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Scania outdoor environment database (ScOut): A data source to study health effects of perceived neighborhood characteristics

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1. Rationale

Research on residential outdoor environments and health has grown in the past decades, contributing to better understanding of how different neighborhood characteristics promote health and well-being throughout the life course, with a potential to reduce health inequalities (Björk et al., 2008; Bodin et al., 2009; Braubach et al., 2017; de Jong et al., 2012; Grahn and Stigsdotter, 2010; Hartig et al., 2014; Kaplan, 1995; Liu et al., 2019; Weimann et al., 2015a; Peters et al., 2020; Van den Berg et al., 2015). Noise and air pollution exposures have been linked to different adverse health events (Bodin et al., 2009; Liu et al., 2019), while exposure to green outdoor environments has been found to have salutogenic effects through stress reduction, restoration (Kaplan, 1995) as well as several other pathways (Braubach et al., 2017). Some studies pointed out the complexity of the associations between different outdoor environment exposures and health due to correlation of different exposures and other moderating factors playing a role in such associations (Weimann et al., 2017). Yet, a number of limitations making causal inference and policy implications uncertain have been identified when it comes to environment and health links (Gascon et al., 2016).

Both, objective and subjective measures have been used to study associations between environmental exposures and health. While clearly associated, objective and perceived outdoor environment exposures likely contain different information, as the agreement between them, at least in case of greenness, tends to be low (de Jong et al., 2011). The advantage of using perceived versus objective aspects of greenness in epidemiologic studies is that the former is more likely to capture important effects on health-related behaviors, which is valuable information when planning new or reshaping already existing neighborhoods (Prins et al., 2009).

Using explorative factor analysis in cross-sectional settings, eight perceived sensory dimensions (PSDs) have been identified as important qualities of green spaces that may support people's health: serene, natural, diverse, cohesive, cultural, open, sheltered and social (Grahn and Stigsdotter, 2010; Grahn et al., 2005). Methodological issues in their assessment should, however, be considered before they are used in epidemiological studies. Perceived outdoor exposure assessments are often based on single point assessments (Gascon et al., 2016), which may lead to bias. For instance, people with lower income tend to perceive their neighborhoods as less attractive and safe than those with higher income (de Jong et al., 2011; Kamphuis et al., 2010). Aggregating

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individual self-reports into area-level estimates could overcome such bias. Furthermore, the exact formulation of the PSDs has been shown to be important to accurately capture the salutogenic potential (de Jong et al., 2012). In addition, collecting subjective measures is resource demanding and not feasible in register studies or large population cohorts.

There is a need to address multiple outdoor characteristics in epidemiologic studies on health outcomes. The reasoning is that greenness, air pollution and road traffic noise often are spatially and temporally correlated (Klompmaker et al., 2019; Tenailleau et al., 2016). Consequentially, single exposure models might be prone to confounding: recent research showed that the effect of green surroundings on diabetes type 2 attenuated when air pollution was included in the model (Klompmaker et al., 2019). Longitudinal studies on perceived multiple environmental exposures on health are rare (Pearce et al., 2016).

To address the above-mentioned challenges related to outdoor environment exposure assessments and to facilitate epidemiological studies on links between neighborhood characteristics and health, we established the Scania outdoor environment database (ScOut) with 24 environmental characteristics covering the residential areas of the Scania region, southern Sweden.

2. Designing ScOut: data sources, sample size, measurements and development

2.1. Data sources, sample size and data management

To build the ScOut database, we included five population studies (de Jong et al., 2011; Weimann et al., 2015b; Carlsson et al., 2006; Östergren et al., 2000; Rosvall et al., 2009; Torngren et al., 2020) conducted in the Scania region in southern Sweden during 2008–2020 where the participants rated their own neighborhood outdoor environment (for details about the assessments see Table 1 and the next subsection of this article): two cross-sectional Scania public health surveys conducted in 2008 and 2012 (n = 26994 and 18852, respectively), and two cohort studies: follow-up surveys in 2010 (n = 7917) and 2016 (n = 6897, of whom 47% participated in 2010) for the Scania public health cohort (SPHC), and the BIG3 population cohort study with recruitment between 2013 and 2019 (n = 18331). All baseline participants in the respective studies were randomly selected from the Swedish total population register. The participants were between ages 18 to 80 in the cross-sectional Scania public health surveys and SPHC, and ages 45 to 75 in the BIG3 study. Only the respondents with available data on their dwelling coordinates in Scania, sex and age were retained (78991/91460: 86%).

The five studies were obtained as five separate datasets, with different names of the variables and answer categories. Each data source was 1. checked for errors, cleaned and text variables converted into numeric values; 2. recoded to harmonize the variable names and answer categories accross the datasets; 3. assigned a study identifier; and eventually 4. pooled together to run the final data checks and analysis. The harmonized list of exposures is provided in Table 1.

