v) building footprints > 4000 sq. m corresponding to large buildings such as factories, railway stations, etc.

Further improvements pertain to the Local connectivity indicators, which have been replaced with a combination of two descriptors more suitable for describing the street network layout, while Dead-end street assigns a Boolean value to each PBs (similar to Node Degree 1), and a new indicator of Regular street grid is implemented as the average angular deviation from the regular street grid with the adjacent streets. This indicator takes the value of 0° if the street forms a right angle (90°) or a flat angle (180°) with all adjacent streets; it takes a value of between 0° and 45° in other cases (figure 4).

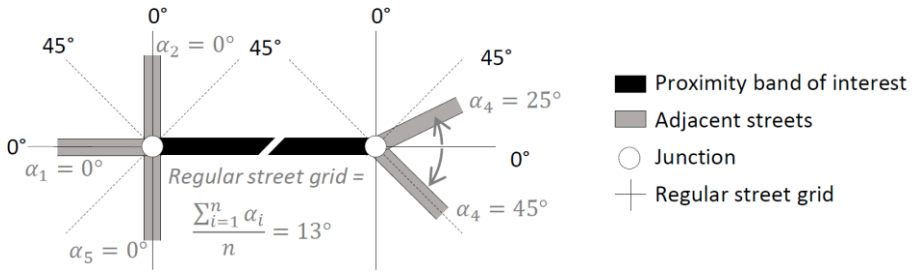


Fig. 4. Regular street grid indicator: average angular deviation from the regular street grid with the adjacent streets.

The other indicators were implemented as in the original version of MFA (see Araldi and Fusco, 2019 for further details). Each indicator relates to a specific PB depth (10, 20 or 50 m from the street edge), specified in Table 1. We obtained an initial set of 17 indicators classified under three categories: Street and Street Network Morphology, Built-up Morphology, and Network-Building Relationship.

Tab. 1. *Definition of the urban form indicators (*see Araldi and Fusco, 2019 for further details)*

Urban fabric component	Name	$S_{ref.}$	Implementation	Output
Street and Street Network Morphology	Street length*	Street surface	Length of the street segment ($L_{str.}$) [m]	$L_{str.}$
	Windingness*		Ratio between Euclidean distance ($L_{eucl.}$) and street length	$1-\left(\frac{L_{eucl.}}{L_{str.}}\right)$
	Regular street grid		Average angular deviation from the regular street grid (α_i) with the adjacent streets (i) [0 to 45°]	$\frac{\sum_{i=1}^{n}\alpha_i}{n}\begin{cases}\alpha \le 45 \rightarrow \alpha_i = \alpha \\ 45 < \alpha \le 90 \rightarrow \alpha_i = 90-\alpha \\ 90 < \alpha \le 135 \rightarrow \alpha_i = \alpha - 90 \\ 135 < \alpha \le 180 \rightarrow \alpha_i = 180-\alpha\end{cases}$
	Dead-end street		Presence of dead-end street [0 or 1]	$\exists\, Deadend\ street$
	Pedestrian area		Ratio between pedestrian area ($S_{ped.}$) and street surf. ($S_{ref.}$)	$\frac{S_{ped.}}{S_{ref.}}$
Built-up Morphology	Prevalence of Building types	50m PB	Ratio between specific building surf. ($S_{\text{x–x m² b.}}$) and total built-up surf. (S_{build}) For: 25–125 sq. m, 125–400 sq. m, 400–2000 sq. m, 2000–4000 sq. m, >4000 sq. m.	$\frac{S_{\text{x–x m² b.}}}{S_{build}}$
	Proximity band coverage ratio*		Ratio between total built-up surf. and PB surf.	$\frac{S_{build}}{S_{ref.}}$
	Building Contiguity*		Weighted average of building fragmentation ($1/N_i$) on attached built-up units (i)	$\frac{\sum_{i=1}^{n}\left(\frac{1}{N_i}S_i\right)}{S_{build}}$
	Specialization of Building Types*		Ratio between specialized building footprint ($S_{\text{sp.b.}}$) and total built-up surf. [%]	$\frac{S_{\text{sp.b.}}}{S_{build}}$
Network-Building Relationship	Building frequency along the street network*	20m PB	Ratio between number of buildings ($N_{\text{b.}}$) and street length [Building/m]	$\frac{N_{\text{b.}}}{L_{str.}}$
	Proximity band building height*		Ratio between building vol. ($V_{b.}$) and PB surf. [m]	$\frac{V_{b.}}{S_{ref.}} = H$
	Open Space Width*		Ratio between open space (S_{nbuilt}) and street length [m]	$\frac{S_{\text{nbuilt}}}{L_{str.}} = W$
	Height/Width Ratio*		Ratio between average building height and average open space width	$\frac{H}{W}$
	Street corridor effect*	10m PB	Ratio between parallel façades ($L_{f.}$) and street length [0–2]	$\frac{L_{f.}}{L_{str.}}$
Vegetation	Linear density of urban trees	10m PB	Ratio between number of trees (N_{tree}) and street length [tree/m]	$\frac{N_{\text{tree}}}{L_{str.}}$
	Visible street vegetation coverage		Ratio between vegetation surface ($S_{\text{veg.}}$) and PB surf.	$\frac{S_{\text{veg.}}}{S_{ref.}}$
	Vegetation coverage	>10m PB		

The 17 indicators described so far provide an overview of the urban morphological characteristics of the skeletal streetscape, taking into account only the spatial organization of streets and buildings. As highlighted in the introduction, in order to investigate the importance of vegetation and of available public space, four indicators were specifically designed for Brussels.

The distribution of vegetation in an urban space plays a part in the design and development of urban fabrics. In some urban fabrics, individual trees serve as landmarks or have been added a posteriori. In

others, small green spaces have been incorporated into the planning of boulevards and urban fragments. More extensive green features might have been planned for specific urban development. Some neighborhoods, such as garden districts, have fully integrated green space as a major component of their urban design. As we see from these examples, vegetation can take different forms and be located in different positions in relation to the other elements of the urban form. While green spaces are traditionally measured as urban facilities, in this study vegetation is treated as a constitutive element of the urban landscape at the same level as building, plot and street elements. For this purpose, we describe and summarize the various spatial configurations as a combination of three specific indicators, bearing in mind the pedestrian perspective (figure 5). Both private and public green spaces are taken into consideration using the vegetation coverage data of Van de Voorde et al. (2010).

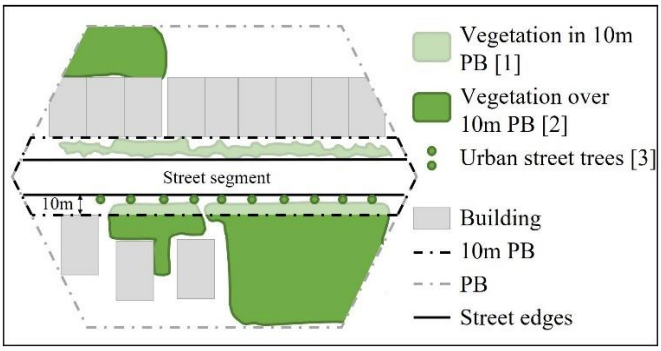


Fig. 5. Vegetation elements considered for the computation of the three vegetation indicators: Visible street vegetation coverage [1], Vegetation coverage [2] and Linear density of urban trees [3].

Visible street vegetation coverage quantifies the green spaces directly visible from the street. It can refer to green spaces in the public domain or private front gardens that can be seen by both passers-by and residents. It corresponds to the ratio of the green surface to the total surface of the 10 m PBs. Vegetation coverage reflects the presence of large green spaces. In our case study, this indicator specifically allows a distinction to be made between the residential fabrics characterizing the eastern and the south-eastern areas of Brussels (as observed in Van de Voorde et al., 2010). Unlike the previous indicator, the vegetation coverage ratio is computed on the basis of the part of the PBs located at > 10 m from the street edge. As demonstrated by Asgarzadeh et al. (2012), the presence of trees along the street edge – especially those covering building façades – is an important aspect from the pedestrian's perspective, but not accounted for in the previous indicators. The Linear density of urban trees has hence been computed as the average number of trees per meter (point data from the Urbis database). These alignments of trees are not always green enough to be detected by remote sensing, but this indicator allows them to be taken into account.

Beyond the vegetation, a further aspect of the urban space considered here is the proportion of the street allocated to pedestrian use. The presence of space devoted to pedestrians is positively correlated with walking (Handy, 2004) and creates meeting places, which provide essential support for social interactions (Gehl, 1987). A Pedestrian area indicator is also included in the form of the ratio of pedestrian area to street surface (as in Gil et al., 2012).

In order to investigate the relative importance of these additional indicators of vegetation and pedestrian areas, the MFA procedure will be implemented twice: first we will consider only 17 indicators of built form and street network; the second implementation takes four additional indicators into account. Comparing the results of these two procedures will allow us to understand the relative importance of vegetation and pedestrian space in the definition and identification of the urban fabrics.

3.3.3. Spatial patterns on a network-constrained space

Instead of studying and combining the raw indicators (as traditionally done in Berghauser and Haupt, 2010; Gil et al., 2012; Harvey et al., 2017), the MFA procedure uses geostatistical analysis for the detection of significant spatial patterns for each streetscape morphological descriptor. The local Moran's I (Anselin, 1995) is computed on a network-constrained space (Yamada and Thill, 2010).

Thanks to these network-constrained geostatistical analyses, we pass from a collection of morphological values for each Proximity Band to morphological patterns that correspond to hot and cold spots of given morphological characteristics, using the usual categories of LISA analysis: High-High (HH), Low-Low (LL), and Non-Significant (NS). These geostatistical classifications are the result of analysis of the values of each PB, taking into consideration the local neighborhood connected by the street network, with a topological depth of three units. For further details see Araldi and Fusco (2016); Fusco and Araldi (2017).

3.3.4. Bayesian clustering approach

The next step consists in studying the spatial co-occurrences of the 21 morphological patterns. The urban fabric seen from the pedestrian point of view is indeed the perception of persistent co-occurrences of given morphological characteristics when exploring urban space. A given urban fabric can be identified by the spatial co-occurrences of every morphological indicator, as well as by a few key characteristics. Clustering approaches aimed at achieving high intra-cluster homogeneity on the basis of variance minimization of the values of all the indicators (such as k–means, SOM and geo-SOM) are not well fitted for this task (Fusco and Perez, 2019). For this reason, Araldi and Fusco (2019) suggest the use of a Bayesian Network clustering of the results of geostatistical analysis to identify urban fabrics. Bayesian Network clustering does not impose cluster homogeneity on all variables (unlike more traditional k-means clustering), deals with categorical variables (such as the outcomes of geostatistical analysis) and allows probabilistic cluster assignment (Fusco and Perez, 2019). These features have proved particularly relevant in the identification of urban fabrics (Araldi and Fusco, 2019).

3.4. Quantitative part

3.4.1. Selected indicators: urban building morphology

Two indicators were developed to assess the building morphology at the street level: the street corridor effect (figure 6) and the street canyon effect. The street canyon effect or height/width ratio is the ratio between average building height and average open space width, while the street corridor effect is the ratio between parallel facades length and street length. This was computed using the Urbis database (UrbIS data, 2019). The two indicators were treated as continuous and categorical variables in the analyses. The street canyon effect was categorized in tertiles. Regarding the street corridor effect, because half of the participant's live in a street with a maximum street corridor effect (ratio = 2), the variable was categorized in this way: maximum corridor effect (WHO,2020), < median, > median of the remaining values.

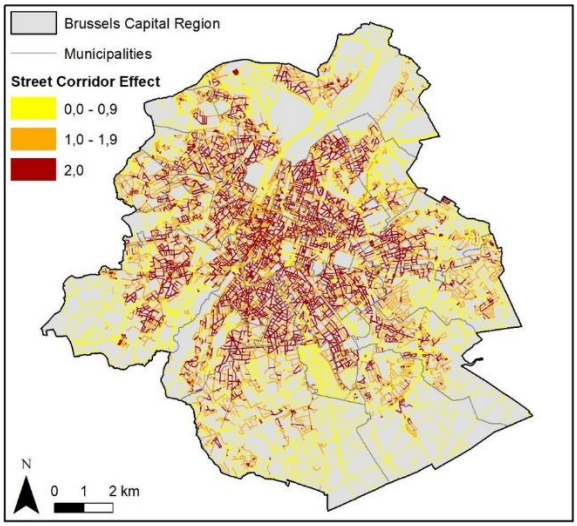


Fig. 6. Street corridor effect in Brussels (ratio between parallel facades length and street length). Data source: Urbis data 2017

3.4.2. Selected indicators: urban greenness

Three sources were used to measure urban greenness: (i) the Google Street View panorama, (ii) urban tree data from the UrbIS open database 2018 (UrbIS data, 2019) and (iii) vegetation coverage data, based on high-resolution remote sensing data (Normalized Difference Vegetation Index threshold value of 0.275) provided by Brussels Environment, the local environment and energy administration (computed by Van de Voorde et al., 2010). NDVI was not used as such but transformed into a binary variable (presence/absence of vegetation).

Urban greenness was assessed at three different levels: At the residence level, the computation of the view of green is based on the closest Google Street View panorama to the residential address based on the method of Li et al. (2015). The view of green is the ratio of the total green area from Google Street View panorama (~picture 360°) to the total area of the panorama. Unfortunately, the season of the pictures could not be controlled for. This measure provides a green view indicator with a ground-level perspective and captures the eye-level street greenery from the doorstep. The variable was used as a continuous and categorical variable (tertiles). At the street level (residential street segment, delimited by two intersections), the linear tree density and the visible street vegetation coverage indicators were computed. The linear tree density is the ratio between the number of trees (point data from Urbis) and the street length. Alignments of trees were taken independently because they are not always detected by remote sensing.

The visible street vegetation coverage indicator is the vegetation coverage (from Brussels Environment) on the street, and 10m on either side. This takes into account the vegetation that is visible from the street such as front gardens, trees in the street and small green spaces. The two indicators were used as continuous and categorical variables. The visible street vegetation coverage was categorized in tertiles. Because of the high proportion of zero values, the linear tree density was categorized in this way: no trees, < median, > median of the remaining values.

At the neighborhood level, vegetation coverage was assessed within two different buffers (600 and 1000m). This more traditional indicator of vegetation was calculated by taking the ratio of vegetation

coverage (from Brussels Environment) in a 600m (or 1000m) circle around the respondent's dwelling (figure 7). The two indicators were used as continuous and categorical variables (tertiles).

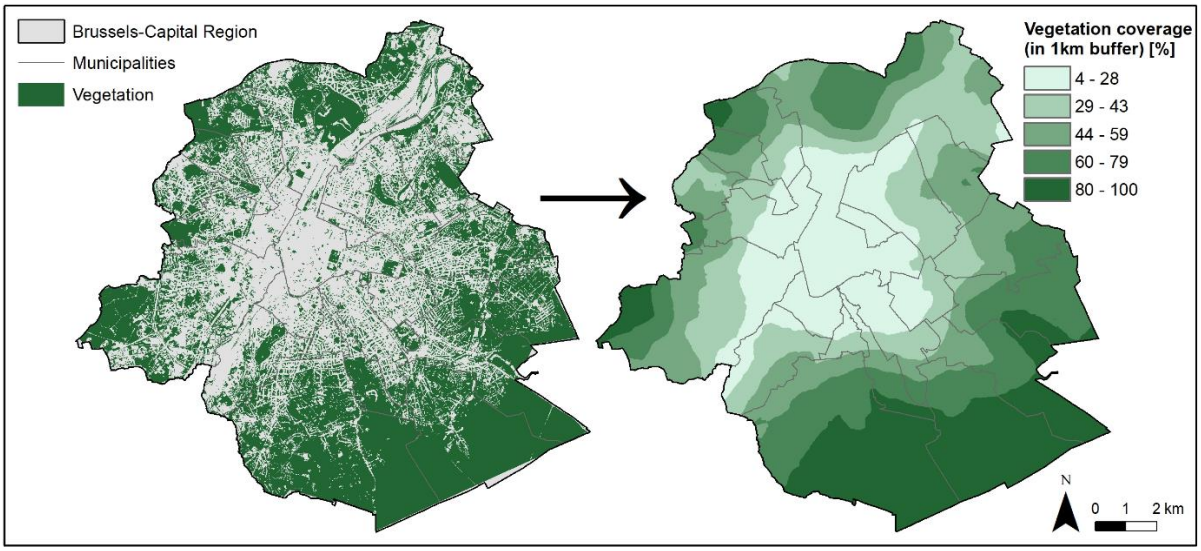


Fig. 7. Vegetation distribution in Brussels. Vegetation distribution in Brussels (left) used to compute a green cover indicator (right, here for a 1 km buffer). Data source: Van de Voorde et al., 2010 and Urbis database, 2017

3.4.3. Selected indicators: air pollution

Exposure at the residence address of participants was obtained through the national monitoring system supervised by the Belgian Interregional Environment Agency (IRCEL – CELINE). Concentrations of various pollutants are assessed on a daily basis through a dense network of stations distributed all over the country. The measurements are interpolated to estimate local exposure taking into account land cover data in combination with a dispersion model (Janssen et al., 2008; Lefebvre et al., 2013; Lefebvre & Vranckx, 2013]. The accuracy of the model to evaluate an individual's real exposure has already been shown in a study comparing modelled particulate matter (PM2.5) and black carbon (BC) at the residence with internal exposure measured in urine (Saenen et al., 2017). Annual average in the year of HIS participation of PM2.5, PM10, BC, ozone (O3) and nitrogen dioxide (NO2) at the participant's residence address were used as indicators of air quality. All the air pollution indicators were used as continuous and categorical variables (tertiles) (figure 8).

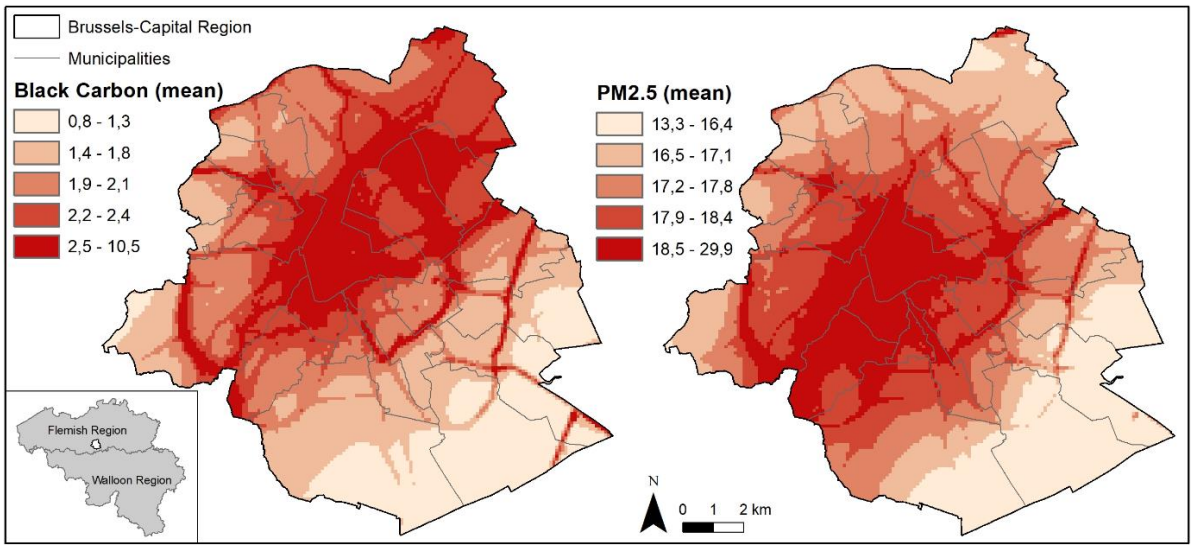


Fig. 8. Air pollution exposure in Brussels. Annual mean (2013) of BC and PM2.5. Data source: IRCEL - CELINE

3.4.4. Selected indicators: noise pollution

An already developed GIS-based noise model was available to estimate residential noise levels as required by the European Noise Directive (2002/49/EC) (Leefmilieu Brussel, 2019; Directive, 2002). The noise database maps noise from respectively road, rail and air traffic and allows an assessment of population exposure across Europe according to harmonized indicators such as day–evening–night noise level (Lden) (Basner and McGuire, 2018). The Lden indicator is an average sound pressure level over all days (12 h), evenings (4 h) and nights (8 h) in a year. Noise maps available for Brussels were obtained from Bruxelles Environnement for the years 2006 and 2011 (Acouphen Environnement, 2008; Bruxelles Environnement, 2011) and were combined with the geographical coordinates of the participants' residence to estimate Lden noise values in 5 dB(A) intervals. Noise pollution was approached through the noise from multiple sources (Lden) indicator since this included most information on residential noise.

3.4.5. Selected indicators: mental health

The mental health status of HIS participants was approached through different validated tools:

The General Health Questionnaire (GHQ-12) (Goldberg and William, 1988) for general well-being is a commonly used screening tool that detects symptoms consistent with poor mental health during the last 2 weeks. The format is a 12-item test with a four-point scale for each response. It includes questions such as: "In the last 2 weeks, were you: (i) able to concentrate, (ii) capable of making decisions, (iii) under stress etc." with the following possible answers: "as usual", "better than usual", "less than usual", "much better than usual".

Using the standard bimodal scoring method (0–0–1-1), the GHQ-12 yields a crude score ranging from 0 to 12 where a cut-off at 4 defines people with probable mental health disorders. The GHQ-12 permits to identify temporary alterations of normal psychological functioning and is sensitive to common psychological disorders, like depression and anxiety (Lundin et al., 2016). We used the dichotomized indicator GHQ-4 with the cut-off value at 4. This cut-off is used in the health interview surveys of other countries and allows international comparisons.

The Symptom Checklist-90-R (hereafter SCL-90R) is a validated tool designed to evaluate a broad range of psychological problems and symptoms of psychopathology. The questionnaire includes 42 items distributed in subscales corresponding to symptoms of different disorders, with a five-point scale for each response. It includes questions such as: "In the last week, to what extent did you feel the following difficulties: (i) feeling no interest in things, (ii) feeling low in energy, (iii) crying easily etc." with the following possible answers: "Not at all", "a little bit", "moderately", "quite a bit", "extremely". We used the subscales for depressive (13 items), anxiety (10 items) and sleeping disorders (3 items). Three binary indicators were calculated on basis of responses to the SCL-90R subscales: the likelihood of presenting anxiety disorders, depressive disorders and sleeping disorders. Subscale scores were calculated as the sum of the items (with 5 options: 0, 1, 2, 3, and 4) divided by the number of items of the subscale. The obtained scores were dichotomized with a cut off at 2 (i.e., [0–1] versus [2–4]).

Not all questions were answered by all participants in the study, which resulted in missing data for a number of questions. Lines with missing data were removed from further analysis. No imputation for missing data was performed since the reason for non-responding was unknown.

3.4.6. Selected indicators: socio-economic status and lifestyle

To describe participant's socio-economic status, we used: age, sex, household composition, highest educational level in the household and the reported household income. The highest educational level in the household was categorized in 3 groups: no diploma or primary education or lower secondary, higher secondary, higher. Other covariates related to lifestyle were included in the multi-exposure models: the level of physical activity based on the short version of the International Physical Activity Questionnaire (IPAQ), the perceived quality of social support (poor versus intermediate or strong support) and the chronic condition (from the Minimum European Health Module) [68]. For the level of physical activity, the proposed levels are: (i) inactive (no activity is reported or some activity is reported but not enough to meet categories 2 or 3) (ii) minimally active (3 or more days of vigorous activity of at least 20 min per day or 5 or more days of moderate activity or walking of at least 30 min per day or 5 or more days of any combination of walking, moderate or vigorous activities achieving a minimum of at least 600 MET-min/week) (iii) health-enhancing physical activity (vigorous activity on at least 3 days and accumulating at least 1500 METminutes/week OR 7 or more days of any combination of walking, moderate or vigorous activities achieving a minimum of at least 3000 MET-minutes/week).

3.4.7. Statistical analysis

All mental health, environmental and socio-economic indicators were described with their 95% confidence interval. The continuous variables were described by their median and the 25th and 75th percentile.

The selection of the environmental indicators included in the multi-exposure regression models was based on the results of previous work, where the relationship between all continuous environmental indicators has been explored through a Principal Component Analysis (PCA) (Pelgrims et al., 2019).

Only BC was included in the multi-exposure models for the following main reasons: (i) all the air pollutants were strongly associated and could therefore not all be included in the model (problem related to the variance inflation factor [VIF]), (ii) it has been shown that BC represents one of the most health-relevant components of PM and could be a valuable indicator to assess the health effects of air quality dominated by primary combustion particles. According to toxicological studies, BC may operate as universal carrier of a large variety of toxic chemicals to the human body and could be a more suitable air quality indicator to evaluate the health risks of traffic-related air pollution.

For each regression model the VIF was used to quantify multi-collinearity between the explanatory variables. A VIF value above 5 was used as a threshold. Correct estimates and valid inferences were obtained by taking the survey weights, strata and clusters relative to the sample design into account. All analyses were performed using the statistical software STATA 14 using the SVY option.

Single exposure models

For each mental health outcome, single-exposure models were fitted using multivariable logistic regressions. Models were adjusted for age, sex, family composition, reported household income, highest educational level in the household and year. Results were reported for both tertiles and continuous terms of the environmental variables. These models were developed for each of the 13 considered environmental stressors: BC, PM2.5, PM10, NO2, O3, View of green, Street visible

vegetation coverage, linear tree density, vegetation coverage 600 m, vegetation coverage 1000 m, noise from multiple source (Lden), street corridor effect, street canyon effect.

Multi-exposure models

For each mental health outcome, multi-exposure models were fitted using multivariable logistic regressions with increasing adjustment for covariates. Model 1 included only the exposure variables without adjustment for socio-economic factors. Model 2 was adjusted for socioeconomic factors. Model 3 was additionally adjusted for lifestyle factors, such as physical activity and perception of social support. Model 4 was additionally adjusted for chronic conditions.

All variables were included as continuous variables. In order to capture the potential non-linear association between the environmental factors and each mental health outcome, we included a quadratic term of each environmental factor in each model. To avoid problem of multicollinearity between the environmental factor and his quadratic term, variables were normalized by subtracting their mean. The quadratic term was retained in the model when it significantly improved the model, according to the Wald test. Interactions were tested between each of the environmental factors and age and sex.

Model 1: Mental health ~ BC + view of green Index + linear tree density + vegetation coverage 1 km buffer + noise from multiple source (Lden) + street corridor effect + street canyon effect.
Model 2: Mental health ~ BC + view of green Index + linear tree density + vegetation coverage 1 km buffer + noise from multiple source (Lden) + street corridor effect + street canyon effect + SES.
Model 3: Mental health ~ BC + view of green Index + linear tree density + vegetation coverage 1 km buffer + noise from multiple source (Lden) + street corridor effect + street canyon effect + SES + social support + physical activity.
Model 4: Mental health ~ BC + view of green Index + linear tree density + vegetation coverage 1 km buffer + noise from multiple source (Lden) + street corridor effect + street canyon effect + SES + social support + physical activity + chronic condition.

Due to the high number of tests performed on the same dataset, we might obtain a false positive finding. To face this problem, we used the Benjamini-Hoshberg method to control for multiple hypotheses testing.

Mediation analysis

We used structural equation models (SEMs) to analyze the multivariate relationships in our dataset. We constructed two a-priori models of associations between physical activity, poor social support, year, noise and the latent variables “distress”, “green space”, “socio-economic status” (SES), and “air pollution”. Distress was estimated from the binary variables depressive disorders, anxiety disorders, sleeping disorders and GHQ≥ 4. The four indicators of distress had high internal consistency (Cronbach’s alpha = 0.73).

