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ORIGINAL ARTICLE

Nature and well-being in seven European cities: The moderating effect of connectedness to nature

Ghozlane Fleury-Bahi¹  | Jean-Michel Galharret²  |
Colin Lemée³ | Inga Wittenberg⁴ | Pablo Olivos⁵ |
Ana Loureiro⁶ | Yvette Jeuken⁷ | Pauline Laille⁸ |
Oscar Navarro¹

¹Nantes Université, Univ Angers, Laboratoire de psychologie des Pays de la Loire, LPPL, UR 4638, Nantes, France

²Laboratoire de Mathématiques Jean Leray UMR 6629, Université de Nantes, Nantes, France

³Université de Brest, Brest, France

⁴Otto-von-Guericke-Universität, Magdeburg, Germany

⁵Universidad Castilla-La Mancha, Albacete, Spain

⁶HEI-Lab, Universidade Lusófona, Lisbon, Portugal

⁷Duneworks, Eindhoven, The Netherlands

⁸Plantes et Cités, Angers, France

Correspondence

Ghozlane Fleury-Bahi, Nantes Université, Univ Angers, Laboratoire de psychologie des Pays de la Loire, LPPL, UR 4638, F-44000 Nantes, France.

Email: ghozlane.fleury@univ-nantes.fr

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Abstract

Well-being is transversal to different urban-related challenges such as increasing urbanization or adaptation to the effects of climate change. One possible response to these challenges is the use of nature in cities. The aim of this study is to investigate how the objective quantity of natural space near the home, the perception of these natural elements, and their perceived availability, moderated by the effect of connectedness to nature, could explain levels of well-being. A survey was conducted among a sample of 1343 participants living in seven European cities. Data were collected online via a questionnaire. Indicators of the

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objective quantity of urban natural space based on remotely sensed satellite imagery were also used. Regression models highlight the association between well-being and perceived amount of nature, accessibility to a community garden, and level of connectedness to nature. A moderating and negative effect of connectedness to nature on the association between the perceived quantity of nature and well-being was also identified. Perception of nature seems to be a better indicator of well-being than the objective one. Results highlight the importance of the social dimension of collective gardens in enhancing well-being. Connectedness to nature could facilitate appropriation of natural elements and its effects on well-being.

KEYWORDS

connectedness to nature, European cities, moderating effect, urban nature, well-being

INTRODUCTION

As more than 50% of the world's population live in urban areas (United Nations Organisation, 2014), adapting cities to climate change, demographic evolutions, and new consumption patterns is crucial and urgent (Kabisch et al., 2014). Due to urban expansion, it is predicted that, by the middle of this century, 66% of the world's population will live in cities and urban areas (UN, 2014). The climate is generally warmer, rainier, less windy, and more polluted in these zones than in rural areas (Emilsson & Ode Sang, 2017). Urbanization could also affect city dwellers because of increases in traffic, noise, and air pollution. The negative effects of urbanization already known, such as higher urban temperature, urban heat island effect, and flooding, might also be increased by climate change.

We need to ask how we can avoid the multiplication of urban heat islands during heat wave episodes, but also how to support biodiversity in urban areas or engagement of citizens in outdoor areas that promote well-being and quality of life of the city dwellers in everyday life. One possible response to these challenges is the presence and use of nature in its different forms within urban areas. For example, the European Commission emphasizes green infrastructures, which are networks of green and water spaces improving environmental conditions and urban citizens' quality of life. In general, studies investigating the link between nature and well-being focus on its restorative effects on urban residents (Collado et al., 2017). Indeed, in such cases, nature is often situated in built environments (Hartig et al., 2014) and includes street trees, urban parks, collective gardens, urban wetlands, and rivers.

Abundant research has documented associations between experiencing nature and subjective well-being (Johansson et al., 2011; Luck et al., 2011; White et al., 2017). When targeting urban environments, many studies have demonstrated various positive effects of urban green

spaces on mental health and well-being (Braubach et al., 2017; de Vries, 2010). More green space in the urban area is linked not only with higher levels of well-being (White et al., 2013) but also with lower levels of depression and anxiety (Beyer et al., 2014; Pope et al., 2015; Reklaitiene et al., 2014), as well as reduced chronic stress (Beil & Hanes, 2013; de Vries et al., 2013; Fan et al., 2011; Nielsen & Hansen, 2007; Roe et al., 2013; Ward-Thompson et al., 2012). Some studies have also highlighted the restorative and positive effect of urban blue spaces on the well-being of city dwellers (Völker & Kistemann, 2015).

In their review, Hartig et al. (2014) specify that contact with nature could have effects on physical and mental health in four different ways: by reducing exposure to challenging environmental conditions (e.g., air quality, urban heat islands, and noise), by helping people maintain adaptive resources and recover from stress, by enhancing physical activity, and by encouraging social cohesion. Passive recreation in urban green spaces, like relaxing, enjoying the sun, or interacting with other people, also contributes to human well-being (Irvine et al., 2013; Kabisch et al., 2015).

