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Research Paper

Urban resilience at eye level: Spatial analysis of empirically defined experiential landscapes

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A B S T R A C T

An unresolved issue in creating resilient cities is how to obtain sustainability benefits from densification while not eroding the capacity of social-ecological systems to generate wellbeing for urban dwellers. To understand how different relationships between urban form and wellbeing together play out, we analysed geocoded experiential data (1460 experiences from 780 respondents) together with variables of the physical environment. Through statistical and spatial analysis, we operationalised resilience principles to assess what urban environments provide "resilience at eye level" – a diversity of experiences and a level of connectivity between them that limit adverse outcomes. We found 8 typologies of experiential landscapes – distinct compositions of 11 categories of experiences. Our analysis shows that typologies with experiences supportive of wellbeing are diverse and exist in environments that balance residents and workplaces, avoid extreme spatial integration and/or density and have accessible nature. Typologies with many experiences hindering wellbeing fail in one or several of these respects. Our findings suggest that resilience principles can act as a guiding heuristic for urban densification that does not compromise human wellbeing.

1. Introduction

An unresolved issue in the urban sustainability discourse is how to undertake the much-needed transformation to lower levels of metabolism while not eroding the capacity of social-ecological systems to generate wellbeing for urban dwellers (Samuelsson et al., 2018). To decrease metabolism, densification is often promoted as a strategy of urban development (Güneralp et al., 2017). But relationships between urban spatial form and wellbeing are complex and differ across different contexts (Kyttä, Broberg, Haybatollahi, & Schmidt-Thomé, 2016), involving several interrelated factors, such as accessibility to services, crowding and loss of direct contact with nature.

Denser environments generally feature greater accessibility to urban services (Bramley & Power, 2009; Kyttä et al., 2016) and promote walking or biking (Durand, Andalib, Dunton, Wolch, & Pentz, 2011). Meanwhile, crowding can challenge wellbeing through perceived unpredictability and sensory overload (Evans & Lepore, 1992). These mechanisms have been extensively explored within the attention restoration literature. Attention restoration theory integrates the roles of stress and directed attention for crowding's negative impact on wellbeing: directed attention being a limited resource needed for information processing, the depletion of which often precedes stress (Kaplan, 1995). Stress can be reduced through experiences that have the qualities of being detached from one's routine, effortlessly fascinating, immersive or involving activities with matching support in the environment (Korpela, Hartig, Kaiser, & Fuhrer, 2001). Nature environments seem particularly fit to offer such experiences (Kaplan, 1995; MacKerron & Mourato, 2013). Despite this, a general decline in urban dwellers' everyday interaction with nature has been observed across the globe (Soga & Gaston, 2016), highlighting the need to re-connect urban dwellers with nature (Andersson et al., 2014).

Understanding how these relationships between urban form and wellbeing together play out is key for building resilient cities, and requires going beyond density to incorporate other variables that paint a richer picture of how humans perceive and use urban space (Samuelsson et al., 2018). Because experiences are a mediator between the environment and wellbeing (Kyttä et al., 2016), we analyse experiential data together with variables of the physical environment, aiming to increase understanding about what types of experiences that promote or hinder wellbeing that exist together, and how these compositions of experiences are related to urban spatial properties.

1.1. Resilience principles

Social-ecological urbanism is an emerging discourse within the wider urban sustainability umbrella, which assumes that cities are complex adaptive systems, and where resilience principles are a promising theoretical toolbox for improving urban planning (Marcus &

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Colding, 2014). Synthesising the literature on social-ecological resilience, Biggs, Schlüter, and Schoon (2015) put forth seven principles for building resilience in social-ecological systems. Three principles concern system properties or processes that enhance resilience, while the remaining four concern how systems are governed. Here, we let the first three principles guide our analysis. They are 1) managing slow variables, 2) maintaining diversity, and 3) managing connectivity.

Complex adaptive systems can exist in several configurations (Biggs, Gordon, Raudsepp-Hearne, Schlüter, & Walker, 2015). The configuration of a system often depends on a small number of 'slow' variables (Holling, 2001). These variables do not have fixed timescales, but change slower than other system variables (Biggs, Gordon et al., 2015). Changes in slow variables are often due either to external disturbance, over which the system has little influence (Walker, Carpenter, Rockstrom, Crépin, & Peterson, 2012). An important part of strengthening the resilience of a desired system configuration is thus to understand what slow variables underlie it and how they are affected by external disturbance.

Connectivity encompasses the structure and strength of interactions between system components. The relationship between connectivity and resilience is not straightforward. Connectivity can facilitate system reorganisation after disturbance (Nyström & Folke, 2001), but also the spread of disturbance itself (Biggs, Biggs, Dakos, Scholes, & Schoon, 2011). Thus, even though there is no simple prescription for how to enhance system resilience by managing connectivity, it will generally involve balancing over-connection and fragmentation (Dakos et al., 2015).

