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Title

Understanding Correlates of Neighborhood Aesthetic Ratings: A European-based Four City Comparison

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Abstract

Evidence of associations between nature and health behaviors and health status is mounting. However, there is a need to deconstruct "natural space" to capture the qualities of green and blue space and the various ways people experience these natural outdoor environments. These experiences influence and sustain changes in health and social behaviors such as physical activity, diet, and social connectedness. In this paper, we examine the social, cultural, and emotional factors that influence people´s perceptions of natural outdoor environments, also referred to as neighborhood aesthetics. Using a population-based sample of 2948 adults in four European cities who participated in the PHENOTYPE study, we developed a quality-based aesthetics index of nearby nature to represent our study outcome. The scale had high internal consistency (Cronbach's alpha 0.86). We assessed its association with common measures of the natural environment (Normalized Difference Vegetation Index (NDVI)), and examined factors that may influence aesthetic ratings. Hypothesized correlates of neighborhood aesthetics including presence of and time in neighborhood nature, perceived environmental stressors and neighborhood social cohesion and attachment were generally confirmed. Contrary to our expectations, respondents born in the country of current residence rated neighborhood aesthetics lower than those born elsewhere and associations with length of residence were not consistent across countries. Interventions designed to influence social, cultural, and emotional processes could improve aesthetics ratings and potentially contribute to better health and wellbeing.

Keywords: Aesthetic ratings, Neighborhood environment, Natural environment, greenness, NDVI

1. Introduction

A large part of our health and well-being is affected by our environment. The residential neighborhood is an everyday environment where people spend a large part of their time and is therefore an important factor in our health (Diez Roux, 2001; Gong et al., 2016; Moore et al., 2018). Urban natural environments, such as parks, street trees, and urban forests have been found to be beneficial to health. Natural environments are thought to offer a place for mental restoration, stress reduction, physical activity, and social interaction (Frumkin et al., 2017; Markevych et al., 2017; Nieuwenhuijsen et al., 2017).

Research often focuses on physical aspects of the environment using characteristics including satellite-derived measures to quantify vegetation and the presence of parks derived from land use maps (Dinand Ekkel and de Vries, 2017). These measures do not provide information about people's perception and quality of natural environments, which is important for understanding why and how people use natural environments (Duncan et al., 2005; Gobster et al., 2007; Kruize et al., 2019; Root et al., 2017). Within the neighborhood context, perceived quality of everyday landscapes may provide information in addition to objective physical measures, but such information is not often used in research (Dinand Ekkel and de Vries, 2017; Frumkin et al., 2017; Litt et al., 2015, 2011; Root et al., 2017).

Perceived aesthetics of the neighborhood reflects tactile, emotional, and sensory processes people experience while being in their neighborhood (Hale et al., 2011; Root et al., 2017) and is a critical determinant of how people experience place. It can be operationalized by assessing people´s perception of the quality of the street-level natural (e.g., nearby nature such as street trees) and physical amenities (e.g., attractive buildings). It can also include water, although less prominent in the nature-health literature, it is an important physical and aesthetic landscape element that is health promotive (Gascon et al., 2017; Völker and Kistemann, 2011). Such subjective evaluations of people's living environment can influence people´s choices for how they use neighborhood space, including natural environments. That is, psychological and social processes can act like triggers that influence health behaviors,and in turn, contribute to physical health and mental wellbeing (Walton, 2014). Previous studies investigating perceived neighborhood aesthetics have thus far occurred in North America and Australia. These studies defined neighborhood aesthetics with various characteristics, for example attractiveness of buildings and landscaping, cleanliness, sights, street and garden maintenance, (quality of) nature, walkability, shade, and lack of incivilities (Ball et al., 2001; Handy et al., 2002; Pikora et al., 2003; Saelens et al., 2003; Sugiyama et al., 2010).

Most of these studies have shown that people's ratings of aesthetics influence proximal emotional and social processes such as place attachment and collective efficacy, respectively, and physical activity behaviors such as walking (Cerin et al., 2013; Humpel et al., 2004; Litt et al., 2015, 2011; Saelens et al., 2003) but do not go further to explain the factors that influence these aesthetic ratings. Root and others (2017)

showed, within the US context, that people's ratings of neighborhood aesthetics are influenced by perceived and observed incivilities, perceived walkability, area-level poverty, foreclosures in the neighborhood, and level of greenness (Root et al., 2017). Environmental stressors such as noise and air pollution, but particularly negative evaluations of such stressors can result in poor ratings of neighborhood aesthetics (Honold et al., 2012). Also individual characteristics that might influence how people interact with their neighborhood, such as dog ownership and length of residence are thought to be positively associated with neighborhood aesthetics as they contribute to place attachment and neighborhood social cohesion (Root et al., 2017; Schipperijn et al., 2010). Furthermore, childhood nature experience might shape nature-oriented attitudes and preferences in adulthood (Asah et al., 2018; Preuß et al., 2019; Thompson et al., 2008; van den Berg et al., 2016) and might affect neighborhood aesthetics ratings too. Along these lines, people´s aesthetic ratings may vary across immigrant status, which may influence cultural preferences by different ethnic and native groups for nearby nature and physical attractiveness of street environment (Peters et al., 2010).

Current environmental and health challenges underscore the need for aligning neighborhood aesthetics, the nearby residential environment, and health. Standard measures of vegetation density such as the Normalized Difference Vegetation Index (NDVI), that do not capture quality and do not distinguish between vegetation type, are not sufficient in assessing the role of the natural environment on health (Dinand Ekkel and de Vries, 2017; Reid et al., 2017). Such measures are often quantified within circular buffers around the residence assuming that captures one's neighborhood, but this may not be accurate or sufficient to explain the link between nearby nature and health. Street-level microenvironments, or residents' perceptions of their local neighborhood might be more relevant (Reid et al., 2018; Root et al., 2017). The use of a measure that captures neighborhood aesthetics could improve our understanding of how people relate to natural environments and how this influences pro-environmental and pro-health behaviors (Gobster et al., 2007). Identifying driving factors of neighborhood aesthetics that we can intervene upon and measure and monitor in the short term could result in more proximal benefits and eventually improve health status over time. That is, rather than expecting changes, for example in body mass index from a park renovation, during the first six months of an intervention, one might measure changes in attitudes about the environment in which residents live, perceptions of safety near their homes, and levels of involvement in civic activities such as attending community meetings (Walton, 2014) as early indicators of impact.

Knowledge of people's experiences of certain landscapes and how these experiences influence their behavior and health could provide clues for creating and sustaining healthy neighborhoods. Exploring connections between perceptions and experiences of landscape quality, and behavior will be useful for urban planners and practitioners, helping to inform their decisions about neighborhood landscape changes that address health promoting processes (Daniel, 2001; Gobster et al., 2007; Jorgensen, 2011). We aimed to investigate the patterns of perceived neighborhood aesthetics and associated

factors in four European cities. We hypothesize that objective nearby nature and nature visits, long length of residency, neighborhood attachment and neighborhood social cohesion, dog ownership, childhood nature exposure and being a native-born citizen are associated with high neighborhood aesthetics ratings. Environmental stressors including neighborhood incivilities, traffic noise annoyance and air pollution worries are hypothesized to be associated with low neighborhood aesthetics ratings. Our main outcome, the aesthetic ratings index, is derived from 13 survey items relating to people´s perceptions of the quality of nearby nature. Included items mapped to different measures of aesthetics including overall natural quality of street, neighborhood and views; appeal of area during commute (sounds, colors, views, familiarity, nature contact, ecological and aestheticvariety), satisfaction with nearby nature quality, maintenance, and safety.