In some studies, the objective amount of green space is measured, for example, by GIS-based measures of the amount of green space and neighborhood vegetation cover in a radius of 300 m to 3 km from the home (van den Berg, Maas, et al., 2010; van Dillen et al., 2012). Other studies take into account access to parks, collective gardens, and other urban green spaces that could promote physical and leisure activities such as gardening (Clayton, 2007; Van den Berg & Custers, 2010) and thus mental health. While the effects of objective indicators of the quantity of green space and indicators of accessibility are well covered in the literature, the lesser studied perception of green space proximity and accessibility also seems to influence health issues. Studies suggest, for example, that viewing green space and window views of nature could generate mental health benefits (Chang & Chen, 2005; Gilchrist et al., 2015; Thompson et al., 2016; Ulrich et al., 1991).

The links between contact with nature and mental health outcomes are complex, however, and challenges remain for understanding the contributing psychological processes behind this association (Brymer et al., 2019; Lawton et al., 2017). When addressing this issue, the role of individual differences in the relationship between the self and the natural environment is important to consider, as this relation with nature could contribute to enhancing well-being and life satisfaction. More precisely, connectedness to nature has been defined as a self-perceived relationship between the self and the natural environment (Schultz et al., 2004) and as an affective individual experience of connection with nature related to individuals' experiential sense of oneness with the natural world (Mayer & Frantz, 2004). Recent studies identified that connectedness to nature is associated with an increase in positive emotional states (Mayer et al., 2009), personal well-being (Cervinka et al., 2012; Howell et al., 2011; Navarro et al., 2019; Wolsko & Lindberg, 2013; Wyles et al., 2017), and psychological health (Kamitsis & Francis, 2013). In the same vein, Nisbet et al. (2011) show positive association between connectedness to nature and positive affects, relaxation, curiosity, and interest. A meta-analysis taking into account studies that operationalized connectedness to nature in a variety of ways showed a small but consistent relationship between connectedness, happiness, life satisfaction, and positive affect (Capaldi et al., 2014).

The aim of the present study is to investigate how objective and perceived amounts of nature around the place of residence and connectedness to nature could explain the level of well-being of city dwellers in seven European cities. There are few studies on this topic that are based on a comparison of cities. Pasca et al. (2021), for example, conducted a study in five European and non-European cities to investigate the effects of exposure to artificial nature

(totally natural, quasi-natural, or non-natural) on connectedness to nature and well-being. Their results highlighted a mediating effect of connectedness to nature on well-being but did not test the potential effect of the respondent's country. More generally, an international study conducted in 15 countries (Skevington et al., 2019) investigated the links between the presence of biodiversity and quality of life without considering the potential role of connectedness to nature.

The originality of the present study lies in the fact that objective and subjective indicators of urban nature are combined in order to analyze their role on well-being. The international approach involving several European cities is also interesting in that it allows us to highlight processes that are independent of the national and cultural context. We hypothesize that the level of well-being is positively linked with

- objective proportion of green and blue spaces around the place of residence,
- perceived amount of natural elements in the neighborhood,
- visibility of green spaces from the home,
- and perceived accessibility to private and/or collective gardens.

Our study also explores a potential pathway related to individual connectedness to nature (CN) to explain association between urban green space and well-being. Thus, we hypothesize that individual well-being is positively associated with connectedness to nature and that the positive effect of the perceived amount of nature on well-being is moderated by the individual's level of CN. Previous research highlighted the mediating effect of CN on the relation between contact with nature and well-being (e.g., Mayer et al., 2009; Pasca et al., 2021). Considering the moderating role of CN completes the previous work by allowing us to identify how CN modulates the link between nature and well-being.

METHODS

Sample and procedure

This research is part of a larger project that is funded by the European Commission. Data were obtained from a convenient sample of 1343 participants (56.4% women, 43.3% men) ranging in age from 17 to 73 years ($M = 38.60$; $SD = 14.33$). Participants live in seven European cities (Albacete in Spain: $n = 190$, 54.7% women, 45.2% men, age: $M = 41.9$, $SD = 12.6$; Amsterdam in the Netherlands, $n = 210$, 59.5% women, 40.5% men, age: $M = 44.5$, $SD = 14.9$; Ankara in Turkey, $n = 156$, 46.8% women, 53.2% men, age: $M = 42.1$, $SD = 10.2$; Lisbon in Portugal, $n = 225$, 63.1% women, 36.9% men, age: $M = 37.5$, $SD = 14.8$; Magdeburg in Germany, $n = 118$, 64.4% women, 35.5% men, age: $M = 32.3$, $SD = 8.6$; Nantes in France, $n = 188$, 63.3% women, 36.7% men, age: $M = 40.5$, $SD = 17.2$; and Szeged in Hungary, $n = 252$, 46.6% women, 53.3% men, age: $M = 31.5$, $SD = 12.6$). The characteristics of the chosen cities regarding climate and administrative situation are presented in Table 1. These cities are diverse in terms of environmental challenges. Indeed, according to the Köppen Climate Classification, their climates are diverse (ranging from oceanic to semi-arid climate), which allows our sample to encompass the variety of the main climates encountered in Europe. One of the criteria the participants had to fulfill to be part of the study was to have lived in their city for at least 1 year.