Diversity is a conditioning attribute for building resilience in complex systems (Berkes et al., 2003). Diversity spreads risks by creating buffers and opening up multiple strategies from which humans can learn in situations when uncertainty is high. Hence, it works similar to an insurance. Diversity also plays a vital role in the reorganization and renewal processes of perturbed systems (Berkes et al., 2003). The importance of diversity has been described for many systems, from genetic to governance systems (Low, Ostrom, Simon, & Wilson, 2003).

In ecosystem management, the resilience approach was developed as a reaction to "command and control" management aimed at managing a few target resources (timber, monoculture crops, or similar) (Holling & Meffe, 1996). A frequent result of command and control management has been reduced natural variation, causing increasingly brittle ecosystems that over time lose their capacity to maintain biodiversity and buffer natural perturbations (Gunderson & Holling, 2002). In parallel to resilience building in ecosystems, Marcus and Colding (2014) argue that resilient city designs need to encapsulate the attractiveness that cities hold for humans in terms of cultural diversity, socioeconomic benefits, and capacity for dealing with the environmental trade-offs that they impose in their growth.

1.2. Linking resilience principles to urban dwellers' wellbeing

Both diversity and connectivity are fundamental in current urban planning and design (Ahern, 2011; Jabareen, 2013). Despite this, diversity and connectivity from an experiential perspective has received little attention in the literature. However, there are several reasons to study these principles. Diversity of positive experiences indicates that people with different attitudes or preferences have experiences contributing to their wellbeing within the same neighbourhood, rather than segregate into different ones. Raymond, Gottwald, Kuoppa, and Kyttä (2016) found that assessing activity diversity and user diversity across a landscape is important for spatially targeting planning to address environmental justice. Diversity across positive and negative experiences is desirable because, assuming negative experiences are to some extent an unavoidable part of urban life, they are more easily remedied by seeking up nearby positively experienced environments. For example, making sure nature areas are accessible is crucial for safeguarding their restorative functioning (Wyles et al., 2017). If the amount of negative experiences can be managed, the effects of crowding on stress outlined above suggests that managing connectivity can be one way of doing this. Furthermore, it is widely held that more people in the streets increase feelings of safety, but this claim has not been thoroughly tested (Dempsey, Brown, & Bramley, 2012) and some evidence contradicts it (Pain & Townshend, 2002).

Experiences are influenced by urban form (Kyttä et al., 2016; Samuelsson et al., 2018). Understanding how the urban environment relates to diversity and connectivity of experiences requires analysing it in ways reflecting the human experience of it. For example, two physically adjacent urban spaces are not necessarily experienced as such. A city street full of activity is often next to a completely void one. Such phenomena have been studied within a field of urban studies dealing with spatial configuration. The overarching finding from this field is that human behaviour in urban spaces depends on how they are topologically related to other spaces (Hillier, 1996). For example, pedestrian movement in spaces is much better predicted by their topological relations than by metric distances between them (Hillier, Penn, Hanson, Grajewski, & Xu, 1993). In explaining these effects, the ecological approach to visual perception (Gibson, 1986) has attracted much attention. Gibson upholds that movement is a necessary and integral part of humans' visual perception and ability to orientate:

> *"An alley in a maze, a room in a house, a street in a town and a valley in a countryside each constitutes a place, and a place often constitutes a vista. […]. To go from one place to another involves the opening up of the vista ahead and closing in of the vista behind […] When the vistas have been put in order by exploratory locomotion, the invariant structure of the house, the town, or the whole habitat will be apprehended." (*Gibson, 1986, p. 198*)*

As we move, we create perceptual units (Marcus, 2015), and thus cognitively organise space in a topological manner (Penn, 2001). Crowded streets often fall on the topologically shortest routes between all destinations in a network, while adjacent ones do not (Hillier et al., 1993; Penn, 2001). The environment also influences our experiences through other senses: one well researched area is that of noise pollution (Goines & Hagler, 2007). This makes urban form, here conceptualised as a slow variable, a powerful tool for the structuring of human experiences. Because urbanisation is a process over which any single city has little influence, we in turn conceptualise it as a disturbance on urban form. The question then becomes how to navigate urbanisation in planning and design. In summary, we are interested in understanding what environments afford "resilience at eye level" – a diversity of experiences and a level of connectivity between them that limits adverse outcomes. Hence, we ask: How can resilience principles help us understand how urban environments structure human experiences? And how should urban environments be structured to afford experiences that promote urban dwellers' wellbeing while undergoing urbanisation?

2. Methods

2.1. Study approach

Our approach is quantitative spatial analysis. We apply public participatory GIS (PPGIS) in Stockholm, Sweden, to obtain a dataset of experiences. PPGIS is a method whereby some targeted group of people or the general public are invited to map experiential knowledge (Brown & Kyttä, 2014). This allows for context-sensitive assessments of landscapes in relation to e.g. happiness and wellbeing (Kyttä et al., 2016). In this paper, we operationalise the diversity principle by creating a statistical classification of experiences based on attributes respondents assigned to them. Connectivity between experiences is assessed by topological spatial analysis. We look at connectivity on the neighbourhood scale, i.e. the scale which most people consider within everyday walking distance (Ståhle, Marcus, & Karlström, 2005). We then create a new classification of experiences based on their own and spatially connected experiences' categories, simultaneously taking diversity and connectivity into account to describe the experiential composition of a landscape. With topological spatial analysis, we estimate and map these typologies across Stockholm. Finally, we perform topological spatial analysis on residents, workplaces, spatial integration, major roads, nature areas and water bodies to assess associations between the physical landscape and experiential composition.