2. Methods

2.1 Study Population

We used a population-based sample of adults from four European cities who participated in the Positive Health Effects of the Natural Outdoor environment in Typical Populations in different regions in Europe (PHENOTYPE) study. Respondents were recruited in Barcelona (Spain), Doetinchem (the Netherlands), Kaunas (Lithuania), and Stoke-on-Trent (United Kingdom). The study areas are diverse in terms of size, population density, climate and land cover (Smith et al., 2017). Doetinchem, the smallest city (56,000 inhabitants) also has the lowest population density (706 inhabitants/km^2) and has a moderate maritime climate. Kaunas (319,000 inhabitants) has a humid continental climate and has a population density of 2046 inhabitants/km^2. Stoke-on-Trent (363,000 inhabitants) has a population density of 1194 inhabitants/km^2 and has a moderate maritime climate. Barcelona is the largest city (1.6 million inhabitants) of the four, is densely built (population density 16,000 inhabitants/km^2), and has a Mediterranean climate. Greenness and access to natural outdoor environments (NOE) varies per city, with Doetinchem being the greenest city with the best NOE access, and Barcelona being the least green city with poorest NOE access (Smith et al., 2017). In each city, 30-35 neighborhoods were selected to have variability in access to NOE and socioeconomic status. Then, a random sample of 30–35 adults aged 18–75 were then invited to participate per neighborhood. Data were collected via a face-to-face questionnaire administered at respondents' homes (postal questionnaire in Kaunas) during May-November 2013. This study was based on respondents that received all questions regarding neighborhood aesthetics (n=2988) and excluding those with missing data, resulting in a study sample of n=2948. The study was conducted in accordance with the Declaration of Helsinki. All respondents provided written informed consent and study protocols were approved by local ethics committees (Nieuwenhuijsen et al., 2014).

2.2 Data

2.2.1 Aesthetics index items

The PHENOTYPE questionnaire survey aimed to investigatethree mechanisms in relation to natural environments and health: physical activity, stress and restoration and social interactions. The choice of NOE indicators was based on these three mechanisms and was achieved via an interactive process of experts in the project team. Questions were derived from existing and validated questionnaires as much as possible, some tailored to the specific objectives of PHENOTYPE. The first questionnaire section "*residential situation in terms of green and blue*" contained questions about availability, use, perceived quality and satisfaction of/with green and blue space at different levels of the residential environment (e.g. street, neighborhood). Candidate items for the aesthetics index arose from this section and contained four main questions, each of which had several sub-questions:

1. Perceived amount of greenness and blue space (street, neighbourhood, window view)
2. Appeal of natural areas during commuting (sounds, colours, view, familiarity, nature contact, nature variety, safety)
3. Neighborhood NOE satisfaction (quality, amount, maintenance, safety)
4. Overall satisfaction with most visited NOE

2.2.2 Correlates of neighborhood aesthetics

2.2.2.1 Individual sociodemographic information

Information about sociodemographic and other individual characteristics included sex, age, educational level (no education or primary school; secondary school/ further education (up to 18 years); university degree or higher), perceived income situation (cannot make ends meet; enough to get by; comfortable); country of birth (in country of residence; outside country of residence); length of residence; and dog ownership (yes; no).

2.2.2.2 Self-reported environmental perceptions and objective streetscape data

We included self-reported information about the time spent in NOE (hours/month); the degree of NOE experience during childhood (never; sometimes; regularly; often; very often); neighborhood attachment (scale 0-12; higher is more attachment) (Ruijsbroek et al., 2017b); and neighborhood social cohesion (scale 0-20; a higher score indicates higher levels of perceived cohesion) (Ruijsbroek et al., 2017b; Sampson et al., 1997). Traffic noise annoyance and air pollution worries were both assessed on a scale ranging from 'not at all' (0) to 'extremely annoyed/worried' (10) (International Organization for Standardization ISO, 2003). The response scale of these two questions was transformed into a scale from 0 to 100. Streetscape audit data were used to assess the degree of incivilities (7 items e.g. litter, alcohol abuse, graffiti, vandalism) and the amount of natural features (6 items e.g. the fraction of visible gardens, garden size, number of trees, size of public green spaces) within neighborhoods. Audits were carried out during April-

August 2013 by two trained auditors in each neighborhood and in a selection of streets that contained rare, but important and characterizing features of the neighborhood (Ruijsbroek et al., 2017b, 2017a).

2.2.2.3 Objective NOE and neighborhood SES data

Data from a geographic information system (GIS) included neighborhood socioeconomic status (SES, low; intermediate; high; based on country-specific data), straight-line distance to nearest NOE, and the number of green spaces in a 300m road network buffer (Smith et al., 2017). Residential surrounding greenness was assessed with the Normalized Difference Vegetation Index (NDVI). This is a measure of the level of vegetation in a certain area (Weier and Herring, 2000) and was derived from satellite images available from Landsat 5 and 8 at a resolution of 30 m×30 m. We obtained cloud-free images within the greenest season (April to September) in the relevant period for this study (2011-2013), and derived images from 21 July 2013 (The Netherlands East), 8 June 2011 (Kaunas), 21 April 2011 (Stoke-on-Trent) and from 16 April 2013 (Barcelona area). Mean NDVI values within a 300m Euclidean buffer around the residence were calculated as estimates of neighborhood surrounding greenness (values ranging from -1 to +1; higher values reflect higher vegetation density). Large waterbodies were excluded before NDVI calculations because of their negative values (Smith et al., 2017). In addition, we constructed another measure of residential surrounding greenness by excluding large green spaces (≥0.25 ha) represented in land cover maps (Urban Atlas 2012 and local data) from the NDVI images, while retaining smaller green spaces, tree cover and street-level vegetation. This second measure of residential surrounding greenness, the NDVI-LITE, captures street-level greenness and might reflect a proximal level of greenness that is more related to neighborhood aesthetics than the standard NDVI (Root et al., 2017). NDVI and NDVI-LITE images for the four cities are shown in Figure 1.

2.3 Development of the aesthetics index

2.3.1 Item selection and internal consistency

Relevant variables for the aesthetics index were a priori selected and theory-informed and had face validity (Root et al., 2017). Preference was given to questions about the direct living environment (e.g. street and neighborhood) instead of questions about more distal environments (e.g. city). We calculated the Cronbach's alpha when putting all items together and for the subscales to assess the internal consistency of the scale(s) (i.e. the extent to which items within a scale are correlated with each other). We also calculated the item-rest correlation to assess the correlation between one item and the scale that is formed by all other items (the rest) (data not shown). A principal component analysis (PCA) was conducted to summarize multidimensional correlated data and to determine the underlying structure of the data by identifying latent variables or components. The choice of how many components to retain was based on the eigenvalues of the components, which should be >1.0. The Kaiser–Meyer–Olkin

(KMO), a measure of sampling adequacy, was 0.88 and indicated that a PCA is deemed appropriate and should result in distinct and reliable factors (Nardo et al., 2008). The PCA identified three components that explained 64% of the variance in the data, and were consistent with the scales of which the items originally were derived from.

Two items with low factor loadings and low item-rest correlation were dropped (safety of NOE commuting route and overall satisfaction of most visited NOE). The final aesthetics index consisted of 13 items. Scales of the individual items, that were all on a 1-5 Likert scale, were normalized and summed. No weighting of items was applied (i.e., all items had the same weight), resulting in an index ranging from 13 to 65 (higher is higher aesthetic value). The Cronbach's alpha's of the subscales ranged from 0.78 to 0.90 and was 0.86 for all items together (Table 1).

2.4 External validation: Correlates of neighborhood aesthetics

Spearman's correlation coefficients were calculated for the aesthetics index and numerical study variables. Pooled linear multilevel (random intercept for city and neighborhood) and city-specific multilevel models (random intercept for neighborhood) were used to analyze associations between individual and neighborhood characteristics, and the aesthetics index. Unadjusted and multivariate analyses (adjusted for age, sex, education level, perceived income situation and neighborhood SES) were conducted. Finally, the pooled multivariate models were additionally adjusted for road traffic noise annoyance and air pollution worries to account for city-level differences in perceived environmental stressors. All analyses were based on complete cases. Associations were considered statistically significant if the 95% confidence intervals did not include zero. All analyses were performed in STATA 14.2 (StataCorp, 2015).

3. Results

3.1 Population characteristics

Population characteristics for the pooled sample and cities are shown in Table 2. Among the 2948 respondents, 55% were female, the median age was 56 years (interquartile range (IQR) 25), and the majority were highly educated (i.e., university degree or higher) (55%). Respondents from Doetinchem, compared to respondents from the other cities, had the highest amount of average residential surrounding greenness (NDVI), the shortest distance to NOE, and spent most time in NOE. By contrast, respondents from Barcelona had the lowest amount of average residential surrounding greenness and street-level greenness (NDVI and NDVI-LITE), the largest distance to NOE, and the lowest amount of neighborhood natural features (based on audits) compared to the other cities. Neighborhood incivilities audit scores were similar across Barcelona, Kaunas and Stoke-on-Trent, but there were fewer incivilities in Doetinchem compared to the other cities. Neighborhood social cohesion and attachment were similar across the cities, except in Kaunas, where attachment was lower than in the other cities. Overall, almost 57% of the respondents reported that they 'often' or 'very often' spent time in NOE during childhood, and this was highest among Doetinchem respondents

(76%) and lowest among Stoke-on-Trent respondents (45%). Traffic noise annoyance and air pollution worries were highest among Barcelona respondents and lowest among respondents from Stoke-on-Trent and Doetinchem.