TABLE 1 Climate classification and administrative characteristics of the seven European cities

City	Climate (Köppen Climate Classification)	Administrative characteristics
Albacete	Semi-arid continental climate (Bsk)	Capital of the province of Albacete in the autonomous community of Castile-La Mancha in Spain
Amsterdam	Oceanic climate (Cfb)	Capital of the Netherlands
Ankara	Continental climate (Csa)	Capital of Turkey
Lisbon	Mediterranean climate (Csa)	Capital and the largest city of Portugal
Magdeburg	Humid continental climate (Dfb)	Capital of the state of Saxony-Anhalt in eastern Germany
Nantes	Oceanic climate (Cfb)	Capital of the Loire-Atlantique department, and prefecture of the Pays de la Loire region
Szeged	Between oceanic (Cfb) and continental (Dfb)	City in the south of Hungary

Data collection was carried out between April 2018 and January 2019. The questionnaire was conducted online on the LimeSurvey platform. All participants were asked for their consent at the beginning and end of the questionnaire. All data, including personal data, were aggregated after collection in order to guarantee confidentiality. The average time taken to fill in the whole questionnaire was between 15 and 20 min. The authors complied with APA ethical standards (<https://www.apa.org/ethics/code>), in accordance with the ethics guidelines of the partner universities and laboratories. Participation in the research was voluntary and informed consent was obtained from all participants.

Measures

Data were collected via a questionnaire, including questions on sociodemographic characteristics and socioeconomic status, well-being, perceived amount of nature in the neighborhood, perceived availability of green space at home and near the home, and connectedness to nature. The data that support the findings of this study are available at <https://mfr.osf.io/render?url=https://osf.io/m5etg/?direct%26mode=render%26action=download%26mode=render>. As the study was carried out in different countries, the questionnaire had to be translated into different languages. All the required versions of the questionnaire were based on the same English version and translated by professional translators. When available, existing versions in the different languages were used. The questionnaire is provided in Appendix A.

Well-being (MHC Short Form)

The Mental Health Continuum Short Form (MHC-SF) was used to measure the level of well-being of the participants (Keyes et al., 2008). We have chosen the MHC-SF rather than other scales (e.g., the Psychological Wellbeing [PWB] Scale by Ryff, 1989) for several reasons. First, it allows us to measure well-being from a global perspective by considering the different

psychological, emotional, and social dimensions of well-being and by allowing the computation of an overall score of well-being; moreover, it is quite a short questionnaire (14 items). Secondly, versions of this scale exist in several of the languages considered in this study (French, Turkish, Dutch, and Portuguese). Items are related to *Eudaimonic* social well-being (five items, e.g., “In the past month, how often did you feel that people are basically good?”), *Eudaimonic* psychological well-being (six items; e.g., “How often did you feel that you had warm and trusting relationships with others?”), and emotional or *Hedonic* well-being (three items; e.g., “How often did you feel satisfied with life?”). For each of the 14 statements, participants were asked to rate themselves on a 6-point Likert scale ranging from 1 (*never*) to 6 (*every day*). The reliability of the scale is good (Cronbach's alpha = .88) for the present study.

Connectedness to Nature Scale (CNS)

In previous studies, different scales have been used to measure the level of connectedness to nature. For example, a single item measure was proposed (Wesley Schultz, 2001), or a version of the implicit associations test (IAT) to measure connectedness to nature (Schultz et al., 2004). We can also identify the Environmental Identity (EID) scale by Clayton (2003) or the Nature Relatedness (NR) scale by Nisbet et al. (2009). For our study, we have chosen the short seven-item version of the “Connectedness to Nature Scale” (CNS) recently developed by Pasca et al. (2017) because versions of the CNS scale exist in several of the languages considered in this study (French, Spanish, German, and Portuguese). This shorter version of the original tool developed by Mayer and Frantz (2004) has adequate levels of reliability and validity. Respondents have to answer all seven items (e.g., “I think of the natural world as a community to which I belong”; “I often feel a kinship with animals and plants”) on a 5-point Likert scale ranging from 1 (*completely disagree*) to 5 (*completely agree*). On the basis of the responses to the seven items, an overall score of connectedness to nature is calculated. The internal coherence of the scale is good (Cronbach's alpha = .87).

Perceived amount of nature near the home

A Perceived Amount of Nature Index was calculated on the basis of the responses to 10 items. This index was designed to account for the way people perceive and assess the amount of nature around their home. Using the typology proposed by Bodéan and Musy (2018), it is possible to identify three major categories of urban natural elements: on the grounds, water, and on buildings. Based on exploratory interviews and on this categorization, 10 elements were selected (green spaces, green spaces left in the wild, private gardens and parks, birds, public parks and gardens, green roofs and walls, collective gardens, aquatic spaces, and insects). For each of these elements, respondents were asked to rate the amount around their home on a 5-point Likert scale ranging from *very few* to *many*: The lowest score for this index is 10, and the highest 50.