Green space was estimated from linear tree density, view of green, vegetation coverage within 600m distance of the residence, vegetation coverage within 1000m of the residence and street visible vegetation coverage. Socio-economic status was estimated from the highest educational level in the household and the reported household income. Noise was estimated from mean annual exposition to noise from multiple source (air traffic, rail traffic, and road traffic) Lden. Air pollution was estimated from mean annual concentrations of PM10, PM2.5, NO2, BC, and O3. All continuous variables were first transformed in z-scores, by subtracting the mean and dividing by the standard deviation. In a first SEM, we hypothesized that green space would lead to reduced air pollution,

increased physical activity and better social support; and that distress would be associated with lower amounts of green space, lack of physical activity, poor social support, low SES, air pollution and noise. The second SEM differed from the first in two ways: we hypothesized that green space would be associated with lower levels of air pollution only, and that air pollution would affect physical activity and social support. We always included a direct effect of year on distress to account for unmeasured variables that may have an impact on distress and that differed between the two survey years. The p-value of the chi-square statistic, the root mean square error of approximation (RMSEA), the standardized root mean square residual (SRMR) and the comparative fit index (CFI) were reported as model fit indices. We report standardized coefficients and their p-value. All models were fit and evaluated using the package lavaan 0.6–7 in R version 3.6.3 (Rosseel, 2012).

3.5. Qualitative part

3.5.1. Sampling strategy

The study was conducted in the Brussels-Capital Region. Five study areas representing a diversity in urban fabric (Guyot et al., 2021), population density, access to green and median income were defined. In each area, we contacted a diverse set of local organizations involved in either environmental, socio-cultural, or health-related activities. Next, we visited the organizations with interest to discuss the recruitment of the participants. Based on the experience and culture of the organization in working with their target population, we developed an individual recruitment plan. Posters and folders with information on the project were left at the organization. The recruitment strategy intended to reach a varied sample in terms of age, gender, education level, employment status and cultural background. However, the large geographical scale and time limitation of the study led to a convenience sampling, based on the willingness of the people we met in the organizations. Knowing the mixed use of language in the Brussels-Capital Region (most spoken: French, English, and Dutch), only participants skilled in Dutch, French, or English with a minimum age of 18 years were included.

3.5.2. Sample

We conducted 28 interviews, of which two were a sit-down interview upon request of the participant. Participants' age ranged from 23 to 87 years, with the majority being between 50 and 70 years (n = 9) and older than 70 years (n = 10). The participant group consisted of 17 women vs 11 men; 9 non-natives vs 19 natives; 12 with non-native parents vs 16 with native parents; 18 with vs 10 without a post-secondary degree; 7 unemployed vs 12 employed vs 9 retired. Ideally the sample should have included more variation in age, however, the results will show that this sample was accurate to get a richly textured understanding on our research question.

3.5.3. Data collection

Data were collected by conducting walking semi-structured interviews during the period March–June 2019. The lead author (LL) conducted most interviews (n = 16), for the native-French speaking participants she was supported by the two French-speaking co-authors (MG, IP). At the beginning of the interview the participants were asked to guide the walk along a self-selected route in the neighborhood that allowed the discovery of places and characteristics that were experienced important in relation to their mental well-being. We further clarified the purpose of the walk by asking about neighborhood aspects provoking positive or negative feelings. We did not provide any definitions of mental well-being as we were rather interested in how the participants expressed links

between their neighborhood environment and mental well-being in their own words. The semi-structured interviews consisted of an open discussion following a list of topics to be explored (Green and Thorogood, 2018). The interviews lasted on average 1,5 h and were transcribed verbatim. Pictures were taken during the walk by the participant or by the interviewer in case the participant preferred so. In March 2020, we invited the participants for a workshop with the purpose to thank them for their participation, and to present and reflect on intermediary project results. 16 out of the 28 participants participated to the workshop.

3.5.4. Data analysis

The data analysis was conducted by LL and followed the Braun and Clarke's guide for doing a thematic analysis (Braun and Clarke, 2006), using Nvivo v12. As a first step, the transcripts were read several times to gain an overall understanding. In a second step initial codes were generated in an iterative process of inductive open coding. For the first interviews the process of open coding and interpreting the quotes was done by a second independent reviewer (HB, HK, ML, RR) to enhance the reliability of the analysis. In the following steps the codes were organized in themes and sub-themes. In a final step, we investigated how the themes related to each other. Coding and theme development were discussed with the other authors. The different backgrounds of the authors (ecology, geography, epidemiology, psychology, social and political sciences, environmental health, primary health care) brought the advantage of gaining diverse perspectives on the results. Following a descriptive qualitative approach, the themes were analyzed with first emphasis on a literal description and then on a more in-depth understanding of the themes through interpretation. The study design, analysis and reporting of the results was co-guided by a theoretical framework that started from the two concepts 'sense of place' (Shamai, 2018) and 'self-regulation' (Baumeister et al., 2007), and two theories ART (Kaplan and Kaplan, 1989) and SRT (Ulrich, 1983). The framework expanded throughout the study with additional concepts and theories as covered in the Discussion. Three experts from the international interdisciplinary expert group on impacts of urban natural spaces on mental well-being, called EKLIPSE, helped to build this framework.

3.6. Validation part

3.6.1. Citizen workshop

In March 2020, we invited the participants of the walking interviews for a half-day workshop with the purpose to thank them for their participation, and to present and reflect on intermediary project results. 16 out of the 28 participants participated to the workshop. The qualitative themes were presented in subgroups (Table 1) and coupled to a member check validation by asking them to provide input on whether the themes accurately reflected their experiences. Afterwards they were divided in four groups and asked to select and rank three themes that they considered most important to their mental well-being, this could be both in positive or negative sense. We then reflected more in-depth on how these themes affected their mental well-being. The aim of the member reflections was to explore any gaps in the results and to assure a shared interpretation of the findings (Koelsch, 2013). At last, they were asked to suggest recommendations or share good practices regarding the most important themes.

Table I. *Overview of the interview themes used during the citizen workshop.*

Themes related to social environment	**Themes related to physical environment**
Contact with neighbors (e.g. friendliness, support)	Functional facilities (e.g. shops, pharmacy, doctor, school)
Community feeling (e.g. sense of belonging, togetherness)	Recreational facilities (e.g. sports centre, theatre, community center)
Diversity among neighborhood residents (e.g. diverse cultures, ages, socioeconomic status)	Green-blue environments (e.g. parks, forests, canal zone, urban gardens)
Social security (e.g. sense of security in your environment)	Aesthetics (e.g. architecture, spatial openness, natural elements)
	Road safety (e.g. cycle paths, zebra crossings, traffic lights) Traffic
	Cleanliness (e.g. maintenance of houses, garbage on the street)
	Noise (e.g. car, airplane, train)
	Environmental hygiene (e.g. air quality, radiation from telephone masts) Contact with neighbors (e.g. friendliness, support)

3.6.2. Expert consultations: environmental and health experts

From May to July 2020, we consulted experts from the (mental) health and environmental sector that are active in the BCR to present and reflect on the results. We consulted in total 14 experts, 7 from the environmental sector (Perspective Brussels, Bral, Architecture Workroom BXL, Brussels Environment, three urban planners) and 7 from the (mental) health sector (Liga Santé Mentale, Plateforme Bruxelloise pour la Santé Mentale, two medical centers, Logo Brussel, Kenniscentrum Wonen Welzijn Zorg, Observatoire de la santé et du social de Bruxelles-Capitale, Woonzorgcentrum Ursulinen). The majority of the consultations were held online due to the pandemic, and rested on average 1,5 hours.

During the consultation we followed an interview script with following topics:

- Current knowledge of links between the urban environment and mental health
- Interest for these links in relation to their own work
- Current translation of these links within own work
- Relevance of translation of these links within own work
- Challenges and needs to translate these links into own practice
- Familiarity with examples from practice regarding these links

After presenting the intermediary results, we asked questions about :

- First reactions on results : did they expect these results / any surprises
- Meaning of these results to their own practice
- Translation of these results to their own practice
- Recommendations based on these results
- Influence of COVID-19 on attention for links between the urban environment and mental health

On the 19th of October 2021, from 9 am until 1 pm, we organized together with Interface Demography (VUB) the symposium "Urban Health in Brussels". During this symposium the two research projects NAMED and Green&Quiet-Brussels(funded by Innoviris and executed by Interface Demography and KULeuven) presented the measured and perceived impact of the living environment (built environment, air quality, noise and public green spaces) on the health and wellbeing of Brussels' inhabitants. This symposium ended with a panel discussion with representatives from Observatoire de la santé et du social de Bruxelles-Capitale, Perspective

Brussels, Bral, Brussels Environment, the Primary Care Zone BruZEL, Centre Ecologie Urbaine Bruxelles, and the Cabinet from Minister Maron. The outcomes of this panel discussion are considered in the results.

3.6.3. Expert consultations: HIS experts

Based on our experiences with the HIS data and the input from the interview results we formulated recommendations to improve the HIS regarding the theme of the project: links between mental health and the urban environment. We discussed these recommendations with the two members of the HIS theme of Sciensano on the 29th of January 2021. We further asked the procedure to hand in recommendations on the HIS.

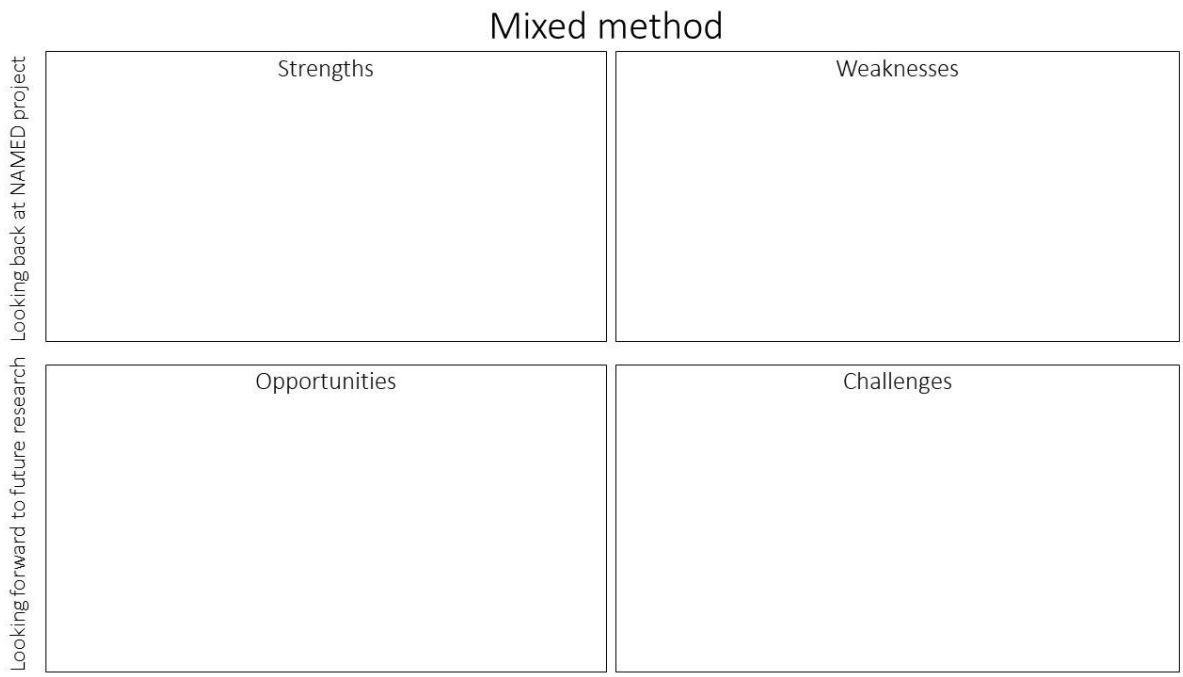
Additionally, we discussed and improved our HIS recommendations with two members of the Observatoire de la santé et du social de Bruxelles-Capitale, an important end-user of the HIS in the BCR. This meeting was held on the 22th of April 2021.

3.6.4. Internal validation exercise

Throughout the project process we had several formal validations of our research methods during the follow-up committees and several informal validations during our team meetings. On the 10th of May 2021 we organized a specific meeting with the research team on methodological implications of our project. To collect all lessons learnt throughout the project on working interdisciplinary and applying a mixed method, we filled out following tables during an open discussion.

Interdisciplinary working

Looking back at NAMED project	Strengths	Weaknesses
Looking forward to future research	Opportunities	Challenges


Mixed method
Looking back at NAMED project
Looking forward to future research
Strengths
Weaknesses
Opportunities
Challenges

4. SCIENTIFIC RESULTS

4.1. Typology part

4.1.1. The role of vegetation in the identification of the urban fabric

Two clusterings were carried out (figure 9). Clustering 1 includes 17 indicators classified under three categories suggested by Araldi and Fusco (2019): Street and Street Network Morphology (except Pedestrian area), Built-up Morphology and Network-Building Relationship. Clustering 2 adds three Vegetation indicators and the Pedestrian area indicator to the previous set. The two clusterings were carried out using the Naïf Bayesian classifier method as presented by Araldi and Fusco (2019): using different random seeds, 1000-step random walks explored the solution space to obtain optimal Bayesian clustering of spatial units. The search constraints were a minimum cluster content of 2% of the spatial units, a minimum average probability of assignment of units to each cluster of 0.9 and a maximum of 20 clusters. The optimal number of clusters was determined using a combined score of the loglikelihood of the clustering solution and of its parametric complexity (i.e. the number of clusters). For clustering 1, within eight random-walk searches, an optimum was always found for the 10-cluster solution. For clustering 2, 12 of the 14 random-walk searches showed an optimum for a 12-cluster solution. A successive refining phase of the cluster solution was carried out by imposing this fixed number of clusters on eight new random walk searches. Results were almost identical, the best one showing a contingency table fit score of 58.59% (clustering 1) and 53.41% (clustering 2). The two values are not directly comparable because the numbers of both indicators and clusters are unequal. Clusters are here designated as UFa, UFb,… and UFj in the case of clustering 1 and UF1, UF2,… and UF12 in the case of clustering 2.

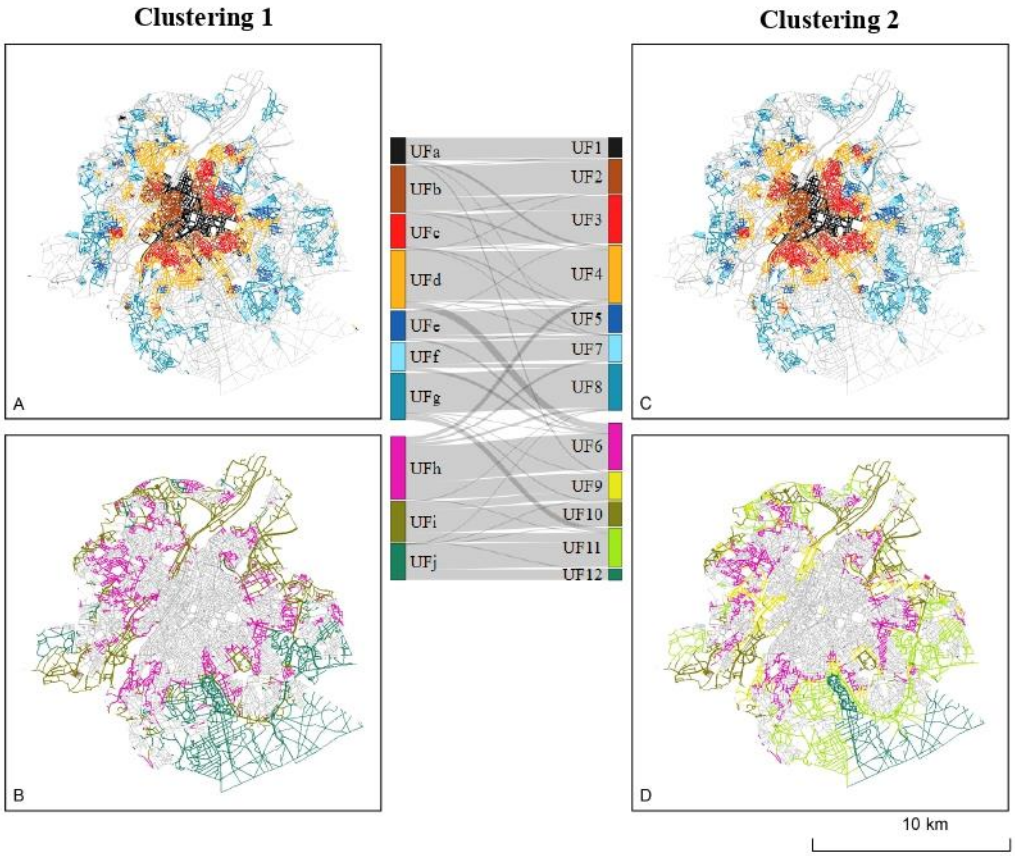


Fig. 9. Clustering of urban fabrics without (A,B) and with (C,D) the three vegetation indicators and the pedestrian area indicator. The middle graph shows the differences between clusterings 1 and 2. The map splitting highlights the urban fabrics that remain almost unchanged (A to C) and those that change more significantly (B to D).

The addition of vegetation and pedestrian area indicators (four variables) does not radically change the mutual information that indicators share with the clustering variable when considered individually (see Table A1, in the Appendix of Guyot et al, 2021). Network-Building relationship indicators are the most correlated with the clustering variable, as well as Building Contiguity, Proximity band coverage ratio and Prevalence of Building type 1 (25–125 sq. m). Vegetation coverage indicators also have high mutual information with the clustering. The projection of the cluster variables in a space of mutual information shows a gradient of urban intensity (see figure A3, in the Appendix of Guyot et al, 2021) that translates on the map as a center-periphery gradient (figure 9).

The delineation of the urban core as an entity distinct from more peripheral and suburban areas is constant in the two clustering outcomes. However, there is no clear cut-off between these two subspaces: not surprisingly, the urban core has a complex shape, with ramifications following main peripheral axes.

Adding vegetation and pedestrian area indicators allows delineation of meaningful new urban fabrics (UF) in the green suburban area of Brussels. Three clusters (h, i, and j) are redistributed among five new clusters (6, 9, 10, 11, and 12) characterized by a higher average class purity in terms of both the new urban fabrics and the entire clusterization outcomes (figure 9 B/D). UFh – which becomes UF6 – fits better with reality, especially as a large cluster is subdivided into smaller ones.

The specialized fabrics found in UFi (and some in UFh) in clustering 1 are split into two clusters in clustering 2: UF9, which takes over the specialized fabrics in a semi-continuous environment, and UF10 in an open environment. The classification of the vegetated suburbs is not accurate in clustering 1. Large green spaces such as forests or parks are not differentiated from green residential neighborhoods. In clustering 2, UFj is divided into two clusters, making it possible to distinguish between natural spaces (UF12) and vegetated suburban spaces (UF11).

The impact of vegetation and pedestrian area indicators is limited as regards the delineation of the central fabrics and the most urbanized periphery. Seven clusters stay almost the same, with a few adjustments: only 17% of variation (figure 9, C). They correspond to high-density, well consolidated central areas and planned residential areas in the suburbs.

These observations are consistent with Hermosilla et al. (2014), who demonstrated that the vegetation distribution allows suburban fabrics to be distinguished from the other urban fabrics while, on the other hand, it becomes less efficient for the characterization of compact urban fabrics. In our study, not only do we confirm these results, but we also demonstrate with the implementation of a clustering procedure how the relative spatial configuration arrangement of vegetation and built forms might help characterize different types of suburban fabric.

However, one type of suburban fabric is excepted from this statement: the ‘garden districts’, which are planned residential fabrics typical of Brussels. Three clusters (UFe, UFf, and UFg, which become UF5, UF7, and UF8) are not significantly impacted by the addition of vegetation indicators despite the fact that vegetation abounds in this type of fabric. These fabrics are therefore already well determined by traditional urban form indicators given their specificities in terms of built form and street network.

In view of what has been discussed so far, we might infer the superiority of the second clustering in our case study. From now on we will focus only on clustering 2. There are three main categories of urban fabric: continuous, semi-continuous and open fabrics (Table 2). The sorting of UF clusters is supported by the statistically significant spatial patterns of each indicator for each cluster ((see Table A2, in the Appendix of Guyot et al, 2021). There is a clear vegetation gradient: low value for UF1 to UF4, high value for UF11 and UF12 and intermediate values in between. This gradient of urban intensity is also clearly apparent in the indicators in the category Network-Building Relationship and visible (to a lesser degree) in the case of the other two categories.

***Table. II**. Characterization of urban fabrics in the BCR on the basis of probabilities of morphological patterns (only p(HH)>0,7 and p(LL)>0,7) and interpretation in terms of built-up functionalities. See Tab. A2 (in the Appendix of Guyot et al, 2021) for detailed results (Picture source: Urbis).*

UF1. Continuous Modern Planned Non-Residential Fabric
- Low vegetation coverage
- Large, tall buildings, absence of narrow buildings
- 'Canyon' effect

→ European Quarter and CBD

UF2. Continuous Traditional Fabric
- Low vegetation coverage
- High regular contiguous buildings
- 'Corridor' and 'Canyon' effect, short, narrow streets
- High building coverage

→ Historical center

UF3. Continuous, Dense Residential Fabric with regular small houses
- Regular and high contiguous buildings
- 'Corridor' and 'Canyon' effect, narrow streets
- Low vegetation coverage and high building coverage

→ Typical Brussels townhouses

UF4. Continuous Residential Fabric with houses and small buildings
- Contiguous buildings
- Low vegetation coverage
- Absence of dead-end streets

→ Typical Brussels townhouses

UF5. Continuous Residential Fabric with regular small houses and wide streets
- Regular narrow adjoining building, no large buildings
- 'Corridor' effect
- Low vegetation coverage in the street

→ Garden neighborhoods

UF6. Semi-continuous Mixed Use/Form Fabric
- Mainly intermediate value (NS) of indicators

→ Intermediate space

200 m

UF7. Semi-continuous Residential Fabric with small houses and small buildings
- Narrow buildings, absence of large buildings
- Presence of vegetation

→ Garden neighborhoods

UF8. Semi-continuous Residential Fabric with houses and average buildings
- Low building coverage
- Wide streets, absence of 'Canyon' effect
- Low-rise isolated buildings

⟶ Garden neighborhoods

UF9. Semi-continuous Specialized Fabrics
- Absence of narrow buildings

→ Industrial zones

UF10. Open Specialized Fabrics
- Low building coverage
- Long, wide streets, absence of 'Canyon'/'Corridor' effect
- Isolated buildings, absence of narrow buildings

→ Industrial zones and business parks

UF11. Open Suburban Residential Fabric
- High vegetation coverage
- Long, wide streets, absence of 'Canyon'/'Corridor' effect
- Low-rise isolated buildings, low building coverage

→ Villas

UF12. Open Natural and Artificial Non-Urbanized Areas
- Few buildings
- High vegetation coverage
- Presence of pedestrian areas

→ Natural spaces

4.1.2 Conclusion

This paper set out to identify the urban fabrics of Brussel in the same way as the traditional urban typo-morphological approach, but using state-of-the-art geoprocessing protocols. We have chosen two guiding principles: taking a human-perspective approach and adding vegetation to the traditional indicators. In order to achieve this goal, the MFA procedure was adapted and implemented in the specific case study of the BCR. Two classifications were tested. Clustering 1 reflects more closely the original method carried out by Araldi and Fusco (2019). Clustering 2 includes the same indicators, but with the addition of three vegetation-related indicators and one pedestrian-area indicator. The results show that the added indicators allow of a better definition of greener peripheral areas, but that their impact is limited as regards the definition of central fabrics and the planned suburban residential fabric (the 'garden districts'). The additional indicators allow of a more detailed classification of the urban fabric. Twelve clusters of urban fabrics were identified, divided into three main groups: continuous, semi-continuous and open fabrics. This provides a new way of dividing up Brussels that can be linked to several chapters in the history of Brussels, such as the construction of 'garden districts' and Brusselization. The method proved to be successful in identifying Brussels urban fabrics and their spatial arrangements. The typologies identified are consistent with the outcomes of previous studies on the morphological characteristics of the BCR, while developing a more finely grained analysis able to detect urban fabrics from the pedestrian's point of view. The addition of vegetation indicators has demonstrated the relevance of vegetation in defining the urban fabric, suggesting that it could be usefully included in further studies of the urban form. Vegetation is here seen as an integral part of the urban landscape and measured in terms of its spatial distribution within the streetscape and the urban fabric environment. This protocol differs strongly from the mainstream approach, where vegetation is considered and measured as a distance-based service with accessibility measures.

The resulting typology can be used in various ways in further work as a contextual factor highlighting the variety of urban fabrics in Brussels. Research on human behaviour and well-being in the city could benefit from a knowledge of urban forms as perceived by the pedestrian in the street. Discontinuities in the urban fabric could be identified by planners with a view to creating a more cohesive urban street landscape. An objective representation of the urban fabric at any given time could also serve as a reference for future interventions on the form of the physical city. The MFA protocol could even be used to assess the potential impact of specific projects on the urban form.

From the methodological point of view, several aspects could be explored further. For example, a sensitivity assessment of statistical and clustering parameter choices would enable the stability of the MFA protocol to be assessed. Outcomes might also vary depending on the underlying street-network impedances and contiguity modelling approaches that reveal how the urban fabric might be perceived differently, in terms of its walkability properties. Finally, the development of an MFA tool for GIS platforms would also allow the study of the urban fabric to be extended to large synchronic and diachronic comparative studies.

4.2. Quantitative part

4.2.1. Data description

A total of 1325 residents of BCR were included in the study population. Table 3 describes all considered variables.

Table III. *Description of the sample population.*

Socio-economic status	
Age median [IQR]/N	47 [34–63]/1325
Sex % [95% CI]/N	
M	50.59 [47.70–53.47]/616
F	49.41 [46.53–52.30]/709
Year % [95% CI]/N	
2008	53.93 [50.19–57.62]/775
2013	46.07 [42.38–49.81]/550
Highest educational level in the household % [95% CI]/N	
No diploma/primary education/lower secondary	19.34 [16.75–22.21]/285
High secondary	26.77 [23.67–30.12]/365
Higher	53.89 [50.22–57.52]/675
Household composition % [95% CI]/N	
Single	35.10 [31.70–38.67]/416
One parent with child [ren]	10.92 [8.91–13.32]/145
Couple without child [ren]	18.86 [16.26–21.76]/277
Couple with child [ren]	29.03 [25.64–32.66]/395
Other/unknown	6.10 [4.53–8.15]/92
Reported household income median [IQR]/N	1460 [1000–2000]/1325
Mental health status	
Probable mental disorders [GHQ ≥ 4] % [95% CI]/N	19.81 [17.40–22.46]/255
Anxiety disorders % [95% CI]/N	9.36 [7.74–11.29]/124
Depressive disorders % [95% CI]/N	15.79 [13.61–18.25]/216
Sleeping disorders % [95% CI]/N	28.22 [25.19–31.46]/351
Environmental factors	
Black carbon [annual mean µg/m^3] median [IQR]	2.24 [1.95–2.62]/1325
NO_2 [µg/m^3] median [IQR]	34.64 [32.04–37.70]/1325
$PM_{2.5}$ [µg/m^3] median [IQR]	19.16 [17.82–20.11]/1325
PM_{10} [µg/m^3] median [IQR]	26.14 [24.11–26.53]/1325
O_3 [µg/m^3] median [IQR]	36.25 [34.49–37.73]/1325
Vegetation coverage 600 m buffer [%] median [IQR]	35.95 [21.64–51.48]/1325
Vegetation coverage 1 km buffer [%] median [IQR]	37.96 [23.80–52.5]/1325
Street visible vegetation coverage [%] median [IQR]	3.99 [0.00–28.38]/1325
View of green median [IQR]	11.28 [6.04–22.36]/1325
Linear tree density median [IQR]	0.04 [0.00–0.15]/ 1325
Linear tree density [categories] % [95% CI]/N	
no trees	28.77 [25.41–32.38]/360
< median	35.64 [32.22–39.20]/483
> median	35.6 [32.19–39.12]/484
Noise from multiple sources Lden [dB] median [IQR]	50.96 [48.02–54.06]/1325
Street canyon effect median [IQR]	0.59 [0.39–0.84]/1325
Street corridor effect [0–2] median [IQR]	1.99 [1.46–2.00]/1325
Street corridor effect [categories] % [95% CI]/N	
< median	24.80 [21.74–28.17]/336
> median	24.6 [21.64–27.76]/333
2	50.6 [46.91–54.28]/656
Lifestyle factors	
Perceived quality of social support % [95% CI]/N	

Socio-economic status	
Strong/intermediate support	77.56 [74.46–80.38]/1036
Poor support	22.44 [19.62–25.54]/289
Level of health enhancing physical activity % [95% CI]/N	
Inactive	33.33 [30.16–36.65]/468
Minimal active	40.58 [37.44–43.79]/537
Enough active	26.10 [23.39–29.00]/320
Chronic condition % [95% CI]/N	33.45 [30.36–36.70]/435

Sleeping disorders were the most frequent reported problems (28%), followed by depressive disorders (16%) and anxiety disorders (9%). The GHQ-4 indicator indicated that nearly 20% of the study population suffers from probable mental disorders.