3.2 Aesthetics index

The median aesthetics rating was 49 (IQR 11), and was highest in Doetinchem (53) and lowest in Barcelona (45). Overall, respondents from Doetinchem rated individual aesthetic items more positively than respondents from other cities (Table 1, Figure 2). More specifically, respondents from Doetinchem rated the amount of nature in their street and neighborhood much higher than the respondents from the other cities. Ratings from respondents from Barcelona on their satisfaction with the amount and quality of nature in the neighborhood and the natural views from their windows were low compared to the other cities (Table 1, Figure 2).

3.3 Correlates of neighborhood aesthetics

A correlation matrix, displaying correlations between the aesthetics index and its correlates (continuous variables only) is shown in Table 3. Incivilities, traffic noise annoyance, air pollution worries and the distance to nearest NOE correlated negatively with aesthetics ratings, while objective indicators of neighborhood greenness and visits to NOE, neighborhood attachment and social cohesion all showed positive correlations with the aesthetics index. NDVI correlated more strongly with the aesthetics index than NDVI-LITE. Incivilities, traffic noise annoyance, air pollution worries and the distance to nearest NOE correlated negatively with the other correlates, but positively with each other. Objective indicators of neighborhood greenness were mostly positively correlated with the other correlates, but interestingly not with neighborhood attachment and social cohesion. Table 4 displays correlations between the aesthetics index and its correlates by city. Correlates of aesthetics differed by city: incivilities were important in Stoke-on-Trent and Barcelona, but not in the other cities. While the objective indicators of neighborhood greenness were important in Doetinchem, Stoke-on-Trent and Barcelona, time spent in NOE was the most important greenness exposure in Kaunas. The NDVI correlated more strongly with the aesthetics index than did the NDVI-LITE, especially in Stoke-on-Trent. Neighborhood attachment and social cohesion were important across all cities, but were statistically more important for aesthetics ratings in Doetinchem and Stoke-on-Trent. The negative correlations between traffic noise annoyance, air pollution worries and aesthetics were highest in the cities with the lowest average noise annoyance and air pollution worries: Stoke-on-Trent and Doetinchem.

3.4 Multilevel analysis

Unadjusted associations between all correlates (including categorical variables) and aesthetics ratings are shown in Table 5. Pooled analyses showed that characteristics associated with higher aesthetics ratings included high neighborhood socioeconomic status, age, a comfortable perceived income situation, presence of and time in neighborhood nature (amount of natural features, number of green spaces, residential

surrounding greenness and street-level greenness, time spent in NOE), neighborhood social cohesion and attachment. Characteristics associated with lower aesthetic ratings were incivilities, traffic noise annoyance, air pollution worries, and being native-born. However, gender and education level were not associated with aesthetics ratings.

City-specific analyses showed that characteristics associated with these ratings differed among the four cities (Table 5). For example, among respondents from Doetinchem, childhood neighborhood experience was a major driver of aesthetics ratings. While a longer length of residency was associated with lower aesthetics ratings in Doetinchem, it showed a positive relationship with aesthetics in Kaunas and Stoke-on-Trent, but no association was observed for the Barcelona sample. For Kaunas respondents, female sex (versus male) was related to lower aesthetics ratings, and dog ownership (versus not owning a dog) was related to higher aesthetics ratings. Among respondents from Stoke-on-Trent, indicators of presence of and time in neighborhood nature were not consistently related to aesthetics ratings. For Barcelona respondents', neighborhood socioeconomic status, neighborhood incivilities, country of birth, and perceived income situation were not related to aesthetics ratings. Finally, NDVI-LITE showed more consistent associations with aesthetics ratings in Doetinchem and Barcelona compared to NDVI, while NDVI-LITE showed weaker associations with aesthetic ratings in Kaunas and Stoke-on-Trent when compared to the NDVI.

After adjustment for age, sex, education level, perceived income situation, and neighborhood socioeconomic status, most of the correlates of neighborhood aesthetics ratings remained (Table 6). However, neighborhood incivilities were no longer associated with aesthetics ratings after the adjustments and length of residency only remained a correlate of aesthetics in Doetinchem. Childhood nature experience and country of residence became stronger correlates of aesthetics ratings after adjustments. Additional adjustment for traffic noise annoyance and air pollution worries did not substantially change the results (Table 7).

4. Discussion

Neighborhood aesthetics describing tactile, emotional and sensory processes that people experience, was rated highest in Doetinchem and lowest in Barcelona. As expected, presence of and time in neighborhood nature, perceived environmental stressors, neighborhood social cohesion and neighborhood attachment were correlates of neighborhood aesthetics. These factors related to neighborhood aesthetics in all four cities, despite the differences among them in, for example, population density, greenness, and climate. Unexpectedly, native-born respondents had lower aesthetics ratings than those born elsewhere. Incivilities, childhood nature experience, dog ownership and length of residence were not consistently associated with neighborhood aesthetics in the four cities and its relevancy for neighborhood aesthetics might be context dependent.

To our knowledge, this is the first study that describes neighborhood aesthetics in European cities and broadens the assessment of aesthetics ratings to include blue spaces. Previous studies from North America and Australia defined neighborhood aesthetics using for example attractiveness of buildings and landscaping, cleanliness, street and garden maintenance, (quality of) nature, walkability, shade, and lack of incivilities (Ball et al., 2001; Handy et al., 2002; Pikora et al., 2003; Saelens et al., 2003; Sugiyama et al., 2010). The focus of these previous studies was however on how neighborhood aesthetics affected walking and other health behaviors. Our aesthetics index included items that tap into the tactile, emotional, and sensual processes people experience in the neighborhood context, hypothesizing that nature can impact health and well-being and that it operates through landscape experiences, not just the presence of nature (Root et al., 2017). Neighborhood aesthetic ratings add more information about the nearby nature experience for residents, which is not captured using only objective NOE indicators. Moreover, we showed that even in Barcelona, the city with the least nearby nature, this type of measure helps to show that people can still appreciate their environment even if objectively, it is not very green or blue. Our study further showed that the mechanisms of change are proximal, through social relationships (as shown with neighborhood attachment and social cohesion) and direct experience (the time spent in nature).

Correlates of aesthetics observed in our study are partly in agreement with those from a previous study in Denver (Root et al., 2017). Similar to our study, a higher amount street-level nature was related to higher aesthetics ratings. Similarly, a recent study investigating the aesthetics (defined as the beauty of the scenery) of landscape images showed that aesthetic preference increased with the increase of number of trees and presence of flowers, water and fish in the images (Wang et al., 2019). In Denver, the authors also found that both objectively measured and perceived incivilities were important for predicting aesthetics ratings (Root et al., 2017). We observed that incivilities (as assessed by auditors) were only related to aesthetics ratings in Stoke-on-Trent, which was the city with the most incivilities, and only in the unadjusted analyses. This might be explained by the relatively low incivilities score in our cities, compared to Denver. The other studied environmental stressors, traffic noise annoyance and air pollution worries, were associated with lower neighborhood aesthetics ratings in all four cities and confirmed previous research (Honold et al., 2012).

Neighborhood social cohesion and attachment were strongly correlated with aesthetics, but not with objective indicators of greenness. The importance of neighborhood social cohesion and attachment for environmental quality was found in studies from several countries, which showed that everyday public spaces are an important resource for social interaction, and for creating a sense of community and place attachment (Cattell et al., 2008; Francis et al., 2012; Knight Foundation, 2010; Litt et al., 2015; Peters et al., 2010). Moreover, a Dutch study showed that social cohesion was an important mediator of the relation between (quantity and quality of) streetscape greenery and health (de

Vries et al., 2013). Thus, aesthetics, social processes and health in neighborhoods are strongly connected.