Green and blue space metrics: Objective quantity of natural space near the home

Geographic data sources based on remotely sensed satellite imagery were used to define green and water space density. The objective was the production of data representing the vegetated

areas of the city as well as the water surfaces. Images from the Sentinel 2 satellite were used. Three images per sector were used: winter, spring, and summer. This guarantees the reliability of the vegetation mask produced. The computation includes radiometric correction (reflectance correction according to the composition of the atmosphere and the ground relief) and the calculation of vegetation, water, and artificialization indices. This was done by differentiating the low (“herbaceous”) and high (“tree”) strata of vegetation. Proportions of green and blue space were calculated in the area located over a radius of 300 m around the home addresses of the people surveyed. Two measurements were obtained: the proportion of the area covered by trees and herbaceous part of the area (green proportion) and the proportion of the area covered by water (water proportion).

Perceived availability of green space at home and near the home

Availability of green space was also considered by asking each participant whether they had a private garden and if they had access to a collective/community garden. A third question was asked relating to visibility of green spaces (private or public) from the place of residence. For these three questions, the response format was dichotomous (yes or no).

Data analysis

We investigated the associations of the level of personal well-being (WB) with the objective amount of green and blue spaces (proportions of the area within a radius of 300 m from the home covered with green or blue space), perceived availability of green space at home and near the home (private garden, collective garden, and view of green space from the home), perceived amount of nature near the home (PAN), and connectedness to nature (CN). A common way to deal with this problem is to use a hierarchical linear regression model. However, in our modeling, we had to take into account that the individuals were clustered within cities. One way to deal with this problem would be to consider a regression in which the coefficients vary by city. However, this approach requires the estimation of a large number of coefficients followed by many tests to compare them. Multilevel models offer an alternative solution (see Gelman & Hill, 2006). Among these models, a distinction can be made between the varying-intercept model and the more general varying-intercept and varying-slope model. In the first, the intercept of the model is written as a constant term (called the fixed effect) to which a Gaussian error (called the random effect) is added. The variance of this error summarizes the different intercepts we should obtain by considering a regression for each city. The varying-slope model is based on a similar decomposition for the slopes of the model. Thus, in this type of model, we consider that the effect of the predictors depends on the city. The *F*-test for nested models and the *t*-test for coefficients available in least square linear regression can be adapted into a multilevel model by the Satterthwaite method (see Giesbrecht & Burns, 1985). Two definitions of the proportion of variance explained (i.e., R^2 in a linear model) have been proposed for multilevel models: marginal R^2 , which can be interpreted as the variance explained by the fixed effects, and conditional R^2 , which can be interpreted as the variance explained by the entire model, including both fixed and random effects. It is also possible to test the interaction between two variables in a multilevel model by considering a fixed effect (or a random effect) on the product of these variables.

The results are arranged in three sections. First, we provide a description of the well-being outcomes across the different cities. Second, we present the correlations between all the variables of interest in our study. Finally, we give the results of the nested multilevel regression models applied to examine the relative contributions of the objective proportions of green and blue space, perceived amount and availability of nature, and level of connectedness to nature (CN) in the prediction of well-being. We particularly investigated the interaction between perceived amount of nature and CN within the overall model. Statistical analyses were performed using R software (Version 4.0.2) and JAMOVI (Version 1.6.2.0).

RESULTS

Preliminary analysis

The mean scores, standard deviation of well-being, and its dimensions are presented in Table 2. The city of Ankara obtained the (significantly) lowest score in terms of well-being ($M = 3.26$, $SD = 0.55$); the cities of Magdeburg ($M = 3.48$, $SD = 0.57$), Nantes ($M = 3.47$, $SD = 0.46$), Szeged ($M = 3.50$, $SD = 0.52$), and Lisbon ($M = 3.62$, $SD = 0.53$) did not have significantly different scores; and the cities with the highest scores were Amsterdam ($M = 3.87$, $SD = 0.48$) and Albacete ($M = 3.79$, $SD = 0.51$).

Bivariate correlations showed well-being to be positively and significantly correlated with age ($r = .107$, $p = .001$), proportions of blue ($r = .069$, $p = .03$) and green ($r = .066$, $p = .04$) space, CN ($r = .23$, $p < .001$), and perceived amount of nature near the home ($r = .095$, $p = .003$). CN was positively and significantly associated with age ($r = .149$, $p < .001$) and negatively and significantly associated with PAN ($r = -.072$, $p = .026$). PAN was related positively and significantly to the proportion of green space ($r = .193$, $p < .001$) and negatively and significantly related to age ($r = -.135$, $p < .001$). Other significant correlations that were less theoretically relevant were not analyzed. Pearson correlation coefficients are presented in Table 3.