2.2. Study area

Our study area is Stockholm municipality, the capital of Sweden. The Stockholm urban region has about 1.5 million inhabitants, of which about 1 million live in Stockholm municipality. It is one of the fastest growing cities in Europe – between 2005 and 2015 the municipality population increased by 20%. The city features a mix of built-up areas, nature and water bodies. Built-up areas include a central business district, mixed-use inner-city neighbourhoods, satellite suburbs with mainly apartments as well as areas of detached houses.

2.3. Experience data

We collected data on people's experiences of Stockholm from a PPGIS survey. The survey was open to the public through an online webpage, and designed to record positive and negative regularly occurring experiences that the people of Stockholm have of their city. In addition to recording an experience as either positive or negative, respondents could provide detailed qualitative information about the experience and demographic information about themselves (for full details, see Giusti, Barthel, & Samuelsson, 2017). These data were optional to record. For this study, we used data on attributes of the experiences, both ones related to the respondent (e.g. actions performed or emotions felt) and ones related to the place (e.g. appearance or functional possibilities). In total, there were 65 attributes (35 for positive experiences and 30 for negative), and these were recorded by respondents as being either present or absent.

The survey was accessible online from September 21st 2015 until May 31st 2016. Information about the survey, as well as interest-raising comments provided by respondents, were spread through social media. It was also featured at Färgfabriken, an art hall and policy-practice arena in southern Stockholm, during an autumn 2015 exhibition, and several municipalities within Stockholm County spread information about the survey online and in local newspapers.

This method of data collection does not produce a sample of participants that is representative of the Stockholm population. However, due to the survey being accessible from home computers and handheld devices and it being designed to be easy to understand and complete, it does produce a large sample of geocoded experiences that can be analysed with respect to many different aspects of city life.

2.4. Other data

To facilitate our spatial analysis, we used an axial map. An axial map is composed of the fewest number of longest straight lines (axial lines) passing through all streets, paths, squares and other open surfaces in a defined urban landscape. Thus, axial lines can be said to represent perceptual units (Marcus, 2015). Our axial map was created in 2012, covering Stockholm municipality together with surrounding municipalities.

We used data on the following variables of the physical environment: residents, workplaces, major roads, nature areas, and water bodies. Data on residents was obtained from a layer with the number of residents per property in 2015, created by Stockholm County's Growth and Regional Planning Administration. Data on working population was obtained from a layer with working population per address in 2008 as point data at address points, created by Stockholm Municipality's City Planning Administration. Data on major roads was obtained from a layer with the road network of Stockholm county in 2016 represented as lines, created by Geographic Data of Sweden. We defined categories representing major roads based on our knowledge of roads in Stockholm. Data on nature areas was obtained from Stockholm municipality's 2014 sociotope map, where recreational public spaces are divided into different categories based on their uses. We defined the categories of this map that mainly feature nature as nature areas. Data on water bodies was obtained from a layer of all water surfaces within Stockholm County, created by Geographic Data of Sweden.

In QGIS (QGIS Development Team, 2015), the area of Stockholm municipality was buffered by 1 km and all features located completely outside of this buffer distance (including experiences and axial lines) were deleted, because we considered 1 km to be the upper limit in metres for two features being spatially adjacent.

2.5. Diversity, connectivity and experiential typologies

To analyse experience diversity, we created a statistical classification of experiences through latent class analysis (LCA) with the R package poLCA (Linzer & Lewis, 2014). In LCA, observed variables (experience attributes) are matched with an unobserved class (experience category). Patterns among observed variables form the basis for classification so that data points within the same class are more similar to each other than to those in other classes, and the number of classes provide a good fit with the data. Any variable can appear in several classes, but the classes are mutually exclusive. We fitted models with 3–10 categories of positive experiences and 2–6 categories of negative experiences, and used Bayesian Information Criterion (BIC) to decide the number of categories. Because LCA assumes uncorrelated variables within classes, we tested for conditional dependence between some attribute pairs that we speculated would be most prone to display it.

To analyse experience connectivity, we used Place Syntax Tool (PST) plugin for QGIS (Ståhle et al., 2017). PST uses axial maps to calculate topological distances between geographical features, i.e. the least amount of turns needed to travel from one feature to the other. Because the average pedestrian trip is around 3 axial turns in Stockholm's inner city compared to 6 in the suburbs (Ståhle et al., 2005), we distinguished inner-city from suburban experiences and analysed them separately, using 3 and 6 turns, respectively, as limits for spatial accessibility.