Unexpectedly, in our fully adjusted models, native-born respondents had, on average, lower aesthetics ratings than those born elsewhere. Reasons why native-born respondents rated neighborhood aesthetics lower than those born elsewhere are unclear. It is known that there are cultural differences in landscape preferences and their use and these often reflect values established earlier in childhood while living in the country of origin (Buijs et al., 2009; Gentin, 2011). We do not, however, have the data to explore the mechanism behind this association further. The number of respondents born outside the country of origin was low, probably due to our inclusion criterion for study participants that needed to speak the local language fluently, which makes the influence of birth place difficult to understand. Nevertheless, this shows that cultural differences, which might vary by social and ethnic groups, is an important factor to take into account when studying neighborhood aesthetics and when designing equitable neighborhood-based interventions to encourage healthy behaviors (de la Barrera et al., 2016; Root et al., 2017).

The relationship between length of residency and aesthetics ratings was inconsistent. As found previously, such factors are associated with neighborhood attachment, and were therefore hypothesized to correlate with neighborhood aesthetics (Comstock et al., 2010; Root et al., 2017). Residential mobility is much lower in Europe compared to the US (Caldera Sánchez and Andrews, 2011) and might therefore be less important for neighborhood aesthetics in an European context. Dog ownership has been associated with visits to neighborhood parks and neighborhood walking (Schipperijn et al., 2010; Zijlema et al., 2019), but was not consistently associated with aesthetics ratings in our study. Furthermore, childhood nature exposure could shape nature-oriented attitudes and preferences in adulthood (Asah et al., 2018; Preuß et al., 2019; Thompson et al., 2008; van den Berg et al., 2016), but childhood nature exposure was only associated with aesthetics ratings in the Doetinchem sample, which had the highest nature exposure.

We found no evidence that the NDVI-LITE, representing street-level greenness was more strongly associated with aesthetics ratings than residential surrounding greenness (NDVI) that included parks and other large green spaces. This is different from what was previously reported in a study in Denver (Root et al., 2017) and previous literature that suggests that humans engage with environmental phenomena at a very proximal scale, one that aligns with the human “perceptible realm” (Gobster et al., 2007). The interactions within this realm, according to Gobster and others, can give rise to aesthetic experiences and lead to subsequent active and healthy lifestyles. The NDVI-LITE version may offer planners and other practitioners a way to more closely represent street-level greenness, moving a step closer to aligning objective measurements with the scale in which people experience natural environments and how they perceive and interact with their neighborhoods, but needs to be studied further.

Limitations of this study include the potential selection bias that occurred due to the use of questions about the quality of natural environments while commuting through those areas (question 2 in the aesthetics index). This question was only answered by respondents that indicated to pass through natural environments and therefore respondents that live or work in less natural areas might have been excluded. It might therefore be difficult to extrapolate these findings to other populations. The NDVI-LITE is meant to capture vegetation outside major green spaces such as street-level vegetation, but the ability to capture street-level vegetation with Landsat 5 and 8 imagery in our study area needs to be further validated. Other types of tree canopy indices could be used to further investigate street-level greenness, neighborhood aesthetics and health. The cross-sectional nature of this study does not allow for determining causal effects. This could mean that neighborhood aesthetics are associated with all the factors studied here, instead of the other way around. Lastly, information we used to construct the aesthetics index might not be available in other studies and this makes replication of our results challenging. We furthermore acknowledge that other information for construction of the aesthetics index (e.g. attractive buildings in the neighborhood) as well as correlates of neighborhood aesthetics (e.g. walkability, ethnicity) that has not been studied here might be important too, but these data were not available in this study.

This study describes a unique and rich dataset on perceptions and evaluations of one's natural outdoor environment. The development of a neighborhood aesthetics index based on prior knowledge and empirically using statistical validation methods is the main strength of this study. The index contains information from 13 questions relating to neighborhood aesthetics, leveraging more information about the aesthetic experience than a single quality question could. The index has good internal consistency, indicating the measurement of a single uni-dimensional construct. Creating a neighborhood aesthetics index that represents a multifaceted construct rather than just the presence or absence of nature could eventually lead to a better understanding of the health benefits of nature. Another benefit of this index is that it refers to the residents' perceived neighborhood instead of a certain buffer around the residence that could be too artificial and does not reflect the actual living environment (Reid et al., 2018). We further used an adaptation of the NDVI measure that excluded large parks and natural areas and thus was focused on smaller green spaces and street greenery. The idea was to more closely relate it to aesthetics ratings than the traditional NDVI measure and thus could provide a more sensitive measure to assess health benefits of nature in the absence of self-reports on neighborhood aesthetics, but this needs confirmation in future studies. Finally, the use of data from four different cities enabled us to evaluate correlates of aesthetics across different places in Europe. Future studies need to look beyond the amount of nature and should examine other perceptual and qualitative factors influencing aesthetics ratings, that we can intervene upon and measure and monitor in the short term and could result in more proximal benefits and eventually improve health status over time. Our study showed commonalities and differences in correlates of aesthetics across

contexts, showing that each city needs to develop its own lens through which one can explore the factors that influence people's ratings of aesthetics.

5. Conclusions

Presence of and time in neighborhood nature, and neighborhood social cohesion and attachment appeared to be major correlates of neighborhood aesthetics. Intervening on such factors, by implementing interventions and policies that encourage place- and people-based connections and engagement, could improve people's aesthetics ratings.

Declaration of interests

☒ The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

☐The authors declare the following financial interests/personal relationships which may be considered as potential competing interests:

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Figure 1. Surrounding greenness (NDVI; left panels) and street-level greenness (NDVI-LITE; right panels) for the same areas. Black dots refer to respondents' residence. 1: Barcelona, 2: Doetinchem, 3: Kaunas, and 4: Stoke-on-Trent.

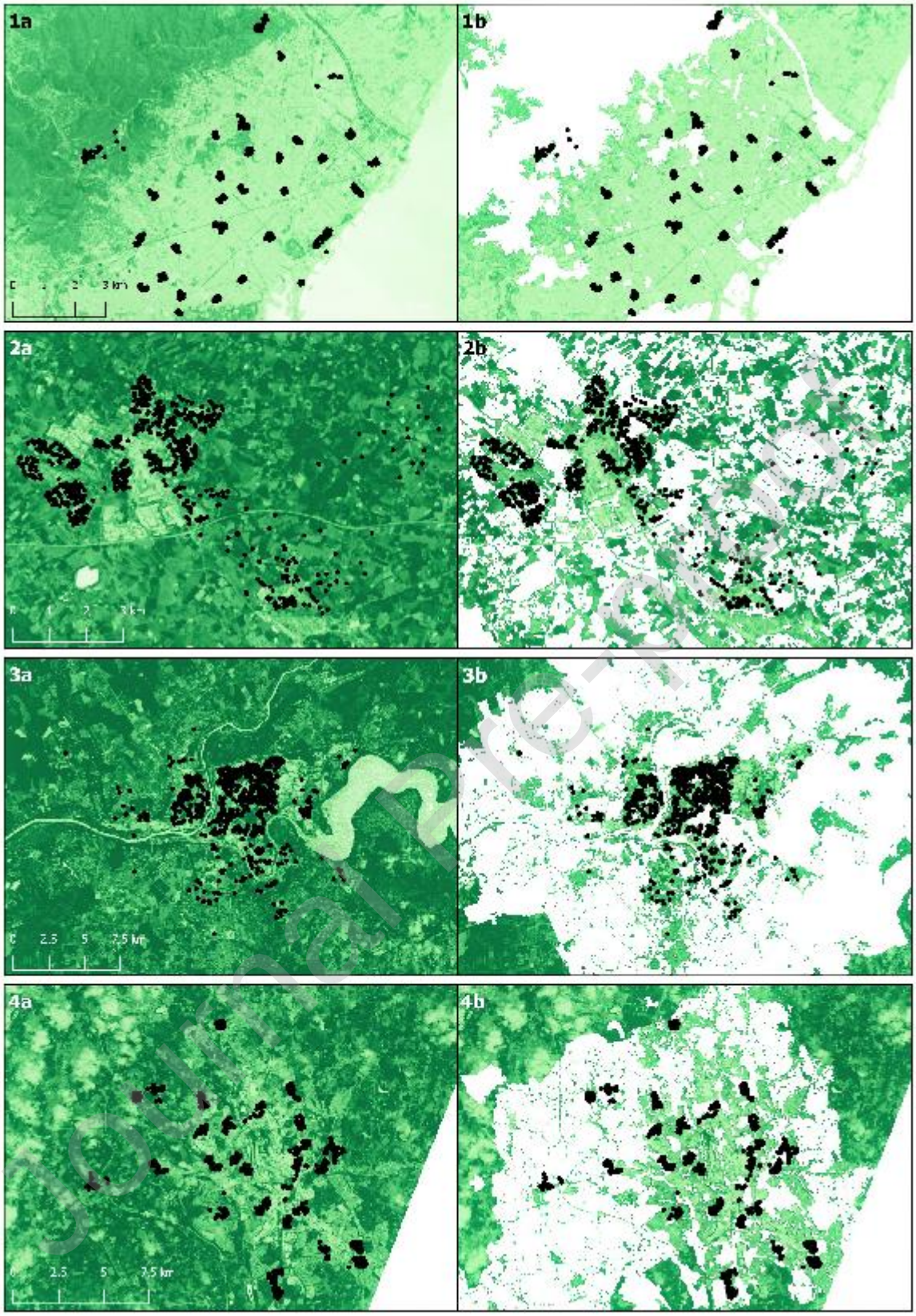

Figure 2. A spider web visualization of the neighborhood aesthetics index items and scores by city. Note. NBH=neighborhood