Main determinants of well-being

The descriptive statistics show that the means of well-being and its dimensions differed among cities, so we constructed models with varying intercepts. Moreover, the ratio of the between-city

TABLE 2 Mean scores of well-being as a function of city

	<i>N</i>	Mean	<i>SD</i>
Albacete	185	3.79 _c	0.516
Amsterdam	196	3.87 _c	0.487
Ankara	147	3.27 _a	0.557
Lisbon	214	3.62 _b	0.534
Magdeburg	118	3.48 _b	0.570
Nantes	177	3.47 _b	0.458
Szeged	249	3.50 _b	0.523

Note: Means with the same subscripts are not significantly different from each other.

TABLE 3 Matrix of Pearson's correlations

		1.	2.	3.	4.	5.	6.
1. Well-being	Pearson's <i>r</i>	—					
	<i>p</i> -value	—					
2. Age	Pearson's <i>r</i>	.104	—				
	<i>p</i> -value	.001	—				
3. Green part	Pearson's <i>r</i>	.066	-.143	—			
	<i>p</i> -value	.044	< .001	—			
4. Water part	Pearson's <i>r</i>	.069	.102	-.164	—		
	<i>p</i> -value	.032	.002	< .001	—		
5. PAN	Pearson's <i>r</i>	.095	-.135	.193	.063	—	
	<i>p</i> -value	.003	< .001	< .001	.052	—	
6. CN	Pearson's <i>r</i>	.230	.149	-.027	.031	-.072	—
	<i>p</i> -value	< .001	< .001	.399	.342	.026	—

Abbreviations: CN, score of connectedness to nature; Green part, objective proportion of green space near the home; PAN, perceived amount of nature near the home; Water part, objective proportion of blue space near the home.

variance to the total variance of well-being (i.e., the interclass correlation) is equal to 13%. This value is sufficient to consider that a multilevel model fits the data better than a linear model. A comparison between the random intercept model and the classical regression model using a likelihood ratio test confirmed that the random intercept model fits the data better, $\chi^2(1) = 55.50$, $p < .001$. The different multilevel models were built step by step. The first model (Model 0) included the controlled variables of gender and age. In the second model (Model 1), green and blue space metric variables were added to the previous ones. In the third model (Model 2), PAN and perceived availability of nature (private garden, collective garden, and visibility of green spaces from the house) were included. Finally, in Model 3, connectedness to nature (CN) was considered in addition. Table 4 presents the results of these nested models. The multilevel regression model revealed that, with the first model, the controlled variables (age: $b = 0.003$, $p = .04$; gender: $b = -0.089$; $p = .008$) contributed significantly to the prediction of well-being ($R^2_m = .011$, $R^2_c = .120$). Introducing green and blue space metric variables (Model 1) did not significantly change the R^2_m ($\Delta R^2_m = .008$, $p = 1.00$); however, green spaces contribute significantly to explaining the level of well-being ($b = 0.003$; $p = 0.013$). The greater the proportion of green space in the neighborhood, the better the level of well-being. When PAN and variables related to perceived availability of nature around the home were added to the model (Model 2), the R^2_m changes significantly ($\Delta R^2_m = .033$, $p = .015$) with significant coefficients for the PAN near the home ($b = 0.131$; $p < .001$) and for availability of collective garden ($b = 0.107$; $p = .004$). So, introducing PAN indicators and perceived availability of collective garden makes the model more significant. When the participant has access to a collective garden and the more numerous the natural elements are perceived to be, the better the participant's level of well-being. Finally, the addition of the score of CN (Model 3) made it possible to significantly improve the fit of the model ($R^2_m = .086$, $R^2_c = .197$; $\Delta R^2_m = .035$, $p \leq .001$), with a significant regression coefficient for CN ($b = 0.134$; $p \leq .001$). This result shows that the level of CN contributes significantly to well-being.

TABLE 4 Multilevel regression analyses for block of variables predicting well-being

Predictor	<i>b</i>	<i>p</i>	Fit	Difference
Model 0:				
(Intercept)	3.521	<.001		
Gender = Male	−0.089	.008		
Age	0.003	.04		
			$R^2_m = .011, R^2_c = .120$	
Model 1:				
(Intercept)	2.585	<.001		
Gender = Male	−0.090	.008		
Age	0.003	.003		
Green part	0.003	.013		
Water part	0.004	.282		
			$R^2_m = .018, R^2_c = .121$	$\Delta R^2_m = .008, p = 1.00$
Model 2:				
(Intercept)	2.363	<.001		
Gender = Male	−0.087	.009		
Age	0.003	.030		
Green part	0.002	.145		
Water part	0.005	.256		
PAN	0.131	.000		
Visibility = 1	0.018	.637		
CGarden = 1	0.107	.004		
PGarden = 1	0.052	.192		
			$R^2_m = .051, R^2_c = .169$	$\Delta R^2_m = .033, p = .015$
Model 3:				
(Intercept)	1.936	<.001		
Gender = Male	−0.065	.046		
Age	0.002	.121		
Green part	0.002	.156		
Water part	0.004	.278		
PAN	0.138	<.001		
Visibility = 1	0.008	.828		
CGarden = 1	0.096	.008		
PGarden = 1	0.033	.393		
CN	0.134	<.001		
			$R^2_m = .086, R^2_c = .197$	$\Delta R^2_m = .035, p < .001$

Abbreviations: CGarden, accessibility to collective gardens; Green part, objective proportion of green space near the home; PAN, perceived amount of nature near the home; PGarden, accessibility to a private garden; CN, score of connectedness to nature; Visibility, visibility of green spaces from the home; Water part, objective proportion of blue space near the home.