2.2. Perceived outdoor environment characteristics

In total, ScOut included 24 perceived outdoor environment characteristics: PSDs (n = 8), blue environments (n = 1), noise (n = 5), air pollution (n = 3), infrastructure (n = 4) and general neighborhood (n = 3). For the formulation of the items, data sources and answer categories see Table 1.

Eight perceived sensory dimensions (PSDs) have been identified as distinct qualities of green spaces that may support people's health (Grahn et al., 2005; Grahn and Stigsdotter, 2010) that have been assessed in the data sources used to build ScOut. PSDs (serene, natural, diverse, cohesive, cultural, open, sheltered and social) were measured within 5–10 min walk (corresponding to a distance of approximately 300 m) from home (Grahn and Stigsdotter, 2010; Grahn et al., 2005). PSDs and an additional item on presence of blue environments were assessed on a 4-point ordinal scale (disagree completely, disagree, agree, agree completely) and "do not know/cannot say". Due to limitations in their original formulations (Stoltz et al., 2012), the PSDs of natural and cohesive were reformulated in 2012, 2016 and BIG3 surveys, and only the revised items were included in ScOut. Followed by a previous study (Björk et al., 2014), the answers "agree" and "agree completely" indicated that the quality was present and were merged, with all other options and missing answers merged and indicating that the quality was absent.

Perceived noise and air pollution were assessed by self-reported distinct items such as annoyance from different noise sources (neighbours, road traffic, railway, air traffic, wind power) and smells (car exhausts, wood burning, industry) on 4- or 5-point ordinal scales depending on the survey. Due to different operationalization of these items in 2008 survey (see Table 1), these data were excluded. In 2012 and 2016 surveys the questions measuring annoyance from noise complied with the ISO/TS 15666 standard, while the formulation and answer options in 2010 were slightly different. As suggested by previous research (Bodin et al., 2012), to be able to combine the data using different scoring scales, we considered the most extreme answer option to indicate the annoyance from noise or air pollution, other answer options indicating limited or absent annoyance. As the question formulations for air pollution annoyance were similar, we treated them the same way.

We also included four distinct items regarding general services, cultural activities, recreational possibilities and public transportation in the neighborhood. Answering "yes" indicated presence of the characteristic versus "no", "no opinion" or a missing value indicating its absence. We have furthermore assessed three items of neighborhood safety, coherence and satisfaction on a 4-graded ordinal scale. The two most extreme answer options indicating the presence of the characteristic were collapsed and indicated positive replies, while all other answer categories and missing values were collapsed and indicated negative replies.

2.3. Reliability analysis

For items serenity, species richness, cultural history, noise from road, train and air traffic that were available in both 2010 and 2016, we assessed the differences between the proportions of agreement in the non-movers within SPHC with McNemar test, as well as Cohen's kappa, the latter adjusted for the agreement by chance (Table 2). There was little (0–5%) difference based on positive proportions between 2010 and 2016 indicated by the McNemar test. Cohen's kappa for three PSDs assessed was around 40%.

As we knew when the majority of the Scania surveys were mailed (September – October in 2008 and 2010 vs November – January in 2012 and 2016), we used the data source as a seasonality indicator. As data for the BIG3 cohort were collected throughout the year, we defined seasonality based on the individual survey scanning in dates as April to October, and November to March. To explore whether there were seasonal effects, we inspected the odds ratios (OR) of the data source for three PSDs (serene, diverse and culture), with 2008 survey and the time window of April to October for BIG3 as references. We expected that the OR would be similar between 2008 and 2010 surveys and would point towards more positive replies than the 2012 and 2016 surveys. We interpreted the OR of the seasonality indicator in the BIG3 dataset in the same way, expecting to see higher OR, and so more positive replies between April and October. We regarded the OR $\geq$ 1.5 (or $\leq$ 0.67 if inversed) as indicating a marked seasonal difference that might require a different approach when handling the data.

We did not find indications for seasonality based on the size and direction of the effects (ORs for seasonality indicators were between

Table 1
Included items (n = 24), survey questions in English, data availability across five data sources and answer options.