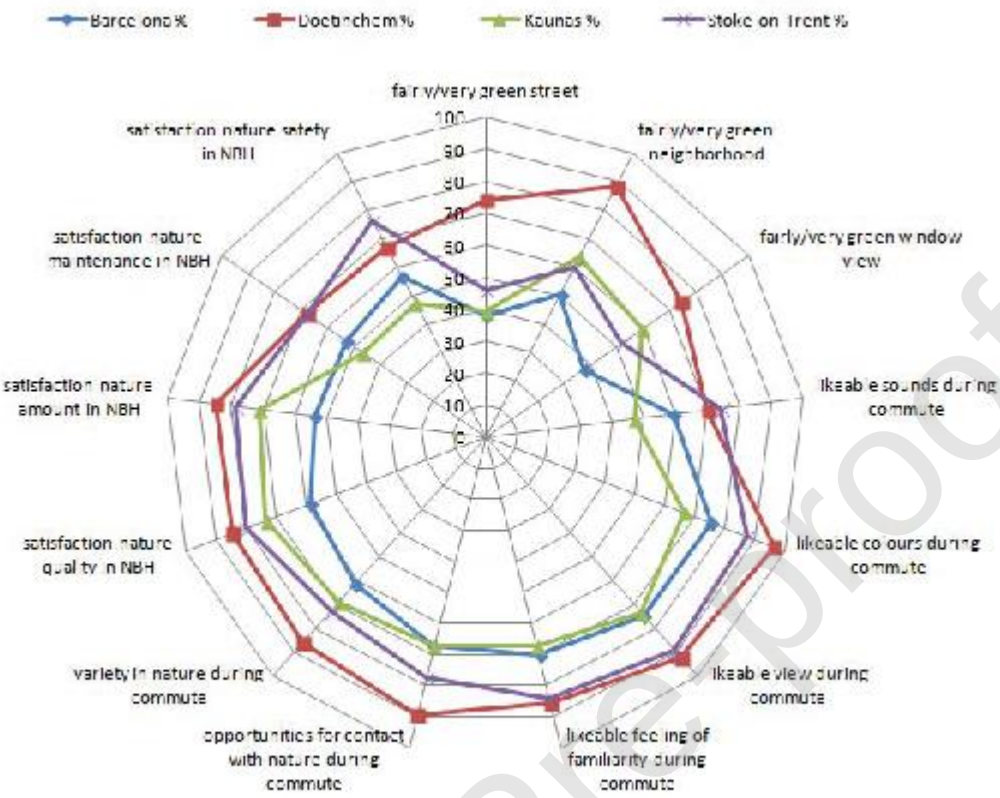

Table 1. Items neighborhood aesthetics index

		categories	Total %	Doetinchem %	Kaunas %	Stoke-on-Trent %	Barcelona %	*Cronbach's alpha*
	Amount of NOE in your living environment							
Q1a	NOE street	not at all	11.1	1.6	10.6	12.4	21.4	
		a little	21.4	15.2	18.8	25.3	29.3	
		neutral	17.8	9.1	31.1	16.1	11.3	
		fairly	34.9	44.1	31.8	33.0	30.0	
		very	14.8	30.0	7.7	13.1	7.9	
Q1b	NOE neighborhood	not at all	3.5	0.5	5.0	5.0	3.8	
		a little	14.7	5.8	7.1	19.7	31.4	
		neutral	15.3	5.4	24.5	15.2	14.5	*0.90*
		fairly	44.0	45.7	48.8	40.7	37.8	
		very	22.6	42.7	14.6	19.5	12.6	
Q1c	NOE view from home	not at all	11.8	3.2	3.2	14.9	30.6	
		a little	15.6	13.2	11.6	19.0	21.3	
		neutral	15.7	9.3	25.7	14.3	10.6	
		fairly	31.6	31.3	39.0	30.3	23.3	
		very	25.3	43.0	20.5	21.5	14.2	
	Appeal of areas during							

	commuting….							
Q2a	I like the sounds	strongly disagree	4.1	1.6	6.3	1.8	5.5	
		disagree	10.1	6.5	15.7	4.5	10.1	
		neutral	25.3	21.9	31.1	19.5	25.1	
		agree	43.4	47.9	35.2	53.9	42.7	
		strongly agree	17.1	22.1	11.7	20.4	16.6	
Q2b	I like the colors	strongly disagree	1.1	0.0	1.9	1.1	1.2	
		disagree	2.5	0.5	2.2	1.6	5.6	
		neutral	16.3	3.1	29.5	9.7	17.7	
		agree	55.5	63.1	45.6	63.8	54.8	
		strongly agree	24.7	33.3	20.9	23.8	20.6	
Q2c	I like the view	strongly disagree	1.2	0.1	2.2	1.1	1.1	*0.85*
		disagree	3.2	0.6	2.8	1.8	7.5	
		neutral	14.3	7.2	21.5	7.9	16.6	
		agree	53.5	55.8	49.2	62.4	51.3	
		strongly agree	27.7	36.3	24.2	26.7	23.5	
Q2d	I like the feeling of familiarity	strongly disagree	1.2	0.1	1.8	1.1	1.5	
		disagree	5.1	2.0	6.0	2.3	9.0	
		neutral	18.1	12.3	25.0	12.4	19.2	
		agree	51.3	55.0	46.7	55.4	50.6	
		strongly agree	24.4	30.6	20.6	28.7	19.7	

Q2e	Opportunities to make contact with nature	strongly disagree	1.4	0.3	2.1	0.9	1.9	
		disagree	6.4	2.9	6.3	6.3	10.5	
		neutral	17.3	7.5	24.5	15.4	20.2	
		agree	48.6	48.8	46.0	55.2	47.8	
		strongly agree	26.3	40.6	21.2	22.2	19.7	
Q2f	Sufficient variety in terms of plants, water, views	strongly disagree	1.9	0.3	2.9	1.4	2.6	
		disagree	8.7	3.8	7.8	9.5	14.9	
		neutral	17.0	9.9	20.3	16.5	21.0	
		agree	50.0	53.8	47.2	57.7	44.9	
		strongly agree	22.4	32.2	21.7	14.9	16.6	
	Satisfaction with							
Q3a	Neighborhood satisfaction NOE quality	very dissatisfied	1.7	0.7	1.4	1.1	3.6	
		dissatisfied	11.0	4.2	11.8	9.1	18.6	
		neutral	13.6	10.4	13.5	9.7	19.5	*0.78*
		satisfied	57.2	59.0	66.3	51.8	46.8	
		very satisfied	16.6	25.7	7.1	28.3	11.6	
Q3b	Neighborhood satisfactio	very dissatisfied	1.8	1.0	1.3	1.1	3.8	

	n amount of NOE							
		dissatisfied	12.8	5.2	12.2	10.0	23.7	
		neutral	13.7	9.1	15.5	10.2	18.8	
		satisfied	53.1	52.3	62.8	54.5	40.5	
		very satisfied	18.6	32.5	8.3	24.2	13.1	
Q3c	Satisfaction with NOE maintenance	very dissatisfied	3.5	1.8	4.1	3.2	4.6	
		dissatisfied	19.6	10.9	30.3	13.1	19.1	
		neutral	19.8	19.2	19.1	16.3	23.3	
		satisfied	47.3	53.9	44.2	47.3	43.8	
		very satisfied	9.9	14.1	2.3	20.1	9.1	
Q3d	Satisfaction with NOE safety	very dissatisfied	2.7	2.2	2.6	2.3	3.7	
		dissatisfied	16.5	11.3	26.5	8.1	14.3	
		neutral	21.4	19.7	23.4	13.4	25.5	
		satisfied	51.5	57.4	44.8	57.9	49.7	
		very satisfied	7.9	9.4	2.6	18.3	6.8	
Aesthetics index (scale 13-65)		**median (IQR)**	**49 (11)**	**53 (7)**	**47 (10)**	**49 (9)**	**45 (13)**	***0.86***