It should be noted that neither adding a varying slope on PAN (i.e., considering that the association between PAN and well-being varied between cities) nor adding a varying slope on CN increased the fit of the model significantly. Indeed, none of the usual criteria (lowest Akaike information criterion [AIC], lowest Bayesian information criterion [BIC], and likelihood ratio test) provided in Table 5 indicate that Model 3a (random intercept and random slope on PAN), Model 3b (random intercept and random slope on CN), or Model 3c (random intercept and random slope on PAN and CN) fits the data significantly better than Model 3 (corresponding to the random intercept model).

The moderating role of connectedness to nature

We investigated the moderation by CN of the association between PAN and WB. From a modeling point of view, this amounts to adding an interaction term between CN and PAN to Model 3 (denoted by Model 3 in Table 4). The coefficient of the interaction term is negative and significant ($b = -0.084$, $p = .013$). This implies that, for an individual with a higher CN score, the association between PAN and WB is significantly weaker than for an individual with a lower CN score. Moreover, the addition of a varying slope to the interaction between CN and PAN does not increase the model fit ($\Delta R^2_c = .008$, $p = .652$), suggesting that the moderating effect of CN on the association between PAN and WB is the same regardless of city.

The moderated effect of CN can be visualized using the Johnson–Neyman technique (Johnson & Fay, 1950). From Model 3 in Table 4, we determined the CN interval in which the PAN is a significant predictor of well-being and the CN interval in which it is not (see Figure 1). When the level of CN is lower than 4.3, an increase in well-being is significantly related to an increase in PAN, but the magnitude of the correlation between these two variables decreases as CN increases. Otherwise, when the level of CN is above 4.3, the relationship between PAN and well-being is not significant.

DISCUSSION

The aim of this paper was to investigate how the objective amount of green and blue space around the home, perceived amount of nature, accessibility to these natural elements, and

TABLE 5 Comparison of the random intercept model with the random slope models on PAN, CN for the prediction of well-being from PAN, and CN controlling gender, age, objective amount of green and blue spaces, and availability of green space at home and near the home

Model	AIC	BIC	Deviance	χ^2	df	<i>p</i>
3 Varying intercept	1230.0	1345.0	1202.0			
3a Varying intercept and varying slope on PAN	1231.2	1309.0	1199.2	2.8	2	.248
3b Varying intercept and varying slope on CN	1233.1	1311.0	1201.2	0.8	2	.667
3c Varying intercept and varying slope on CN and on PAN	1234.1	1316.8	1200.1	1.9	3	.600

Abbreviations: AIC, Akaike information criterion; BIC, Bayesian information criterion; CN, connectedness to nature; PAN, perceived amount of nature near the home.

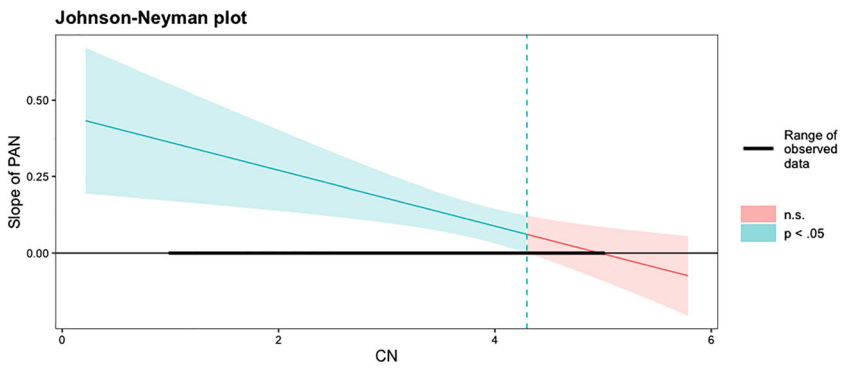


FIGURE 1 Representation of the slope of PAN on well-being according to the level of CN. The range of observed values of CN is [1.0, 5.0]. CN, connectedness to nature; PAN, perceived amount of nature near the home

connectedness to nature could explain the level of well-being of city dwellers in seven European cities. We hypothesized that the level of well-being is positively linked with objective amount of green and blue space near the home, perceived amount of nature in the neighborhood, visibility of green spaces from the home, and perceived accessibility to private and/or collective gardens. The performed statistical analyses allowed the study to take into account the different coefficients regardless of the city.