Regarding the environmental variables, the median of the annual mean exposure to black carbon was 2.24 µg/m3. While the median of exposure to vegetation coverage (1000m buffer) was 38%, the median of the view of green was only 11%. Furthermore, 29% of the population study lived in streets without trees. Half of the study population lived in streets with a maximum street corridor effect (=2), with a median of exposure equal to 1.99 (IQR: 0–2). The median of exposure to the street canyon effect was 0.59 (IQR: 0.04–2.89). The median of the annual mean exposure to noise from multiple from sources was 50.96 dB (IQR: 48.02–54.06).

A correlation matrix of all the environmental factors can be found in the additional files (Additional file 1, in the Appendix of Pelgrims et al, 2021). With regard to lifestyle, 22% of the population perceived the quality of the social support as poor and 33% of the population declared to suffer from a chronic condition. Just over a quarter of the population was physically active enough to have a positive impact on health.

4.2.2. Single-exposure models

In single-exposure models, exposure to nearly all pollutants (in tertiles) was positively and significantly associated with depressive disorders (Table 4).

Table IV. *Single-exposure models*

Exposure		GHQ-4		Anxiety disorders		Depressive disorders		Sleeping disorders	
		Adj. OR [95% IC]	**p**	**Adj. OR [95% IC]**	**p**	**Adj. OR [95% IC]**	**p**	**Adj. OR [95% IC]**	**p**
BC (µg/m^3)	Tertile 2 vs 1	1.36 [0.89–2.07]	0.15	1.51 [0.83–2.75]	0.17	1.60 [0.99–2.59]	0.05	1.35 [0.91–2.01]	0.13
	Tertile 3 vs 1	1.24 [0.77–1.99]	0.38	1.51 [0.83–2.74]	0.17	1.98 [1.20–3.26]	0.008	1.34 [0.89–2.01]	0.16
	1 µg/m3	1.00 [0.76–1.33]	0.95	1.07 [0.79–1.45]	0.65	1.33 [0.99–1.78]	0.05	1.12 [0.88–1.43]	0.35
NO_2 (µg/m^3)	Tertile 2 vs 1	1.02 [0.68–1.55]	0.92	1.66 [0.94–2.93]	0.08	1.87 [1.18–2.96]	0.007	1.07 [0.73–1.58]	0.72
	Tertile 3 vs 1	0.95 [0.62–1.45]	0.8	1.51 [0.87–2.61]	0.14	1.58 [0.99–2.51]	0.05	1.20 [0.81–1.78]	0.35
	1 µg/m3	0.99 [0.96–1.03]	0.72	1.01 [0.97–1.04]	0.65	1.02 [0.99–1.05]	0.12	1.01 [0.99–1.04]	0.32
$PM_{2.5}$ (µg/m^3)	Tertile 2 vs 1	1.08 [0.66–1.76]	0.77	0.74 [0.39–1.42]	0.36	0.79 [0.47–1.33]	0.38	1.01 [0.63–1.60]	0.97
	Tertile 3 vs 1	1.05 [0.55–1.99]	0.88	0.80 [0.36–1.70]	0.57	1.34 [0.71–2.51]	0.36	1.60 [0.89–2.87]	0.11
	1 µg/m3	1.01 [0.85–1.20]	0.88	1.05 [0.86–1.29]	0.62	1.12 [0.95–1.32]	0.19	1.10 [0.94–1.28]	0.23
PM_{10} (µg/m^3)	Tertile 2 vs 1	1.19 [0.74–1.93]	0.47	1.31 [0.71–2.40]	0.38	1.93 [1.13–3.29]	0.02	1.29 [0.82–2.01]	0.27
	Tertile 3 vs 1	1.10 [0.60–2.04]	0.75	1.10 [0.50–2.41]	0.82	3.02 [1.49–6.10]	0.002	1.66 [0.94–2.93]	0.08
	1 µg/m3	1.06 [0.77–1.45]	0.71	1.06 [0.71–1.58]	0.79	1.75 [1.51–2.42]	0.002	1.29 [0.96–1.72]	0.08
O_3 (µg/m^3)	Tertile 2 vs 1	0.82 [0.54–1.25]	0.36	1.01 [0.60–1.68]	0.95	0.59 [0.38–0.92]	0.02	0.79 [0.54–1.15]	0.22
	Tertile 3 vs 1	1.00 [0.66–1.51]	0.99	0.78 [0.45–1.35]	0.37	0.56 [0.37–0.89]	0.01	0.72 [0.49–1.05]	0.09
	1 µg/m3	0.98 [0.92–1.05]	0.64	0.97 [0.89–1.05]	0.43	0.88 [0.55–0.95]	0.001	0.95 [0.89–1.01]	0.11
Veg. coverage 600 m	Tertile 2 vs 1	1.28 [0.86–1.92]	0.22	1.06 [0.63–1.78]	0.81	1.12 [0.73–1.77]	0.59	1.12 [0.77–1.64]	0.53

Exposure		GHQ-4		Anxiety disorders		Depressive disorders		Sleeping disorders	
		Adj. OR [95% IC]	p	Adj. OR [95% IC]	p	Adj. OR [95% IC]	p	Adj. OR [95% IC]	p
buffer (%)	Tertile 3 vs 1	1.01 [0.66–1.56]	0.96	1.02 [0.61–1.72]	0.93	0.88 [0.56–1.49]	0.59	0.93 [0.64–1.36]	0.73
	25% increase	0.98 [0.80–1.21]	0.85	1.06 [0.80–1.41]	0.65	0.94 [0.75–1.17]	0.36	0.98 [0.80–1.19]	0.85
Veg. coverage 1 km buffer (%)	Tertile 2 vs 1	1.32 [0.88–1.97]	0.17	1.14 [0.68–1.90]	0.62	1.12 [0.73–1.72]	0.59	1.09 [0.76–1.56]	0.64
	Tertile 3 vs 1	0.95 [0.62–1.47]	0.82	1.04 [0.62–1.75]	0.87	0.77 [0.49–1.20]	0.25	1.13 [0.77–1.67]	0.53
	25% increase	0.99 [0.80–1.24]	0.97	1.02 [0.76–1.36]	0.89	0.91 [0.72–1.13]	0.39	1.02 [0.84–1.23]	0.86
Street visible veg. coverage (and 10 m on either sides) (%)	Tertile 2 vs 1	0.98 [0.67–1.52]	0.92	1.00 [0.61–1.65]	0.97	1.04 [0.68–1.57]	0.86	1.24 [0.84–1.80]	0.27
	Tertile 3 vs 1	0.92 [0.63–1.42]	0.68	0.80 [0.47–1.34]	0.39	0.77 [0.50–1.21]	0.26	1.08 [0.74–1.56]	0.68
	25% increase	1.02 [0.86–1.23]	0.84	1.02 [0.81–1.31]	0.81	0.91 [0.73–1.27]	0.38	0.99 [0.83–1.18]	0.88
View of green	Tertile 2 vs 1	1.23 [0.82–1.84]	0.3	1.38 [0.82–2.33]	0.22	1.03 [0.66–1.59]	0.89	0.81 [0.56–1.18]	0.27
	Tertile 3 vs 1	1.08 [0.70–1.65]	0.73	1.42 [0.82–2.45]	0.21	1.10 [0.69–1.75]	0.68	0.90 [0.60–1.34]	0.61
	10 units increase	1.01 [0.88–1.16]	0.87	1.09 [0.91–1.31]	0.33	1.07 [0.90–1.22]	0.43	0.99 [0.85–1.22]	0.83
Tree density	<P50 tree vs 0	0.92 [0.61–1.39]	0.71	0.96 [0.57–1.62]	0.87	0.82 [0.52–1.27]	0.37	0.66 [0.45–0.99]	0.04
	>P50 tree vs 0	0.99 [0.65–1.49]	0.96	0.97 [0.56–1.69]	0.92	0.90 [0.57–1.42]	0.65	0.70 [0.47–1.05]	0.09
	25 trees/100 m increase	1.03 [0.89–1.19]	0.69	0.97 [0.80–1.66]	0.93	0.99 [0.93–1.05]	0.67	0.94 [0.62–1.40]	0.76
Noise from multiple source Lden (dB)	Tertile 2 vs 1	1.00 [0.66–1.51]	0.88	0.73 [0.44–1.32]	0.34	0.86 [0.54–1.38]	0.54	1.27 [0.84–1.93]	0.25
	Tertile 3 vs 1	0.88 [0.59–1.32]	0.43	1.01 [0.59–1.73]	0.97	1.46 [0.91–2.33]	0.11	1.39 [0.95–2.02]	0.09
	1 dB	1.00 [0.98–1.04]	0.75	1.00 [0.97–1.03]	0.75	1.03 [0.99–1.06]	0.11	1.00 [0.98–1.04]	0.33
Street canyon effect	Tertile 2 vs 1	1.00 [0.66–1.49]	0.85	0.88 [0.50–1.54]	0.66	1.31 [0.83–2.07]	0.24	0.88 [0.58–1.35]	0.98
	Tertile 3 vs 1	1.15 [0.77–1.71]	0.23	1.17 [0.71–1.94]	0.54	1.31 [0.81–2.10]	0.27	0.91 [0.62–1.74]	0.35
	1 unit increase	1.15 [0.78–1.69]	0.22	1.03 [0.64–1.68]	0.88	1.16 [0.78–1.72]	0.46	1.03 [0.74–1.44]	0.84
Street corridor effect [0–2]	>P50 vs < P50	0.91 [0.58–1.43]	0.65	1.12 [0.62–2.00]	0.7	1.18 [0.70–1.98]	0.56	0.88 [0.58–1.35]	0.55
	2 (max) vs < P50	1.02 [0.68–1.52]	0.75	0.88 [0.52–1.49]	0.63	1.31 [0.81–2.12]	0.22	0.91 [0.62–1.74]	0.65
	1 unit increase	1.02 [0.75–1.39]	0.88	0.88 [0.59–1.31]	0.54	1.12 [0.75–1.61]	0.58	0.97 [0.72–1.31]	0.85

Notes: Models adjusted for sex, age, family composition, reported household income, highest household educational level and year

Table V. *Multi-exposure model for psychological distress*

GHQ-4	Model 1		Model 2		Model 3		Model 4	
Factor	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**
BC (1 µg/m^3 increase)	0.86 [0.61–1.22]	0.40	0.97 [0.69–1.38]	0.87	0.95 [0.65–1.39]	0.78	0.96 [0.64–1.43]	0.84
Veg. coverage-1 km buffer (25% increase)	0.85 [0.64–1.14]	0.29	1.05 [0.78–1.40]	0.75	1.06 [0.78–1.44]	0.70	1.03 [0.75–1.41]	0.86
View of green (10 units increase)	1.03 [0.84–1.25]	0.77	1.03 [0.84–1.26]	0.78	0.95 [0.85–1.28]	0.64	1.06 [0.87–1.30]	0.57
Density of tree (25 trees/100 m increase)	1.07 [0.72–1.60]	0.73	1.12 [0.74–1.67]	0.60	1.07 [0.96–1.06]	0.74	1.06 [0.70–1.59]	0.79
Noise from multi. Source Lden (1 dB increase)	1.01 [0.98–1.04]	0.50	1.01 [0.98–1.04]	0.46	1.01 [0.98–1.04]	0.52	1.01 [0.98–1.05]	0.35
Canyon effect (1 unit increase)	1.20 [0.80–1.80]	0.38	1.29 [0.83–2.01]	0.26	1.42 [0.91–2.23]	0.12	1.32 [0.84–2.06]	0.23
Corridor effect (1 unit increase)	0.96 [0.66–1.41]	0.85	1.04 [0.70–1.55]	0.84	1.03 [0.00-1.53]	0.86	1.10 [0.74–1.63]	0.62
Social support (Poor vs strong)					2.13 [1.44–3.13]	< 0.001	1.94 [1.29–2.92]	< 0.001
Physical activity (Minimal active vs inactive)					1.07 [0.74–1.55]	0.70	1.13 [0.77–1.66]	0.52
Enough active vs inactive					0.48 [0.30–0.79]	< 0.001	0.55 [0.34–0.88]	0.01
Chronic condition (Yes vs no)							2.38 [1.67–3.39]	< 0.001

Notes: Models 2,3, 4 were adjusted for sex, age, family composition, reported household income, highest household educational level and year. Model 3 was additionally adjusted for physical activity and social support. Model 4 was additionally adjusted for chronic condition

Table VI. *Multi-exposure model for anxiety disorders*

ANXIETY DISORDERS	Model 1		Model 2		Model 3		Model 4	
Factor	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**
BC (1 µg/m^3 increase)	1.07 [0.76–1.51]	0.68	1.09 [0.76–1.57]	0.62	1.16 [0.78–1.71]	0.47	1.16 [0.77–1.74]	0.47
Veg. coverage-1 km buffer (25% increase)	0.77 [0.51–1.79]	0.21	1.04 [0.70–1.55]	0.83	1.07 [0.72–1.61]	0.72	1.00 [0.65–1.56]	0.97
View of green (10 units increase)	1.08 [0.85–1.45]	0.55	1.12 [0.87–1.49]	0.81	1.01 [0.88–1.50]	0.99	1.00 [0.89–1.51]	0.82
Density of tree (25 trees/100 m increase)	0.83 [0.47–1.46]	0.51	0.91 [0.51–1.63]	0.37	0.77 [0.45–1.30]	0.31	0.76 [0.44–1.26]	0.29
Noise from multi. Source Lden (1 dB increase)	1.01 [0.97–1.05]	0.50	1.00 [0.97–1.04]	0.76	1.00 [0.96–1.03]	0.32	1.00 [0.97–1.04]	0.27
Canyon effect (1 unit increase)	1.02 [0.61–1.68]	0.94	1.14 [0.66–1.98]	0.63	1.13 [0.61–2.10]	0.70	1.07 [0.58–1.97]	0.82
Corridor effect (1 unit increase)	0.91 [0.56–1.46]	0.69	0.99 [0.59–1.69]	0.99	0.98 [0.57–1.67]	0.94	1.01 [0.59–1.74]	0.97
Social support (Poor vs strong)					5.52 [3.57–8.54]	< 0.001	4.99 [3.22–7.74]	< 0.001

ANXIETY DISORDERS	Model 1		Model 2		Model 3		Model 4	
Factor	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**
Physical activity (Minimal active vs inactive)					0.59 [0.35–1.01]	0.06	0.63 [0.37–1.07]	0.09
Enough active vs inactive					0.57 [0.30–1.07]	0.08	0.67 [0.37–1.22]	0.19
Chronic condition (Yes vs no)							3.19 [1.89–5.41]	< 0.001

Notes: Models 2,3, 4 were adjusted for sex, age, family composition, reported household income, highest household educational level and year. Model 3 was additionally adjusted for physical activity and social support. Model 4 was additionally adjusted for chronic condition

Table VII. *Multi-exposure model for depressive disorders*

DEPRESSIVE DISORDERS	Model 1		Model 2		Model 3		Model 4	
Factor	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**
BC (1 µg/m^3 increase)	1.18 [0.88–1.58]	0.28	2.48 [1.33–4.63]	0.004	2.44 [1.28–4.62]	0.007	2.46 [1.30–4.66]	0.006
BC (quadratic term)			0.73 [0.53–0.99]	0.04	0.74 [0.53–1.01]	0.06	0.75 [0.53–1.03]	0.08
Veg. coverage-1 km buffer (25% increase)	0.83 [0.61–1.12]	0.24	1.41 [0.96–2.05]	0.08	1.43 [0.96–2.12]	0.08	1.40 [0.92–2.13]	0.11
View of green (10 units increase)	1.17 [0.55–1.49]	0.08	1.17 [0.93–1.49]	0.19	1.21 [0.95–1.54]	0.27	1.23 [0.97–1.58]	0.12
Density of tree (25 trees/100 m increase)	1.08 [0.64–1.82]	0.14	1.10 [0.62–1.96]	0.18	0.99 [0.57–1.69]	0.13	0.99 [0.81–1.23]	0.08
Noise from multi. Source Lden (1 dB increase)	1.03 [0.99–1.06]	0.77	1.02 [0.99–1.05]	0.73	1.02 [0.99–1.05]	0.96	1.03 [0.99–1.06]	0.99
Canyon effect (1 unit increase)	1.10 [0.72–1.69]	0.65	1.12 [0.70–1.81]	0.52	1.28 [0.78–2.09]	0.32	1.23 [0.75–2.02]	0.40
Corridor effect (1 unit increase)	1.26 [0.79–2.00]	0.31	1.47 [0.88–2.48]	0.14	1.45 [0.87–2.42]	0.16	1.61 [0.96–2.69]	0.07
Social support (Poor vs strong)					4.06 [2.74–6.03]	< 0.001	3.82 [2.51–5.80]	< 0.001
Physical activity (Minimal active vs inactive)					0.78 [0.52–1.19]	0.25	0.85 [0.55–1.31]	0.46
Enough active vs inactive					0.40 [0.22–0.70]	0.002	0.47 [0.27–0.84]	0.01
Chronic condition (Yes vs no)							3.06 [2.06–4.54]	< 0.001

Notes: Models 2,3, 4 were adjusted for sex, age, family composition, reported household income, highest household educational level and year. Model 3 was additionally adjusted for physical activity and social support. Model 4 was additionally adjusted for chronic condition

Table VIII. *Multi-exposure model for sleeping disorders*

SLEEPING DISORDERS	Model 1		Model 2		Model 3		Model 4	
Factor	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**	**OR (95% IC)**	**p**
BC (1 µg/m^3 increase)	0.98 [0.74–1.29]	0.87	1.21 [0.89–1.64]	0.23	1.22 [0.90–1.66]	0.19	1.26 [0.92–1.71]	0.14
Veg. coverage-1 km buffer (25% increase)	0.96 [0.74–1.26]	0.78	1.15 [0.87–1.49]	0.33	1.15 [0.87–1.52]	0.32	1.13 [0.85–1.51]	0.39
View of green (10 units increase)	0.97 [0.83–1.10]	0.50	0.97 [0.82–1.01]	0.38	0.97 [0.82–1.15]	0.46	0.98 [0.82–1.16]	0.32
Density of tree (25 trees/100 m increase)	0.96 [0.64–1.44]	0.71	0.96 [0.62–1.47]	0.72	0.90 [0.60–1.35]	0.73	0.89 [0.60–1.33]	0.78
Noise from multi. Source Lden (1 dB increase)	1.01 [0.98–1.04]	0.86	1.01 [0.98–1.04]	0.85	1.01 [0.98–1.04]	0.61	1.01 [0.99–1.04]	0.58
Canyon effect (1 unit increase)	1.03 [0.70–1.51]	0.89	1.05 [0.71–1.56]	0.79	1.03 [0.69–1.53]	0.89	0.96 [0.65–1.44]	0.86
Corridor effect (1 unit increase)	0.92 [0.65–1.30]	0.64	0.99 [0.69–1.42]	0.95	0.99 [0.68–1.42]	0.94	1.05 [0.73–1.51]	0.81
Social support (Poor vs strong)					2.76 [1.95–3.89]	< 0.001	2.60 [1.84–3.67]	< 0.001
Physical activity (Minimal active vs inactive)					0.84 [0.59–1.20]	0.34	0.88 [0.62–1.26]	0.49
Enough active vs inactive					0.91 [0.60–1.37]	0.64	1.00 [0.67–1.51]	0.99
Chronic condition (Yes vs no)							2.10 [1.52–2.91]	< 0.001

Notes: Models 2,3, 4 were adjusted for sex, age, family composition, reported household income, highest household educational level and year. Model 3 was additionally adjusted for physical activity and social support. Model 4 was additionally adjusted for chronic condition

PM2.5 was the only pollutant for which no significant association was observed with mental health. Ozone (in tertiles and continuous) was negatively associated with depressive disorders. A significant linear trend was observed in the association between BC, PM10 (in tertiles) and depressive disorders.

No significant association was found between any of the mental health outcomes and the following green exposure indicators: view of green, vegetation coverage (600m buffer), vegetation coverage (1000m buffer) and visible street vegetation coverage. A significant negative association was found between the linear tree density (in categories) and sleeping disorders.

No significant association was found between any of the mental health outcomes and noise from multiple sources, street canyon and street corridor effect.

4.2.3. Multi-exposure models

Tables 5 – 8 display the results of the multi-exposure models for psychological distress, anxiety disorders, depressive disorders and sleeping disorders.

In Model 1, which included BC, linear tree density, view of green, vegetation coverage (1000m buffer), noise from multiple source (Lden), street corridor effect and street canyon effect, a positive and significant association was observed between BC exposure and depressive disorders.

In Model 2, which was additionally adjusted for socioeconomic factors, the association between BC exposure and depressive disorders remained. For depressive disorders, the quadratic term of BC was included in the model since it significantly improved the model. The negative sign of the quadratic term means that the relationship between BC and depressive disorders is concave instead of linear.

In Model 3, which was additionally adjusted for physical activity and perceived social support, BC exposure remained significantly associated with depressive disorders. For depressive disorders, the quadratic term of BC was included in the model since it significantly improved the model. Poor social support was significantly correlated with all mental health outcomes.

In Model 4, which was additionally adjusted for chronic condition, BC exposure remained positively and significantly associated with depressive disorders (figure 10). For depressive disorders, the quadratic term of BC was included in the model since it significantly improved the model. The presence of a chronic condition was strongly correlated with all mental health outcomes. Physical activity and social support remained associated with all mental health outcomes, except for sleeping disorders.

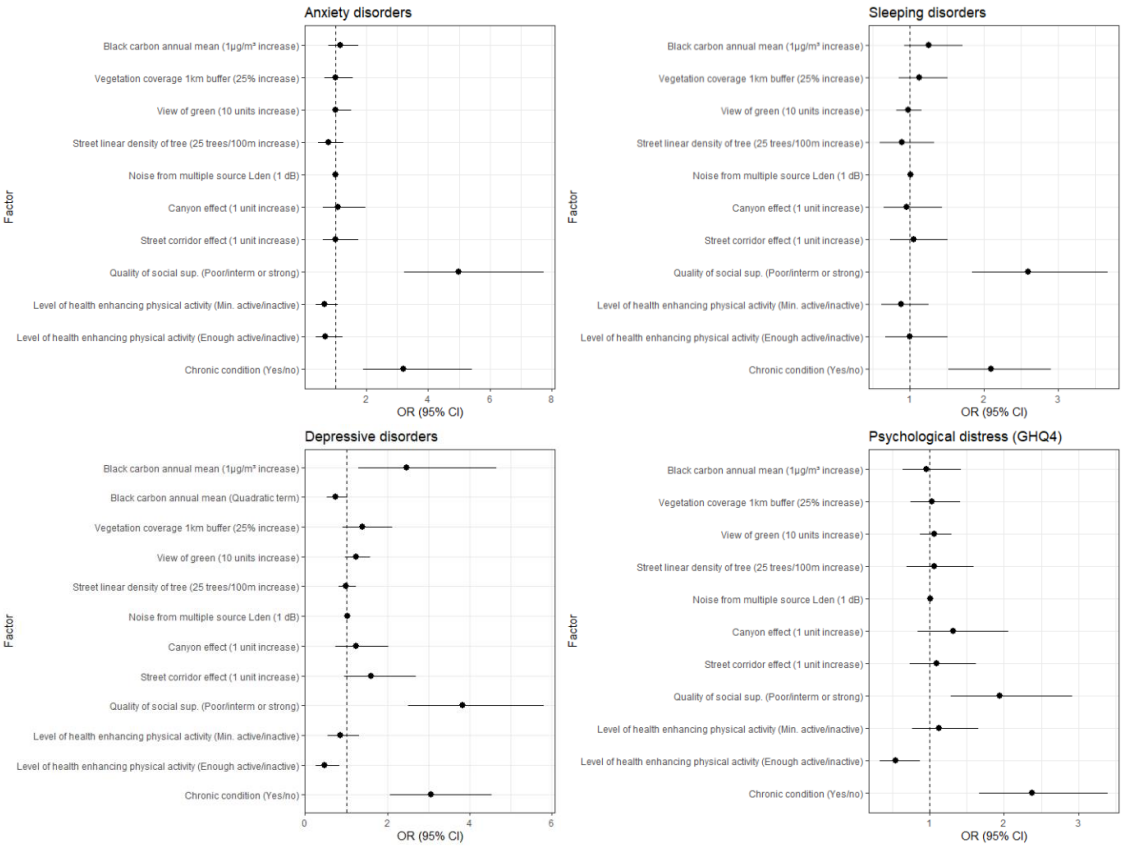


Fig. 10. Forest plots of the fully adjusted models (model 4) for each mental health outcome.

The mean VIF for model 1, 2, 3 and 4 were respectively 1.6, 1.44, 1.39, and 1.38. None of the VIF exceeded the value of 3. No significant interactions were found between environmental factors and sex and age.

The Benjamini-Hoshberg method was used to control for multiple hypotheses testing. By taking into account the 41 tests by outcome (41 * 4) and a False Discovery Rate among the significant results of 10%, all the associations between BC and depressive disorders remained significant.

Forest plots for the other models are available in the additional files: model 1 (Additional file 2, in the Appendix of Pelgrims et al, 2021), model 2 (Additional file 3, in the Appendix of Pelgrims et al, 2021), model 3 (Additional file 4, in the Appendix of Pelgrims et al, 2021).

4.2.4. Mediation analysis

Both SEMs provided support for the hypothesized inverse association between air pollution and green space (standardized coefficient $\beta std = -0.61$, $p = 0.02$), for the inverse associations between physical activity and distress ($\beta std = -0.11$, $p < 0.001$), and between SES and distress ($\beta std = -0.19$, $p < 0.001$), and for the association between poor social support and distress ($\beta std = 0.32$, $p < 0.001$), with an effect of year ($p = 0.04$).

The SEMs did not support our hypothesized direct and indirect associations between green space, air pollution, noise and distress. Indirect effects, calculated by multiplying the coefficient of the unstandardized parameter estimates of the constituent paths are displayed in the additional files (Additional file 6, in the Appendix of Pelgrims et al, 2021).