NOE: natural outdoor environment

Table 2. Population characteristics

	Total n=2948	Doetinchem n=816	Kaunas n=957	Stoke-on-Trent n=442	Barcelona n=733
Aesthetics index, median (IQR)	49 (11)	53 (7)	47 (10)	49 (9)	45 (13)
SES NBH, %					
low	29.3	30.5	26.4	29.6	31.4
medium	39.7	39.7	47.4	35.3	32.1
high	31.1	29.8	26.1	35.1	36.6
Distance to nearest NOE (m), median (IQR)	105 (181.5)	44 (82)	114 (167)	83 (99)	279 (324)
Number of GS 300m (RNW), mean (SD)	1.46 (1.64)	2.75 (2.01)	0.93 (1.07)	1.32 (1.16)	0.82 (1.21)
Time spent in NOE (h/month), median (IQR)	4 (11.25)	10 (8.25)	4 (11.75)	4 (19.25)	4 (11.75)
Age, median (IQR)	56 (25)	56 (12)	59 (14)	45 (15)	44 (16)
Sex, %					
male	44.8	42.9	39.6	54.3	48.0
female	55.2	57.1	60.4	45.7	52.0
NOE childhood experience, %					
never	2	0.9	2.0	2.3	3.1
sometimes	12.2	6.4	8.8	52.9	15.0
regularly	23.4	16.4	33.0	26.0	16.8
often	20	28.7	24.7	15.8	26.6
very often	37.4	47.7	31.6	29.2	38.2
NBH attachment, median (IQR)	7 (3)	8.2 (2.3)	5.9 (2.4)	8.7 (2.4)	8.5 (2.3)
NBH social cohesion, median (IQR)	12.1 (3.5)	13.7 (3.3)	10.4 (2.9)	12.9 (3.7)	11.9 (3.1)

Education level, %					
low	4.7	1.1	1.8	4.3	12.6
medium	40.1	47.4	26.0	60.2	37.7
high	55.2	51.3	72.2	33.0	49.7
Born in this country, %					
yes	90.9	95.7	96.2	93.4	76.9
no	9.1	4.2	3.8	6.6	23.1
Time of residence (years), median (IQR)	17.1 (23.6)	15 (19)	27 (23)	11 (18)	13 (21)
Dog ownership, %					
yes	33.5	21.7	52.4	34.2	21.8
no	66.5	78.3	47.6	65.8	78.2
Audit Incivilities, median (IQR)	4 (4.25)	1.8 (1.9)	5 (3)	6 (4.3)	5.5 (3)
Audit amount of natural features, median (IQR)	15 (6.8)	16.5 (3.8)	16 (6)	15.5 (4.3)	7 (4)
NDVI (average in 300m residential buffer), mean (SD)	0.46 (0.16)	0.55 (0.09)	0.54 (0.07)	0.48 (0.08)	0.23 (0.11)
NDVI-LITE (average in 300m residential buffer), mean (SD)	0.40 (0.15)	0.47 (0.08)	0.51 (0.07)	0.42(0.08)	0.18 (0.06)
Traffic noise annoyance	30.8 (28.0)	22.3 (22.5)	33.8 (28.2)	20.3 (27.1)	42.5 (28.5)
Air pollution worries	37.0 (30.5)	21.6 (22.7)	41.2 (30.7)	21.1 (26.3)	58.1 (25.0)

NOE: natural outdoor environment; GS: green spaces RNW: road network NBH: neighborhood; NDVI: Normalized Difference Vegetation Index; NDVI-LITE: vegetation outside major green spaces.

Table 3. Correlations matrix aesthetics index and correlates (total sample n=2948)

	Aesthetics	Incivilities	Amount natural features	Distance to NOE	Number of GS	NDVI 300m	NDVI-LITE	Time in NOE	Age	NBH attachment	NBH social cohesion	Time of residence	Noise annoyance	Air pollution worries
Aesthetics index	1													
AUDIT incivilities	-0.29	1												
AUDIT amount of natural features	0.27	-0.30	1											
Distance to nearest NOE	-0.36	0.40	-0.40	1										
Number of GS 300m (NW)	0.31	-0.42	0.39	-0.53	1									
NDVI (average in 300m residential buffer)	0.32	-0.26	0.59	-0.43	0.37	1								
NDVI-LITE (average in 300m residential buffer)	0.21	-0.12	0.57	-0.32	0.22	0.89	1							
Time spent in NOE	0.25	-0.04	0.05	-0.08	0.10	0.11	0.07	1						

Age	0.10	-0.05	0.24	-0.11	0.01	0.32	0.35	0.06	1			
Neighborhood attachment	0.27	-0.15	-0.08	-0.05	0.10	-0.12	-0.21	0.09	-0.07	1		
Neighborhood social cohesion	0.36	-0.28	0.10	-0.18	0.21	0.07	-0.02	0.10	-0.04	0.63	1	
Time of residence current address	-0.03	0.09	0.11	0.05	-0.10	-0.22	0.27	0.03	0.54	-0.02	-0.09	1
Traffic noise annoyance	-0.30	0.19	-0.20	0.19	-0.11	-0.21	-0.17	-0.06	-0.02	-0.16	-0.18	0.03
Air pollution worries	-0.33	0.27	-0.29	0.29	-0.21	-0.31	-0.26	-0.04	-0.06	-0.10	-0.19	0.02

NOE: natural outdoor environment; GS: green spaces RNW: road network NBH: neighborhood; NDVI: Normalized Difference Vegetation Index; NDVI-LITE: vegetation outside major green spaces. Note. Spearman's correlations

Table 4. Correlates of aesthetics by city

	Aesthetics index			
	Doetinchem	Kaunas	Stoke-on-Trent	Barcelona
AUDIT incivilities	0.01	0.04	-0.21	-0.11
AUDIT amount of natural features	0.17	0.01	0.03	0.34
Distance to nearest NOE	-0.23	0.01	-0.20	-0.38
Number of GS 300m (NW)	0.10	0.04	0.01	0.35
NDVI (average in 300m residential buffer)	0.25	0.14	0.23	0.48
NDVI-LITE (average in 300m residential buffer)	0.23	0.10	0.16	0.47
Time spent in NOE	0.19	0.35	0.15	0.26
Age	0.11	-0.01	0.24	0.03
Neighborhood attachment	0.30	0.17	0.37	0.25
Neighborhood social cohesion	0.27	0.24	0.31	0.22
Time of residence current address	-0.01	0.03	0.15	0.01
Traffic noise annoyance	-0.24	-0.22	-0.25	-0.16
Air pollution worries	-0.24	-0.17	-0.21	-0.11

NOE: natural outdoor environment; GS: green spaces RNW: road network NBH: neighborhood; NDVI: Normalized Difference Vegetation Index; NDVI-LITE: vegetation outside major green spaces. Note. Spearman's correlations

Table 5. Unadjusted associations between neighborhood and individual characteristics, and the neighborhood aesthetics index