The complete model highlights the association between well-being and perceived amount of nature around the home, perceived accessibility to a collective or community garden, and level of connectedness to nature. More precisely, level of well-being increases with the perceived amount of nature in the neighborhood, with the level of individual connectedness to nature, and when the inhabitant has access to a community garden. The overall model does not allow us to identify a significant role of the objective amount of green or blue space in the area around the home.

With Model 1, we investigated the link between the objective amounts of green and blue space near the home and the well-being of city dwellers. Despite the fact that introducing objective indicators of green and blue spaces did not make the model significant, it was shown that the objective measure of green space (including both wooded and herbaceous parts of the area around the home) contributes significantly to the explanation of individual well-being. So, well-being is significantly linked with the proportion of green space around the home, but not with the proportion covered by water. Consequently, Model 1 tended to highlight that the objective amount of green space near the home contributes to explaining the level of well-being. The link between the objective amount of green space and mental health outcomes has already been identified in the literature (Astell-Burt & Feng, 2019; Barton & Rogerson, 2017; Roe et al., 2017; van Dillen et al., 2012). However, when perception of the amount of natural elements near the home was introduced into the model (Model 2), this variable appeared more important than the objective one. Our results tend to highlight that perception of nature near the home is a better indicator of well-being than the objective one. This result, which shows a more relevant role of the perceived amount of nature than the objective amounts of green and blue spaces, could be interpreted according to the transactional approach. In psychology, the transactional approach can help to explain such results and transactional models have demonstrated the importance of the evaluation of

a situation to explain level of quality of life or stress (Amerigo & Aragonés, 1997; Lazarus & Folkman, 1984). It is not only the objective attributes of the environment that favor quality of life and well-being or, conversely, the appearance of stress but also the individual's evaluation of these attributes made on the basis of personal and psychological characteristics (Fleury-Bahi et al., 2013). Previous research has shown that environmental perceptions could be stronger predictors of perceived health and quality of life than objective measures (Ellaway et al., 2001; Parra et al., 2010; Wen et al., 2006).

Going further, Model 2 helped us to identify a link between well-being and perceived availability of a collective or community garden, but no link with possession of a private garden. Indeed, a recent systematic review on community gardens (Genter et al., 2015) revealed that community gardening reduces stress, contributes to a healthier lifestyle, and generates social opportunities. More precisely, community gardens, unlike private ones, serve as a source of socialization and creation of social bonds and support (see Draper & Freedman, 2010, for a review). Taking the example of allotment gardens, which are a subtype of the more general category of community gardens, van den Berg, van Winsum-Westra, et al. (2010), after checking whether individuals had access to a garden at home, found impacts of allotment gardening on health and well-being, especially among older respondents. It is possible that this social dimension of community gardens contributes to explaining their role in enhancing well-being compared with private ones.

Our study also explores the link between connectedness to nature and well-being, and the moderating role of connectedness to nature on the association between contact with nature and well-being. Indeed, the links between contact with nature and well-being are complex, and one way to improve understanding of this phenomenon is to focus on individual differences and, more precisely, on connectedness to nature, which is the self-perceived relationship between the self and the natural environment. Thus, we hypothesized that individual well-being is positively associated with connectedness to nature and that the positive effect of the perceived amount of nature near the home on well-being is moderated by the individual's level of connectedness to nature. According to our hypothesis, our results show that the level of connectedness to nature contributes significantly to well-being: The more the individual is connected to nature, the higher the level of well-being they declared. This is in agreement with a number of other studies that highlighted this link (e.g., Cervinka et al., 2012; Howell et al., 2011; Navarro et al., 2019; Wolsko & Lindberg, 2013), including an international study comparing five countries (Pasca et al., 2021). We also investigated the moderation by CN of the association between perceived amount of nature near the home and well-being and found a significant and negative interaction. When individuals have high CN, the association between the perceived amount of urban nature and well-being is weaker than for those with lower scores. Our results also suggest that this moderation of the association between PAN and WB by CN is the same regardless of city. This result is original and suggests that for people with high levels of connectedness, the quantity of perceived nature near the home necessary to observe a contribution to well-being is smaller than for people with a lower level of connectedness. It could be hypothesized that connectedness to nature, as an affective individual experience of contact with nature and the self-perceived relationship between the self and the natural environment, facilitates contact with and appropriation of natural elements and consequently its effects on well-being. Mayer and Frantz (2004) defined connectedness to nature as a feeling of kinship and an affective experience of connection with nature. Some authors assume that a biophilic disposition underlies connectedness to nature, proposing that connectedness to nature is universal with regard to the

relationship between one's self-image and nature (Mayer et al., 2009; Olivos-Jara et al., 2020; Schultz et al., 2004). One would, therefore, expect a positive link with well-being and, being a baseline, its effects could be observed by default rather than by presence. The fact that there are no differences between cities would support this idea. Consequently, people with a higher level of connectedness to nature will benefit most by the addition of even small urban green areas. At the same time, supporting connectedness to nature of people with low CN levels could be an interesting lever to increase their well-being. Thus, while further greening of cities represents significant potential for health (e.g., air quality), just small additions of green spaces might have a big impact as far as well-being is concerned, depending on the level of connectedness to nature.