The fit indices pointed toward suboptimal model fit: $p < 0.001$, CFI = 0.68 (threshold> 0.90), RMSEA = 0.172 [95% CI: 0.168–0.175] (threshold< 0.08), SRMR = 0.10 (threshold< 0.08). The chi-square for model 1 and 2 were respectively 6455.868 (df = 161) and 6459.926 (df = 161) and $P < 0.001$ (threshold> 0.05). All coefficients of the SEMs are available in the additional files (Additional file 5, in the Appendix of Pelgrims et al, 2021). The path diagram of model 1 was visualized in figure 11 and the path diagram of model 2 is available in the additional files (Additional file 7, in the Appendix of Pelgrims et al, 2021).

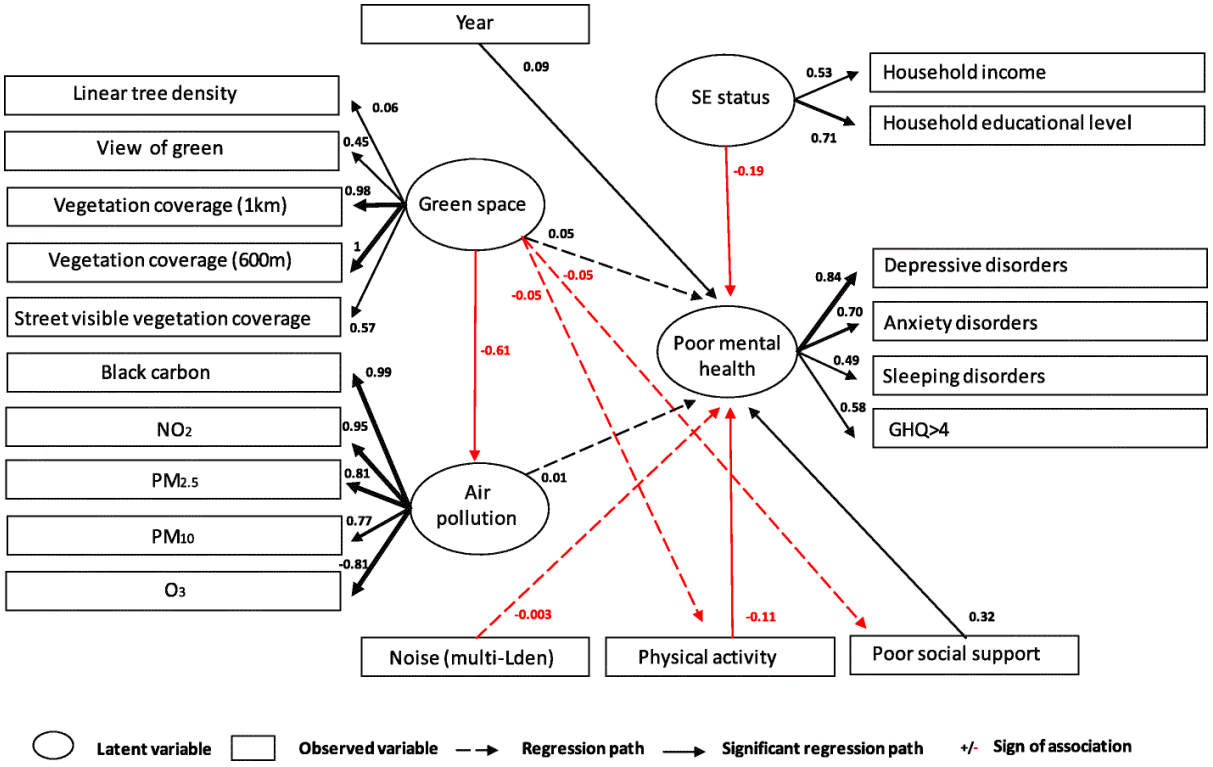


Fig. 11. Structural equation model of the associations between green space, air pollution, noise, socioeconomic status (SE status), social support, physical activity and mental health in adults in Brussels (Model 1)

4.2.5. Conclusion

We investigated whether specific features of the urban environment, like air pollution, urban greenness, noise and urban building morphology, such as the street corridor effect and the street canyon effect, were correlated with different dimensions of mental health of the citizens of the Brussels-Capital Region. Our results suggest that traffic related air pollution (black carbon, NO2, PM10) exposure was positively associated with higher odds of depressive disorders. No association between urban greenness, noise, building morphology and mental health could be demonstrated. Strong effect size was found for air pollution and depressive disorders: after controlling for all covariates, the odds of depressive disorders were twice as high for those who were highly exposed to black carbon compared to those who were less exposed. This association remained in multi-exposure models adjusted for greenness, noise, urban morphology and socio-economic factors.

These findings have important implications because the majority of the BCR population resides in areas where particulate matter concentrations are above the WHO guidelines. This suggests that public policies aiming at reducing traffic related-air pollution may play a role in also reducing the burden of depressive disorders in the Region of Brussels.

4.3. Qualitative part

4.3.1. Physical neighborhood factors in relation to mental well-being

Green-blue spaces

The most common response of the participants regarding green-blue spaces was the feeling of escaping from the city hustle and to take a break from daily routines – reflecting ART's concept of 'being away' (Kaplan and Kaplan, 1989) and relating to SRT (Ulrich, 1983). Other responses to mental well-being in relation to green-blue spaces involved: connecting to nature, exploring nature, getting fresh air, relaxing, rebuilding energy – relating to SRT (Ulrich, 1983). Some participants mentioned the importance of green-blue spaces to maintain their physical activities, and as such contributing to mental well-being.

participant A, 60 yr: "*There is one absolutely magical place, there's nothing similar to that, it is a park that really draws a lot of people from the neighborhood. It's a place where you can get connected to nature. As soon as you get there, you feel away from the city. There are birds, flowers, and something to look at, and a community garden where you can rent a garden space and trees and a bit of sculpture, just a chill place to go for a walk.*"

As indicated by this participant, also structural diversity in terms of the presence of artistic features, flowers, big trees and fountains was mentioned to enhance park experiences – providing an image of ART's concept of 'soft fascination' (Kaplan and Kaplan, 1989). For some participants large parks and for others enclosed intimate parks strengthened the feeling of being away – complementing ART's concept of 'extent' (Kaplan and Kaplan, 1989). Contrary, car disturbance, dog fouling, and trash accumulation led to negative park experiences.

participant B, 46 yr: *"There is one park, where I have been with my four children, but not with the last one. Because it is overcrowded and dirty. It's impossible to go to the playground. Also a question of hygiene, it is too dirty. The sand is no more sand. There is glass, tiles, wood."*

Neighborhood services

We distinguish between functional services and recreational services. Most important functional services mentioned were public transport, commercial (grocery stores, bars, restaurants), and welfare services (pharmacies, medical houses, and schools). Especially the proximity of these services related to positive responses in relation to mental well-being as participants were able to meet their needs on walking distance. It further contributed to a sense of security – relating to the concept of 'place dependence' as part of sense of place (Wartman and Purves, 2018).

participant B, 46 yr: *"The proximity to shops is a very strong point, because you can run out of food or drinks in the middle of the night and there is always a night shop that is open. We are also surrounded by 5 pharmacies, it is important, that is to say if we fall ill during the night, we always have a pharmacy on duty near the house."*

Among recreational services, participants mentioned cultural activities, community centers, sport and play facilities. Sport facilities supported physical activity, and was by some participants mentioned as a strategy to cope with negative feelings – indicating the restorative potential of these environments (Baumeister et al., 2007; Korpela et al., 2001). Several participants were annoyed by the lack of play facilities for children. Educational and art-related activities were linked to feelings of personal enrichment.

participant C, 74 yr: *"We are both city people. The luxury of going to theater, to music, to performances. For me, art is a real enrichment, a way of seeing how people are doing things in different ways, creating something. I can enjoy that."*

Neighborhood design and maintenance

Regarding the neighborhood design, historic architecture, openness, light incidence, and natural elements (figure 12) were mentioned across the participant group and seemed to contribute positively to mental well-being through feelings of fascination and relaxation – adding to ART's concept of 'soft fascination' and SRT (Kaplan and Kaplan, 1989).

participant D, 37 yr: *"Sometimes I come here to sit in the sun, because we live in shady streets and I live in a house where we do not see much of the sun. I come and sit here, it feels good. With the fountain. Sometimes I come here and sit down for the sound of the water. As I have some health problems, I like the sound of the water. It calms me down."* (figure 12)

Several participants related central neighborhood squares with a village-like character to feelings of being away from the city – extending ART's concept of 'being away' (Kaplan and Kaplan, 1989). Historical elements further made the neighborhood conducive for discovery and contributed to the pleasure of walking.

participant E, 70 yr: *"And here there are beautiful houses. I am such a person who goes into neighborhoods, always to look at the houses. As someone else goes to a forest for trees, to me it's the houses. The facades, the architecture, and so on, I sometimes wonder how it can remain standing."*

The participants from different neighborhoods experienced great difference in maintenance. Where some were pleased with the well-maintained sidewalks and houses, others were confronted with trash accumulation and housing abandonment. The continued presence of clandestine garbage dumps caused negative feelings of frustration and despair among some participants (figure 13).

participant F, 37 yr: *"I do not like walking around in the neighborhood because it is so dirty and because it strikes me and annoys me very much. Emotionally I attach a lot of importance to that which is terrible because it is something very typical for this neighborhood. It seems like an unsolvable problem."*

Traffic

A lack of traffic safety, more precisely bike and pedestrian safety, was linked to feeling insecure, but also to annoyance and confusion by the lack of good infrastructure. Some participants expressed their concerns about traffic-related air pollution and avoided therefore busy streets Traffic noise caused annoyance, impeded to relax and disturbed bird sounds. In one specific neighborhood, several participants mentioned suffering from the noise from airplanes, sometimes causing sleeping disturbance.

participant G, 48 yr: "*You see a lot of planes landing there. It's very noisy, and especially of course you suffer in summer, when you're more outside, I suffer in early morning, especially when it's summer, because they don't respect the EU regulation to stop night flights or to reduce dramatically night flights between 23h and 7h, here they actually start at 6, and sometimes even earlier. It has happened to me regularly to be really woken up by the noise. So I think noise is also important in the concept of environment, and here there is a margin for improvement."*

Contrary, several participants mentioned how they appreciated the calmness in different contexts: silent places, calm streets, calm neighborhoods. The absence of noise was also associated with

taking a break from the city hustle – broadening ART's concept of 'being away' (Kaplan and Kaplan, 1989).

Cellphone towers

Cellphone towers were an unexpected problem mentioned by several participants. Except for one that directly linked personal fatigue to the radiation from cellphone towers, the other participants were mainly concerned about potential health effects because they were being informed upon the risks.

participant H, 75 yr: *"It's more because I know, it's more because I've been informed. I am careful, I try to put out everything that can be harmful for the night, but despite everything it's still a nuisance I think. And this is something secret actually, the radiation from cellphone towers."*

Fig. 12. Urban design can offer relaxation and fascination. **Fig. 13.** Trash can cause frustration and despair.

4.3.2. Social neighborhood factors in relation to mental well-being

Neighbor ties

Some experienced great mutual support among neighbors which contributed to feeling secure in their neighborhood. Several participants mentioned the importance of having a sense of community with the relating outcomes of feeling part of a bigger community, not being isolated, mutual understanding and support. Good neighbor ties made several participants feel at home and attached to their neighborhood – underpinning the concept of 'place attachment' (Wartman and Purves, 2018).

participant C, 74 yr: *"I think the type of contact is of paramount importance, that you have such contact with people that you feel at home, and that was in the neighborhood, I felt at home there because of the substantive contacts and the interesting people."*

Contrary, two participants mentioned to have suffered from neighbor conflicts. Others expressed the importance of remaining some anonymity in relation to their mental well-being.

participant I, 70 yr: *"Here it is too much, as now I know you, I must know your girlfriend, I have to know your boyfriend, or I have to know your boyfriend's friend. Here, I have too many connections. Less connections, that's what I'm looking for. Too much stress here, too much stress."*

Neighborhood diversity

Most participants indicated to welcome or embrace neighborhood diversity in all its forms (cultural, age, economic diversity). Cultural diversity contributed positively to mental well-being as some participants felt enriched by contact with other cultures because of the opportunity to learn and to broaden personal views. Some participants experienced more tolerance and solidarity among neighbors and an ease to connect. The mix of different cultural and age groups was also mentioned to bring liveliness to the neighborhood and supported a sense of security as more people were present on the streets.

participant J, 65 yr: *"In this neighborhood people accept that there is a diversity, and in the end it no longer matters what origin you come from, but you see that people manage to get along and I find that very cool, I find that so enriching. Diversity in the sense of not concentrating people, not in houses, not in neighborhoods, not in streets, but trying to have a good mix and that is the best way to live together in a peaceful way, I think this neighborhood really bears witness to that, even though there are very beautiful mansions, it is not a white neighborhood, it is a mixed neighborhood and I feel very comfortable with that."*

Although most participants cheered on diversity, some participants also declared to experience difficulties to cope with different mentalities and to connect with some groups due to language barriers. A lack of good neighbor ties between diverse groups was a prerequisite for intolerance, and even racism. Some participants also mentioned that the concentration of specific groups of residences (e.g. expats, ethnic groups, refugees, homeless people) decreased the sense of community, and affected in some cases the sense of security in the neighborhood. Furthermore, confrontations with severe poverty evoked feelings of injustice and incomprehension.

Neighborhood security

Regarding neighborhood security, participants referred to problems with loitering, vandalism, squatters, drugs dealing, substance use, and burglary. A lack of neighborhood security negatively affected mental well-being in the sense that some participants were blocked in their daily activities as they were scared to go out at night, or to pass by some specific places. One participant encountered a severe lack of security, causing sleeping disturbance. Contrary to others who highlighted the comfort of feeling safe walking by night through their neighborhood.

participant K, 54 yr: *"The neighborhood, I find it less secure now. Now I would less dare to go out at night than before. Because we have a lot of people who have arrived from countries at war in fact in the neighborhood. Here we do not feel safe because our cars are vandalized, the young people are entering the hallway, we had squatters in the building who slept there. These are people who have arrived and who have no papers. So it's not so much security."*

4.3.3. Social, physical, personal, and institutional factors: a socioecological approach

Taking a socioecological approach, a conceptual framework was designed to illustrate the interactions between the personal, social, physical, and institutional factors of the neighborhood's influences on mental well-being (figure 14). These interactions are explained in following paragraphs.

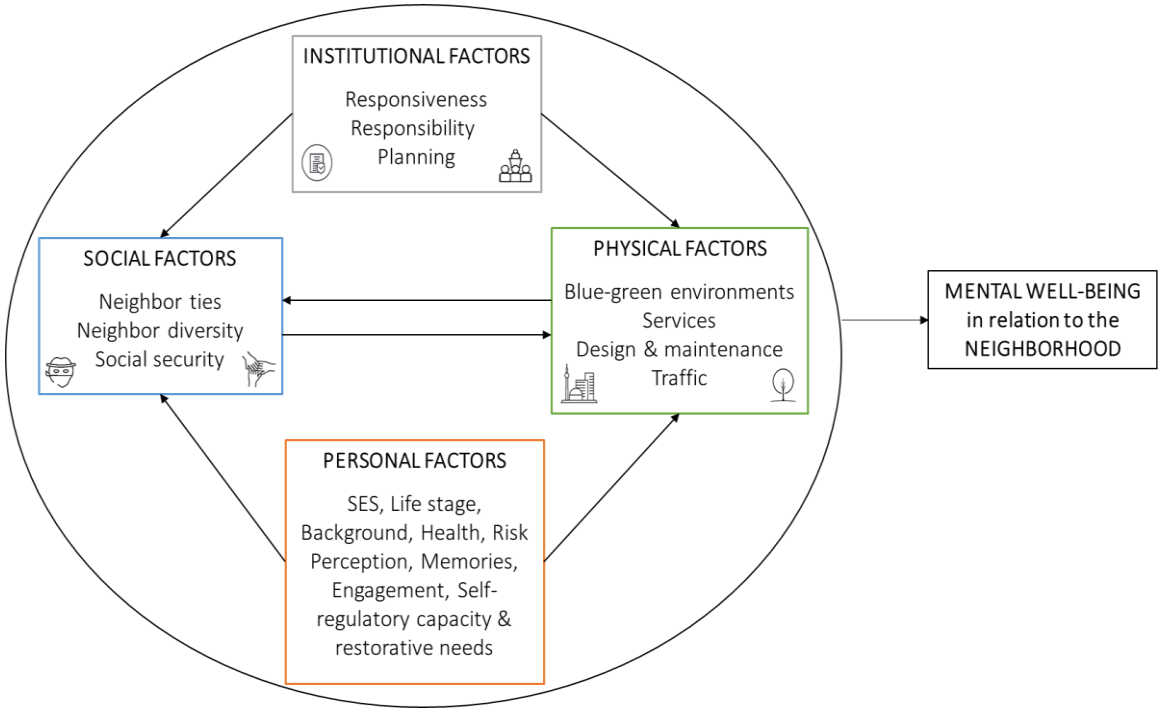


Fig. 14. Socio-ecological framework illustrating the interactions between personal, social, physical, institutional factors describing the influences of the neighborhood environment on mental well-being.

Social – physical interactions

Several physical neighborhood factors were mentioned to strengthen neighbor ties among diverse neighbors. Neighborhood parks, commercial, recreational, and community services provided opportunities to spontaneously meet a diversity of neighbors. Especially, services that have been present for a longer time contributed to trustworthy relationships with the owner and to regular meetings with neighbors. Also the presence of schools was mentioned to be important for community building. Several participants referred to citizen-based neighborhood initiatives in public space (urban gardening, neighbor parties, neighbor committees) as important catalysts of neighbor bonding and enhancing a sense of community.

participant L, 51 yr: *"The communal composting brought a total change. Thanks to that I met everyone. I was able to identify them too, which is always good. That's the end of putting people in a certain context. Getting to know people I never spoke to, to whom sometimes I had prejudices. It allowed me to say hello and talk to people in the street, it's a lot nicer. It contributes a lot. Here I felt much safer, saying "here it is home"."*

The participants provided as well good examples of how physical factors could inhibit neighbor contact, such as broad-trafficked lanes due to the related traffic noise and wideness of the street.

Social – physical – institutional interactions

Contrary, institutional planning for convivial neighborhood squares could enhance community building as explained by following participant:

participant G, 48 yr: *"What I experience is that the two main squares nearby have become even more convivial. So actually the municipality invested in making these squares more nicer and really like gathering places. I mean real squares not parking spots. I've seen across in society, at least in Belgium, that there is an increasing need for community. For bringing people together. And I think*

the municipality authorities are listening to this. So they're indeed creating spaces where people can meet and personally I think this is increasingly important."

This example covers another important institutional factor that was appreciated by several participants, namely the responsiveness of the local municipality to personal requests or local needs. Several participants referred to the importance of the municipality to respond supportive to the growing amount of initiatives based on citizen engagement, however, without the risk of escaping their own responsibility as explained by this woman:

participant F, 37 yr: *"What I think is problematic, is that they don't look with the district itself to see how this trash issue can be solved. Their answer was "you are going to solve it by putting artworks here". When I asked "we are going to put those things, but how are we going to solve that?", they answered "that will happen automatically" (figure 13)."*

Most participants were in favor of participatory planning involving local residents to adapt plans to local needs as some felt that current planning was still dominated by private interests of developers. Regarding this participatory planning they emphasized the importance of bringing together diverse neighbors as this would help to strengthen neighbor ties, create a better mutual understanding and a broader consensus for changes in the neighborhood. Current 'participation' seemed to be mostly induced by neighbors themselves (e.g. neighborhood committees, action groups or petitions) with difficulties to reach diverse groups in the community.

participant C, 74 yr: *"I think the neighborhood committees are important, at least that is how I experienced it, because you can put pressure on the municipality ... but what I can assess less well is how that evolution is within the Moroccan, Turkish community … I feel that they are so isolated, more like on their own."*

Several participants felt a lack of institutional responsiveness to the increased number of homeless people, and reacted with incomprehension when confronted with social injustice. However, during the walks several participants were pleased with the presence of social organizations as important mediators of social inclusion. The example of churches as being catalysts of social inclusion of vulnerable groups in society was brought up on several occasions.

participant M, 75 yr: *"I lived for 9 months on the street in Brussels. I had no money. I will never forget the moment I ended up in this church, there was a pastor preaching and after the mass he says: "you are new for sure". I say "yes". "Come," he says, "let's have a cup of coffee and eat a cake." And that is how I got there and ended up living here. That is getting chances in Brussels, that is important."*

Social – physical – personal interactions

Participant M is an extreme example of how your SES defines your way of living and interaction with external factors, but also other participants addressed financial constraints to their choice of living and ended up living in neighborhoods characterized by low economic profiles, and an accumulation of social and physical problems. For example, trash accumulation was mentioned to cause conflicts and more intolerance between neighbors. Overpopulation and substance use were reasons for some participants to avoid specific places in the neighborhood. These neighborhoods were in strong contrast to neighborhoods dominated by high SES profiles where participants mentioned to feel privileged, reflecting existing environmental inequalities.

participant D, 37 yr: "*Nature is missing here! … If I would have the means, I would leave to seek tranquility, in a calm house, with a garden. Because it's true that it's very noisy here."*
Some participants illustrated that both positive as negative social interactions in the neighborhood were sometimes shaped by personal background such as religion.

participant B, 46 yr: *"Previously, there was not this controversy that we have today where people are labelled as the Poles, the Belgians, or the Moroccans. We lived in harmony so everyone lived together and there was no hatred or difference. It changed because of terrorism in neighboring countries or even in our country. I am of the Muslim religion, I am veiled and it scares a lot of people, it scares us too because we are still targeted in the first rank."*

While negative social experiences resulted for some participants in the detachment from given places, most participants felt attached to their neighborhood or specific places in their neighborhood based on positive memories.

participant N, 73 yr: *"The fact that I now live here makes me think of the time when I was sixteen years old. I have good memories of that time. That was my childhood neighborhood. And that is also the pleasant part of that neighborhood, it's in the middle of the city, and close to the neighborhood where I live. So now I am an old man, and then I was a young bastard, the two are so close together, that's why those walks are always so pleasant."*

Although place attachment occurred mostly among participants that have been living for a longer period in the neighborhood, some participants that were personally engaged in the neighborhood over a shorter period showed attachment based on their social encounters.

participant O, 23 yr: *"Here already from the start, I have been actively looking for ways to connect with people. It happened that I went door to door to announce events or to give fruits and vegetables that we had in excess."*

Related to one's life stage, some participants referred to some important age adaptations in blue-green spaces that enhanced their experiences, such as benches and flat soils for elderly, and secured playgrounds and toilets for children – relating to ART's concept of 'compatibility (Kaplan and Kaplan, 1989). A person's life stage might also influence the importance of the neighborhood environment. Some participants explained that having children or reaching higher ages made them more depending on the neighborhood environment – relating to the concept of 'place dependence' associated with sense of place (Wartman and Purves, 2018).

participant F, 37 yr: *"I am constantly in my environment, when I did not have my child then I was in my cocoon and the contacts we had back then were from work, that was my environment. Now my environment has become much more my home and that is just as important."*

The capacity for self-regulation differed among the participant group. Some expressed a real sense of powerlessness regarding trash accumulation, while one participant responded as follow to the presence of trash "*My well-being tells me to "avoid anything negative" you see?*" (man F, 70 yr). Others turned their frustrations into actions leaving them with a positive feeling.

participant D, 37 yr: *"For example to make our neighborhood more pleasant, I planted roses here. I made flower boxes to make it a little prettier. Cleaner. I find boxes, I put one there, one there and people throw their trash in it and everyone is happy."*

Several participants indicated the restorative potential of green-blue spaces as it offered the possibility for self-regulation of negative feelings (Baumeister et al., 2007; Korpela et al., 2001), but self-regulatory needs might differ depending on personal difficulties, such as health issues or difficult life time events.

participant E, 70 yr: "*There, I went when I was a bit annoyed or something, then I would sit next to that tree of life, that is a fountain and then all those worries of you would flow with the water away. It's great, that's a philosophical garden. An oasis of peace in the full noise. There you are locked between four walls. When my husband died, I have often been crying in this park."*

4.3.4. Results in the context of existing concepts and theories

To better understand underlying mechanisms explaining links between the neighborhood environment and mental well-being, we further discuss our results within the context of existing concepts and theories.

The interviews covered a range of urban stressors such as noise, trash accumulation, air pollution, introducing the concept of urban overload (Geller, 1980). This concept states that high levels of urban stimulation overload the attentional system, have negative effects on the perception of the city, and might result in stress and mental fatigue (Berto et al., 2015, Geller, 1980). Our results showed that participants living in deprived neighborhoods were more confronted with this urban overload. The accumulation of physical stressors such as garbage dumps together with social stressors such as insecurity is a phenomenon explained by the broken window theory (Teixeira, 2016). This theory suggests that a lack of response to minor incivilities such as a broken window triggers a spiral of decay that lead to a breakdown of social order, and eventually invites criminal activities (Teixeira, 2016). Senses of powerlessness, helplessness, insecurity, lost control, distrust, and fatalism have been put forward as mechanisms underlying the negative effects of neighborhood disorder on mental well-being (Teixeira, 2016, Geis and Ross, 1998). Neighborhood disorder has been further described to be psychologically distressing with the possibility to lead in the short term to feelings of fear and anxiety, and over a longer period to depression (Hill and Angel, 2005).

Many participants referred to this urban sensory overload in their need to escape from the city. Green-blue spaces served here as an important source of stress recovery (Ulrich, 1983) and attention restoration (O'Brien et al., 2014; Cheesbrough et al., 2019). Similar to previous research that has indicated the importance of nearby nature to take a break from workloads, several participants, also unemployed, visited natural environments to break their daily routines (Degenhardt and Buchecker, 2012). Additionally, half of the participants referred to natural environments as being their favorite place, which itself is known to carry restorative effects (Korpela and Ylén, 2009).

The finding that a park not necessarily needs to be large to be restorative as stated in the concept of ‘extent’, is in accordance with existing evidence (Nordh et al., 2009). Besides size, also enclosure, intimacy, and structural diversity of blue-green spaces strengthened restorative experiences (Nordh et al., 2009, Grahn and Stigsdotter, 2010). Especially, structural diversity in terms of the presence of water elements, flowers, big trees, and art features, evoked feelings of relaxation and fascination. These findings answer to some extent the question on how soft fascination looks like (Joye and Dewitte, 2018). Additionally, the concept of ‘compatibility’ in terms of age adaptations illustrated the importance of person-related green space qualities to improve urban nature experiences. Our study therefore supports the growing amount of evidence on the importance of green space qualities in relation to mental health outcomes (Van Dillen et al., 2012; Grahn and Stigsdotter, 2010). The interview results add to the review findings of qualitative evidence on park characteristics influencing park use. The review provides an extensive overview of perceived qualities and could serve as a good starting point for future research (McCormack et al., 2010).

Our study results support the existing evidence stating that the restorative potential does not limit to natural environments (Bornioli et al., 2018). The participants illustrated that the general absence of noise, and the neighborhood design in terms of village-like neighborhood squares, natural elements, light incidence, openness and historical architecture also offered a mental break from the city. Additionally, some participants referred to positive sounds in relation to their mental well-being, such as water or bird sounds. These findings are supported by existing qualitative evidence on the restorative effects of bird and water sounds (Ratcliffe et al., 2013, Völker and Kistemann, 2013). Generally, the interviews emphasized the importance of having enough opportunities to find

peace in the middle of the city hustle, and that both auditory and visual features of natural and non-natural environments can contribute to this.