		Total n=2948	Doetinchem n=816	Kaunas n=957	Stoke-on-Trent n=442	Barcelona n=733
AESTHETICS INDEX (scale 13-65)		β (95% confidence interval)	β (95% confidence interval)	β (95% confidence interval)	β (95% confidence interval)	β (95% confidence interval)
Neighborhood SES	*low*	reference	reference	reference	reference	reference
	medium	0.68 (-0.71, 20.8)	0.40 (-1.47, 2.27)	1.04 (-0.08, 2.17)	**3.14 (1.20, 5.07)**	-1.16 (-5.51, 3.19)
	high	**2.03 (0.61, 3.45)**	0.15 (-1.79, 2.09)	**2.43 (1.16, 3.70)**	**5.15 (3.19, 7.10)**	1.16 (-3.18, 5.50)
AUDIT incivilities	*scale 0-24*	**-0.26 (-0.50, -0.02)**	0.07 (-0.47, 0.61)	0.05 (-0.20, 0.30)	**-0.33 (-0.63, -0.03)**	-0.46 (-1.19, 0.28)
AUDIT amount of natural features	*scale 0-30*	**0.40 (0.25, 0.55)**	**0.39 (0.15, 0.63)**	0.06 (-0.09, 0.20)	0.27 (-0.08, 0.61)	**0.82 (0.45, 1.20)**
Distance to nearest NOE		-0.01 (-0.01, 0.00)	**-0.02 (-0.03,-0.02)**	0.001 (-0.002, 0.004)	**-0.01 (-0.02, -0.003)**	**-0.01 (-0.01, -0.01)**
Number of GS 300m (RNW)		**0.27 (0.05, 0.48)**	0.14 (-0.10, 0.38)	0.25 (-0.19, 0.68)	0.17 (-0.44, 0.79)	**0.86 (0.09, 1.62)**
NDVI (average in 300m residential buffer), city specific quartiles	*quartile 1*	reference	reference	reference	reference	reference
	quartile 2	0.42 (-0.33, 1.17)	0.98 (-0.14, 2.10)	0.64 (-0.64, 1.92)	-1.58 (-3.64, 0.47)	0.86 (-1.02, 2.74)
	quartile 3	**2.13 (1.33, 2.93)**	**2.62 (1.44, 3.81)**	**1.29 (0.02, 2.55)**	1.29 (-0.89, 3.46)	**4.10 (1.70, 6.50)**
	quartile 4	**4.00 (3.15, 4.85)**	**3.51 (2.19, 4.83)**	**3.47 (2.21, 4.73)**	**4.01 (1.62, 6.39)**	**6.28 (3.53, 9.03)**
NDVI-LITE (average in	*quartile 1*	reference	reference	reference	reference	reference

300m residential buffer), city specific quartiles						
	quartile 2	**0.96 (0.19, 1.73)**	**2.02 (0.88, 3.16)**	0.95 (-0.36, 2.28)	-1.17 (-3.44, 1.11)	1.24 (-0.62, 3.11)
	quartile 3	**1.68 (0.88, 2.49)**	**2.53 (1.32, 3.74)**	**1.25 (0.01, 2.48)**	-0.01 (-2.34, 2.32)	**3.35 (0.86, 5.83)**
	quartile 4	**3.58 (2.73, 4.44)**	**4.07 (2.75, 5.39)**	**2.62 (1.39, 3.85)**	2.02 (-0.53, 4.57)	**7.78 (4.96, 10.60)**
Time spent in NOE	*h/month*	**0.04 (0.03, 0.04)**	**0.05 (0.03, 0.07)**	**0.04 (0.03, 0.05)**	0.01 (-0.01, 0.03)	**0.04 (0.02, 0.07)**
Age		**0.03 (0.01, 0.05)**	**0.05 (0.02, 0.09)**	0.03 (-0.004, 0.06)	**0.09 (0.05, 0.14)**	-0.01 (-0.04, 0.02)
Gender	*male*	reference	reference	reference	reference	reference
	female	-0.39 (-0.88, 0.10)	0.34 (-0.44, 1.12)	**-1.02 (-1.95, -0.10)**	-0.17 (-1.51, 1.16)	-0.66 (-1.67, 0.36)
Childhood NOE experience	*never*	reference	reference	reference	reference	reference
	sometimes	1.14 (-0.74, 3.02)	**5.64 (1.21, 10.07)**	-0.57 (-4.13, 2.99)	2.07 (-2.50, 6.64)	0.21 (-2.99, 3.42)
	regularly	1.12 (-0.69, 2.92)	**5.68 (1.42, 9.94)**	-1.13 (-4.44, 2.17)	1.94 (-2.62, 6.50)	1.10 (-2.07, 4.28)
	often	1.14 (-0.67, 2.94)	**6.68 (2.47, 10.90)**	-1.30 (-4.64, 2.04)	-0.79 (-5.47, 3.89)	1.53 (-1.53, 4.60)
	very often	1.71 (-0.07, 3.49)	**6.92 (2.72, 11.11)**	-1.34 (-4.66, 1.97)	1.02 (-3.52, 5.56)	2.84 (-0.16, 5.84)
Neighborhood attachment	*scale 0-12*	**0.70 (0.60, 0.81)**	**0.68 (0.51, 0.85)**	**0.58 (0.40, 0.77)**	**1.00 (0.72, 1.27)**	**0.72 (0.49, 0.95)**
Neighborhood social cohesion	*scale 0-20*	**0.49 (0.41, 0.57)**	**0.39 (0.27, 0.51)**	**0.55 (0.40, 0.70)**	**0.58 (0.40, 0.77)**	**0.46 (0.27, 0.65)**

Born in country of residence	*no*	reference	reference	reference	reference	reference
	yes	**-1.32 (-2.22, -0.42)**	-0.18 (-2.11, 1.75)	-2.08 (-4.45, 0.29)	**-2.81 (-5.52, -0.10)**	-1.22 (-2.49, 0.05)
Level of education	*low*	reference	reference	reference	reference	reference
	medium	-0.45 (-1.72, 0.83)	-2.42 (-6.13,1.30)	-1.36 (-4.86, 2.14)	-1.67 (-5.0, 1.68)	0.74 (-1.02, 2.50)
	high	-0.18 (-1.47, 1.10)	-1.93 (-5.64, 1.78)	-0.48 (-3.92, 2.95)	-1.50 (-4.97, 1.97)	0.17 (-1.65, 1.98)
Perceived income situation	*cannot make ends meet*	reference	reference	reference	reference	reference
	enough to get along	0.82 (-0.05, 1.69)	0.73 (-0.44, 1.90)	**3.04 (0.88, 5.19)**	**4.65 (1.45, 7.86)**	-0.52 (-2.15, 1.12)
	comfortable	**2.36 (1.48, 3.25)**	**1.56 (0.47, 2.65)**	**5.24 (2.93, 7.54)**	**7.39 (4.23, 10.55)**	0.29 (-1.51, 2.09)
Dog ownership	*no*	reference	reference	reference	reference	reference
	yes	0.20 (-0.35, 0.76)	-0.74 (-1.68, 0.21)	**1.22 (0.31, 2.13)**	-0.32 (-1.77, 1.12)	-0.28 (-1.62, 1.07)
Time of residence current address	*<2 years*	reference	reference	reference	reference	reference
	2-10 years	0.15 (-0.83, 1.13)	**-2.19 (-4.04, -0.33)**	**3.19 (0.77, 5.62)**	1.14 (-1.09, 3.36)	-0.75 (-2.41, 0.92)
	>10 years	0.30 (-0.60, 1.20)	**-2.35 (-4.14, -0.56)**	**2.15 (0.09, 4.20)**	**2.98 (0.90, 5.06)**	-0.58 (-2.06, 0.90)
Traffic noise annoyance	*scale 0-100*	**-0.05 (-0.06, -0.04)**	**-0.06 (-0.08, -0.04)**	**-0.07 (-0.08, -0.05)**	**-0.05 (-0.08, -0.03)**	**-0.02 (-0.04, -0.00)**
Air pollution worries	*scale 0-100*	**-0.04 (-0.05, -0.03)**	**-0.06 (-0.08, -0.04)**	**-0.04 (-0.06, -0.03)**	**-0.05 (-0.08, -0.03)**	-0.02 (-0.04, 0.01)

NOE: natural outdoor environment; GS: green spaces RNW: road network NBH: neighborhood; NDVI: Normalized Difference Vegetation Index; NDVI-LITE: vegetation outside major green spaces. Bold font indicates p<.05.