Item	Survey question in English	Data source					Answer options
		2008	2010	2012	2016	BIG3	
	Think of nature within 5–10 min walking distance from where you live. For example this can be green spaces, parks or forest areas. Do you agree with the following statements? Choose an option from each line! Nature in the area where I live …						
Serene	… is quiet, one can hear nature's own sound	x	x	x	x	x	Completely disagree - Disagree - Agree - Completely agree - Do not know/No opinion
Natural (original)	… is wild, it has developed without human impact	x	x				Completely disagree - Disagree - Agree - Completely agree - Do not know/No opinion
Natural (revised)	… has nature that is wild and fascinating			x	x	x	Completely disagree - Disagree - Agree - Completely agree - Do not know/No opinion
Diverse	… has a large diversity of animal and plant species	x	x	x	x	x	Completely disagree - Disagree - Agree - Completely agree - Do not know/No opinion
Cohesive (original)	… is a large cohesive area	x	x				Completely disagree - Disagree - Agree - Completely agree - Do not know/No opinion
Cohesive (revised)	… forms a large and coherent area, separated from the outside world			x	x	x	Completely disagree - Disagree - Agree - Completely agree - Do not know/No opinion
Cultural	… makes you feel the historical heritage, for example ancient monuments, old trees, constructions	x	x	x	x	x	Completely disagree - Disagree - Agree - Completely agree - Do not know/No opinion
Open	… has an open area for, for example, ball games or picnics				x	x	Completely disagree - Disagree - Agree - Completely agree - Do not know/No opinion
Sheltered	… has a cosy and safe place for relaxation or children's free games				x	x	Completely disagree - Disagree - Agree - Completely agree - Do not know/No opinion
Social	… has a meeting place with entertainment activities, people moving, catering or kiosk				x	x	Completely disagree - Disagree - Agree - Completely agree - Do not know/No opinion
Blue environments	… is close to the sea, lakes, or streams, which offers relaxation				x		Completely disagree - Disagree - Agree - Completely agree - Do not know/No opinion
Noise – neighbours	In 2008: In the past three months have you felt annoyed by one of the following at close proximity to your home? Noise from neighbours In 2012 and 2016: If you think about the last 12 months, when you are at home, how much are you disturbed or bothered by: Noise from neighbours	x		x	x		In 2008: Yes, at least once a day - Yes, at least once a week - Yes, more seldomly - No, never In 2012 and 2016: Not at all disturbed - Not very much disturbed - Disturbed quite a lot - Disturbed a lot - Extremely disturbed
Noise – road traffic	In 2008: In the past three months have you felt annoyed by one of the following at close proximity to your home? Noise from road traffic In 2010: Are you bothered by noise from road traffic, trains or flights? Road traffic In 2012 and 2016: If you think about the last 12 months, when you are at home, how much are you disturbed or bothered by: Noise from road traffic	x	x	x	x		In 2008: Yes, at least once a day - Yes, at least once a week - Yes, more seldomly - No, never In 2010: Not at all - Not very much - Quite a lot - A lot In 2012 and 2016: Not at all disturbed - Not very much disturbed - Disturbed quite a lot - Disturbed a lot - Extremely disturbed
Noise – train traffic	In 2008: In the past three months have you felt annoyed by one of the following at close proximity to your home? Noise from train traffic In 2010: Are you bothered by noise from road traffic, trains or flights? Noise from trains In 2012 and 2016: If you think about the last 12 months, when you are at home, how much are you disturbed or bothered by: Noise from train traffic	x	x	x	x		In 2008: Yes, at least once a day - Yes, at least once a week - Yes, more seldomly - No, never In 2010: Not at all - Not very much - Quite a lot - A lot In 2012 and 2016: Not at all disturbed - Not very much disturbed - Disturbed quite a lot - Disturbed a lot - Extremely disturbed
Noise – air traffic	In 2008: In the past three months have you felt annoyed by one of the following at close proximity to your home? Noise from air traffic In 2010: Are you bothered by noise from road traffic, trains or flights? Noise from flights In 2012 and 2016: If you think about the last 12 months, when you are at home, how much are you disturbed or bothered by: Noise from air traffic	x	x	x	x		In 2008: Yes, at least once a day - Yes, at least once a week - Yes, more seldomly - No, never In 2010: Not at all - Not very much - Quite a lot - A lot In 2012 and 2016: Not at all disturbed - Not very much disturbed - Disturbed quite a lot - Disturbed a lot - Extremely disturbed

(*continued on next page*)

Table 1 (*continued*)

Item	Survey question in English	Data source					Answer options
		2008	2010	2012	2016	BIG3	
Noise – wind power	In 2012: If you think about the last 12 months, when you are at home, how much are you disturbed or bothered by: Noise from wind power			x			In 2012: Not at all disturbed - Not very much disturbed - Disturbed quite a lot - Disturbed a lot - Extremely disturbed
Air pollution – car exhausts	In 2008: In the past three months have you felt annoyed by one of the following at close proximity to your home? Car exhausts In 2012 and 2016: If you think about the last 12 months, when you are at home, how much are you disturbed or bothered by following: Car exhausts	x		x	x		In 2008: Yes, at least once a day - Yes, at least once a week - Yes, more seldomly - No, never In 2012 and 2016: Not at all disturbed - Not very much disturbed - Disturbed quite a lot - Disturbed a lot - Extremely disturbed
Air pollution – wood burning	In 2008: In the past three months have you felt annoyed by one of the following at close proximity to your home? Wood burning smoke In 2012: If you think about the last 12 months, when you are at home, how much are you disturbed or bothered by following: Wood burning smoke	x		x			In 2008: Yes, at least once a day - Yes, at least once a week - Yes, more seldomly - No, never In 2012: Not at all disturbed - Not very much disturbed - Disturbed quite a lot - Disturbed a lot - Extremely disturbed
Air pollution – industries	In 2008: In the past three months have you felt annoyed by one of the following at close proximity to your home? Smells from industry In 2012: If you think about the last 12 months, when you are at home, how much are you disturbed or bothered by following: Smells from industry	x		x			In 2008: Yes, at least once a day - Yes, at least once a week - Yes, more seldomly - No, never In 2012: Not at all disturbed - Not very much disturbed - Disturbed quite a lot - Disturbed a lot - Extremely disturbed
Neighborhood satisfaction	What is it like living in your neighborhood?	x		x		x	Very good - Quite good - Quite bad - Bad - Do not know
Neighborhood safety	Do you feel safe walking alone in the neighborhood at dark?	x	x	x	x	x	Very safe - Quite safe - Quite unsafe -Unsafe - Never walking alone when it is dark (the latter option only in 2008 survey)
Neighborhood coherence	Do you feel rooted and belonging to the neighborhood?	x	x	x	x		To large extent - To some extent Not really - Not at all
General services	Think about the environment where you live, do you think that there are good general services?	x		x		x	Yes - No–No opinion
Cultural activities	Think about the environment where you live, do you think that there are sufficient cultural activities?	x		x		x	Yes - No–No opinion
Recreational possibilities	Think about the environment where you live, do you think that there are good recreational possibilities?	x		x		x	Yes - No–No opinion
Public transportation	Think about the environment where you live, do you think that there is good public transportation?	x		x		x	Yes - No–No opinion