This study does, however, have some limitations, particularly because the characteristics of the sample do not allow access to generalizable results. Another limitation is that we could not control for socioeconomic status in the regression models as originally planned. This is an important limitation because this variable is known to have an impact on well-being. By controlling for it, we could have identified whether connectedness to nature had an effect independently of socioeconomic status. This control could not be performed because there were too much missing data for the questions that measured this variable. The findings need to be strengthened by ongoing research in the field and, for example, by experimental studies with virtual reality to test the effect of different categories and amounts of natural elements. The subsamples for each city are rather small. Therefore, although one strength of this study is the combination of objective indicators with subjective data collected with a questionnaire, it is not possible to conduct the analysis for each city and consider, for example, the role of cultural differences concerning gardening, appreciation of green and blue spaces, or social contact. Moreover, this appreciation is based on an evaluation of the quantity and not the quality of the elements of nature. It would indeed have been interesting to associate qualitative and quantitative assessment in our study.

CONCLUSION

The results highlight the importance of subjective appreciation of green and blue spaces in the neighborhood in terms of inhabitants' well-being. They also highlight the preponderant role played by the level of connectedness to nature. These results could be extended by experimental work that would operationalize nature in the city through augmented or virtual reality. In particular, this would allow identification of the elements of nature that are more specifically entailed. This would also offer the possibility to highlight the psychological processes involved. In terms of recommendations for policy and practice, it could, therefore, be interesting to take the subjective appreciation of these spaces and the perceived need for change by involving the people living in an area very early on in the process of urban development. Moreover, the importance of a social dimension in community gardening, which might explain the difference between the role of individual and collective gardens, suggests an opportunity to foster the well-being of city dwellers on a social as well as an individual level. Furthermore, environmental education promoting connectedness to nature could contribute to higher levels of well-being.

CONFLICT OF INTEREST

On behalf of all authors, the corresponding author states that there is no conflict of interest.

ETHICS STATEMENT

The authors complied with APA ethical standards (<https://www.apa.org/ethics/code>), in accordance with the ethics guidelines of the partner universities and laboratories. Participation in the research was voluntary and informed consent was obtained from all participants.

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available at <https://osf.io/m5etg/?direct%26mode=render%26action=download%26mode=render>.

ORCID

Ghozlane Fleury-Bahi  <https://orcid.org/0000-0002-0564-7298>

Jean-Michel Galharret  <https://orcid.org/0000-0003-2219-8727>

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APPENDIX

To begin, a few questions about you and your daily environment. This information is strictly confidential and anonymous.

Q1- Are you ...?

- Female
- Male

Q2- How old are you?

Q3- What is your highest level of education?

Q4- What is your current situation?

Q5- What is the name of your street? Please write your answer here:

The answer to this question is strictly confidential. It should allow us to identify more precisely the characteristics of the urban space that surrounds you.

Q6- Do you have a private garden?

- Yes
- No

Q7- Do you have access to a community or shared garden?

- Yes
- No

Q8- Are any green spaces (private or public) visible from your place of residence?

- Yes
- No

Q9- How would you describe your neighborhood? For each of the following elements, indicate whether you think they are rare or numerous (5-point scale from *very few* to *very many*):

- Buildings

- Green spaces
- “Wild” green spaces (river banks, wasteland, ...)
- Birds
- Public gardens or parks
- Vegetated surfaces (vegetated walls or roofs)
- Collective/shared gardens
- Aquatic spaces (river banks, lakes, ponds, ...)
- Insects

Q10- Place a check mark in the box that best represents experiences and feelings during the past month (from 1 *never* to 6 *always*). During the past month, how often did you feel ...

- happy
- interested in life
- satisfied with life
- that you had something important to contribute to society
- that you belonged to a community (like a social group, school, neighborhood, etc.)
- that you belonged to a community (like a social group, school, neighborhood, etc.)
- that our society is a good place, or is becoming a better place, for all people
- that people are basically good
- that the way our society works made sense to you
- that you liked most parts of your personality
- good at managing the responsibilities of your daily life
- that you had warm and trusting relationships with others
- that you had experiences that challenged you to grow and become a better person
- confident to think or express your own ideas and opinions
- that your life has a sense of direction or meaning to it

Q11- We all have a different relationship with nature. For each of the following statements, please indicate whether you agree or disagree with them (5-point scale: *strongly agree* to *strongly disagree*):

- I think of the natural world as a community to which I belong.
- When I think of my life, I imagine myself to be part of a larger cyclical process of living.
- I often feel a kinship with animals and plants.
- I feel as though I belong to the Earth as equally as it belongs to me.
- I often feel a sense of oneness with the natural world around me.
- I feel that all inhabitants of Earth, human and nonhuman, share a common “life force.”
- I often feel like I am only a small part of the natural world around me, and that I am no more important than the grass on the ground or the birds in the trees.