Table 6. Multivariate associations between individual and neighborhood characteristics and the neighborhood aesthetic index (models adjusted for age, sex, education level, perceived income situation, neighborhood SES)

		Total n=2948	Doetinchem n=816	Kaunas n=957	Stoke-on-Trent n=442	Barcelona n=733
AESTHETICS INDEX (scale 13-65)		β (95% confidence interval)	β (95% confidence interval)	β (95% confidence interval)	β (95% confidence interval)	β (95% confidence interval)
AUDIT incivilities	*scale 0-24*	-0.19 (-0.44, 0.05)	0.08 (-0.54, 0.70)	0.07 (-0.15, 0.29)	-0.16 (-0.45, 0.14)	-0.50 (-1.24, 0.25)
AUDIT amount of natural features	*scale 0-30*	**0.37 (0.22, 0.51)**	**0.40 (0.17, 0.62)**	0.03 (-0.10, 0.15)	0.23 (-0.06, 0.52)	**0.82 (0.43, 1.21)**
Distance to nearest NOE		**-0.01 (-0.01, -0.004)**	**-0.02 (-0.03, -0.02)**	0.001 (-0.002, 0.004)	**-0.02 (-0.03, -0.01)**	**-0.01(-0.02, -0.01)**
Number of GS 300m (NW)		**0.28 (0.07, 0.50)**	0.16 (-0.08, 0.39)	0.31 (-0.13, 0.74)	0.05 (-0.55, 0.65)	**1.13 (0.37, 1.89)**
NDVI (average in 300m residential buffer), city specific quartiles	*quartile 1*	reference	reference	reference	reference	reference
	quartile 2	0.17 (-0.60, 0.94)	0.81 (-0.32, 1.93)	0.37 (-1.00, 1.73)	-1.85 (-3.83, 0.12)	0.602 (-1.34, 2.54)
	quartile 3	**2.06 (1.24, 2.87)**	**2.45 (1.26, 3.64)**	**1.49 (0.15, 2.83)**	0.92 (-1.17, 3.00)	**4.00 (1.50, 6.50)**
	quartile 4	**3.82 (2.95, 4.69)**	**3.38 (2.06, 4.69)**	**3.57 (2.24, 4.90)**	**2.71 (0.39, 5.02)**	**6.11 (3.21, 9.02)**
NDVI-LITE (average in 300m residential buffer), city specific quartiles	*quartile 1*	reference	reference	reference	reference	reference

	quartile 2	**0.80 (0.02, 1.59)**	**2.03 (0.90, 3.16)**	0.51 (-0.92, 1.94)	**-2.23 (-4.36, -0.11)**	1.11 (-0.78, 3.00)
	quartile 3	**1.53 (0.71, 2.36)**	**2.35 (1.13, 3.58)**	1.19 (-0.12, 2.50)	-1.36 (-3.64, 0.91)	**3.69 (1.11, 6.27)**
	quartile 4	**3.55 (2.67, 4.43)**	**4.08 (2.73, 5.42)**	**2.77 (1.45, 4.09)**	0.36 (-2.27, 2.98)	**8.11 (5.15, 11.08)**
Time spent in NOE	*h/month*	**0.03 (0.03, 0.04)**	**0.05 (0.03, 0.07)**	**0.04 (0.03, 0.05)**	0.004 (-0.01, 0.02)	**0.05 (0.02, 0.08)**
Childhood NOE experience	*never*	reference	reference	reference	reference	reference
	sometimes	1.32 (-0.55, 3.20)	**5.67 (1.28, 10.07)**	-0.78 (-4.30, 2.74)	2.59 (-1.94, 7.13)	0.20 (-2.99, 3.39)
	regularly	1.41 (-0.40, 3.21)	**5.91 (1.70, 10.13)**	-1.42 (-4.68, 1.84)	3.07 (-1.48, 7.61)	1.36 (-1.81, 4.52)
	often	1.53 (-0.27, 3.33)	**7.18 (3.01, 11.36)**	-1.25 (-4.55, 2.05)	0.52 (-4.19, 5.22)	1.68 (-1.36, 4.72)
	very often	**2.05 (0.28, 3.83)**	**7.35 (3.19, 11.50)**	-1.69 (-4.97, 1.58)	2.32 (-2.20, 6.85)	**3.12 (0.15, 6.09)**
Neighborhood attachment	scale 0-12	**0.66 (0.55, 0.77)**	**0.70 (0.54, 0.87)**	**0.54 (0.35, 0.74)**	**0.78 (0.49, 1.07)**	**0.71 (0.48, 0.95)**
Neighborhood social cohesion	scale 0-20	**0.44 (0.36, 0.52)**	**0.38 (0.26, 0.50)**	**0.47 (0.31, 0.62)**	**0.46 (0.27, 0.64)**	**0.46 (0.27, 0.65)**
Born in country of residence	*no*	reference	reference	reference	reference	reference
	yes	**-1.68 (-2.60, -0.76)**	-0.33 (-2.25, 1.60)	**-2.47 (-4.89, -0.06)**	**-3.08 (-5.86, -0.30)**	-1.24 (-2.57, 0.09)
Dog ownership	*no*	reference	reference	reference	reference	reference
	yes	0.42 (-0.15, 1.00)	-0.51 (-1.46, 0.46)	**1.31 (0.38, 2.24)**	0.22 (-1.21, 1.66)	-0.33 (-1.70, 1.04)
Time of residence current address	*<2 years*	reference	reference	reference	reference	reference
	2-10 years	-0.25 (-1.25, 0.74)	**-2.46 (-4.30, -0.63)**	1.87 (-0.72, 4.47)	0.08 (-2.14, 2.31)	-0.53 (-2.22, 1.16)

	>10 years	-0.34 (-1.30, 0.62)	**-3.22 (-5.04, -1.41)**	1.80 (-0.65, 4.25)	1.17 (-1.10, 3.43)	-0.48 (-2.02, 1.06)
Traffic noise annoyance	*scale 0-100*	**-0.05 (-0.06, -0.04)**	**-0.06 (-0.08, -0.04)**	**-0.07 (-0.08, -0.05)**	**-0.05 (-0.07, -0.02)**	**-0.02 (-0.04, -0.00)**
Air pollution worries	*scale 0-100*	**-0.04 (-0.05, -0.03)**	**-0.06 (-0.08, -0.04)**	**-0.04 (-0.05, -0.02)**	**-0.04 (-0.06, -0.01)**	-0.02 (-0.04, 0.00)

NOE: natural outdoor environment; GS: green spaces RNW: road network NBH: neighborhood; NDVI: Normalized Difference Vegetation Index; NDVI-LITE: vegetation outside major green spaces. Bold font indicates p<.05.

Table 7. Multivariate associations between individual and neighborhood characteristics and the neighborhood aesthetic index (models adjusted for age, sex, education level, perceived income situation, neighborhood SES, traffic noise annoyance, air pollution worries)

		Total n=2948
AESTHETICS INDEX (scale 13-65)		β (95% confidence interval)
AUDIT incivilities	*scale 0-24*	-0.12 (-0.35, 0.12)
AUDIT amount of natural features	*scale 0-30*	**0.33 (0.19, 0.47)**
Distance to nearest NOE		**-0.01 (-0.01, -0.004)**
Number of GS 300m (NW)		**0.34 (0.14, 0.55)**
NDVI (average in 300m residential buffer), city specific quartiles	*quartile 1*	reference
	quartile 2	0.06 (-0.68, 0.81)
	quartile 3	**1.87 (1.08, 2.66)**
	quartile 4	**3.53 (2.68, 4.37)**
NDVI-LITE (average in 300m residential buffer), city specific quartiles	*quartile 1*	reference
	quartile 2	**0.79 (0.02, 1.56)**

	quartile 3	**1.37 (0.56, 2.18)**
	quartile 4	**3.38 (2.52, 4.24)**
Time spent in NOE	*h/month*	**0.03 (0.02, 0.04)**
Childhood NOE experience	*never*	reference
	sometimes	1.35 (-0.49, 3.18)
	regularly	1.59 (-0.17, 3.36)
	often	1.70 (-0.06, 3.46)
	very often	**2.19 (0.45, 3.92)**
Neighborhood attachment	scale 0-12	**0.58 (0.48, 0.69)**
Neighborhood social cohesion	scale 0-20	**0.39 (0.32, 0.47)**
Born in country of residence	*no*	reference
	yes	**-1.68 (-2.60, -0.76)**
Dog ownership	*no*	reference
	yes	0.36 (-0.19, 0.92)
Time of residence current address	*<2 years*	Reference
	2-10 years	-0.26 (-1.65, 1.13)
	>10 years	-0.39 (-1.78, 0.99)

NOE: natural outdoor environment; GS: green spaces RNW: road network NBH: neighborhood; NDVI: Normalized Difference Vegetation Index; NDVI-LITE: vegetation outside major green spaces. Bold font indicates p<.05.