For each experience, we calculated accessibility values of physical variables. Spatial integration is a measure of the average shortest topological distance from an axial line to all other axial lines within a catchment radius, that is standardised between 0 and 1 and then inverted in order for measurements to be comparable across different networks (Bafna, 2003). We calculated spatial integration values with a 3-turn radius for axial lines overlapping with the inner city and with a 6-turn radius for those outside the inner city, and assigned spatial integration values to experiences from the closest axial line. We also calculated the number of residents and workplaces within 3 and 6 axial turns, respectively. Finally, we calculated the fewest number of turns to the closest feature for the variables major roads, nature areas and water bodies. After the accessibility analyses, experiences outside Stockholm municipality were removed from further analysis, to avoid bias due to edge effects.

Based on diversity and connectivity of experiences, we assigned them to experiential landscape typologies. We did this by clustering based on a Gaussian Mixture Model (GMM), using R package mclust (Scrucca, Fop, Murphy, & Raftery, 2016). We limited the clustering to experiences with at least 9 other experiences being connected to them. In GMM, clusters are described by the mean and standard deviation parameters and are allowed to contain covariance. The popular clustering method k-means is a special case of GMM were covariance is assumed to be 0. We chose GMM because we anticipated covariance between some experience categories. Because GMMs are parametrised, the number of clusters and their covariance structure can be decided by model BIC comparison. We fitted models of 3 to 8 clusters for each of the 14 covariance structures available in mclust and chose model based on BIC scores.

To illustrate differences between typologies, we created schematic network graphs of typology averages using the R package igraph (Csárdi & Nepusz, 2006). As a measurement of diversity, we calculated Pielou's evenness index of connected experiences. As a measurement of connectivity, we calculated the total sum of connected experiences. Lastly, we calculated the proportion of positive to total connected experiences. These three variables were calculated both for each experience and typology averages, and then plotted against each other.

To estimate and map typologies across Stockholm, we created a grid with cells of 10 m resolution covering Stockholm municipality. From the centre of each cell, the number of axial steps as well as the distance in metres to the closest experience was calculated. Cells that had one typology to which they were topologically closest were assigned that typology, while cells that were an equal number of axial steps from two or more typologies were assigned the typology they were closest to in metres.

Associations between experiential composition and the physical environment were analysed by producing boxplots of physical variables in different typologies.

3. Results

3.1. Responses to PPGIS survey

The survey recorded 1460 experiences with attribute data within the study area, from 780 respondents. Out of these, 1034 (70.8%) were positive and 426 (29.2%) were negative. 469 respondents recorded information about their gender and age group. 226 (48.2%) were men, 234 (49.9%) were women and 9 (1.9%) defined themselves as neither. The most frequent age group was people aged 25–34 (161 respondents, 34.3%), followed by people aged 35–44 (113 respondents, 24.1%). 63 respondents were 24 years old or younger (13.4%), 82 were aged 45–54 (17.5%) and 50 were 55 years old or older (10.7%).

3.2. Experience categories

LCA showed that our sample is made up of 11 experience categories – 7 positive and 4 negative (Fig. 1). None of the attribute pairs that we assessed displayed significant conditional dependence within categories, meaning that confounding between attributes did not influence the categorisation.

Positive categories with many experiences are not characterised by obviously urban attributes. The most common attributes of *P2*