Despite the need to escape from the city hustle, this study confirms that urban stimulation might as well contribute positively to mental well-being (Geller, 1980). While all participants appreciated calmness, several also enjoyed submerging themselves in vibrant places, often characterized by cultural diversity. Similar to other qualitative evidence (Cattell et al., 2008), feeling close to the social activity going on, and not necessarily social encounters, contributed to these positive experiences. It would be interesting to further investigate when urban stimulation becomes an overload and when it becomes a pleasure.

The concept of social capital as "the sum total of positive relationships including families and neighbors that serve as buffers to the negative influences within one's immediate environment" might partly explain how citizens weigh up positive and negative neighborhood experiences (Almedom, 2005). Informal neighbor ties are described as important buffers against the negative effects of neighborhood disorder (Geis and Ross, 1998). In our study, participants emphasized the importance of good community ties for mental well-being. Among several interviews, strong neighbor ties or social memories in the neighborhood contributed to feeling attached to the neighborhood or specific places in the neighborhood. Contrary, some participants became detached from a meaningful place due to social conflicts in the neighborhood. Place detachment is defined as "to distance themselves from a place as a result of negative experiences, events, or memories" (Shamai, 2018). These findings confirm that based on different social experiences, people might attribute different values to places in relation to their mental well-being (Rollero and De Piccoli, 2010).

Consistent with the findings of Cattell et al (2008), stable neighborhood services were mentioned to stimulate community ties. Participants referred to trustworthy relationships with the owner or casual encounters with neighbors. Such weak ties are known to contribute to mental well-being in terms of 'feeling of home', 'security', 'practical as well as social support', and 'a sense of belongingness' (Forrest and Kearns, 2001; Kawachi and Berkman, 2001). Where supporting evidence exist for our findings on the social qualities of public meeting spaces ('Yotti'Kingsley and Townsend, 2006), we could not identify studies investigating the role of stable neighborhood services on social capital. In contrast to most current evidence on social capital, one participant illustrated how social capital could also lead to mental distress. One study found a similar result where the obligations of time and energy required of an active resident in a deprived neighborhood served as an extra source of stress (Mitchell and LaGory, 2002). However, little attention seemed to have gone to negative effects of social capital on mental well-being.

Another way in which neighborhood services improved the mental well-being of our participants can be explained by the Person-Environment Fit-theory. This theory posits that congruence between personal preferences or needs and environmental presses fosters environmental satisfaction and psychological well-being (Kahana et al., 2003). Where this theory held for almost all participants, several older participants confirmed that this theory even becomes more relevant with age because of a higher dependency on local facilities (Kahana et al., 2003).

4.3.5. Conclusion

Although a broad range of quantitative research has found some trends in associations between urban environment characteristics and indicators for mental illness and well-being, conclusions are not unambiguous (Benita et al., 2019; Clark et al., 2007; Gascon et al., 2015; Moore et al., 2018; Rautio et al., 2018). The current qualitative study illustrates that this inconsistency between study results might be explained by the complex interactions that occur between personal, physical, social, and institutional factors in relation to mental well-being. Despite a general recognition of this

complexity, most studies still tend to focus on either physical or social environmental factors, and ignore important interactions between those factors (Francis, 2010; Lorenc et al., 2012; Diez Roux and Mair, 2010). The socio-ecological framework presented in this paper can guide future research to pay more attention to the variety of factors and interactions among those factors. Additionally, the theories and concepts we introduced in this section could strengthen future efforts to unravel the underlying mechanisms explaining influences of the neighborhood environment on mental well-being (Roux and Mair, 2010).

Participatory planning can offer the opportunity to detect and respond to complex interactions in the neighborhood environment. Similar to previous research, most participants supported citizen involvement in neighborhood planning (Francis et al., 2015). Community participation itself can improve mental well-being by strengthening feelings of empowerment and the sense of community, especially in vulnerable neighborhoods (Francis et al., 2015; Teixeira, 2016; White et al., 2017). However, community representation in those participatory processes are still of great concern (Hutcheson Jr, 1984). Making participatory planning too formal risks to only consider opinions of engaged residents (Hutcheson Jr, 1984). Based on our experiences, we recommend approaching community organizations and medical centers as they have already built trustworthy relationships with groups that are more difficult to reach.

Regarding planning priorities, our results are in contrast with a previous study suggesting that, to improve mental well-being, priority should be given to tackle neighborhood problems (e.g. loitering, trash) instead of investing in positive attributes (e.g. sport facilities, blue-green infrastructure) (O'campo et al., 2009). Our study rather supports the "fixed window theory" (Teixeira, 2016) that already small environmental improvements such as a communal composting or flower pots can have a positive impact on neighborhood problems. Additionally, escaping to natural environments served as an important strategy to cope with neighborhood stressors, and were clearly missed by participants living in more deprived neighborhoods (Degenhardt and Buchecker, 2012). Therefore, we rather suggest an integrated planning approach.

With this study we aimed to highlight the complexity of factors influencing mental well-being in relation to the neighborhood environment and to inspire future research and planning practices. However, we are aware of the limits to what can be detected and considered in such a complex system. Therefore, we like to embrace Richard Sennett's saying, "the city is complex, full of contradictions and ambiguities. Complexity enriches he experience; brightness impairs that" (p. 15, Sennett, 2018).

4.4. Validation part: citizen workshop

No disagreements occurred, but some important additions of themes or links between themes were made.

Sense of community was the theme that was picked up as one of the most important themes in relation to well-being, followed by sense of security and blue-green space. One extra theme was added in one group, namely "homeless people" since there was a shared concern and frustration about fact that there is so much empty housing in Brussels and still so many people live on the street.

Following suggestions were made by the participants for themes they were less satisfied with or missing in their neighborhood.

Sense of community:
- Invest in social infrastructure: create and maintain pleasant public space where neighbors can interact.
- Provide ways to exchange services, for example through the online network application Hoplr
- Support neighbor initiatives, for example the initiation of urban gardens.
- Create stronger connections between neighbors and local services, for example by organizing informal meetings between the local police, cleaning staff, municipality, and neighbors.
- Hire a facilitator to makes connections between different typologies of users in the neighborhood.

Sense of security:
- Indicate a central reporting point or volunteering person in the street or neighborhood that fosters the contact between neighbors and the local police regarding local issues.
- Provide enough recreational facilities or activities to avoid vandalism because of bore-out.

Green-blue space:
- Invest in more green infrastructure in the city center.
- Investigate possibilities for demolition to create green spaces where they are lacking.
- Inform people on presence and accessibility of all Brussels parks, for example through medical houses.
- Define a “betonstop” for the BCR.
- Legally protect all existing parks.
- Support small-scale greening of neighborhoods

Neighborhood diversity (cultural, age, economic diversity):
- Provide a social framework to support innovative living forms that mix population groups.
- Invest in affordable housing and more qualitative social housing.
- Maintain affordable and multicultural provision of cultural activities.
- Create multifunctional places that allow a mixity of users.

Functional services:
- Provide free public transport.
- Create more schools.
- The creation of pleasant public space will attract functional services.

Neighbor contact:
- Facilitate individual initiatives and engagement to organize neighbor parties or provide help to neighbors.
- Invest in social infrastructure, such as pleasant public space where neighbors can interact.
- Maintain free space that neighbors can fill in themselves based on their own needs.

Cleanliness of neighborhood:
- Invest more in education and sensibilisation, especially in school environments.
- Maintain a close contact between neighbors and municipality to easily report on local problems.
- Organize informal meetings, cleaning activities and cooperations between cleaning staff and neighbors.

Traffic safety:
- Plan the city on the size of children.
- Strengthen the regional vision on less and slower cars, by implementing zone 30, speed bumps, sensibilisation campaigns to use less the car, sharing systems, limit parking lots, car-free

zones, tax advantage for non-drivers, enough parking lots close to car-free zones, good public transport (balance between car limitations and alternatives)
- Abandon big trucks in the city center by creating centers of distribution at the periphery of the BCR.
- Finalize and promote the use of the RER train around Brussels.
- It is the institutional role in listening to different stakeholders before making new mobility plans.


4.5. Validation part: consultations with environmental and health experts

4.5.1. Spontaneous associations with the theme 'urban environment – mental health'

Within the environmental sector, the direct links between the urban environment and mental health are not well known. Currently, mental health is implicitly addressed through themes, such as livability, silence and tranquillity, public space, housing and public space linked to poverty (urban degradation, vacancy, high concentration of poverty, little greenery, little outdoor environment), green in the city, mobility (air pollution mainly in association with physical health, noise, road safety), heat island effect, social cohesion (sense of community "being part of a crowd bigger than yourself", combating loneliness), reintroduction of water into the city (the sound of running water, the cooling effect).

Expert 1 - *"We do not yet have any insight into direct links or what the specific parameters are. It's more of a gut feeling. We especially want to reintroduce the landscape into the vicinity and we assume that in this way it contributes to well-being and happiness."*

Within the health sector, the experts spontaneously associated the theme with following topics: the city architecture (importance of aesthetics to show that residents are worth it), housing (indoor housing state reflects mental health state - *"The house as a third skin"*, housing remains the highest priority in terms of mental health - *"The solution is real housing as the first pillar*", increase in mental health problems among homeless and social housing residents, moisture problem, lack of outdoor space), green (feeling that in new projects little attention is paid to green space and play area), cleanliness, space (space allows to move, to clear the head and to be creative - "*Physical space gives mental space*", feeling of being locked up), public space (play area, overpopulation in the public space of vulnerable neighborhoods), mobility (city bustle, unsafe environment for the elderly and children, traffic unsafety can indirectly lead to loneliness because inhabitants do not dare to come outside their house, air pollution mainly in association with physical health), environment linked to

poverty (strong contrasts between neighborhoods in terms of visible poverty, such as garbage, urban degradation, vacancy, combination of high concentration of poverty, little greenery, and little outdoor environment, that translates into a form of fatalism among the people living in deprived neighborhoods, also percentage with psychosis higher in cities, poverty and unemployment as determinants of mental health), social cohesion (social segregation, social isolation, more social connections in cities, decrease in solidarity), heat stress, school environment (raising awareness about mental health), silence and tranquility (silent façade - *"Actually everyone should be able to sleep with their window open"*).

4.5.2. Current translation of these associations with the theme in own practice

The health experts encountered the theme in their own practice through the link with housing, the contextualization of the patient, environment on prescription, and neighborhood participation.

Link with housing

The health actors indicate that they experience the theme strongly in their practice through the link between mental health and housing. General practitioners in vulnerable neighborhoods regularly hear about housing problems during their consultations. Furthermore, it was indicated that home visits are especially important in precarious neighborhoods or with elderly patients, because maintenance of the home can often reflect the mental state of the patient. Because of the trusting relationship with the general practitioner, patients usually do not clean up and you get a realistic picture of the home situation. Now fewer home visits than in the past to work more efficiently, so that general practitioners now have less access to this information.

Rather than linking it to mental health, the association with living quality is more readily made in certain diagnoses such as asthma or allergies. Within the Brussels-Capital Region there is a green ambulance that can be consulted at the request of the general practitioner to check the patient's home quality.

Mental health actors are increasingly in demand from the social housing and homeless sectors because these target groups often suffer the most from mental health problems, but these sectors lack the necessary knowledge.

Contextualizing the patient

More knowledge about the type of neighborhood and type of residence and the impact on mental health can help care actors to gain more understanding for the patient, and possibly help them find solutions. The experience of working in more vulnerable and at the same time unattractive neighborhoods strongly suggests to the care actors that the visual impression of a neighborhood can weigh psychologically.

Expert 2 - *"The street scene itself already gives a very big impression or impresses you and I think also in the long term, while people are so used to it, they are not aware of it, a certain form of fatalism. We also don't get any further, others move but we don't have the chance to move, etc. I do think that has an influence on people psychologically."*

The same healthcare expert indicated that when he started his medical house, a lot of attention was paid to creating a pleasant environment with lots of light, a space, not too medical, rather a house of trust as it *"gives a certain respect for people, we do it for you and you are worth doing that."* The same can be said for investments in upgrading the neighborhood.

On a more theoretical level, reference was also made to health models that include the link with the environment, but that have little practical translation.

Neighborhood on prescription

On the one hand, reference was made to the health coaches who mainly inform patients about prevention and encourage physical activity, whereby they see that some start cycling along the canal.

On the other hand, reference was made to the connection of care practice with the neighborhood offer by referring patients to neighborhood activities or by going out with the patients in the neighborhood. The importance of small neighborhood initiatives to connect local residents was repeatedly emphasized. The emphasis in such a referral is rather on mental health issues.

Neighborhood participation

Some have been involved in participatory planning processes to represent the voice of the patients or organize discussion moments with the patients in order to identify their needs. Also often involved in the run-up to municipal elections to provide advice on new policy.

The environmental experts encountered the theme in their own practice through the link with planning social spaces, to support interventions based on health arguments, health in territorial analysis, and through participatory processes.

Planning social space

A great deal of attention is already being paid to the importance of spatial infrastructure for strengthening social cohesion. This mainly focuses on how spontaneous encounters can be stimulated through shared space.

Expert 3- *"For example at street level, everyone has a basic relationship with a street, often a level with which people connect more quickly. Those moments of encountering each other in the street are underestimated in where solidarity arises. Therein lies the underlying idea of contact theory: when you meet, prejudices disappear. So there is a need to create places in the space to allow that kind of contact. Who would have thought that the width of a stairwell was designed with that in mind."*

Health as an argument

Rather than mental health, physical health is often put forward as an argument for certain spatial interventions. This is particularly the case in the mobility debate, for example in defense of the low-emission zone.

Mental well-being rather than mental illness

It is clearly stated that planning does not start from certain syndromes, but rather looks at how the general well-being can be increased.

Health in territorial analysis

For some urban development zones, the characteristics (demographic, social, economic) from a specific area, but also the issues regarding the environment, such as air pollution, noise pollution are studied in advance. In addition, since a few years also the health state of the local residents is included, and the offer of social and welfare services (specific demands and needs). Recently, a pilot health impact study was initiated for the urban renewal of the South Station, where the impact on health and wellbeing from the future plans are evaluated and taken into account in the realization of the plans.

Through participatory processes

Resident consultations are often based on the question of what residents feel good or bad about in the neighborhood environment.

4.5.2. Challenges and needs to translate the theme in own practice

The integration of the theme within healthcare practices is challenged by a lack of knowledge, a limited or unknown neighborhood offer, resistance to change, and the complexity of the theme.

Lack of knowledge

The link between mental health and living environment is not addressed in the healthcare education program. The topic is often considered too abstract, for which there is still little scientific evidence. This causes caregivers to intuitively avoid the topic rather than to discuss it. Furthermore, caregivers lack methods to translate the theme into their consultations.

The spatial context of the patient is hardly known because of the decrease in home visits and because general practitioners do not necessarily live where they work.

Limited or unknown neighborhood offer

If the neighborhood of the healthcare practice has few recreational or green spaces, it automatically becomes more challenging to refer the patient to the surrounding environment. This often requires a commitment from the healthcare practice to work with patients to discover the potential of the neighborhood.

Resistance to change

There are many forms of resistance that complicate attention to the link between health and the environment in the healthcare sector:
- referral to the environment is limited to out-of-the-box family physicians;
- the living environment often not considered a priority as many patients are in survival mode;

- it is easier and quicker to address individual lifestyle than environmental factors and land use planning;
- neighborhood development projects are linked to complex files with many private owners and interests leading to an interest in participation to be lost over time;
- the reform 107 of the mental health sector increased competition for budgets between mental health services, resulting in inadequate cooperation with each other and with, for example, the housing sector.
- a strong separation exists between welfare and health services, causing limited integrated thinking within primary health care.
- patients themselves not familiar with advices linked to health promotion.

Expert 2 – *"It is also difficult to sell, for example in our medical house we have a health promotor, but how do you explain people that someone that does not measure any pressure, does not give injections, does not prescribe medications, that they are important, and even more important in life than those momentaneous interventions from a doctor or nurse."*

Complex theme requires broad approach

It is generally accepted that mental health problems are complex because of the intertwining of combined problems. Therefore, the importance of a broad approach is prioritized with:
- a broad dialogue with various welfare and care partners is needed (general practitioners, homeless, social housing);
- a double action: tackle the causes and provide the necessary help;
- integrated solutions;
- participatory detection of care needs starting from a broad view on care.

The integration of the theme within planning practices is challenged by a current lack of knowledge, a lack of a broad base of support, gentrifying effects, temporal mismatch, multiple claims on public space, insufficient housing policies, the inconsistency between administrations, and potential risks of focusing on health in planning.

Lack of knowledge

Current planners lack detailed knowledge on the impact of the urban environment on mental health, and instruments to implement this knowledge, such as clear design principles or instruments supporting the dialogue between municipalities and project developers to claim more environmental qualities in future developments. Current guidelines such as the Environmental Impact Assessment, lack a human factor, so attention to wellbeing, or are very little picked up by developers because they are non-binding, such as the BeSustainable toolbox.

Lack of accurate data

A big problem is that data on a more fine scale are missing, current data often limits to the neighborhood scale. Another fact is that for example data on air pollution are collected on 3-4 m height, which is not the height where people breath this air. So depending on the typology of the street, e.g. street canyon, the effect can be completely different.

Lack of broad mind shift

Especially regarding the mobility theme, the change from car use to active mobility demands a drastic change of mentality. The experts struggle with the sense of urgency on one hand, and the need to get support from a broad audience on the other hand. The urgency demands short-term drastic interventions that may lead to polarization in society, while the latter demands a long-term process of informing, sensitizing and involving citizens.

Expert 4 - *"Normality has to be made abnormal before drastic interventions can happen."*

Gentrification

It is a reality within planning that improving the quality of the living environment may result in increased living prices. However, the experts emphasize that this should not be a reason to not invest in low socioeconomic neighborhoods, because they notice that these people also demand a better living quality with more green, more road safety and less noise.

Expert 4 - *"Themes such as greening and slow mobility are often associated with gentrification, driving away the "poorer population", but if you speak to the so-called poor people in the Anneessens neighborhood, for example, they themselves also want less noise from cars and they also want more greenery. But it is not this public that puts those themes on the agenda."*

Temporal mismatch

First of all, there is a mismatch in the immediate demand for action regarding urban – mental health issues versus the political debate that takes 5 years. Secondly, a mismatch exists between the moment of designing the city and the actual realization (see Brouckère 15 years), whereby the intervention no longer meets current needs (see non-green squares in Brussels).

Multiple claims on public space

A planner is challenged by meeting the interests of different stakeholders that make different claims, for example greenery versus cultural events versus traffic flow. It is very difficult to take into account all arguments at the same time.

Insufficient housing policies

The increasing demand for social housing versus the increasing housing prices underly the insufficiency to provide affordable qualitative housing. It seems a long-standing problem where a lot of actors feel powerless because of the lack of investment, the neighbor protests against social housing, the real estate cycles and related corruption.

Inconsistency between administrations

The inconsistency between federal, regional, and local responsibilities regarding this theme make it difficult to translate broad policy objectives into practice. Additionally the themes occur at different policy levels, health is a federal responsibility, while welfare and care is divided among regional and municipal policy makers.

Potential risks of centralizing human health in planning

Where most experts agree that human health is a good starting point in planning, some also highlight potential risks of doing so. First of all, some non-ecological decisions might be sometimes healthier, so where to put more weight. Secondly, focusing on the negative health effects of the urban environment may motivate people to move away from the city. Often the negative perceptions will remain longer, even when situations have improved. In the past health arguments were sometimes abused for economic purposes (see the Noordwijk, or the Zenne), something that could also happen in new development projects to sell their product.

4.5.3. Collaboration between healthcare and planning

Arguments

A collaboration with medical homes offers the opportunity to reach a wider audience of residents for participation in participatory moments within local development plans or environmental research.

Expert 5 – "*In our working, we booked some small successes in our workshops together with medical houses in which we walked with neighbors through the neighborhood to measure black carbon. I will not say that this will have a big long-term effect, it is part of a total approach. But those kind of methods can serve the future to translate themes such as air pollution more concretely to wellbeing and to make people more aware about it. It is only through this consciousness that people can organize themselves in a collective manner to ask for change."*

Furthermore, examples where healthcare actors themselves were involved within the planning process show that such actors provide important nuance to existing dogmas within planning.

Expert 6 - *"Those conversations gave a lot of insight to understand logics that were new to us, but were very guiding in how you organize space. Like public versus private."*

Additionally, the dialogue on spatial issues with health actors can help put the issue on their agenda as well. Currently, the knowledge and expertise are very divided, there are health actors, wellbeing actors, environmental actors, so collaboration and exchange of expertise are highly important.

Opportunities

In addition to the involvement of care institutions in participatory planning or environmental research, joint study days or project calls offer good opportunities to get to know each other's domains better and to stimulate collaborations. A knowledge platform that bundles current knowledge and exemplary projects can provide inspiration for new collaborations. Since a few years there is a structural collaboration with the healthcare sector "Care in the City", where planners and caregivers come together every three months, and in which they work around the link between health and planning through specific projects.

Approach

To encourage the planning industry to make the reflex to care, there is a need for a political signal that puts the issue on the agenda.

Expert 7 - *"There are very few project developers who already include these qualities. Political leadership is practical. Someone who sets the lines and has players who will commit to it. A Prime*

Minister who says that urban planning and care are really important for this legislature is a success. The political change is not there yet."

In addition, the compartmentalization of the administrations and the box-ticking within the various competences must be broken to promote coalitions at different levels of scale.

Expert 8 - *"There is, of course, an institutional obstacle, because all of your health and welfare is one jurisdiction, and spatial planning and housing is another. Health and Spatial Planning is federal, Housing is regional. Welfare and health care is regional. That remains a difficult one, where you always get stuck. And the weird thing is that everyone knows that."*

Projects organized in a co-creative manner allow for the development of a shared vision from the beginning and then translate it into spatial principles. Special attention to the process within such a project allows to draw important lessons towards collaboration.

Expert 9 - *"Through cocreation, we developed a vision where these actors were at the table with us and we as architects translate the knowledge that is put on the table into spatial principles (down to square meters)."*

4.5.4. Influence of COVID-19 on theme

Theme on agenda of both sectors

In both sectors, the initial lockdown during the health crisis resulting from COVID put the issue more firmly on the agenda. The lockdown has encouraged planners to look at urban design from a health lens.

Expert 10 - *"We see that there is a momentum now to push that at an ambition level. I think that's still the most important thing that we do indeed take mental well-being as a parameter for a good project."*

Primary care workers in vulnerable neighborhoods were made more aware about the gap between their own lifestyles and patients. Often they noticed that because of too much shock and too little information about the current measures, patients stayed inside unless they were explicitly told by the doctor that they could take a walk.

Magnification of social environment inequalities

Overall, the lockdown mostly caused an exaggeration of problems that were already present before the crisis. Sensitivity to the strong social environmental inequalities increased in both sectors. For example, experts saw that in densely populated neighborhoods with little public space, residents tended to stay inside their small apartments. Thus, the lockdown certainly accentuated more strongly how important public space becomes to those who live small-town.

This contrast is also noted in the fact that for some, the lockdown meant a positive rediscovery of their neighborhood while for others, little changed as they have little sense of the environment outside the home anyway. The observation that the measures during the first lockdown did not take

into account the most vulnerable groups was evident in the multiple confrontations between police and homeless people as they were forbidden to stay in one place.

Within the planning sector, a post-covid scientific committee has been formed to describe housing of the future, each time falling back on pain points that have lasted for years.

Separation of physical health, mental health and well-being

For the experts, the crisis reflected very strongly the hierarchy in the current care system. Initial attention was focused on hospitals, and only when it was already largely too late was attention turned to nursing homes. Next in line was mental health care and finally attention was paid to the in-home situations. The fact that the welfare sector has been so little involved highlights the limited integration of welfare and health in current thinking. Furthermore, one expert also cites that the crisis shows that there is a need for alternative small-scale, hybrid care solutions to make the care system more resilient.

Impact on mental health

Regarding the impact of the covid crisis on mental health, several findings, mainly from mental health experts, were shared. The negative impact of the lockdown was reflected in the triggering or reinforcement of existing mental health problems (including paranoia), the increase in substance use and the increase in requests for mental health services and the increase in substance use among certain groups (ex-prisoners). In addition, only limited support could be provided through the online alternative. An expert also saw the well-being of able-bodied residents of a residential care center deteriorate sharply due to the cessation of social (outdoor) activities.

On the other hand, a survey by UCL "Covid and I" showed that in the first lockdown, people with lower SES showed better mental health outcomes than people with higher SES. The experts presented several hypotheses. Lower social pressure provides less stress, where for higher SES the workload may have remained the same or even increased. Another reason may lie in the nature of the situation described above in the residential care center, that namely residents with higher SES experienced stronger limitations in their day-to-day activities than those with lower SES.

Political priority

On the one hand, there is a feeling among the experts that the theme has also reached political agendas. In particular, there is recognition of the importance of good quality and sufficient public space. Especially in the area of mobility, bicycle infrastructure has been built at an accelerated pace, which at the same time has caused polarization between cyclists and motorists. The effect of the lockdown on air quality was also strong, but was quickly reversed after the lockdown, partly due to increasing car use for fear of contamination. On the other hand, there is a fear that just the covid crisis is pushing the issue, especially the housing issue just more into the background.

Revival of the suburban dream

Finally, there is also a suspicion that the lockdown leaves a very negative perception on the city and triggers a move away from the city. People dream of a house with a large garden. However, this has a dispersed living as a result, an increasing loss of habitat and a higher risk of spreading viruses. On

the other hand, this could be refuted for a stronger argument for more attention to independently functioning neighborhood metabolisms in a city as explained by following expert.

Expert 11 - *"That idea of walking to the store and the doctor, so much more self-functioning neighborhood metabolisms, that that would make the city a lot more resistant, that that would also reduce your spread through the city, and directly so much more the infections. So I think this crisis teaches how a city can operate on a much smaller scale, a neighborhood scale than we currently realize."*

4.6. Validation part: consultations with HIS experts

4.6.1. Major implications of changes

At first, each replacement breaks the trend for long-term monitoring / follow-up research. Secondly, the HIS is already very extended, adding new questions is less desirable than replacing old ones. Thirdly, Sciensano receives a lot of requests, so important to limit to the essential suggestions.

4.6.2. Methodological changes

Checkbox (present/absent) for environmental issues

One of our suggestions was to introduce a checkbox to collect more easily and more detailed environmental data in the HIS. The experts agreed that the layout is indeed nicer, but since these questions are face-to-face the layout doesn't really matter. Additionally, it is more difficult for participants to answer a yes/no than have more options via a Likert-scale. Nonetheless, the data are analyzed as binary variables.

If the question would be part of the written questionnaire, than a combination of the checkbox with a Likert-scale would be useful.

Walking interview method

We suggested rather the walking interview method could help to reduce reverse causation as the interviewer gets a real look on the neighborhood environment, e.g. using a checkbox.

The experts indicate that it could have an added value but is not feasible (& desirable) for several reasons:

- The surveys are conducted by 200 different interviewers that receive an intensive training. Adding tasks to their list is undesirable because they already have a lot of things to think about.
- For each household they often have to conduct more than 1 interview, going out with all of them seems very difficult to organize.
- Already confronted with complaints by the interviewers that they feel underpaid for the job, so adding this additional workload would not be accepted. Lack of funding to support more qualitative methods.
- Walking interviews in non-urban areas are less interesting.
- With 200 different interviewers / observers, you will have an important observer bias, with the interview data conducted by the same interviewer being correlated.

Subjective vs objective environmental data

For the previous HIS wave (2018) there was a big discussion on rather the questions on environment should stay in the HIS, but both the commissioners from Brussels and Flanders were very much in favor to keep them.

