# Multiple pathways link urban green- and bluespace to mental health in young adults

Angel M. Dzhambov[a,*], Iana Markevych[b,c], Terry Hartig[d], Boris Tilov[e,f], Zlatoslav Arabadzhiev[g], Drozdstoj Stoyanov[g], Penka Gatseva[a], Donka D. Dimitrova[h]

[a] Department of Hygiene and Ecomedicine, Faculty of Public Health, Medical University of Plovdiv, Plovdiv, Bulgaria
[b] Institute and Clinic for Occupational, Social and Environmental Medicine, University Hospital, LMU Munich, Munich, Germany
[c] Institute of Epidemiology, Helmholtz Zentrum München – German Research Center for Environmental Health, Neuherberg, Germany
[d] Institute for Housing and Urban Research, Uppsala University, Uppsala, Sweden
[e] Medical College, Medical University of Plovdiv, Plovdiv, Bulgaria
[f] Department of Management, Faculty of Economics and Management, University of Agribusiness and Rural Development, Plovdiv, Bulgaria
[g] Department of Psychiatry and Medical Psychology, Faculty of Medicine, Medical University of Plovdiv, Plovdiv, Bulgaria
[h] Department of Health Management and Healthcare Economics, Faculty of Public Health, Medical University of Plovdiv, Plovdiv, Bulgaria

## ARTICLE INFO

## ABSTRACT

*Background:* A growing body of scientific literature indicates that urban green- and bluespace support mental health; however, little research has attempted to address the complexities in likely interrelations among the pathways through which benefits plausibly are realized.

*Objectives:* The present study examines how different plausible pathways between green/bluespace and mental health can work together. Both objective and perceived measures of green- and bluespace are used in these models.

*Methods:* We sampled 720 students from the city of Plovdiv, Bulgaria. Residential greenspace was measured in terms of the Normalized Difference Vegetation Index (NDVI), tree cover density, percentage of green areas, and Euclidean distance to the nearest green space. Bluespace was measured in terms of its presence in the neighborhood and the Euclidean distance to the nearest bluespace. Mental health was measured with the 12-item form of the General Health Questionnaire (GHQ-12). The following mediators were considered: perceived neighborhood green/bluespace, restorative quality of the neighborhood, social cohesion, physical activity, noise and air pollution, and environmental annoyance. Structural equation modelling techniques were used to analyze the data.

*Results:* Higher NDVI within a 300 m buffer around the residence was associated with better mental health through higher perceived greenspace; through higher perceived greenspace, leading to increased restorative quality, and subsequently to increased physical activity (i.e., serial mediation); through lower noise exposure, which in turn was associated with lower annoyance; and through higher perceived greenspace, which was associated with lower annoyance. Presence of bluespace within a 300 m buffer did not have a straightforward association with mental health owing to competitive indirect paths: one supporting mental health through higher perceived bluespace, restorative quality, and physical activity; and another engendering mental ill-health through higher noise exposure and annoyance.

*Conclusions:* We found evidence that having more greenspace near the residence supported mental health through several indirect pathways with serial components. Conversely, bluespace was not clearly associated with mental health.

## 1. Introduction

Approximately one billion people on a global scale meet the criteria for a common mental disorder (Steel et al., 2014), accounting for about one third of years lived with disability (Vigo et al., 2016). A growing body of scientific literature indicates that natural urban environments, such as green- and bluespace, might support mental health, but the evidence regarding how benefits are realized has significant gaps

(Gascon et al., 2015, 2017).

Greenspace, a term encompassing both overall vegetation level and green spaces (e.g., parks, gardens) (Teylor and Hochuli, 2017), has been in the spotlight of environmental research longer than bluespace, so a conceptual framework about the mechanisms underlying its effect has been proposed and tested empirically. Putative pathways include mitigation of harmful exposures and annoyance caused by noise and air pollution; psychological restoration and stress reduction; and encouragement of health-enhancing behaviors, such as physical activity and social interactions (Hartig et al., 2014; Markevych et al., 2017; WHO, 2016). However, results have been mixed. For example, some studies observed significant mediation through social cohesion (e.g., Dadvand et al., 2016; de Vries et al., 2013; Maas et al., 2009; Sugiyama et al., 2008), but others have failed to identify such an indirect effect (e.g., Triguero-Mas et al., 2015, 2017). In other studies, stress reduction (Triguero-Mas et al., 2017) and mitigation of traffic emissions (Gascon et al., 2018) emerged as more important mediators than physical activity and social cohesion.