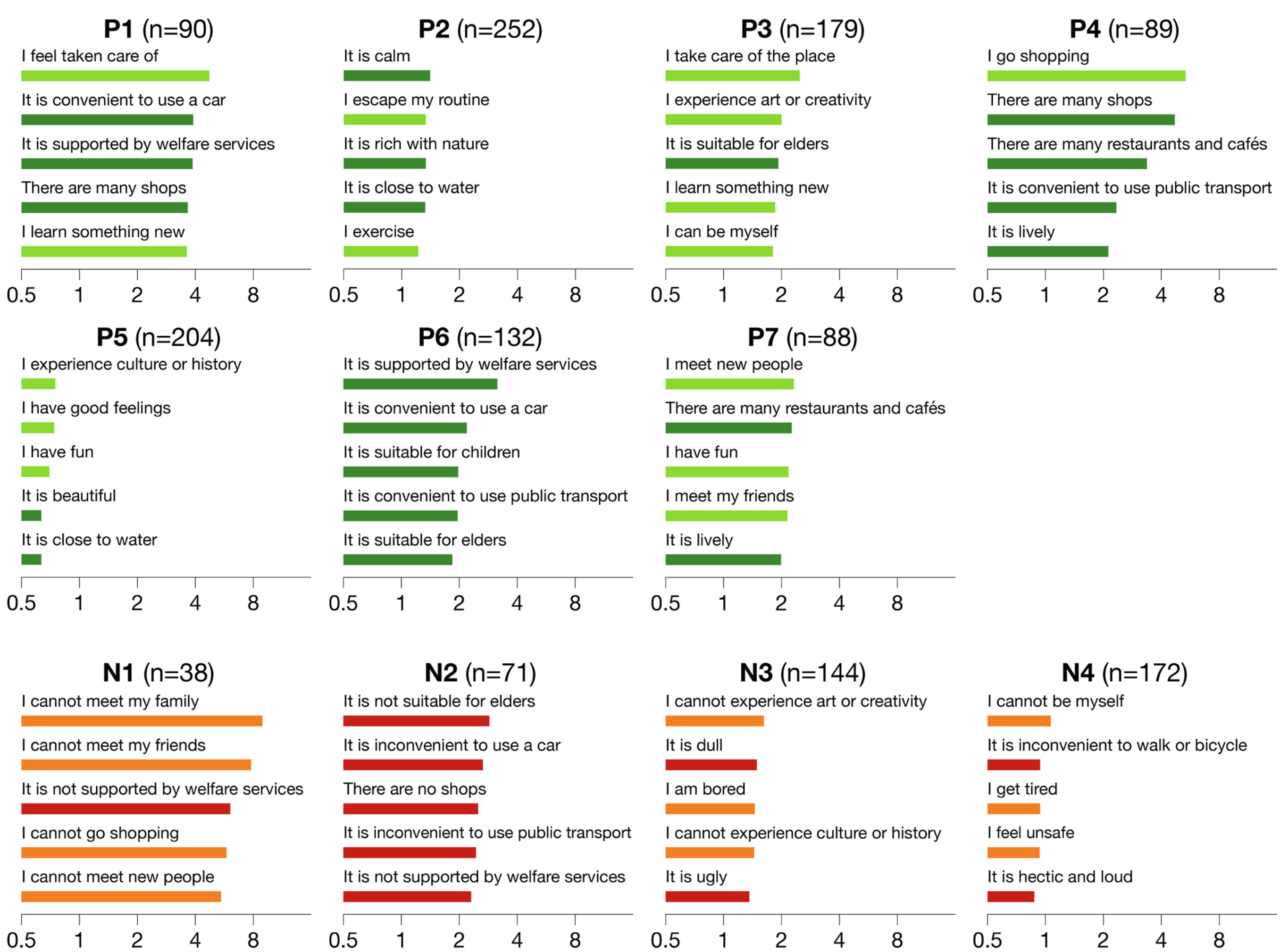

Fig. 1. Categories of experiences, as classified by LCA. The top two rows show 7 categories of positive experiences, while the bottom row shows 4 categories of negative experiences. For each category, the five attributes with the highest relative occurrence are listed. Scales denote relative occurrence, i.e. 2 means that the attribute is twice as common within the category as compared to the whole dataset. Attributes can appear in several categories, but each experience belong to only one category. Attributes related to the respondent have brighter bars, while attributes related to the place have darker.

(n = 252) are calmness, escape from one's routine and nature. For *P5* (n = 204) they are presence of culture or history and good feelings. By contrast, categories directly related to urbanity contain fewer experiences. Common attributes of *P7* (n = 88) are related to socialising, while for *P4* (n = 89) they are related to shopping. Among the negative experiences, the most common category *N4* (n = 172) often feature restrictions of being oneself and difficulties to walk or bicycle. For *N3* (n = 144), common attributes are difficulties of experiencing art or creativity and dullness.

Although Stockholm's inner city covers a much smaller area than the suburbs, most experiences are located there. This is especially true of negative experiences, whereas positive ones are more evenly distributed. Categories *P4*, *P5* and *P7* are most concentrated towards Stockholm's central parts, with about two thirds of experiences being located in the inner city, whereas those in *P3* and *P6* are mostly found in the suburbs (around 55%). Negative categories are less different from each other with respect to an inner city/suburban divide – *N4* is somewhat more common in the inner city (72%) whereas *N1* is somewhat less common (61%).

3.3. Typologies of experiential landscapes

999 experiences had at least 9 other experiences being connected to them. With these, we fitted GMMs of 3–8 clusters. For all covariance structures, more clusters resulted in lower BIC scores, indicating that there might be more than 8 typologies. However, because we considered more than 8 typologies too many for a conducive analysis, we proceeded with 8.

Some typologies are contained to specific areas, while others exist in several neighbourhoods across the city (Fig. 2). Four typologies were found mainly in the inner city. *Hyper-connected negative* (n = 41) was found along main roads in the northern part of the inner city. It has the highest connectivity (i.e. average number of other experiences connected to an experience) of any typology, but also little diversity and the second lowest proportion of positive experiences (36%) (Fig. 3). *Connected negative* (n = 158) was found throughout the inner city. It features a similar experiential composition to *Hyper-connected negative,* but with roughly two thirds of the connectivity. All four categories of negative experiences are relatively common in these two typologies (Fig. 4). *Connected positive* (n = 100) was found on the island of Södermalm and to its immediate south. This typology has slightly lower connectivity than *Connected negative* but has a more diverse experience composition and a much higher proportion of positive experiences (67%). Common experiences in this typology are related to shopping and socialising. Lastly, *Secluded urbanity* (n = 168) was mostly found in parks, along the water or in Stockholm's old town. Outside of the inner city, it was found in some suburban centres. This typology has an experience composition similar to *Connected positive*, but with roughly a third of the connectivity.