It would be interesting to complement the HIS with objective environmental data from other data sources, as done in NAMED. In our recommendations we could look into more existing data sources to complement the HIS, although it would be still important to check the validity of these data. (e.g. Fix-my-street)

The current HIS capacity does not allow for coupling each wave of HIS data with objective environmental data. It is only possible if project-based like done in NAMED or in another project where the HIS data are complemented with data on medication use. However, if we think this data coupling on a general base would be interesting, this suggestion could be envisioned internally with the environment team of Sciensano.

Cultural sensitivity

The questions in the HIS are internationally validated, so assumed to apply to different cultures. During the face-to-face interviews the participants do have the possibility to ask for clarification on the written questions if not well understood.

During the interviewer selection, attention is paid to the match between the interviewer and interviewees (e.g. choosing an interviewer who also lives in the area and is familiar with the context, or has a shared cultural background).

Local HIS

The purpose of the local HIS was to obtain more fine-scale health data. The local HIS is a simplified version of the national HIS, so no other questions are added. The environmental data are present. This project is still going on so no official report on the results yet.

4.6.3. Procedure to suggest changes to the HIS

Before every new HIS wave, the previous HIS is sent around and evaluated. There is a fixed time span to advise new questions. It is not a formal procedure, e.g. introduced by federal government, it is rather a consulting process with a lot of negotiation. Suggestions are made through two types of procedures:

1) The public health commissioners (public health institutions that are using the HIS data) are consulted to ask rather they have new suggestions for the next HIS (questions or topics they're interested in to handle over the long-term, etc.).

2) External parties (mostly university professors) can provide suggestions through a conceptual paper clarifying the objective, the added value and argumentation for the suggested changes (see example). These suggestions are only introduced if the argumentation is strong enough and backed up by the commissioners.

Suggestions from public health commissioners gain more weight since they are the final & frequent users of the HIS, and also provide the funding for the HIS. For Brussels this is Observatorium voor Welzijn en Gezondheid.

4.6.4. Problem of non-respondents

We found out that there are a lot of missing data in the current HIS, especially for the questions on SES and mental health, and especially for specific groups of respondents (single parents, elderly, low SES, non-European country of birth). This problem is recognized by the experts, as well the type of profiles among non-respondents. At the moment, due to the low number of respondents, it is not recommended to start working with the results of HIS 2018. One sees a trend of less and less low SES respondents participating in survey because of two reasons:
- more people of low SES refusing to participate
- The interviewer effect: Some interviewers are afraid to conduct surveys in certain neighborhoods (characterised by low SES), so they avoid these neighborhoods and choose other participants.

As a result, based on HIS in Brussels, health indicators show an improving health trend in numbers, but one knows from other data with better samples such as mortality, administrative data (incomes etc), IMA data that this is not the case.

The experts noted that another question in the HIS gets answered more and is therefore more useful as an indicator of SES: to what extent do you manage to make ends meet at the end of the month? However, this is a binary variable, so it is not as strong as the income question.

Also in relation to the question about education level the experts observe problems since it is often difficult for non-European respondents to classify their diploma in our distribution system. In addition, there is also a fairly large elderly population in Brussels who often do not have a higher education because it was less of an issue at the time, but who therefore do not necessarily have a lower socio-economic status. So education level is also not an ideal indicator of economic status.

These issues are currently discussed with Sciensano. One possibility is to work through local social facilities to reach a wide audience, but the main hurdle remains the time investment.

4.6.5. Importance of HIS data

HIS data are very widely used to support policy, answer parliamentary questions and develop valid health indicators relevant to Brussels. For mental health data, HIS is the main data source for now. The IMA database also contains data on antidepressant use, but e.g. therapies are not yet included because reimbursement is still limited. Hopefully, with the current evolution, this data will also be made available.

Parliamentary questions are also answered on the basis of the available data, regardless of the type of data, either quantitative or qualitative.

Research projects giver the opportunity it to work more deeply with various data sources and to link qualitative research to them.

4.6.6. Fine-scale data

For more geographical detail in such surveys, you always run up against privacy issues. For 3000 HIS respondents in Brussels, the results cannot be viewed on a finer scale than the region because there are not enough respondents per municipality / district to be representative.

The Observatory, however, is trying to create variables at the statistical sector or district level with regard to social inequalities. Health variables present in IMA database can already serve as indicators at lower level, but are limited to medication use / reimbursements.

However, fine-scale health data are very important because of the trend towards neighborhood-oriented care within policy and practice. Quantitative data are relevant to form maps to easily compare different areas and detect challenges. Qualitative research is relevant to understand the underlying determinants. Quantitative and qualitative research are therefore considered to be of equal value so the Observatory always tries to answer certain questions by means of a mixed method. Within the community care projects, the available variables provide an initial picture, but the data set is very limited. Therefore, this is normally supplemented with qualitative research, for example, organizations and residents are surveyed to learn more about the functioning of the neighborhood.. More complex data analyses again require expertise that is not present among those involved, while qualitative methods are easier to learn.

4.7. Validation part: internal exercise

The internal validation within our research team resulted in following lessons regarding the use of mixed method and working together from different disciplines.

Mixed method

Strengths	Weaknesses / challenges
• Complementary approaches to a complex issue • Quantitative research guided parts of qualitative research • Qualitative research helped to communicate quantitative results • Good internal learning process • More emphasis on practice and policy relevance • Talks to two types of decision makers : quantitative for evidence-based decisions and monitoring qualitative for decision makers interested in the "why", the mechanisms, talks more to the general public • Invites more to reflect on own research methods • Two different perspectives on topic	• Time consuming to understand and integrate both parts • Difficult to combine methods that work so differently • Lack of true integration of both parts • Both parts parallel conducted, while quanti followed by quali could have brought more focus in quali • Attempts to integrate resulted in too broad data collection in qualitative part • Participants of quanti not same as participants of quali • Creates lots of data to handle • Risk of oversimplifying communication to stakeholders • Qualitative evidence on importance of green subordinated to non-significant quantitative evidence • Format of project defined at start, gives little flexibility to fulfill certain needs or conduct analyses that arise during project • Lack of predefining mixed method in NAMED project

Interdisciplinary working

Strengths	Weaknesses / challenges
• Learning from each other, lot of different expertise • What worked well: informal small meetings on specific questions • Strong motivation to keep working on project even without budget • Bilingualism in the group • Quanti's being highly involved in qualitative method development, data collection, reporting of results • Richness in perspectives on research results: from knowledge on biological mechanisms to social underlying mechanisms - especially for discussing and augmenting the results; everyone has an extended view on specific literature and can provide in this way different inputs • High responsiveness by quanti's to answer questions from quali's • We had fun, it was a nice collaborative atmosphere :-) • At least tried to not get isolated on own island	• In-depth reflection was missing during the big meetings (see also challenges) • Change of several team members during project • Budget for personal was a challenge • Frequency of interaction between partners weakened over duration of project (COVID? Budget finished?) • Lack of fixed follow-up committee throughout four years • Lack of time to optimize interprofessional knowledge exchange • Quali's less involved in statistical model/ indicator building e.g. green quality measure • Not always easy to understand quantitative steps undertaken - linked to lack of strong statistical knowledge among quali's • inter - or multi-disciplinary sometimes results into, but should not, require training of individuals in all disciplines.

5. CONCLUSIONS

1. Mental health benefits from a socially cohesive environment
2. Mental health benefits from a physically active environment
3. Citizens are unequally affected by negative and positive environmental factors
4. Motorized traffic harms mental health
5. Nature strengthens mental health
6. Cities are complex systems, with urban mental health outcomes depending on many interactions

5.1. Mental health benefits from a social cohesive environment

The quantitative part showed that in the different statistical models, social support was always significantly associated with nearly all mental health outcomes (Pelgrims et al., 2021). This implies that social support is an important determinant to mental health.

In the qualitative part, participants confirmed the importance of good community ties for mental well-being. Some experienced great mutual support among neighbors which contributed to feeling secure in their neighborhood. Several participants mentioned the importance of having a sense of community with the relating outcomes of feeling part of a bigger community, not being isolated, mutual understanding and support. Good neighbor ties or social memories in the neighborhood made several participants feel at home and attached to their neighborhood or specific places in their neighborhood. (Lauwers et al., 2021)

5.2. Mental health benefits from a physically active environment

The quantitative part showed that in the different statistical models, physical activity was always significantly associated with nearly all mental health outcomes (Pelgrims et al., 2021). This implies physical activity is an important determinant to mental health.

Regarding physical activity, the interviews learned us that several participants needed physical activity to cope with negative feelings, to break their routine, and to feel healthy. Additionally, having the possibility to walk to neighborhood services, such as local stores, supported a sense of security and improved neighborhood satisfaction. (Lauwers et al., 2021)

5.3. Citizens are unequally affected by negative and positive environmental factors

The quantitative part showed that following groups are more exposed to air pollution, have less access to green spaces and are more exposed to noise pollution from multiple sources in their residential environment: people with a lower level of education, people with lower income, and people with a non-European country of birth. Aircraft noise during the night mainly affects people with a higher socio-economic status. (Pelgrims et al., 2021)

The qualitative part highlighted that some neighborhoods suffered greatly from neighborhood socio-economic deprivation, referring to the low physical position (vandalism, graffiti, loitering, litter, abandoned buildings) and low social position (substance use, loitering, dealing, crime, harassment,

violence) and economical position (income, education level) of a neighborhood (van Vuuren et al., 2014). (Lauwers et al., 2021)

In these neighborhoods, the continued presence of clandestine garbage dumps and vandalism caused negative feelings of frustration and despair. Regarding neighborhood security, participants referred to problems with loitering, vandalism, squatters, drugs dealing, substance use, and burglary. A lack of neighborhood security negatively affected mental well-being in the sense that some participants felt restricted in their daily activities as they were scared to go out at night, or to pass by some specific places. Also annoyance to noise from the traffic and people was mentioned to contribute to mental distress. Finally, participants living in more deprived neighborhoods mentioned to experience a great lack of nearby nature and recreational space. (Lauwers et al., 2021)

5.4. Motorized traffic harms mental health

The data-driven part found a significant association between traffic-related air pollution and depressive disorder (Pelgrims et al., 2021).

In the qualitative part some participants expressed their concerns about traffic-related air pollution and therefore avoided busy streets. A lack of traffic safety, more precisely bike and pedestrian safety, was linked to feeling insecure while cycling or walking, but also to annoyance and confusion by the lack of good infrastructure. Especially, for people with children the lack of traffic safety was a burden to their mental well-being as they constantly needed to keep an eye out and did not dare to let their children go out alone. (Lauwers et al., 2021)

Traffic noise affected mental well-being as it caused annoyance, impeded people to relax and disturbed bird sounds. The interviews clarified the importance of having a good balance between liveliness and calmness in a neighborhood, and to have nearby opportunities to find peace. Some referred to their individual residence where they suffered from sleeping problems due to noise from air traffic, mainly in high socio-economic neighborhoods close to the airport with a high frequency of take-offs and landing. (Lauwers et al., 2021)

5.5. Nature strengthens mental health

Once adjusted for socio-economic and lifestyle data, the quantitative part could not demonstrate a significant positive effect of residential greenness on mental health based on the available data (Pelgrims et al., 2021). On one hand, this lack of association may be related to methodological issues (these are elaborated in a separate document on methodological recommendations). On the other hand, Brussels-Capital Region is a city with very high environmental inequalities: economic status and green space availability are highly correlated as explained above. This makes it difficult to disentangle the impact of socio-economic factors and green spaces on mental health (Pelgrims et al., 2021).

However, the qualitative part strongly underlines the importance of nature to mental health. The most common response of the participants regarding green spaces was the feeling of escaping from the city hustle and to take a break from daily routines. Other responses to mental well-being in relation to green spaces involved: connecting to nature, exploring nature, getting fresh air, relaxing, rebuilding energy. Natural environments were also visited for the self-regulation of negative feelings. Some participants mentioned the importance of green spaces to maintain their physical and

social activities, and as such contributing to mental well-being. Additionally, participants referred to small blue-green infrastructure such as trees, flower beds, and fountains contributing to a feeling of fascination and relaxation. (Lauwers et al., 2021)

5.6. Urban mental health is complex

The quantitative part showed the importance of both personal determinants, such as socio-economic status and physical activity, social determinants, such as the quality of social support, and physical determinants, such as poor indoor housing quality and air quality to mental health (Pelgrims et al., 2021).

The qualitative part highlighted the broad range of factors (social, physical, personal, institutional) and interactions among those factors that better explain how Brussels' inhabitants experience their neighborhood in relation to their mental health (figure 1). For example, social diversity in the neighborhood contributed positively to mental health as some participants experienced more tolerance and solidarity among neighbors and an ease to connect. Among the physical factors, neighborhood services, such as public transport, commercial (grocery stores, bars, restaurants), and welfare services (pharmacies, medical houses, and schools) were mentioned to contribute positively to mental health as these services met individual needs and offered a certain comfort and sense of security. (Lauwers et al., 2021)

Several physical neighborhood factors such as parks, local services and citizen-based initiatives were mentioned to support neighbor ties and strengthen a sense of community. Difficult personal life events were shown to enforce restorative needs to cope with negative feelings and sometimes motivated visits to specific places. Regarding the institutional factors, tailoring policies to neighborhood contexts through participatory planning and responsiveness to local demands were mentioned to be important to improve neighborhood satisfaction. A detailed description of all factors and interactions can be read in the published article by Lauwers et al. (2021).

6. RECOMMENDATIONS FOR PRACTICE AND POLICY

1. Plan socially
2. Promote physical activity
3. Prioritize low income neighborhoods and implement strategies to counter (green) gentrification
4. Reduce motorized traffic
5. Create and maintain qualitative green infrastructure
6. Tailor to local contexts and work transdisciplinary

6.1. Plan socially

The physical environment should not be viewed separately, but rather in relation to the social environment. Therefore, it is considered important to include local inhabitants into (urban) planning. One can plan socially by shaping space through a social process. In other words, planning through participation in order to detect subtle daily experiences and sensitivities and to create a dialogue between inhabitants with different perceptions on the neighborhood.

Furthermore, socio-spatial planning puts emphasis on equity and inclusion, which is about not letting the same voices claim the future of the environment, but making an extra effort to let a diversity of users, and in particular the most vulnerable users, have their say and their place in the neighborhood.

Finally, providing free space, financial support or material to support citizen-initiated neighborhood projects, or including these initiatives into future development plans allows to maintain the social value of these projects on the long term.

6.2. Promote physical activity

Physical activity can be promoted by investing in walkable and bikeable neighborhoods. Following major principles are proposed to improve walkability: accessibility, connectivity, comfort, legibility, context, and sharing (Zuniga-Teran et al., 2017). Following major principles are proposed to improve bikeability: directness, connectivity, attractiveness, safety, and future proof (Bendiks et al., 2013).

Besides improving the infrastructure to support active mobility, physical activity can also be promoted through medical prescription. Therefore, we call for a better uptake of the existing project « Bewegen Op Verwijzing » in the medical centers of the Brussels-Capital Region.

6.3. Prioritize low income neighborhoods, but counter green gentrification

Generally, spatial quality contributing to better mental health seems to be at the expense of affordability. Developments in the neighborhood often lead to an increase of house and rental prices, pushing the current residents away. Green, environmental, or ecological gentrification is a process in which cleaning up pollution or providing green amenities increases local property values and attracts wealthier residents to a previously polluted or disenfranchised neighborhood (Dooling, 2009). However, the risk for gentrification should not be a reason not to invest in more affordable,

less attractive neighborhoods, because also among these residents there is a desire for more livability, characterized by more greenery, less noise and more safety. Recent literature includes some strategies to counter this gentrifying effect (Anguelovski et al., 2019): 1) dissect the role that finance capital and financialization play in urban greening – unpacking financial actors, their intermediaries and economic beneficiaries is an important next step for green gentrification research, 2) adapt a multi-actor approach in planning discussions to strive for combined goals of urban greening, equitable economic redevelopment and environmental equity, 3) aim for early co-production to better align new developments with diverse current users and to help residents to feel recognized and more attached to the created space. The Urban Green Justice toolkit provides additional strategies on this issue (Oscilowicz et al., 2021).

Other strategies to monitor both quality and affordability, include the principle called "skimming" in which part of the increase in value due to greening, slowed mobility or other forms of qualitative developments in the public space, flows back to the community. This profit can then be used to invest in for example social housing.

There is also a great deal of potential in innovative housing projects (see joint housing projects, LogingFirst, Community Land Trust), but the number of examples remains too limited and the realization an administrative tangle due to gaps in the current legislation, demanding for an adaptive legislative framework. Finally, stronger solidarity mechanisms between the richer and poorer neighborhoods and a region- rather than municipal-based tax system could reduce these inequalities.

Neighborhoods characterized by a lower socio-economic score both low in indoor and outdoor quality. A combination of overpopulation in small housing and a limited supply of public space often leads to conflict in those neighborhoods. Therefore it is necessary to develop public space with attention to the private living situations of local inhabitants. Living small directly associates with more public space use, so the availability and size of public space should be aligned with private living conditions. Additionally, the activities possible in this public space should meet shortcomings experienced due to limited private space.

6.4. Reduce motorized traffic

The move from the individual car to more collective and active travel modes requires an enormous change in mentality. Raising awareness about the sense of urgency and the negative impact of air pollution on (mental) health can help to reduce the often strong polarization between proponents and counterparts, as this demonstrates that the intervention benefits everyone in terms of (mental) health. Furthermore, small-scale actions such as cycling lessons or a bicycle library help to warm and include a wide audience to more active modes.

Reducing motorized traffic demands a combination of hard and soft interventions. Hard or traffic management interventions are strategies aimed at modifying social conditions and structures. These measures aim to change transportation behavior by altering the physical environment (e.g. closing roads, building bicycle lanes, etc.) and through legal or economic policies (e.g. prohibiting car traffic in city centers, congestion pricing, introducing parking fees, etc.). Soft interventions or psychological interventions are “strategies aimed at influencing people’s perceptions, beliefs, attitudes, values, and norms”(Semenescu et al, 2020).

Regarding soft interventions, research shows that targeting social, cultural, and moral norms are most effective, followed by the ones targeting information and awareness of own driving behavior (e.g. by keeping track of own car use). Soft interventions that focus on recognizing and broadening understanding of own travel behavior, deepening own environmental understanding, and making plans to use the public transit system instead of personal vehicles were also shown to be successful. Regarding information and awareness raising, research showed that combining a personal talk with information delivery is a more effective way to trigger behavioral change than the delivery of information alone. Finally, research suggests that the combination of personal (e.g. amount of money saved) and prosocial (e.g. emitting pollutants that were avoided) feedback may be especially effective in overcoming the inertia of driving habits (Nakayama et al., 2005; Graham et al., 2011; Bamberg, 2013; Semenescu et al, 2020).

Considering the existing evidence, the magnitude of air quality benefits from hard interventions is rather modest. Road/congestion pricing and low emission zones in European city centers appear to be moderately successful in improving air quality, while speed management strategies, trip reduction strategies, vehicle and fuel regulation and technology development have been successful in greatly reducing emissions rates in many countries. Aggressive traffic management strategies, or combinations of multiple smaller traffic management strategies seem necessary to generate substantial benefits (Bigazzi and Rouandleau, 2017).

More specifically for the Brussels-Capital Region, it was also suggested to continue focusing on good alternatives: continue good and affordable public transport, better exploit the potential of the RER train and up-scale the use of cargo-bikes across different sectors.

6.5. Create and maintain qualitative blue-green infrastructure

The NAMED project learned us that in relation to mental health, the quality of a green space was not necessarily defined by its extent. Both small and big sized green spaces were considered important. Regarding smaller green spaces, the quality was often defined by its close distance, its cleanliness, its intimacy (e.g. walled), and its structural diversity (e.g. presence of colorful flowers, art works, big trees, water elements, etc.). Regarding the larger green spaces, qualities included its extent allowing to wander around or sport for a while, its open view, its large trees, its diversity in terms of animals and plants, the absence of cars, its potential to do different kind of activities, etc. The quality of a green space is also defined by its adaptations to different users, e.g. the presence of a playground, toilet for both children and elderly, an outdoor fitness, a running trajectory, benches, etc. These findings add to an overview of perceived green space qualities provided by Mccormack et al. (2010) that could serve as a good starting point to plan green spaces.

Brussels-Capital Region covers a lot of big qualitative green spaces, however, as illustrated these are not equally distributed. Therefore, it is important to make them also available for less affluent neighborhoods through creation or to improved access by public transport. If no space is available in close distance to these neighborhoods, investment should go towards improved quality of small-scale blue-green infrastructure.

To increase availability and accessibility also the development of a strong blue-green network as a basis for a performant and biodiverse open green space network is important. Some concrete strategies are:

1) enforce the existing public green spaces by maintaining and extending them;
2) enforce the blue network and soften (unpaved) squares and streets;
3) deconstruct mobility infrastructure and integrate them in the landscape;
4) improve the outdoor space of public facilities to provide ecological and social opportunities.

An additional greening strategy might be the implementation of minimum green norms in real-estate or urban spatial development plans. Such norms define the type, the minimum area of green space that should be created and the maximum distance. Flanders region developed guiding (not binding) green standards, however, there seems a need to update these standards with current knowledge on the impact of nature on (mental) health. Such minimum standards can be included in construction plans through regulations. Brussels Environment already provides the Be Sustainable toolbox to better incorporate these qualities in development plans. However, project developers are not yet spontaneously using such tools. It requires political ambition to get real estate developers to consider the quality of the surrounding environment. An instrument that makes project developers aware of the importance of greenery could support policy makers during the negotiation process.

Finally, it also seems that many inhabitants are not familiar with the availability of nature in the Brussels-Capital Region, so increased awareness on the availability and access, e.g. through medical centers, might support a wider audience to profit from the mental health benefits of nature.

6.6. Tailor to local contexts and work transdisciplinary

To improve mental health in relation to the urban environment, mental health care and urban planning should tailor to local contexts. One way to do this is through neighborhood-based care and planning.

Neighborhood-based care refers to the integration of local healthcare services into the neighborhood environment. Possible strategies include a strong network between local healthcare and neighborhood services, a good overview of the neighborhood offer in medical centers, and opening healthcare facilities to the wider public. Networks in which medical centers are in contact with community organizations and initiatives help to bring inhabitants closer to care, to adapt care to patients' needs and to better detect mental problems such as loneliness. Experts stated that a good overview of the neighborhood offer in medical centers can provide low-threshold solutions for a large percentage of people who suffer from mental health problems and fail to reactivate themselves in society. Healthcare facilities themselves can contribute to the neighborhood offer by for example organizing healthy cooking workshops or making the garden more accessible, and as such informing inhabitants on health promotion and disease prevention.

By neighborhood-based planning we refer to planning that adapts neighborhood developments to the neighborhood context by proactively involving local inhabitants and services in the planning process and by adapting developments, also after realization, to meet local needs. A well-established neighborhood-based care network could support neighborhood-based planning by informing on local health needs and reaching a wide audience to participate in the planning process. Furthermore, the NAMED project learned us that opening the dialogue on spatial themes with health actors can help to introduce or strengthen the environmental theme on the medical agenda.

The NAMED project learned us that collaborating across different research disciplines and including both expert and citizen views helped to better comprehend the complex relationship between mental health and the urban environment.

Current health and environmental institutions that respectively inform health and environmental policies tend to work in silos because of the difficulty to access each other's data and often the lack of expertise to couple both data. Joint project calls, study days and an exchange platform would help to build a strategy towards knowledge and policy integration. This integration would be further motivated by a political signal underlining its importance and a breakdown of administrative silos to promote coalitions across different policy domains and levels.

7. RECOMMENDATIONS FOR FUTURE RESEARCH

1. Exploit new methods and databases to gather environmental, socioeconomic, and mental health data
2. Involve a good mix of expertise to get different perceptions on the theme
3. Mix methods to obtain a broad and critical view on the theme
4. Allow more flexibility in project calls to enable new research questions and analyses throughout project
5. Adapt project formats to the challenges of mixed method and interdisciplinary research
6. Involve end-users as active partners in the project to increase practice and policy relevance

7.1. Exploit new methods and databases

First of all, the NAMED project showed the challenges of collecting mental health and socioeconomic data, as a lot of these data were missing in the survey. This issue may strongly influence the research outcomes and demands a critical review of how to collect these data among diverse inhabitants, and especially those in most vulnerable living conditions. More qualitative methods were suggested to overcome this issue.

Another problem that we also faced in our project concerning the use of multiple environmental indicators, is the fact that they are strongly interlinked. For example, in our project we found strong correlations between air pollutants and vegetation coverage, and between indicators for the natural and the built environment. Strong correlations between urban environmental factors make it difficult to disentangle simple causal relations with mental health outcomes. This issue requires a bigger sample size, but also more available fine-scale data. Also reference was made to the exploitation of other data sources, such as sport applications or the intermutualities databank (IMA) to improve the statistical model.

Experts referred to the use of citizen science as new research method for several reasons. One advance is that as a researcher you can start thinking about which questions people have and how these can scientifically be translated. It also allows citizens from the start of a project to reflect on the scientific process and broaden their understanding on for example what air pollution actually is. Also throughout the process of such projects with the involvement of citizens, scientists, intermediary actors and policy makers, a whole movement is born that presses the political agenda. It also helps to keep citizens informed and to sensitize them about the problems, so they better know which choices to make.

7.2. Involve a good mix of expertise

A good mix of expertise brings richness in perspectives on the research results: from knowledge on biological mechanisms to social underlying mechanisms. Everyone has an extended view on specific literature and can provide in this way different inputs to augment the results.

The interdisciplinary character of the project implies the involvement of different types of stakeholders, stemming from the environmental, planning and (mental) health sector. It became

clear in the communication of our results that different types of end-users would pick out those results that are most relevant to their work instead of considering the broad picture. For example, one environmentalist mainly focused on the impact of air pollution, one planner was mainly interested in deriving design principles from the results, and the health professional in the determinants of mental health. Given the broad range of factors considered, and different approaches to investigate the links between mental health and the urban environment, it was very challenging to provide clear take-home messages to the end-users involved in the project. Therefore, the involvement of communication science as an extra discipline seems highly relevant to better communicate the results to a broad audience and to translate them into outcomes interesting for practice and policy.

Finally, also one expert suggested the involvement of economics to develop research focusing on cost-benefits of specific preventive interventions as these outcomes will trigger more easily policy makers.

7.3. Mix methods

The combination of quantitative and qualitative research definitely contributed to a broad and rich view on the theme. It further helped to illustrate the complexity of associations between environmental and mental health factors. Additionally, both parts talk to two types of stakeholders: quantitative research applies to evidence-based decisions and monitoring, where qualitative research applies to decision makers interested in the underlying mechanisms. Furthermore, the qualitative results are more comprehensive for the general public and therefore helped to better communicate the quantitative results.

Although, we made a great attempt to integrate the quantitative and qualitative part at several stages of the project, the study design challenged a true integration. Initially, we intended to first conduct the quantitative analysis to guide the qualitative research design. However, due to long ethical procedures and postponements in data obtainment the quantitative analysis was delayed, and was therefore in parallel with the qualitative data collection.

This lack of guidance in the qualitative design resulted in an overcollection of data and lack of focus in the qualitative design. Knowing now the quantitative results, the qualitative study could have invested more in explaining more in-depth the environmental inequalities by focusing on four types of groups: high socio-economic individuals living in non-green neighborhoods, high socio-economic individuals living in green neighborhoods, low socio-economic individuals living in green neighborhoods, and low socio-economic individuals living in green neighborhoods.

Additionally, the difference in approaching mental health between both parts challenged the integration of both results. Where the quantitative part mainly analyzed associations with mental disorders, the qualitative part questioned mental well-being in relation to the neighborhood environment. Knowing now the significant association between air pollution and depressive disorders, it might have been interesting to focus on experiences of individuals with depressive disorder in the qualitative part to complement the quantitative result.