Table 2
Differences in outdoor environment assessments among the non-movers (N = 3707) in the SPHC between 2010 and 2016.

N = 3707	% positive in 2010	% positive in 2016	p-value for McNemar test	Cohen's kappa
Serenity	80%	79%	.47	.37
Species richness	55%	54%	.15	.46
Cultural history	44%	39%	<.001	.40
Noise – road traffic	1%	1%	.06	.21
Noise – train traffic	0.2%	0.2%	1	−.002
Noise – air traffic	0.2%	0.1%	.45	−.001

0.98 and 1.32). Additional analysis of the BIG3 cohort also did not indicate seasonal effect (ORs between 1.01 and 1.21). We therefore proceeded with pooling the data across the data sources.

2.4. Area aggregation and scores of perceived outdoor environment characteristics

Ecometric modelling and statistical analyses were performed with SPSS, version 26.0 (IBM Corp, Armonk, NY). The exact modelling details have been described previously (de Jong Kim et al., 2011, 2012). Geocodes of the residential addresses of the participants were used to group them into area units of 1 km^2, resulting in 5472 different 1 km^2 areas covering approximately 97% of the total population in Scania. The proportions of positive assessments for each outdoor environment quality were then estimated in each area using a random effects logistic regression (ecometric) model with individual and area levels. Areas with very few individuals obtained a proportion similar to the overall mean, therefore areas with only one individual (n = 1952) were accepted.

To avoid bias due to perception being affected by sociodemographic factors (de Jong et al., 2011; Kamphuis et al., 2010), the models were adjusted for demographic and socioeconomic characteristics as well as seasonality. These included age, sex (male, female), country of origin (Nordic (i.e. Sweden, Norway, Finland, Denmark, Iceland), other), education (primary, secondary, college/university, other), economic difficulties during the last 12 month (yes, no) and the type of residence (own house, condominium, rental/other).

2.5. Correlations between perceived outdoor environment scores

We assessed Spearman (r_s) correlation coefficients between different characteristics on the area and individual levels and stratified them into negligible/weak (0 - <0.3), moderate (≥0.30 - <0.70) and strong (≥0.70 - <1) (same intervals for negative r_s).

On the area-level, positive moderate correlations were found between serene, natural, diverse, cohesive and cultural (Table 3, above the diagonal). These PSDs correlated negatively with social, general services, cultural activities and public transportation. Perceived air pollution and noise from different sources generally exhibited moderate to strong positive correlations on the area-level. An exception was train traffic noise that was negatively correlated with all other noise and air pollution sources. Area-level correlations were overall weaker than the individual-level correlations (Table 3, below the diagonal), which could

Table 3
Spearman correlations of the area- and individual-level (above and below the diagonal, respectively) perceived sensory dimensions, noise and air pollution (17 items).