Secluded ambiguous (n = 110) and *Family-friendly* (n = 108) have similar levels of connectivity and proportion of positive experiences as *Secluded urbanity*. *Secluded ambiguous* is found in suburban centres close

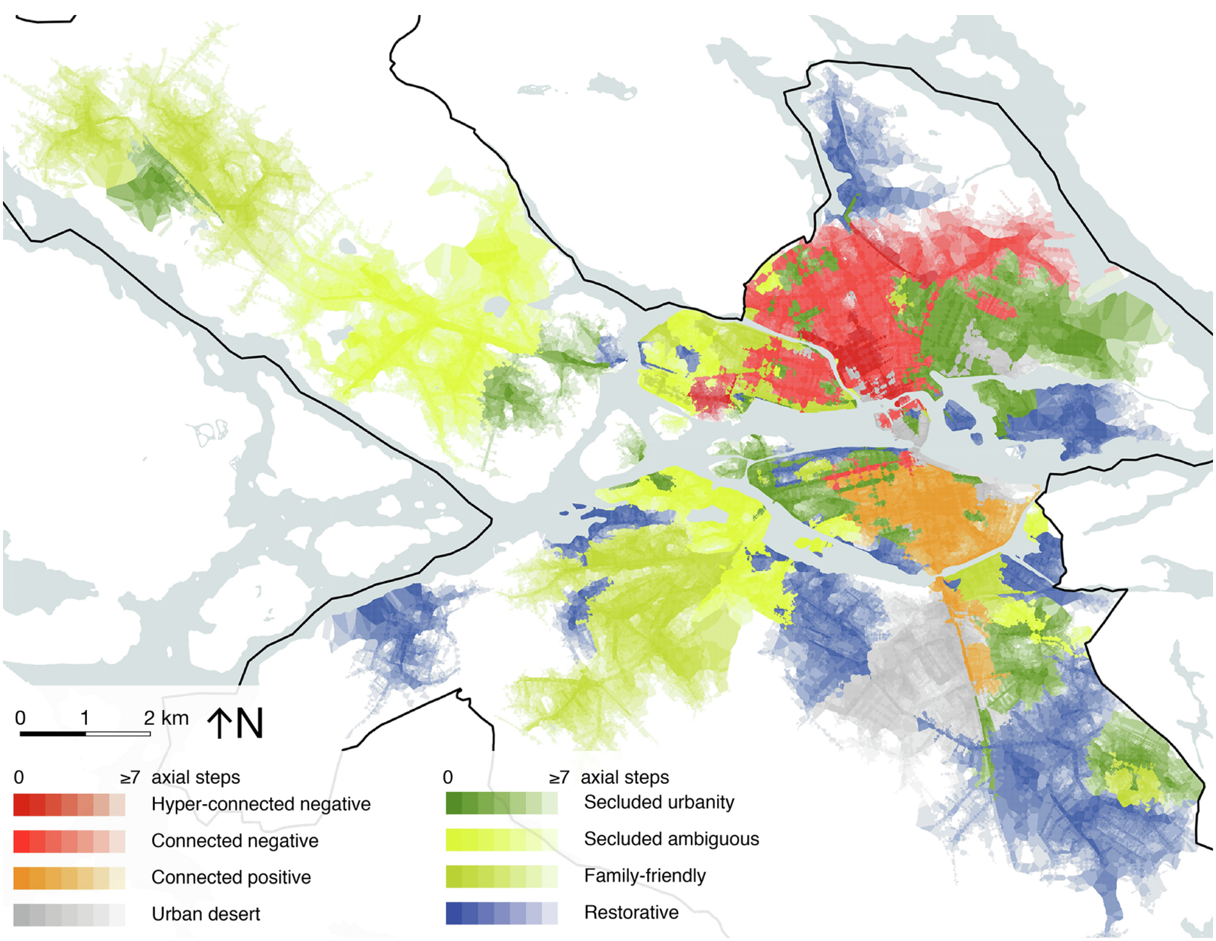

Fig. 2. Map of estimated distribution of experiential typologies across Stockholm. Cells were assigned to the typology of the experience they are closest to, measured in axial steps. In the case of two or more typologies being equally close, cells were assigned to the typology of the experience they are closest to in metres. In order to give an impression of how certain estimations are, transparency of cells reflect how many axial steps away they are from a data point. Cells on the same axial line as a data point have no transparency while cells that are 7 or more axial steps away from a data point are fully transparent.