Generally, a sequential mixed method design is recommended, in which either the quantitative data is collected first and guides the qualitative data collection, or vice versa. However, this design is much more challenging in terms of project timing.

7.4. Allow more flexibility in project calls

A common problem in scientific research is that project calls require a detailed predefined project description with fixed work packages and deliverables. However, this reduces greatly the flexibility to meet certain needs or conduct analyses that arise during the project. Because of the high motivation and interest among the researchers in the NAMED project, extra analyses were mainly conducted on voluntary basis even when the budget was finished.

7.5. Adapt project formats to mixed method and interdisciplinary research

Quantitative and qualitative researchers often have different backgrounds and therefore need more time to understand each other well and merge different research methods and paradigms. In our project, we benefited from the fact that one researcher of the quantitative team had previous experience in qualitative research, and vice versa for the qualitative team.

A mixed method design demands integration of both study parts at one or several stages of the project. This means that the individual research work does not end when finishing individual work packages. In our project, this integration took mainly place at the stages of project writing, data collection and reporting of the results.

Given the multiple quantitative data sources and the extended qualitative interviews, there was a lot of data to handle within this project.

Additionally, a mix of expertise demands more time to understand each other's disciplines and to consider different perceptions on the theme.

In the NAMED project, we experienced the benefits of planning frequent small informal meetings between some disciplines to answer together specific research questions. These meetings were more productive than the full team meetings, that were mainly useful to present and discuss each other's methods and findings. Also a high responsiveness between team members fostered the collaboration. For future research, we suggest to develop more shared work packages and to narrow-down the focus in both the quantitative and qualitative part to better attune both parts to each other and optimize data collection and analysis.

7.6. Involve end-users as active partners

In the NAMED project, we learnt the relevance of consulting experts from the field to evaluate our research and translate the results to practice and policy. However, we felt this involvement was at a too late stage of the project. Therefore, we recommend to involve all relevant actors (experts in the field, citizens, policy makers, etc.) from the start of the project to produce outcomes that are most relevant to practice and policy. Additionally, we suggest to include them as active (paid) partners in the project to give more weight to their input and to acknowledge them for their time investment.

8. RECOMMENDATIONS FOR THE HEALTH INTERVIEW SURVEY

We are aware that changes to the Health Interview Survey should narrow down to the minimum because of the continuity of the HIS over years. Therefore, we suggest three options of for adaptation of the HIS based on the findings in the NAMED project:

- Option 1: locally tailored HIS including minor adaptations, conducted every 5 years
- Option 2: national adapted HIS including moderate adaptations, conducted every 10 years
- Option 3: HIS data merging with available environmental databases, conducted every 5 years

8.1. Option 1: locally tailored HIS including minor adaptations

In this section we cover minor adaptations to the face-to-face questionnaire on 'health and environment', including one new question on social problems in the neighborhood, one change of question on access to nature, and one merge of two separated questions on respectively accumulation of rubbish, and vandalism, graffiti, and the deliberate damage of property. The latter adaptation is related to the concept of neighborhood disorder, which is described in the previous section "NAMED findings relevant to the Health Interview Survey 2018". Additionally, an important recommendation concerning the non-responses is included. These changes do not result in an extension of the current face-to-face questionnaire on 'health and environment'.

A lack of access to nature and neighborhood disorder are both themes that are more common in urban contexts. Therefore, we suggest to include these adaptations rather in a HIS that is locally tailored to and conducted in urban contexts.

HE0105 – suggested changes to existing item: access to nature made more specific.

Current question	**Suggested question**
In your local area or neighborhood, how much of a problem are each of the following conditions	In your local area or neighborhood, how much of a problem are each of the following conditions
Lack of access to parks or other green or recreational public places	Lack of access to nature (e.g. parks, forests, nature reserves, rivers, water ponds)
1. Not at all a problem 2. Minor problem 3. Fairly big problem 4. Very big problem 9. Don't know 0. No answer	1. Not at all a problem 2. Minor problem 3. Fairly big problem 4. Very big problem 9. Don't know 0. No answer

HE0103 & HE0104– merging questions on physical disorder

Current question	**Suggested question**
In your local area or neighborhood, how much of a problem are each of the following conditions	In your local area or neighborhood, how much of a problem are each of the following conditions
Accumulation of rubbish	Accumulation of rubbish, vandalism, abandoned buildings

1. Not at all a problem 2. Minor problem 3. Fairly big problem 4. Very big problem 9. Don't know 0. No answer	1. Not at all a problem 2. Minor problem 3. Fairly big problem 4. Very big problem 9. Don't know 0. No answer
Vandalism, graffiti or deliberate damage of property	
1. Not at all a problem 2. Minor problem 3. Fairly big problem 4. Very big problem 9. Don't know 0. No answer	

HE010X – new question on social disorder

English version
In your local area or neighborhood, how much of a problem are each of the following conditions
Substance use, drug dealing, burglary, harassment, violence, crime
1. Not at all a problem 2. Minor problem 3. Fairly big problem 4. Very big problem 9. Don't know 0. No answer

Tackling non-responses

One way to tackle the issue of the non-responses in the HIS, would be to highlight which profiles of people tend to respond less or provide incomplete information and to take more time with them after the interview to explain why it is important to completely fill out the questionnaire. The response rate to the numerous question on household income is rather low compared to the descriptive question "Thinking of your household's total available income is your household able to make ends meet…(1. with great difficulty 2. with difficulty 3. with some difficulty 4. fairly easily 5. easily 6. very easily"). This suggests that perhaps the latter operates as a better proxy for economic status.

8.2. Option 2: national adapted HIS including moderate adaptations

This section includes the suggestion to shift the questions regarding the theme 'health and environment' from the face-to-face questionnaire to the written questionnaire to gain more

environmental information. Since this option implies a broader collection of environmental factors, it is suggested to include this list only every second cycle of the HIS round. Also since these factors will not change so rapidly over time. A pilot phase could test the usefulness of this more detailed list of information.

In your local area or neighborhood, how much of a problem are each of the following conditions?						
Maintenance	**Not at all a problem**	**Minor problem**	**Fairly big problem**	**Very big problem**	**Don't know**	**No answer**
Accumulation of rubbish						
Vandalism (graffiti, damage)						
Lack of road maintenance						
Lack of sidewalk maintenance						
Abandoned buildings						
Nature	**Not at all a problem**	**Minor problem**	**Fairly big problem**	**Very big problem**	**Don't know**	**No answer**
Lack of street vegetation (trees, fountains, flowers)						
Lack of natural places (parks, forests, reserves)						
Overpopulation of natural places (parks, forests, reserves)						
Poor maintenance of street vegetation						
Poor maintenance of natural places						
Facilities	**Not at all a problem**	**Minor problem**	**Fairly big problem**	**Very big problem**	**Don't know**	**No answer**
Lack of healthy food facilities						
Lack of sport facilities						
Lack of play facilities						
Lack of schools						
Lack of public transport						
Noise	**Not at all a problem**	**Minor problem**	**Fairly big problem**	**Very big problem**	**Don't know**	**No answer**
Noise from road traffic						
Noise from airplane traffic						
Noise from train, tube or tram traffic						
Noise from nearby business						
Noise from neighbors						
Traffic safety	**Not at all a problem**	**Minor problem**	**Fairly big problem**	**Very big problem**	**Don't know**	**No answer**
Lack of pedestrian safety						
Lack of bike safety						
Lack of driver safety						
The speed of traffic						
The volume of traffic						

Social environment	Not at all a problem	Minor problem	Fairly big problem	Very big problem	Don't know	No answer
Substance use						
Drugs dealing						
Burglary / thievery						
Verbal or physical harassment						
Crime						

8.3. Option 3: HIS data merging with available environmental databases

In this section we suggest to couple each HIS wave with objective environmental data that are currently available, as was also done in the NAMED project. We learned during the consultations with health and environmental organizations that currently the expertise to merge those databases is lacking. Therefore, we recommend to collaborate for each HIS wave with an appropriate university that can offer the necessary expertise. This of course requires a national budget that supports this cyclic data merging.

Additionally, this data merging should follow an ethical procedure as done in the NAMED project. Information on participants' home address was linked with the corresponding environmental indicators. Sciensano had only access to anonymized HIS data, with no detailed information on participants' localization: data of each participant were associated with a unique ID defined by Statistics Belgium. Thanks to a partnership with this federal institution, it was possible to convert the participant IDs into the corresponding National Register numbers and thus trace back to the geographical coordinates "x,y" of participants' home. The UCLouvain was then able to convert these coordinates into the corresponding environmental indicators and forward the information to Sciensano who linked it to HIS data. The merged database contained information on participants' mental health, demographic, socioeconomic status, lifestyle and environmental perception and on the attributes of their living environment in terms of built/non-built environment, air and noise pollution. This procedure is summarized in following figure (figure 15):

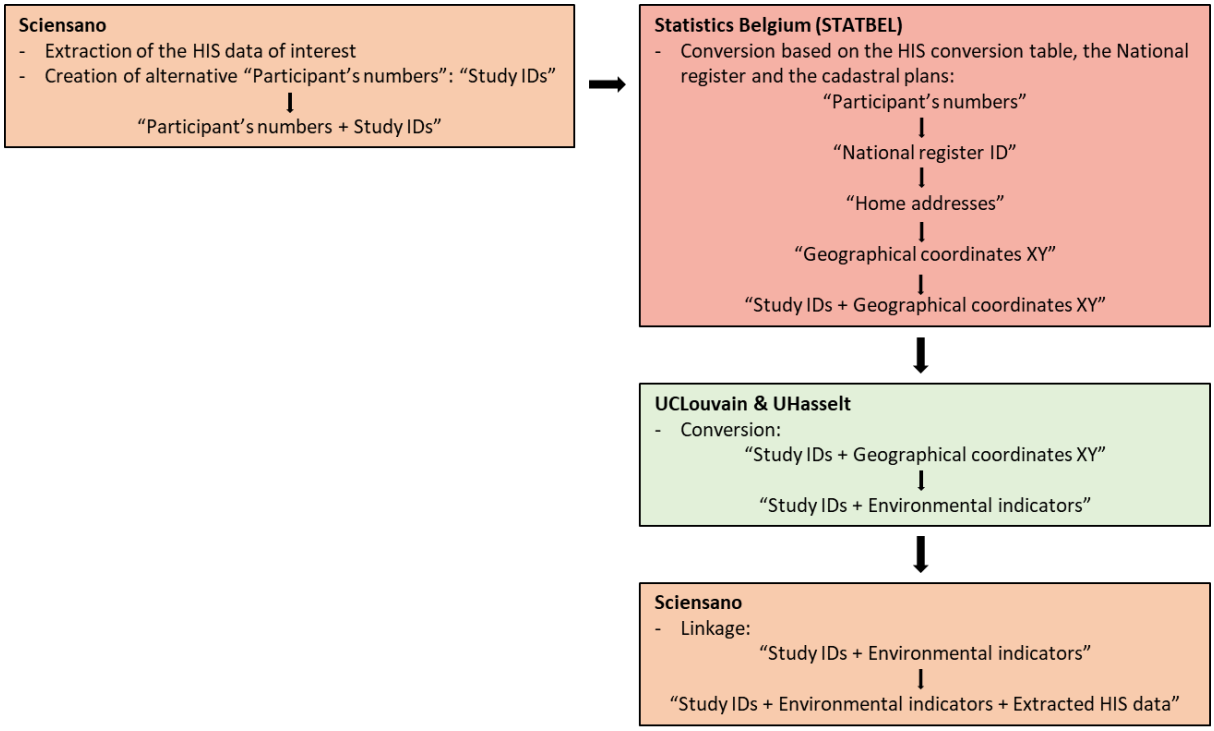


Fig. 15. Summary of data-merging procedure.

We focus in this section to databases available for the Brussels-Capital Region, but this option can be extended to databases available for the other regions.

8.3.1. Environmental data sources included in the NAMED project

First of all, we refer to the environmental data sources that were included in the NAMED project and are described in the Methodoloy section.

8.3.2. Additional environmental data sources

Besides the environmental data used in the NAMED project, additional environmental data sources are suggested to improve our understanding on mental health and environmental linkages. However, the data sources should be validated before application.

Temperature

Recent studies emphasize the rising threat of urban heat stress to mental health outcomes, i.e. anxiety and sleep, social functioning, depression, behavioral disorders and psychoactive substance use (Mirzaei et al. 2020; Wong et al. 2018).

Current data on urban heat islands in Brussels can be extracted from the geo.Brussels database: https://geobru.irisnet.be/geonetwork/srv/dut/catalog.search#/metadata/73b4f29a-cff0-4d6a-a239-cb99d3140531

Also high indoor household temperatures are shown to negatively affect mental health (Lima et al., 2020), however, are more difficult to measure through objective temperature data (i.e. energy performance). One could suggest to add following question in the HIS face-to-face questionnaire on housing to extract this information.

	Current question	Added question
LO05	Are there times in the winter when you cannot keep your home warm enough?	Are there times in the summer when you cannot keep your home cool enough?
LO05L	1. Never 2. Occasionaly 3. Quite often 4. Most of the time 9. Don't know 0. No answer	1. Never 2. Occasionaly 3. Quite often 4. Most of the time 9. Don't know 0. No answer

Blue space

In the NAMED project we did not incorporate blue space, summarized as all visible surface waters in space, nonetheless, scientific evidence indicates emotional and restorative benefits of blue spaces to mental well-being (Völker & Kistemann, 2011; [b]Beute et al., 2020).

Current blue space data could be extracted from the Urbis database:
https://datastore.brussels/web/urbis-download

Physical problems

Currently citizens of Brussels can report problems with the road infrastructure, accumulation of rubbish, green infrastructure, signalization, lighting, urban furniture, monument or abandoned car through an application called 'Fix My Street' (https://fixmystreet.brussels/). These data could serve as an indication for neighborhood deprivation in terms of low physical position, however, their use should incorporate the selection bias of these data. An attempt to use these data and control for selection bias has been made by Guyot et al (2021) which could serve as a starting point for developing an indicator of neighborhood deprivation.

Currently citizens of Brussels can report problems with the road infrastructure, accumulation of rubbish, green infrastructure, signalization, lighting, urban furniture, monument or abandoned car through an application called 'fix-my-street'. These data could serve as an indication for neighborhood deprivation in terms of low physical position, however, their use should incorporate the reporting bias of these data.

9. DISSEMINATION AND VALORISATION

9.1. Project website

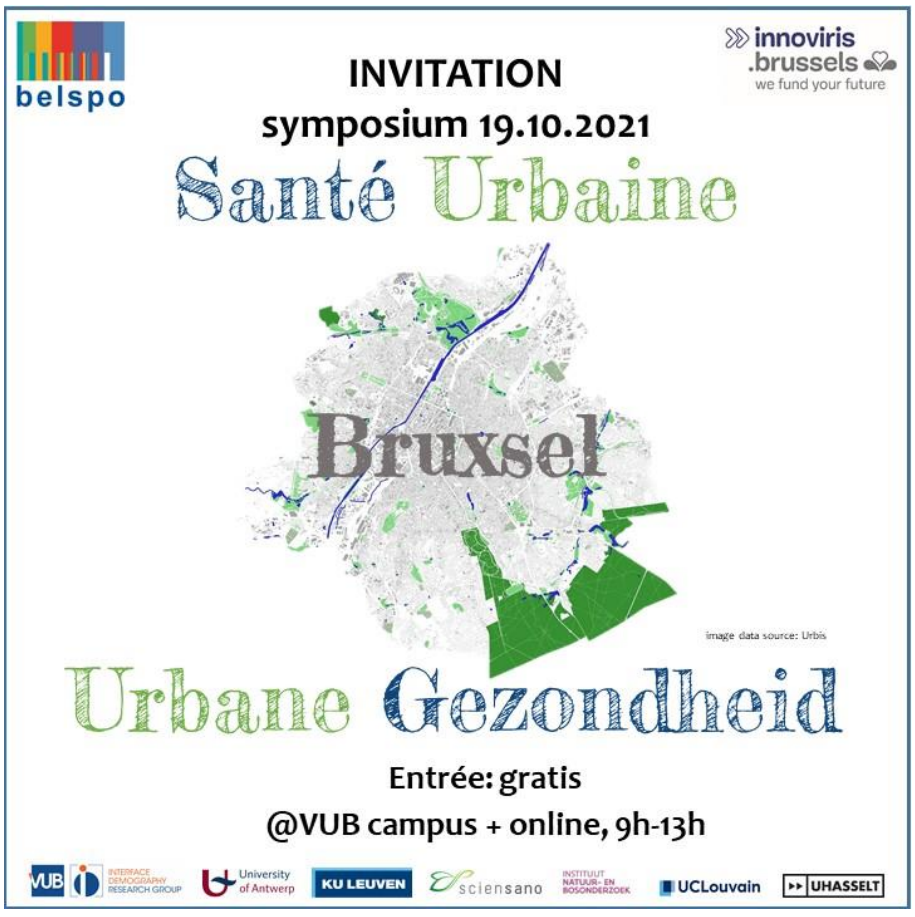
Dutch: https://www.uantwerpen.be/nl/projecten/named/

French: https://www.uantwerpen.be/en/projects/named-french/

English: https://www.uantwerpen.be/en/projects/named/

9.2. Symposium Urban Health on 19th of October 2021

On the 19th of October 2021, we organized together with the VUB Green & Quiet Brussels project a symposium in hybrid form on Urban Health in Brussels. 40 participants attended physically, while 60 participants attended virtually.



9.3. Popular press

French radio interview:

https://bx1.be/categories/news/etude-named-comment-relier-le-bien-etre-des-bruxellois-a-leur-environnement/

Dutch popular press:

https://www.despecialist.eu/nl/nieuws/groene-ruimte-creeert-mentale-ruimte-groen-is-bepalend-voor-mentaal-welzijn-brusselaars.html

https://nl.metrotime.be/lifestyle/studie-groen-en-goede-buren-maken-brusselaars-gelukkig

https://www.bruzz.be/stedenbouw/onderzoek-groen-buurt-creeert-mentale-rust-2021-10-18

French popular press:

https://www.moustique.be/actu/belgique/2021/10/18/ce-qui-est-bon-pour-la-sante-mentale-des-bruxellois-213434

http://www.vivreici.be/article/detail_les-espaces-verts-et-le-contact-avec-les-voisins-favorisent-le-bien-etre-des-bruxellois?id=525838

https://www.rtbf.be/info/regions/detail_les-espaces-verts-et-le-contact-avec-les-voisins-favorisent-le-bien-etre-des-bruxellois?id=10862462

https://bx1.be/categories/news/les-espaces-verts-et-le-contact-avec-les-voisins-favorisent-le-bien-etre-des-bruxellois-selon-une-etude-de-luniversite-danvers/

English popular press:

https://www.thecherawchronicle.com/research-greenness-in-the-neighborhood-creates-psychological-peace/

9.4. Participation to conferences

2017

Poster at the European Conference on Biodiversity and Health in the face of Climate Change (27-29th June 2017, Bonn, Germany) by An Van Nieuwenhuyse from Sciensano https://www.ecbcc2017.com/european-conference-on-biodiversity-and-climate-change-ecbcc/downloads-presentations/

Poster at the 14th International Conference on Urban Health (26-29th September 2017, Coimbra, Portugal) by Ariane Guilbert from Sciensano http://www.isuhconference.org/

2018

L Lauwers, 2018, Poster at Qualitative Research on Mental Health conference, 20-22th September 2018, Berlin, Germany (https://www.uantwerpen.be/en/projects/named/research-material/).

Presentation at the AAG Annual Meeting 2018 (USA) by Madeleine Guyot : Guyot M., Araldi A., Fusco G. et Thomas, I. « Multiple Fabric Assessment: application to the case of Brussels » https://aag.secure-abstracts.com/AAG%20Annual%20Meeting%202018/abstracts-gallery/13400

2019

M Guyot, A Araldi, G Fusco, I Thomas, 2019, Une typologie du paysage urbain bruxellois dans une perspective de recherche en santé, Les quatorzièmes Rencontres de Théo Quant, Besançon, France

S Trabelsi, I Thomas, 2019, Using medication data as proxy for health: some spatial issues, Les quatorzièmes Rencontres de Théo Quant, Besançon, France

Abstract submitted at Resistance is in the Air: Citizens, science and air pollution International interdisciplinary symposium (25-26th April 2019, Brussels, Belgium) by Ingrid Pelgrims (http://www.cosmopolis.be/news-event/call-abstracts-citizens-science-and-air-pollution?platform=hootsuite

Guyot, M., Alessandro A., Giovanni F., and Thomas, I. Urban street landscape and well-being in Brussels. European Colloquium on Theoretical and Quantitative Geography (Luxembourg, from 05/09/2019 to 09/09/2019).

Pelgrims, Ingrid, E. M. De Clercq, P Hautekiet, S Trabelsi, M Guyot, I Thomas, H Keune, et al. "Association between Mental Health and the Perception of Residential Stressors in Belgium." Poster presented at the 31st annual conference of the International Society for Environmental Epidemiology , on Airs, Waters, Places, Utrecht, The Netherlands, August 2019. https://isee2019.org/.

Pelgrims, Ingrid, H Keune, I Thomas, H Bastiaens, R Remmen, Tim S Nawrot, and E. M. De Clercq. "Impact of the (Non-) Built Environment on Mental Health in Brussels : The NAMED PROJECT." Poster presented at the Etats généraux de l'air de Bruxelles, Brussels, Belgium, April 2019. http://www.brusselsair.org/inex/.

Pelgrims, Ingrid, H Keune, I Thomas, H Bastiaens, R Remmen, Tim S Nawrot, S Trabelsi, M Guyot, L Lauwers, and E. M. De Clercq. "Disentangling the Link between Built/Non-Built Environment and Mental Health in Brussels." Poster presented at the The International Societies of Exposure Science (ISES) and Indoor Air Quality and Climate (ISIAQ) joint conference on the built, natural, and social environments: impacts on exposures, health and well-being, Kaunas, Lithuania, August 2019. http://isesisiaq2019.org/.

2020

Lauwers, L. Link stedelijke leefomgeving en mentale gezondheid. Studentensymposium Universiteit Gent "Natuur en Gezondheid" (Gent, 5/3/2020)

Pelgrims, I, H Bastiaens, B Devleesschauwer, H Keune, T Nawrot, R Remmen, N Saenen, M Guyot, en E M De Clercq. "Validity of air pollution annoyance to assess long-term exposure to air pollution in Belgium". 16th World Congress on Public Health - Rome 2020, 12 - 17 October 2020 (Virtual).

L Lauwers presented NAMED results and lead a break-out session on 12/12/2020 in the context of the citizens' conference "Finger on the pulse: COVID-19 and air quality in BXL", organized by Bral via an online zoom meeting.

H Keune included NAMED outcomes in several (broader thematic overview) presentations :
- 20200609 AIM (International Association of Mutual Benefit Societies)
- 20201001 Congres 'De gezonde en veerkrachtige gemeente' VIBE
- 20201116 ANB workshops natuur & zorg

2021

P Hautekiet, I Pelgrims, E M. De Clercq, H Keune, T S. Nawrot, N D. Saenen. Air pollution and the mental health status of the Belgian population. ISEE Young 2021, 4th Early Career Researchers Conference on Environmental Epidemiology, Basel, Switserland, 18-19 February 2021 (Virtual).

H Keune included NAMED outcomes in several (broader thematic overview) presentations :
- 20210321 symposium ‘De Arts van Morgen 2021’ KULeuven
- 20210401 Expert Days PIXII 'Gezondheid en comfort'

10. PUBLICATIONS

Guyot M, Araldi A, Fusco G, Thomas I. The urban form of Brussels from the street perspective: The role of vegetation in the definition of the urban fabric. Landscape and Urban Planning. 2021 Jan 1;205:103947. https://doi.org/10.1016/j.landurbplan.2020.103947

Hautekiet, Pauline, Tim S. Nawrot, Stefaan Demarest, Johan Van der Heyden, Ilse Van Overmeire, Eva M. De Clercq, en Nelly D. Saenen. "Environmental Exposures and Health Behavior in Association with Mental Health: A Study Design". Archives of Public Health 78, nr. 1 (december 2020): 105. https://doi.org/10.1186/s13690-020-00477-0

Lauwers L, Trabelsi S, Pelgrims I, Bastiaens H, De Clercq E, Guilbert A, Guyot M, Leone M, Nawrot T, Van Nieuwenhuyse A, Remmen R. Urban environment and mental health: the NAMED project, protocol for a mixed-method study. BMJ open. 2020 Feb 1;10(2):e031963. http://dx.doi.org/10.1136/bmjopen-2019-031963

Lauwers L, Leone M, Guyot M, Pelgrims I, Remmen R, Van den Broeck K, Keune H, Bastiaens H. Exploring how the urban neighborhood environment influences mental well-being using walking interviews. Health and Place. 2021 Jan 1;67:102497. https://doi.org/10.1016/j.healthplace.2020.102497

Pelgrims, Ingrid, Brecht Devleesschauwer, Madeleine Guyot, Hans Keune, Tim S. Nawrot, Roy Remmen, Nelly D. Saenen, e.a. "Association between urban environment and mental health in Brussels, Belgium". BMC Public Health 21, nr. 1 (1 april 2021): 635. https://doi.org/10.1186/s12889-021-10557-7

Pelgrims, I, H Bastiaens, B Devleesschauwer, H Keune, T Nawrot, R Remmen, N Saenen, M Guyot, en E M De Clercq. "Validity of air pollution annoyance to assess long-term exposure to air pollution in Belgium". European Journal of Public Health 30, nr. ckaa166.088 (1 september 2020). https://doi.org/10.1093/eurpub/ckaa166.088

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12. REFERENCES

ACOUPHEN ENVIRONNEMENT - Dec 2008. Carte de multi-exposition Bruxelles Environnement. Cadastre du bruit des transports routier, ferroviaire, aérien, trams et métro aérien de la Région de Bruxelles-Capitale [Internet]. [cited 2020 Dec 23]. Available from: https://document. environnement.brussels/opac_css/elecfile/IBGE_Multi_2006_1.pdf.

Almedom, A.M., 2005. Social capital and mental health: an interdisciplinary review of primary evidence. Soc. Sci. Med. 61, 943–964.

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. doi:10.1111/j.1600-0047.2004.00327.x\

An R, Zhang S, Ji M, Guan C. Impact of ambient air pollution on physical activity among adults: a systematic review and meta-analysis. Perspect Public Health. 2018;138(2):111–21.

Anguelovski I, Connolly JJ, Garcia-Lamarca M, Cole H, Pearsall H. New scholarly pathways on green gentrification: What does the urban 'green turn'mean and where is it going?. Progress in human geography. 2019 Dec;43(6):1064-86.

Anisman H, Hayley S. Inflammatory factors contribute to depression and its comorbid conditions. Sci Signal. 2012;5(244):pe45.

Anselin, L. (1995). Local indicators of spatial association – LISA. Geographical Analysis, 27(2), 93–115. https://doi.org/10.1111/j.1538-4632.1995.tb00338.x.

Araldi, A., & Fusco, G. (2016). Urban Form from the Pedestrian Point of View: Spatial Patterns on a Street Network. 9th International Conference on Innovation in Urban and Regional Planning (INPUT 2016), 32–38. https://hal.archives-ouvertes.fr/hal-01417484.

Araldi, A., & Fusco, G. (2019). From the street to the metropolitan region: Pedestrian perspective in urban fabric analysis. Environment and Planning B: Urban Analytics and City Science, 46(7), 1243–1263. https://doi.org/10.1177/2399808319832612.

Asgarzadeh M, Lusk A, Koga T, Hirate K. Measuring oppressiveness of streetscapes. Landsc Urban Plan. 2012;107(1):1–11.