	Serene	Natural	Diverse	Cohesive	Cultural	Open	Sheltered	Social	Blue environments	Noise – road traffic	Noise – train traffic	Noise – air traffic	Noise – neighbours	Noise – wind power	Air pollution – car exhausts	Air pollution – burning smoke	Air pollution – industry
Serene	1	,53	,62	,40	,35	,18	,26	-,12	,28	-,09	-,09	,05	,06	,12	0,02	,07	,17
Natural	,91	1	,65	,61	,46	,20	,27	-,16	,29	-,09	-,09	,05	,06	,12	0,02	,07	,25
Diverse	,90	,94	1	,55	,51	,10	,16	-,25	,23	,05	-,22	,20	,15	,24	,12	,19	,28
Cohesive	,83	,90	,89	1	,50	,17	,22	-,20	,20	,11	-,25	,26	,21	,31	,21	,25	,25
Cultural	,56	,58	,66	,58	1,00	,12	,12	-,16	,25	,13	-,25	,29	,19	,28	,19	,23	,28
Open	,32	,26	,22	,33	0,00	1	,59	,20	,14	,18	-,26	,29	,19	,31	,22	,27	-,12
Sheltered	,49	,43	,40	,45	,13	,78	1,00	,12	,21	-,18	,09	-,17	-,10	-,18	-,18	-,19	-,08
Social	-,32	-,31	-,34	-,28	-,01	,05	,01	1	,17	-,22	,07	-,15	-,13	-,14	-,20	-,14	-,25
Blue environments	,37	,42	,37	,35	,34	,13	,20	,20	1,00	-,18	,18	-,31	-,12	-,32	-,21	-,33	,15
Noise – road traffic	-,05	0,01	,05	,03	,18	-,35	-,28	-,04	0,02	1,00	-,36	,65	,48	,55	,72	,51	,42
Noise – train traffic	,27	,26	,25	,23	,11	,08	,17	-,20	,05	-0,01	1	-,58	-,26	-,49	-,35	-,35	-,32
Noise – air traffic	,42	,44	,46	,41	,25	-,12	,06	-,44	,18	,26	,20	1	,50	,73	,63	,67	,54
Noise – neighbours	,05	,13	,13	,15	,04	-,12	-,11	-,14	,10	,19	-,02	,23	1	,47	,63	,37	,61
Noise – wind power	,35	,39	,40	,35	,28	-,19	-,04	-,35		,25	,17	,69	,33	1,00	,61	,75	,64
Air pollution – car exhausts	-,06	0,00	,03	-0,01	,09	-,35	-,33	-,11	,04	,55	-,02	,23	,23	,32	1,00	,53	,56
Air pollution – burning smoke	,26	,31	,30	,29	,15	-,06	0,00	-,36		,15	,14	,40	,29	,52	,18	1,00	,52
Air pollution – industry	,33	,37	,38	,34	,21	-,16	-,05	-,34		,18	,19	,64	,37	,78	,29	,45	1,00