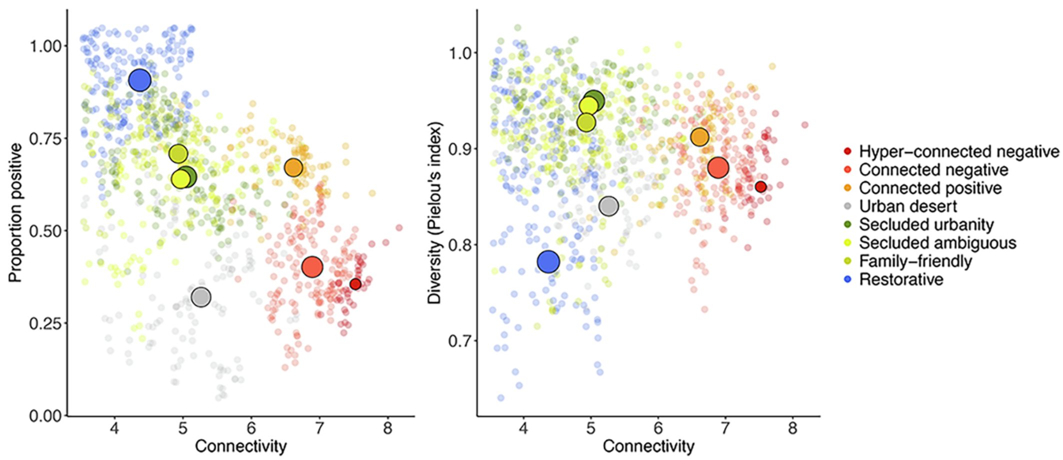

Fig. 3. Relationships between connectivity, proportion positive experiences and diversity in the different experiential typologies. Connectivity is measured as the number of other experiences connected to an experience and shown on a logarithmic scale with base 2. Diversity is measured as Pielou's evenness index, i.e. experiences with a more even distribution of experiences from different categories connected to them get a higher score. Data points in the background show individual experiences, colour-coded by their respective typologies, and are jittered to avoid over-plotting. Typology averages are shown by the circles in the foreground, their size being proportional to the number of experiences in that typology. There is a general trade-off pattern between connectivity and proportion positive experiences, but *Connected positive* and *Urban desert* deviate to either side of this pattern. The highest diversity of experiences occur in typologies with intermediate connectivity levels, while more connected typologies generally display lower diversity.

to the inner city, with common experiences somewhat surprisingly relating both to experiencing and not being able to experience art or creativity. *Family-friendly* is more scattered, appearing in remote suburbs as well as the inner-city district of Kungsholmen, with common experiences relating to places being family-friendly and providing possibilities for shopping. *Urban desert* (n = 124) is predominantly found close to three large infrastructure junctions along Stockholm's main north-south axis. Connectivity in this typology is comparable to *Secluded urbanity* but it has the lowest proportion of positive experiences (32%). Experiences that dominate this typology relate to places being inconvenient or lacking possibilities to socialise. The last typology, *Restorative*, is the most common (n = 190) and the most scattered, found predominantly in larger nature areas or along the water. It has the lowest connectivity and highest proportion positive experiences (91%). It is also the least diverse, being heavily dominated by experiences relating to escaping one's routine or taking care of the place.

3.4. Associations with physical variables

We analysed how variables of the physical environment varied for the different experience typologies (Fig. 5). Spatial integration is closely associated with connectivity of experiences. Typologies with higher connectivity – *Hyper-connected negative*, *Connected negative* and *Connected positive* – have higher spatial integration than other typologies. There is a similar association between the number of accessible residents and workplaces added together and connectivity. However, when analysing the proportion of workplaces to residents and workplaces added together, a clear association emerged where typologies with more negative experiences feature a higher proportion of workplaces. Typologies with a higher diversity of experiences – *Connected positive, Secluded urbanity, Secluded ambiguous* and *Family-friendly* – generally have moderate levels of spatial integration and density, and more residents than workplaces.

There are no obvious general patterns concerning accessibility to major roads, nature areas and water bodies in different typologies. However, *Urban desert* is generally far from nature areas while *Restorative* are close to them. Interestingly, *Restorative* often display great variation in other variables, indicating that it is more closely related to a single physical variable rather than a combination of several, as opposed to e.g. *Hyper-connected negative*, *Connected negative* or *Connected positive.*

4. Discussion

In this paper, we developed a method for operationalising resilience principles in the analysis of human experiences in an urban landscape. While an increasing amount of research has been done on city-wide resilience, our method represents a promising way for exploring urban resilience at eye level, that is, the level where people experience the city (Marcus & Colding, 2014). Accessibility researchers (Kwan, Murray, O'Kelly, & Tiefelsdorf, 2003) and urban morphologists (Hillier, 1996) have independently pointed out the lack of knowledge at this scale of urban space. It is important to develop such knowledge to better understand the dynamics of the city as a nested complex adaptive system. Our focus has been to shed new light on what clusters of experiences contribute to or hinder wellbeing and their relation to urban form – a critical slow variable in such complex systems. The study builds on previous work exploring relationships between urban form and wellbeing in two ways: by measuring both the urban environment and human experiences in it in ways consistent with the ecological approach to perception and behaviour, and by exploring patterns among different relationships simultaneously. We found considerable differences in the experiential compositions of typologies that display associations with urban form. In the remaining part of this paper, we focus our discussion of results around three topics: 1) a critical reflection on the method, 2) specific ways in which experiences could be regarded as mediators between environment and wellbeing and 3) how our overall findings can translate to guiding heuristics for urban development.