Attademo L, Bernardini F, Garinella R, Compton MT. Environmental pollution and risk of psychotic disorders: a review of the science to date. Schizophr Res. 2017;181:55–9.

Bamberg S. Applying the stage model of self-regulated behavioral change in a car use reduction intervention. Journal of Environmental Psychology. 2013 Mar 1;33:68-75.

Basner M, McGuire S. WHO environmental noise guidelines for the European region: a systematic review on environmental noise and effects on sleep. Int J Environ Res Public Health. 2018;15(3):519.

Baumeister, R.F., Schmeichel, B.J., Vohs, K.D., 2007. Self-regulation and the executive function: the self as controlling agent. In: Kruglanski, A.W., et al. (Eds.), Social Psychology: Handbook of Basic Principles. Guilford Press, New York, US, pp. 516–539.

Bendiks, S., Degros, A., & Colville-Andersen, M. (2013). Fietsinfrastructuur: Nai010 uitgevers/nai010 Publishers.

Benita, F., Bansal, G., Tunçer, B., 2019. Public spaces and happiness: evidence from a large-scale field experiment. Health Place 56, 9–18.

Berghauser Pont, M., & Haupt, P. (2010). SPACEMATRIX, Space. Density and Urban Form: NAi Publishers.

Berto, R., Barbiero, G., Pasini, M., Pieter, U., 2015. Biophilic design triggers fascination and enhances psychological restoration in the urban environment. J. Biourbanism 1, 27–34.

Beyer KMM, 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.

Bigazzi AY, Rouleau M. Can traffic management strategies improve urban air quality? A review of the evidence. Journal of Transport & Health. 2017 Dec 1;7:111-24.

Bijl RV, Ravelli A, Zessen G van. 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. doi:10.1007/s001270050098

Block ML, Calderón-Garcidueñas L. Air pollution: mechanisms of neuroinflammation and CNS disease. Trends Neurosci. 2009;32(9):506–16.

Bornioli, A., Parkhurst, G., Morgan, P.L., 2018. The psychological wellbeing benefits of place engagement during walking in urban environments: a qualitative photoelicitation study. Health Place 53, 228–236.

Braun, V., Clarke, V., 2006. Using thematic analysis in psychology. Qual. Res. Psychol. 3, 77–101.

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.

Bruxelles Environnement. Rapport 2011-2014 van de staat van het leefmilieu: Exposition de la population au bruit des transports [Internet]. 2011 [cited 2021 Jan 6]. Available from: https://environnement.brussels/lenvironnement-etat-des-lieux/rapports-sur-letat-de-lenvironnement/rapport-2011-2014/bruit-0.

Buoli M, Grassi S, Caldiroli A, Carnevali GS, Mucci F, Iodice S, et al. Is there a link between air pollution and mental disorders? Environ Int. 2018;118:154–68.

Cattell, V., Dines, N., Gesler, W., Curtis, S., 2008. Mingling, observing, and lingering: everyday public spaces and their implications for well-being and social relations. Health Place 14, 544–561.

Cheesbrough, A.E., Garvin, T., Nykiforuk, C.I., 2019. Everyday wild: urban natural areas, health, and well-being. Health Place 56, 43–52.

Clark C, Paunovic K. WHO environmental noise guidelines for the European region: a systematic review on environmental noise and quality of life, wellbeing and mental health. Int J Environ Res Public Health. 2018;15(11):2400.

Clark C, Crumpler C, Notley H. Evidence for environmental noise effects on health for the United Kingdom policy context: a systematic review of the effects of environmental noise on mental health, wellbeing, quality of life, Cancer, dementia, birth, reproductive outcomes, and cognition. Int J Environ Res Public Health. 2020;17(2):393.

Clark, C., Rowan, M., Stansfeld, S.A., Candy, B., 2007. A systematic review of the evidence on the effect of the built and physical environment on mental health. J. Publ. Ment. Health 6, 14.

Cox DTC, Shanahan DF, Hudson HL, et al. Doses of neighborhood nature: the benefits for mental health of living with nature. Bioscience 2017;117:147–55.

De Beule, M., & Dessouroux, C. (2011). Bruxelles, ses bureaux, ses employés (Brussels, its offices, its employees) (Direction Étude et Planification (Ministère de ma Région de Bruxelles-Capitale) and La Fonderie asbl).

Degenhardt, B., Buchecker, M., 2012. Exploring everyday self-regulation in nearby nature: determinants, patterns, and a framework of nearby outdoor recreation behavior. Leisure Sci. 34, 450–469.

De Keersmaecker, M.-L., Frankhauser, P., & Thomas, I. (2003). Using fractal dimensions for characterizing intra-urban diversity: The example of brussels. Geographical Analysis, 35(4), 310–328. https://doi.org/10.1111/j.1538-4632.2003.tb01117.x.

de Vries S, Ten Have M, van Dorsselaer S, van Wezep M, Hermans T, de Graaf R. Local availability of green and blue space and prevalence of common mental disorders in the Netherlands. BJPsych Open. 2016;2(6): 366–72.

de Vries S, van Dillen SME, Groenewegen PP, Spreeuwenberg P. Streetscape greenery and health: stress, social cohesion and physical activity as mediators. Soc Sci Med. 2013;94:26–33.

Diez Roux, A.V., Mair, C., 2010. Neighborhoods and Health.

DIRECTIVE 2002/49/CE du Parlement européen et du Conseil du 25 juin 2002 relative à l'évaluation et à la gestion du bruit dans l'environnement [Internet]. 2002 Jul [cited 2021 Jan 6] p. 12–25. Report No.: Journal Officiel n° L 189. Available from: http://publications.europa.eu/resource/cellar/0354 e2a3-4ee8-45a2-aa4a-090036045111.0010.04/DOC_1.

Dooling S. Ecological gentrification: A research agenda exploring justice in the city. International Journal of Urban and Regional Research. 2009 Sep;33(3):621-39.

Dzhambov AM, Lercher P. Road traffic noise exposure and depression/anxiety: An updated systematic review and meta-analysis. Int J Environ Res Public Health. 2019;16(21):4134.

Echevarria Sanchez GM, Van Renterghem T, Thomas P, Botteldooren D. The effect of street canyon design on traffic noise exposure along roads. Build Environ. 2016;97:96–110.
Evans GW. The built environment and mental health. J Urban Health Bull N Y Acad Med 2003;80:536–55. doi:10.1093/jurban/jtg063

Fong KC, Hart JE, James P. A review of epidemiologic studies on greenness and health: updated literature through 2017. Curr Environ Health Rep. 2018; 5(1):77–87.

Forrest, R., Kearns, A., 2001. Social cohesion, social capital and the neighborhood. Urban Stud. 38, 2125–2143.

Francis, J., 2010. Associations between Public Space and Mental Health in New Residential Developments. University of Western Australia.

Francis, J., Giles-Corti, B., Wood, L., Knuiman, M., 2015. Neighborhood influences on mental health in master planned estates: a qualitative study of resident perspectives. Health Promot. J. Aust. 25, 186–192.

Fusco, G., & Araldi, A. (2017). Significant patterns in urban form – Spatial analysis of morphological indicators. Revue Internationale de Géomatique, 27(4), 455–479. https://doi.org/10.3166/rig.2017.00045.

Fusco, G., & Perez, J. (2019). Bayesian network clustering and self-organizing maps under the test of indian districts. A comparison. Cybergeo : European Journal of Geography.. https://doi.org/10.4000/cybergeo.31909.

Galea S, Ahern J, Rudenstine S, et al. Urban built environment and depression: a multilevel analysis. J Epidemiol Community Health 2005;59:822–7. doi:10.1136/jech.2005.033084

Gascon M, Sánchez-Benavides G, Dadvand P, Martínez D, Gramunt N, Gotsens X, et al. Long-term exposure to residential green and blue spaces and anxiety and depression in adults: a cross-sectional study. Environ Res. 2018;162:231–9.

Gascon M, Triguero-Mas M, Martínez D, Dadvand P, Forns J, Plasència A, et al. Mental health benefits of long-term exposure to residential green and blue spaces: a systematic review. Int J Environ Res Public Health. 2015;12(4): 4354–79.

Gehl, J. (1987). Life Between Buildings: Using Public Space. Island Press.

Geis, K.J., Ross, C.E., 1998. A new look at urban alienation: the effect of neighborhood disorder on perceived powerlessness. Soc. Psychol. Q. 232–246.

Geller, D.M., 1980. Responses to urban stimuli: a balanced approach. J. Soc. Issues 36, 86–100.

Gil, J., Beirão, J. N., Montenegro, N., & Duarte, J. P. (2012). On the discovery of urban typologies: Data mining the many dimensions of urban form. Urban Morphology, 16(1), 27.

Gisle L. Santé mentale. Bruxelles: : WIV-ISP 2014. https://his.wiv-isp.be/fr/Documents partages/WB_FR_2013.pdf

Goldberg D, William P. A user's guide to the general health questionnaire. Berkshire: NFER-NELSON; 1988.

Gong Y, Palmer S, Gallacher J, Marsden T, Fone D. A systematic review of the relationship between objective measurements of the urban environment and psychological distress. Environ Int. 2016;96:48–57.

Graham J, Koo M, Wilson TD. Conserving energy by inducing people to drive less. Journal of Applied Social Psychology. 2011 Jan;41(1):106-18.

Grahn, P., Stigsdotter, U.K., 2010. The relation between perceived sensory dimensions of urban green space and stress restoration. Landsc. Urban Plann. 94, 264–275.

Green, J., Thorogood, N., 2018. Qualitative Methods for Health Research. sage.

Gruebner O, Rapp MA, Adli M, Kluge U, Galea S, Heinz A. Cities and mental health. Dtsch Arztebl Int. 2017;114(8):121–7.

Guyot, M., Araldi, A., Fusco, G., Thomas, I., 2021. The urban form of Brussels from the street perspective: the role of vegetation in the definition of the urban fabric. Landsc. Urban Plann. 205, 103947.

Halpern D. Mental Health and The Built Environment: More Than Bricks And Mortar? Routledge 2014.

Handy, S. (2004). Critical Assessment of the Literature on the Relationships Among Transportation, Land Use, and Physical Activity (pp. (p. 102).). and Land Use.

Harvey, C., Aultman-Hall, L., Troy, A., & Hurley, S. E. (2017). Streetscape skeleton measurement and classification. Environment and Planning B: Urban Analytics and City Science, 44(4), 668–692. https://doi.org/10.1177/0265813515624688

Helbich M, Yao Y, Liu Y, Zhang J, Liu P, Wang R. Using deep learning to examine street view green and blue spaces and their associations with geriatric depression in Beijing, China. Environ Int. 2019;126:107–17.

Hermia JP, Sierens A. Belges et étrangers en Région bruxelloise, de la naissance aujourd'hui. Brussels: IBSA, 2017.

Hermosilla, T., Palomar-Vázquez, J., Balaguer-Beser, Á., Balsa-Barreiro, J., & Ruiz, L. A. (2014). Using street based metrics to characterize urban typologies. Computers, Environment and Urban Systems, 44, 68–79. https://doi.org/10.1016/j.compenvurbsys.2013.12.002.

Hill, T.D., Angel, R.J., 2005. Neighborhood disorder, psychological distress, and heavy drinking. Soc. Sci. Med. 61, 965–975.

Hooghe L, Marks G. Unraveling the central state, but how? types of multi-level governance. Am Polit Sci Rev 2003;97:233‑43.

Hutcheson Jr., J.D., 1984. Citizen representation in neighborhood planning. J. Am. Plann. Assoc. 50, 183–193.

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.

Janssen N, Gerlofs-Nijland M, Lanki T, Salonen R, Cassee F, Hoek G, et al. Health Effects of Black Carbon [Internet]. WHO Regional Office for Europe; 2012 [cited 2019 Oct 7] p. 96. Available from: https://stg-wedocs.unep.org/bitstream/handle/20.500.11822/8699/Health_effects_black_carbon.pdf?sequence=3&isAllowed=y.

Jordan A. The governance of sustainable development: taking stock and looking forwards. Environ Plann C Gov Policy 2008;26:17‑33.

Joye, Y., Dewitte, S., 2018. Nature's broken path to restoration. A critical look at Attention Restoration Theory. J. Environ. Psychol. 59, 1–8.

Kahana, E., Lovegreen, L., Kahana, B., Kahana, M., 2003. Person, environment, and person-environment fit as influences on residential satisfaction of elders. Environ. Behav. 35, 434–453.

Kaplan, R., Kaplan, S., 1989. The Experience of Nature: A Psychological Perspective. CUP Archive.

Kawachi, I., Berkman, L.F., 2001. Social ties and mental health. J. Urban Health 78, 458–467.

Keune H, Koppen G, Morrens B, et al. Extended peer evaluation of an analytical Deliberative decision support procedure in environmental health practice. Eur. j. risk regul. 2014;5:25‑35.

Kim K-N, Lim Y-H, Bae HJ, Kim M, Jung K, Hong Y-C. Long-term fine particulate matter exposure and major depressive disorder in a communitybased urban cohort. Environ Health Perspect. 2016;124(10):1547–53.

Kioumourtzoglou M-A, Power MC, Hart JE, Okereke OI, Coull BA, Laden F, et al. The Association Between Air Pollution and Onset of Depression Among Middle-Aged and Older Women. Am J Epidemiol. 2017;185(9):801–9.

Koelsch, L.E., 2013. Reconceptualizing the member check interview. Int. J. Qual. Methods 12, 168–179.

Korpela, K.M., Hartig, T., Kaiser, F.G., Fuhrer, U., 2001. Restorative experience and selfregulation in favorite places. Environ. Behav. 33, 572–589.

Korpela, K.M., Yl´en, M.P., 2009. Effectiveness of favorite-place prescriptions: a field experiment. Am. J. Prev. Med. 36, 435–438.

Lauwers L, Trabelsi S, Pelgrims I, Bastiaens H, De Clercq E, Guilbert A, Guyot M, Leone M, Nawrot T, Van Nieuwenhuyse A, Remmen R. Urban environment and mental health: the NAMED project, protocol for a mixed-method study. BMJ open. 2020 Feb 1;10(2):e031963. http://dx.doi.org/10.1136/bmjopen-2019-031963

Lauwers L, Leone M, Guyot M, Pelgrims I, Remmen R, Van den Broeck K, Keune H, Bastiaens H. Exploring how the urban neighborhood environment influences mental well-being using walking interviews. Health and Place. 2021 Jan 1;67:102497. https://doi.org/10.1016/j.healthplace.2020.102497

Ledent, G. (2017). Genèse de la maison bruxelloise (Genesis of the Brussels house). In P. Ananian & B. Declève, Montréal et Bruxelles en projet, Regards croisés sur la densification et le projet urbain (Presses Universitaires de Louvain, pp. 127–156).

Lee ACK, Maheswaran R. The health benefits of urban green spaces: a review of the evidence. J Public Health (Oxf). 2011;33(2):212–22.

LEEFMILIEU BRUSSEL-BIM. 49. DOELSTELLINGEN EN METHODOLOGIE VAN DE GELUIDSKADASTERS IN HET BRUSSELS HOOFDSTEDELIJK GEWEST [Internet]. COLLECTIE FACTSHEETS, THEMA GELUID; 2018 [cited 2020 Dec 23]. Available from: https://document.environnement.brussels/opac_css/elecfile/Geluid_49.

Larkin A, Hystad P. Evaluating street view exposure measures of visible green space for health research. J Expo Sci Environ Epidemiol. 2019;29(4): 447–56.

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.

Li X, Zhang C, Li W, Ricard R, Meng Q, Zhang W. Assessing street-level urban greenery using Google street view and a modified green view index. Urban For Urban Green. 2015;14(3):675–85.

Lorenc, T., Clayton, S., Neary, D., Whitehead, M., Petticrew, M., Thomson, H., Cummins, S., Sowden, A., Renton, A., 2012. Crime, fear of crime, environment, and mental health and wellbeing: mapping review of theories and causal pathways. Health Place 18, 757–765.

Lundin A, Hallgren M, Theobald H, Hellgren C, Torgén M. Validity of the 12- item version of the general health questionnaire in detecting depression in the general population. Public Health. 2016;136:66–74.

Markevych I, Schoierer J, Hartig T, Chudnovsky A, Hystad P, Dzhambov AM, et al. Exploring pathways linking greenspace to health: theoretical and methodological guidance. Environ Res. 2017;158:301–17.

McCormack GR, Rock M, Toohey AM, Hignell D. Characteristics of urban parks associated with park use and physical activity: A review of qualitative research. Health & place. 2010 Jul 1;16(4):712-26.

Memon RA, Leung DYC, Liu C-H. Effects of building aspect ratio and wind speed on air temperatures in urban-like street canyons. Build Environ. 2010; 45(1):176–88.

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. doi:10.1016/j.jaac.2010.05.017

Mitchell, C.U., Lagory, M., 2002. Social capital and mental distress in an impoverished community. City Community 1, 199–222.

Mohajeri N, Gudmundsson A, Kunckler T, Upadhyay G, Assouline D, Kämpf JH, et al. A solar-based sustainable urban design: the effects of city-scale street-canyon geometry on solar access in Geneva, Switzerland. Applied Energy. 2019;240:173–90.

Moore, T., Kesten, J., L´opez-L´opez, J., Ijaz, S., Mcaleenan, A., Richards, A., Gray, S., Savovi´c, J., Audrey, S., 2018. The effects of changes to the built environment on the mental health and well-being of adults: systematic review. Health Place 53, 237–257.

Nakayama S, Takayama JI. Ecotravel coordinator program: Effects on travel behavior and environmental attitude. Transportation research record. 2005;1924(1):224-30.

Nordh, H., Hartig, T., Hagerhall, C., Fry, G., 2009. Components of small urban parks that predict the possibility for restoration. Urban For. Urban Green. 8, 225–235.

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.

O'brien, L., Morris, J., Stewart, A., 2014. 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. Publ. Health 11, 6171–6192.

O'campo, P., Salmon, C., Burke, J., 2009. Neighborhoods and mental well-being: what are the pathways? Health Place 15, 56–68.

Oscilowicz E, Lewartowska E, Levitch A, Luger J, Hajt-marova S, O'Neill E, Planas Carbonell A, Cole H, Rivera Blanco C, Monroe E, 2021. Policy and planning tools for urban green justice: Fighting dis-placement and gentrification and improving accessi-bility and inclusiveness to green amenities.

Peen J, Schoevers RA, Beekman AT, Dekker J. The current status of urban-rural differences in psychiatric disorders. Acta Psychiatr Scand. 2010;121(2):84–93.

Pelgrims I, Keune H, Thomas I, Bastiaens H, Remmen R, Nawrot T, et al. Assessing the impact of (non-) built environment on mental health in Brussels. In Kaunas, Lithuania: Poster presented at ISES-ISIAQ conference; 2019.

Pelgrims I, Devleesschauwer B, Guyot M, Keune H, Nawrot T, Remmen R, Nelly D. Saenen, e.a. Association between urban environment and mental health in Brussels, Belgium. BMC Public Health 21, nr. 1 (1 april 2021): 635. https://doi.org/10.1186/s12889-021-10557-7

Perez, J., Araldi, A., Fusco, G., & Fuse, T. (2019). The character of urban Japan: Overview of Osaka-Kobe's Cityscapes. Urban Science, 3(4), 105. https://doi.org/10.3390/urbansci3040105.

Power MC, Kioumourtzoglou M-A, Hart JE, Okereke OI, Laden F, Weisskopf MG. The relation between past exposure to fine particulate air pollution and prevalent anxiety: observational cohort study. BMJ. 2015;350:h1111.

Pun VC, Manjourides J, Suh H. Association of Ambient air Pollution with depressive and anxiety symptoms in older adults: results from the NSHAP study. Environ Health Perspect. 2017;125(3):342–8.

Rao M, Prasad S, Adshead F, et al. The built environment and health. Lancet Lond Engl 2007;370:1111–3. doi:10.1016/S0140-6736(07)61260-4

Ratcliffe, E., Gatersleben, B., Sowden, P.T., 2013. Bird sounds and their contributions to perceived attention restoration and stress recovery. J. Environ. Psychol. 36, 221–228.

Rautio N, Filatova S, Lehtiniemi H, Miettunen J. Living environment and its relationship to depressive mood: a systematic review. Int J Soc Psychiatry. 2018;64(1):92–103.

Reed MS. Stakeholder participation for environmental management: a literature review. Biol Conserv 2008;141:2417‐31.

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. doi:10.1111/j.1600-0447.1993.tb03411.x

Renn O. Participatory processes for designing environmental policies. Land use policy 2006;23:34‐43.

Rollero, C., De Piccoli, N., 2010. Does place attachment affect social well-being? Eur. Rev. Appl. Psychol. 60, 233–238.

Rosseel Y. Lavaan: An R package for structural equation modeling. J Stat Softw. 2012;48(1):1–36.

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.

Sass V, Kravitz-Wirtz N, Karceski SM, Hajat A, Crowder K, Takeuchi D. The effects of air pollution on individual psychological distress. Health Place. 2017;48:72–9

Semenescu A, Gavreliuc A, Sârbescu P. 30 Years of soft interventions to reduce car use–A systematic review and meta-analysis. Transportation research part D: transport and environment. 2020 Aug 1;85:102397.

Sennett, R., 2018. Building and Dwelling: Ethics for the City. Farrar, Straus and Giroux.

Shamai, S., 2018. Measuring negative sense of place: Israeli settlers' forced migration.
Geojournal 83, 1349–1359.

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 Netw Open 2018;1:e180298.

Statbel, the Belgian statistical office. statbel. fgov. be, 2018. Available: statbel. fgov. be/ en [Accessed cited 2019 Nov 18].

Stessens, P., Khan, A. Z., Huysmans, M., & Canters, F. (2017). Analysing urban green space accessibility and quality: A GIS-based model as spatial decision support for urban ecosystem services in Brussels. Ecosystem Services. https://doi.org/10.1016/j.ecoser.2017.10.016.

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.

Sugiyama T, Leslie E, Giles-Corti B, et al. Associations of neighborhood greenness with physical and mental health: do walking, social coherence and local social interaction explain the relationships? J Epidemiol Community Health 2008;62:e9.

Teixeira, S., 2016. Beyond broken windows: youth perspectives on housing abandonment and its impact on individual and community well-being. Child Indicators Research 9, 581–607.

Triguero-Mas M, Dadvand P, Cirach M, Martínez D, Medina A, Mompart A, et al. Natural outdoor environments and mental and physical health: relationships and mechanisms. Environ Int. 2015;77:35–41.

Tzivian L, Winkler A, Dlugaj M, Schikowski T, Vossoughi M, Fuks K, et al. Effect of long-term outdoor air pollution and noise on cognitive and psychological functions in adults. Int J Hyg Environ Health. 2015;218(1):1–11.

Ulrich, R.S., 1983. Aesthetic and Affective Response to Natural Environment. Behavior and the Natural Environment. Springer.

UrbIS data — CIRB-CIBG-BRIC [Internet]. [cited 2019 Oct 11]. Available from: https://cirb.brussels/fr/nos-solutions/urbis-solutions/urbis-data/urbis-data

Vanaken G-J, Danckaerts M. Impact of green space exposure on Children's and adolescents' mental health: a systematic review. Int J Environ Res Public Health. 2018;15(12):2668.

van den Berg AE, Maas J, Verheij RA, Groenewegen PP. Green space as a buffer between stressful life events and health. Soc Sci Med. 2010;70(8): 1203–10.

van den Bosch M, Meyer-Lindenberg A. Environmental Exposures and Depression: Biological Mechanisms and Epidemiological Evidence. Annu Rev Public Health. 2019;40:239–59.

Vanderhaegen, S., & Canters, F. (2017). Mapping urban form and function at city block level using spatial metrics. Landscape and Urban Planning, 167, 399–409. https://doi. org/10.1016/j.landurbplan.2017.05.023.

Van de Voorde, T. (2017). Spatially explicit urban green indicators for characterizing vegetation cover and public green space proximity: A case study on Brussels Belgium. International Journal of Digital Earth, 10(8), 798–813. https://doi.org/10.1080/ 17538947.2016.1252434.

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 (report no: ActuaEvol/09). Brussels: Cartography and GIS Research Group, Department of Geography, Vrije Universiteit Brussel, 2010.

Van Dillen, S.M., De Vries, S., Groenewegen, P.P., Spreeuwenberg, P., 2012. Greenspace in urban neighborhoods and residents' health: adding quality to quantity. J. Epidemiol. Community Health 66, e8. -e8.

Vardoulakis S, Fisher BEA, Pericleous K, Gonzalez-Flesca N. Modelling air quality in street canyons: a review. Atmos Environ. 2003;37(2):155–82.

Völker, S., Kistemann, T., 2013. Reprint of:"I'm always entirely happy when I'm here!" Urban blue enhancing human health and well-being in Cologne and Düsseldorf, Germany. Soc. Sci. Med. 91, 141–152.

von Lindern E, Hartig T, Lercher P. Traffic-related exposures, constrained restoration, and health in the residential context. Health Place. 2016;39: 92–100.

Wartmann FM, Purves RS. Investigating sense of place as a cultural ecosystem service in different landscapes through the lens of language. Landscape and Urban Planning. 2018 Jul 1;175:169-83.
White, J., Greene, G., Farewell, D., Dunstan, F., Rodgers, S., Lyons, R.A., Humphreys, I., John, A., Webster, C., Phillips, C.J., 2017. Improving mental health through the regeneration of deprived neighborhoods: a natural experiment. Am. J. Epidemiol. 186, 473–480.

WHO. Mental disorders [Internet]. [cited 2020 May 7]. Available from: https://www.who.int/news-room/fact-sheets/detail/mental-disor

Wilkins CH, Sheline YI, Roe CM, Birge SJ, Morris JC. Vitamin D deficiency is associated with low mood and worse cognitive performance in older adults. Am J Geriatr Psychiatry. 2006;14(12):1032–40.

World Health Organization. Depression and other common mental disorders: Global Health estimates [internet]. Geneva: World Health Organization; 2017. Available from: https://apps.who.int/iris/bitstream/handle/10665/254610/WHO-MSD-MER-2017.2-eng.pdf

Yamada, I., & Thill, J.-C. (2010). Local Indicators of Network-Constrained Clusters in Spatial Patterns Represented by a Link Attribute. Annals of the Association of American Geographers, 100(2), 269–285. https://doi.org/10.1080/00045600903550337.

'Yotti'kingsley, J., Townsend, M., 2006. 'Dig in'to social capital: community gardens as mechanisms for growing urban social connectedness. Urban Pol. Res. 24, 525–537.

Zarghami E, Karimimoshaver M, Ghanbaran A, SaadatiVaghar P. Assessing the oppressive impact of the form of tall buildings on citizens: height, width, and height-to-width ratio. Environ Impact Assess Rev. 2019;79:106287.

Zeng Y, Lin R, Liu L, Liu Y, Li Y. Ambient air pollution exposure and risk of depression: a systematic review and meta-analysis of observational studies. Psychiatry Res. 2019;276:69–78.

Zhao T, Markevych I, Romanos M, Nowak D, Heinrich J. Ambient ozone exposure and mental health: a systematic review of epidemiological studies. Environ Res. 2018;165:459–72.

Zijlema WL, Wolf K, Emeny R, Ladwig KH, Peters A, Kongsgård H, et al. The association of air pollution and depressed mood in 70,928 individuals from four European cohorts. Int J Hyg Environ Health. 2016;219(2):212–9.

Zuniga-Teran, A. A., Orr, B. J., Gimblett, R. H., Chalfoun, N. V., Marsh, S. E., Guertin, D. P., & Going, S. B. (2017). Designing healthy communities: Testing the walkability model. Frontiers of Architectural Research, 6(1), 63-73.