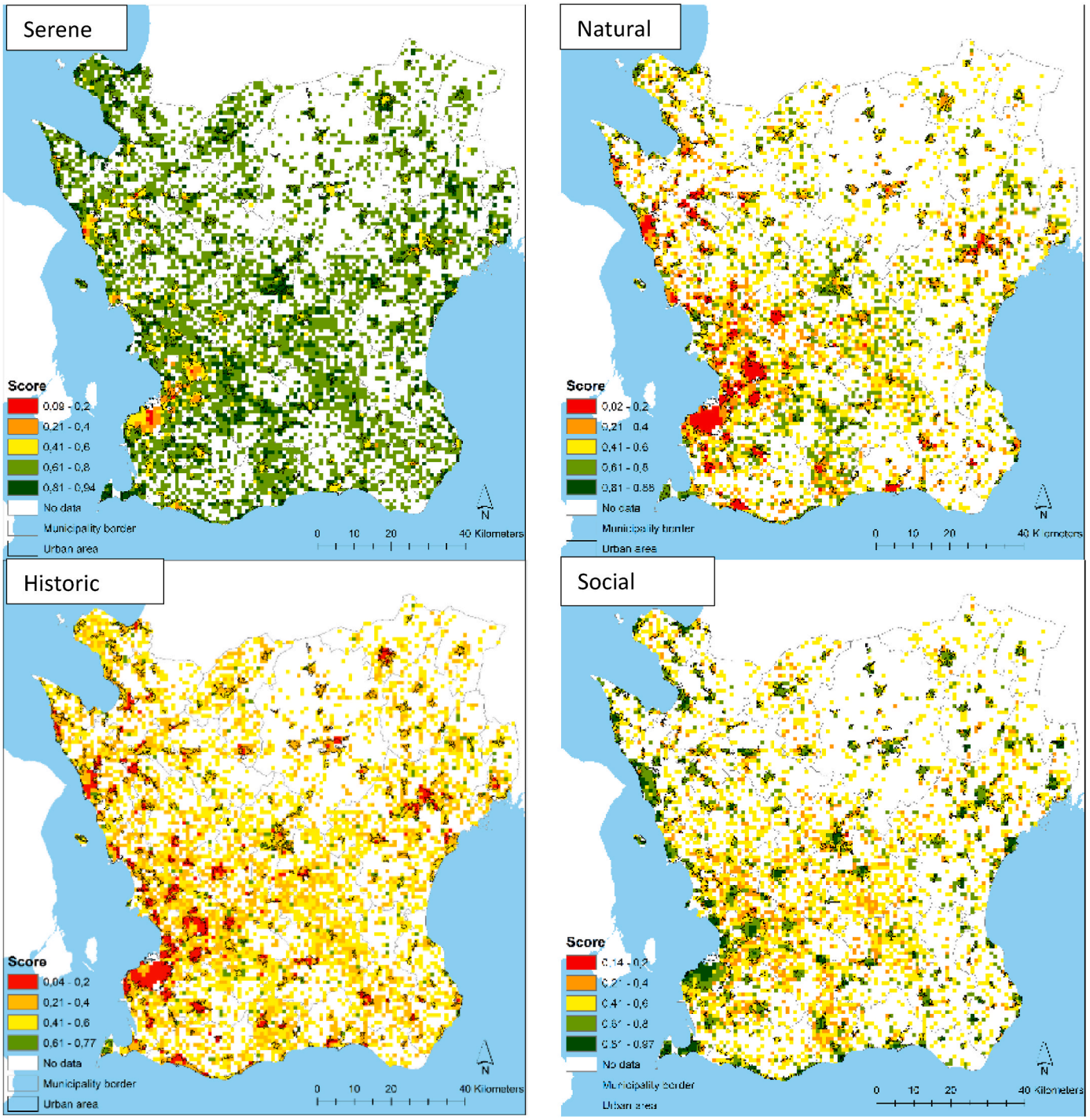

Fig. 1. Visualizing perceived sensory dimensions of serene, natural, historic and social.

be explained by that they are less prone to single-source (intra-individual) correlations in perceptions.

2.6. Visual presentation of perceived outdoor environment scores

Visual presentation of area-level scores was done by plotting colour coded area-level scores with ArcGIS. For most PSDs (for example serene, nature and historic) the scores were the lowest in and around major cities, except for social, were in cities it was the most positive (Fig. 1). We can see clear differences within the major cities themselves: the scores of historic within the historic city centers were higher than outside the city centers.

Positive scores of blue environments were found along the sea and inland blue areas. Noise and air pollution were mostly reported in major cities. Noise from aircraft traffic was observed around the Malmö airport. Neighborhood satisfaction and safety were lower in cities, while for recreational possibilities, public transportation, general services and cultural activities scores were more positive in cities (data not shown).

3. Discussion

To our knowledge, ScOut is an (inter)nationally unique data source in its nature and size that includes 24 outdoor environment characteristics over a period of 12 years and covering approximately 97% of the

population in Scania, one of the most densely populated counties in Sweden. ScOut can be used to study both the effects and complexity of multiple perceived outdoor environment characteristics on health, and well-being, as long as the studies are based in Scania and there is a possibility to link to the individual participant data or on the geocode level.

3.1. Future studies

ScOut provides a source of data on perceived outdoor environment characteristics that enables assessment of subjective environmental exposures in register studies and other population studies in Scania. The role of perceived outdoor environment characteristics could be assessed on outcomes such as occurrence or exacerbations of the underlying medical conditions, hospitalizations and mortality The Malmö Diet Cancer Study, EpiHealth, The Swedish CArdioPulmonary bioImage Study, Good Aging in Skåne or RELOC-AGE (Zingmark et al., 2021) studies, as well as on perceived health outcomes in cohorts such as SPHC and others. Several such studies are currently in progress. The study based on SPHC is assessing the role of the neighborhood environment on obesity trajectories mediated through a physical activity pathway (Rebouillat et al. in progress). Another study based on SPHC is investigating the effects of the co-existing perceived outdoor environment exposures, such as PSDs, blue environments, neighborhood coherence and safety on laboratory-confirmed COVID-19 disease (Mtutu et al. in progress). A register-based study to look into the interaction between the indoor and close outdoor environments on a variety of health outcomes, including mortality, health care use, as well as stroke, influenza and COVID-19 (related) clinical outcomes is in planning. All in all, any health outcomes could be studied in cross-sectional or longitudinal studies in relation to the 24 close outdoor environment characteristics included in ScOut, addressing the co-existence of different outdoor environment characteristics.

3.2. Methodological challenges

Several methodological strengths and challenges, together with planned solutions are important to consider for future studies. Fourteen percent of records were excluded due to missing information on their dwelling coordinates, sex or age, with the majority due to technical issues and/or lacking consent to retrieve the geocode data. Most items included in ScOut have been used in numerous previous studies to assess outdoor exposures (Björk et al., 2008; de Jong et al., 2011, 2012; Weimann et al., 2015b). This enables comparison of perceived outdoor exposures and their associations with health outcomes across studies.

Four PSDs (serene, natural, diverse and cohesive) correlated strongly with each other (r_s 0.72–0.94) on the individual level. These PSDs have in previous studies been associated with each other. In addition, they have proven to be valuable in terms of recovery from stress, and have also been considered to strengthen each other's recreational values if they occur together (Pálsdóttir et al., 2018; Stoltz and Grahn, 2021). This suggests that these four PSDs should not be investigated separately to address potential confounding. At the same time, including highly correlated variables in prediction modelling is likely to reduce the precision of the estimated regression coefficients, which would be a reason to combine such items into a single score (de Jong et al., 2012). Methodological considerations for combining several items into a score should be explored in future studies.