In recent years, the interest in bluespace as a protective factor in the urban environment has been gaining momentum (Grellier et al., 2017). Bluespace, defined as an accessible outdoor environment that prominently features water (after Grellier et al., 2017), is hypothesized to support mental health through many of the mediators proposed for greenspace. For example, areas with more bluespace might have fewer sources of noise and air pollution (cf. Markevych et al., 2017). Some types of bluespace might mask traffic noise perceptually or energetically with pleasant water sounds and reduce noise annoyance (cf. Li et al., 2012; Leung et al., 2014; Kang, 2012; Kang et al., 2016). Bluespace might also mitigate the heat island effect, reduce stress, and facilitate social contacts and physical activity (Grellier et al., 2017). However, few epidemiological studies have been able to quantify the effect of bluespace on mental health and well-being (Gascon et al., 2017). Some reported better mental health for participants living closer to bluespace (e.g., Brereton et al., 2008; MacKerron and Mourato, 2013; White et al., 2013a; Völker et al., 2018) or in a neighborhood with more bluespace (e.g., Alcock et al., 2015; White et al., 2013b), but others did not find a significant association (e.g., Triguero-Mas et al., 2015; Gascon et al., 2018; Bezold et al., 2018). Moreover, studies that explicitly set out to investigate underpinning pathways have been scarce (e.g., Triguero-Mas et al., 2015; Gascon et al., 2018). Hence, the epidemiologic evidence on this subject remains thin. This holds especially for less affluent European countries and with regard to inland bluespace (Gascon et al., 2017).

The mixed findings referenced above could partially be due to the fact that the majority of previous studies were not specifically designed to collect comprehensive information on potential mediators and account for the possibility that mediating processes might be intertwined (Dzhambov et al., 2018). More specifically, green/bluespace might enhance neighborhood restorative quality, and thereby promote social contacts and outdoor physical activity, behaviors that commonly occur together in single episodes, and that in turn might relate to better mental health (Barton et al., 2016; Dzhambov et al., 2018). At the same time, by mitigating noise and air pollution, greenspace might reduce environmental annoyance, and thus increase restorative quality by making the residential environment more appealing settings for spending time outdoors (von Lindern et al., 2016). Other literature indicates that higher noise annoyance might harm mental health directly (van Kamp and Davies, 2008) or indirectly through increasing interpersonal distance and inhibiting social cohesion in the neighborhood (Jones et al., 1981; Cohen and Spacapan, 1984; Dzhambov et al., 2017). Disregarding the possibility of such an interplay might entail spurious conclusions as to the importance of a particular pathway (Dzhambov et al., 2018) or even counterintuitive findings, such as neighborhood greenness being inversely related to physical activity (e.g., Gascon et al., 2018). In a previous study (Dzhambov et al., 2018), we addressed the issue by demonstrating that in single and parallel mediation models physical activity and social cohesion did not appear to mediate the effect of objectively-measured greenspace on mental health, but when neighborhood restorative quality was added to the model as their antecedent factor, those paths became significant. Nevertheless, more research is needed to replicate these findings for greenspace and to expand the model to incorporate bluespace. If multiple mediators can work together, an omnibus model encompassing several serial mediation components would be more comprehensive than a piece-wise estimation of each serial mediation path (cf. Dzhambov et al., 2018).

A related issue has to do with the fact that specific environmental measures might be relevant to different mediators (cf. Markevych et al., 2017). For example, the mere presence of vegetation in the living environment might be sufficient for reducing air pollution, but people's perceptions provide more useful information about their actual interaction with green/bluespace. Therefore, studies looking at the capacity of natural environments to support health should also consider perceptual measures in addition to the spatial ones (Markevych et al., 2017). For instance, perceived greenspace quality was found to partially mediate the effect of objective greenspace accessibility and usability on neighborhood satisfaction (Zhang et al., 2017), and self-reported time spent in greenspace mediated the effect of residential greenness on mental health (van den Berg et al., 2017a). It follows that perceptual measures might be a link in the causal chain between green/bluespace and other mediators, such as neighborhood restorative quality or environmental annoyance.

The present study examines different plausible pathways linking green/bluespace to mental health, with a focus on how objective and perceived measures of green/bluespace fit a model in which multiple pathways are specified to work together. Uncovering these intricate mechanisms should help to advance epidemiological research in this area.

## 2. Methods

### 2.1. Study design and sampling

This study builds on previous research (Dzhambov et al., 2018) by extending it to a larger and more homogenous sample of young adults, which is an understudied group in the field (cf. Gascon et al., 2015, 2017). Data were collected between October and November 2017 from the Medical University in Plovdiv, the second largest city in Bulgaria. To be included in our study, students had to be aged 18 – 35 years (defining young adulthood; e.g., Petry, 2002) and resident in Plovdiv or the near provinces in Southern Bulgaria for the last six months. We used a convenience sample in order to achieve sufficient variability in the data. We targeted potential participants with different ethnic and cultural background, age, and program enrollment. During a class/lecture, members of the research group advertised the study, informing the students about its general objectives, and asked them to complete a questionnaire. The study was presented as an omnibus survey on "neighborhood environment and quality of life". In addition to socio-demographic factors, residential environment, mental and general health, participants were asked to report their current living address, which was needed for subsequent assignment of geographic variables. Since a member of the research group was present, participants had the opportunity to give feedback and receive clarifications about each question. On average, completing the questionnaire took about 15 – 20 min. The study design was approved by the Ethics Committee at the Medical University of Plovdiv (Dzhambov et al., 2018). Participants signed informed consent forms. No incentives were offered.

Of the 1 000 students invited, 823 agreed to participate (82% response rate). Residential addresses were converted to geocodes manually by inspecting each address with the help of Google maps. Of the 788 participants left in the dataset after data cleaning, we were able to successfully geocode the residences of 720, because the others had