Merging different data sources into ScOut was done with caution: we looked into agreement between 2010 and 2016 measurements as well as seasonality. We merged the datasets after concluding the outdoor assessments are rather stable over time, and season. ScOut can also be seen as a database in progress as upon emerging new data, they can be linked to ScOut and possible changes in exposures over time could be reassessed. ScOut can be linked on 1 km^2 areas, but different area sizes and definitions could be generated. Other techniques, such as interpolation, could be explored to further develop the methodology and generate continuous surfaces as an alternative to using fixed grids to avoid the assumption that all respondents within a square are located at the center. Individual users of ScOut are also free to use the actual ratings or other categorizations than those we have suggested. It is also possible to add additional geographical data on, for example, socioeconomic conditions and population density.

3.3. Conclusion

To be able to study the effects and complexity of multiple perceived outdoor environment characteristics on health and well-being and reduce single-source bias, we compiled a database based on the available resources in Scania, southern Sweden, 2008–2019, including area-aggregated assessments of 24 characteristics. We found that PSDs were robust to seasonal changes. We observed clear visible patterns between different characteristics, with correlations between them ranging from negligible to strong, confirming the complexity of the perceived environment. ScOut is a unique data source in its nature and size, in Sweden and abroad, covering areas where approximately 97% of the population live.

Declarations

Ethics approval and consent to participate

The current study was approved by the Swedish Ethical Review Board (Dnr. 2020–01446). Consent to participate in the current study was not necessary.

Consent for publication

Not applicable.

Availability of data and materials

ScOut database is hosted by the Lund University Population Research Platform (LUPOP). Area-level data can be made available upon request to lupop@ed.lu.se to interested researchers, but access to individual-level data will generally require a new ethical permission.

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Credit author statement

Giedre Gefenaite: Conceptualization, Methodology, Formal analysis, Data curation, Visualization, Writing – original draft, Funding acquisition, Kristoffer Mattisson: Methodology, Formal analysis, Data curation, Writing – review & editing, Visualization, Patrik Grahn: Conceptualization, Writing – review & editing, Funding acquisition, Per-Olof Östergren: Conceptualization, Resources, Writing – review & editing, Jonas Björk: Conceptualization, Methodology, Formal analysis, Writing – review & editing, Funding acquisition, Supervision

Declaration of competing interest

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Data availability

Data will be made available on request.

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References

Björk, J., Albin, M., Grahn, P., Jacobsson, H., Ardö, J., Wadbro, J., et al., 2008. Recreational values of the natural environment in relation to neighbourhood satisfaction, physical activity, obesity and wellbeing. J. Epidemiol. Community Health 62 (4), e2.

Björk, J., Rittner, R., Cromley, E., 2014. Exploring inter-rater reliability and measurement properties of environmental ratings using kappa and colocation quotients. Environ. Health 13 (1), 86.

Bodin, T., Albin, M., Ardö, J., Stroh, E., Östergren, P.O., Björk, J., 2009. Road traffic noise and hypertension: results from a cross-sectional public health survey in southern Sweden. Environ. Health 8 (1), 1–10.

Bodin, T., Björk, J., Öhrström, E., Ardö, J., Albin, M., 2012. Survey context and question wording affects self reported annoyance due to road traffic noise: a comparison between two cross-sectional studies. Environ. Health 11 (1), 1–9.

Braubach, M., Egorov, A., Mudu, P., Wolf, T., Thompson, C.W., Martuzzi, M., 2017. Effects of urban green space on environmental health, equity and resilience. In: Nature-based Solutions to Climate Change Adaptation in Urban Areas. Springer, pp. 187–205. Cham.

Carlsson, F., Merlo, J., Lindström, M., Östergren, P.O., Lithman, T., 2006. Representativity of a postal public health questionnaire survey in Sweden, with special reference to ethnic differences in participation. ScandJPublic Health 34 (2), 132–139.

de Jong, K., Albin, M., Skärbäck, E., Grahn, P., Wadbro, J., Merlo, J., et al., 2011. Area-aggregated assessments of perceived environmental attributes may overcome single-source bias in studies of green environments and health: results from a cross-sectional survey in southern Sweden. Environ. Health 10 (1), 4.

de Jong, K., Albin, M., Skärbäck, E., Grahn, P., Björk, J., 2012. Perceived green qualities were associated with neighborhood satisfaction, physical activity, and general health: results from a cross-sectional study in suburban and rural Scania, southern Sweden. Health Place 18 (6), 1374–1380.

Gascon, M., Triguero-Mas, M., Martínez, D., Dadvand, P., Rojas-Rueda, D., Plasència, A., et al., 2016. Residential green spaces and mortality: a systematic review. Environ. Int. 86, 60–67. Journal Article).

Grahn, P., Stigsdotter, U.K., 2010. The relation between perceived sensory dimensions of urban green space and stress restoration. Landsc. Urban Plann. 94 (3–4), 264–275.

Grahn, P., Stigsdotter, U., Berggren-Bärring, A.M., 2005. A planning model for designing sustainable and healthy cities. The importance of people's need of recreational environments in an urban context. In: Inspiring Global Environmental Standards & Ethical Practices National Association of Environmental Professionals, NAEP 30th Annual Conference, April 16-19, 2005, Alexandria, VA (Journal Article).

Hartig, T., Mitchell, R., De Vries, S., Frumkin, H., 2014. Nature and health. AnnuRevPublic Health 35, 207–228. Journal Article).

Kamphuis, C.B., Mackenbach, J.P., Giskes, K., Huisman, M., Brug, J., Van Lenthe, F.J., 2010. Why do poor people perceive poor neighbourhoods? The role of objective neighbourhood features and psychosocial factors. Health Place 16 (4), 744–754.

Kaplan, S., 1995. The restorative benefits of nature: toward an integrative framework. J. Environ. Psychol. 15 (3), 169–182.

Klompmaker, J.O., Janssen, N.A., Bloemsma, L.D., Gehring, U., Wijga, A.H., van den Brink, C., et al., 2019. Associations of combined exposures to surrounding green, air pollution, and road traffic noise with cardiometabolic diseases. Environ. Health Perspect. 127 (8), 087003.

Liu, C., Chen, R., Sera, F., Vicedo-Cabrera, A.M., Guo, Y., Tong, S., et al., 2019. Ambient particulate air pollution and daily mortality in 652 cities. N. Engl. J. Med. 381 (8), 705–715.

Östergren, P.O., Merlo, J., Lindström, M., Rosvall, M., Lithman, T., Ali Khan, F., 2000. Hälsoförhållanden I Skåne: Folkhälsoenkät Skåne 2000. Region Skåne, Malmö (Journal Article)).

Pálsdóttir, A.M., K Stigsdotter, U., Persson, D., Thorpert, P., Grahn, P., 2018. The Qualities of Natural Environments that Support the Rehabilitation Process of Individuals with Stress-Related Mental Disorder in Nature-Based Rehabilitation (Journal Article)).

Pearce, J., Shortt, N., Rind, E., Mitchell, R., 2016. Life course, green space and health: incorporating place into life course epidemiology. Int. J. Environ. Res. Publ. Health 13 (3), 331.

Peters, M., Muellmann, S., Christianson, L., Stalling, I., Bammann, K., Drell, C., et al., 2020. Measuring the association of objective and perceived neighborhood environment with physical activity in older adults: challenges and implications from a systematic review. Int. J. Health Geogr. 19 (1), 1–20.

Prins, R.G., Oenema, A., van der Horst, K., Brug, J., 2009. Objective and perceived availability of physical activity opportunities: differences in associations with physical activity behavior among urban adolescents. Int. J. Behav. Nutr. Phys. Activ. 6 (1), 1–9.

Rosvall, M., Grahn, M., Modén, B., Merlo, J., 2009. Hälsoförhållanden I Skåne: Folkhälsoenkät Skåne 2008. Universitetssjukhuset MAS.

Stoltz, J., Grahn, P., 2021. Perceived sensory dimensions: an evidence-based approach to greenspace aesthetics. Urban For. Urban Green. 59, 126989. Journal Article).

Stoltz, J., Grahn, P., Brundell-Freij, K., Björk, J., Skärbäck, E., 2012. Malmöbors Upplevelse Av Fem Utemiljökaraktärer (Journal Article)).

Tenailleau, Q.M., Bernard, N., Pujol, S., Parmentier, A.L., Boilleaut, M., Houot, H., et al., 2016. Do outdoor environmental noise and atmospheric NO2 levels spatially overlap in urban areas? Environ. Pollut. 214, 767–775. Journal Article).

Torngren, K., Rylance, R., Björk, J., Engström, G., Frantz, S., Marko-Varga, G., et al., 2020. Association of coronary calcium score with endothelial dysfunction and arterial stiffness. Atherosclerosis 313, 70–75. Journal Article).

Van den Berg, M., Wendel-Vos, W., Van Poppel, M., Kemper, H., van Mechelen, W., Maas, J., 2015. Health benefits of green spaces in the living environment: a systematic review of epidemiological studies. Urban For. Urban Green. 14 (4), 806–816.

Weimann, H., Rylander, L., Albin, M., Skarback, E., Grahn, P., Ostergren, P.O., et al., 2015a. Effects of changing exposure to neighbourhood greenness on general and mental health: a longitudinal study. Health Place 33, 48–56. Journal Article).

Weimann, H., Rylander, L., Albin, M., Skärbäck, E., Grahn, P., Östergren, P.O., et al., 2015b. Effects of changing exposure to neighbourhood greenness on general and mental health: a longitudinal study. Health Place 33, 48–56. Journal Article).

Weimann, H., Rylander, L., van den Bosch, M.A., Albin, M., Skärbäck, E., Grahn, P., et al., 2017. Perception of safety is a prerequisite for the association between neighbourhood green qualities and physical activity: results from a cross-sectional study in Sweden. Health Place 45, 124–130. Journal Article).