4.1. Reflection on the method

The method applied in this paper was developed in order to operationalise resilience principles in the analysis of human experiences of an urban landscape. Several factors were critical in enabling us to do this. First, PPGIS can gather data with high experiential precision. This enabled us to create an empirical classification of experiences. Second, both our experience dataset and the public data of Stockholm has high spatial precision, enabling spatial analysis on a level of detail of

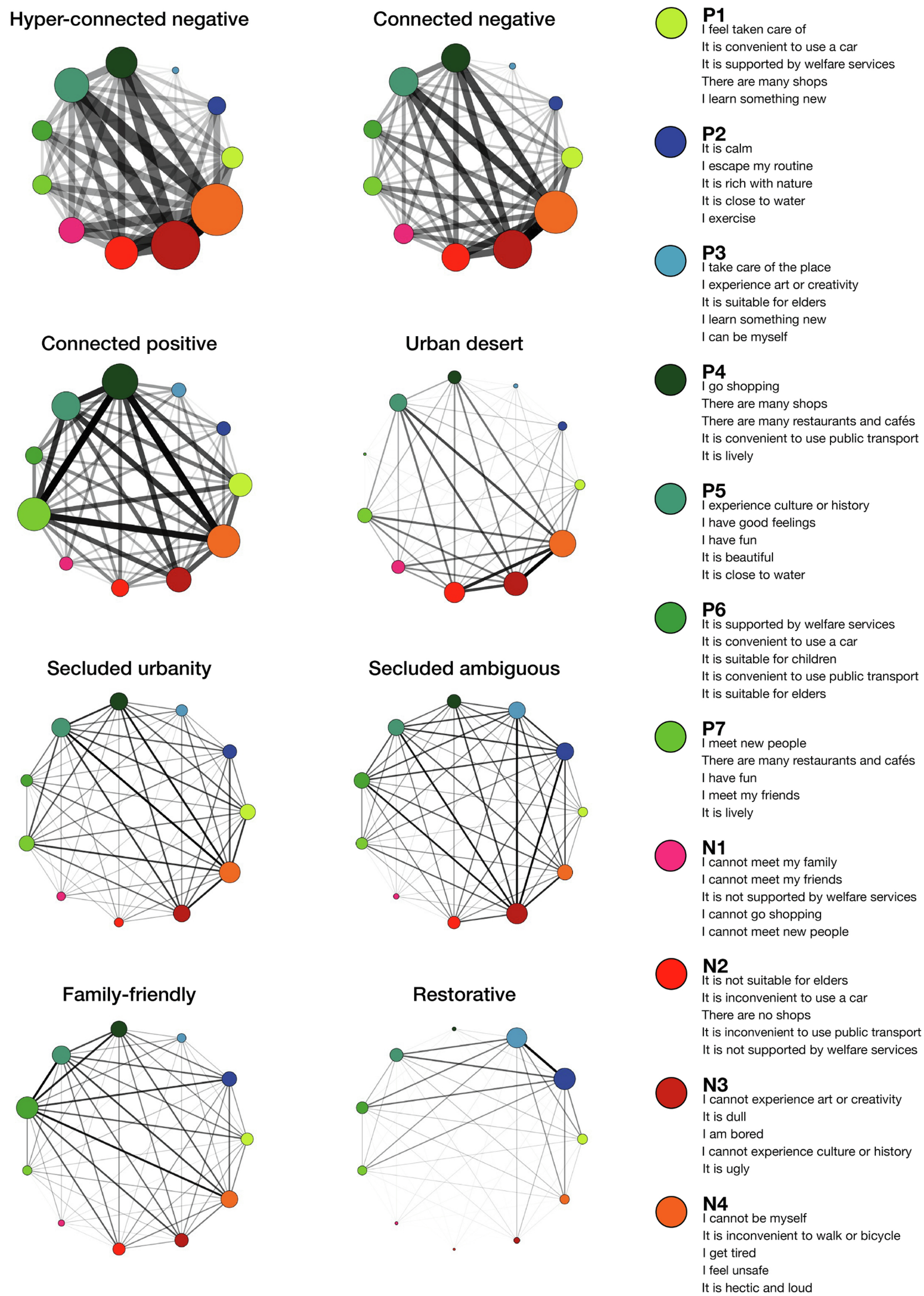

Fig. 4. Experiential composition and connectivity in the different experiential typologies. Each experience category is represented by a different-coloured circle, and sizes of circles for different typologies correspond to the frequency of experiences of that category accessible from an experience in that typology. Widths and transparency of lines between experiences are proportional to the combined prevalence of the two types of experiences they are connecting, to give an impression of what categories of experiences dominate a certain typology.

individual experiences. Third, because PPGIS can gather large amounts of data we were able to distinguish several associations between environments and specific types of experiences simultaneously. The spatial method is also of direct interest to planning, because it uncovers specific areas where interventions could be directed to make cities more attractive to live in.

Yet, our method also has some significant limitations. On a general level, difficulties encountered by groups of participants in expressing ideas through digital technology is a well-documented problem, commonly referred to as the "digital divide" (Katz & Gonzalez, 2016). In our sample, most people are between 25 and 44 years old, so there is a risk that the experiences of e.g. older people are not represented in our

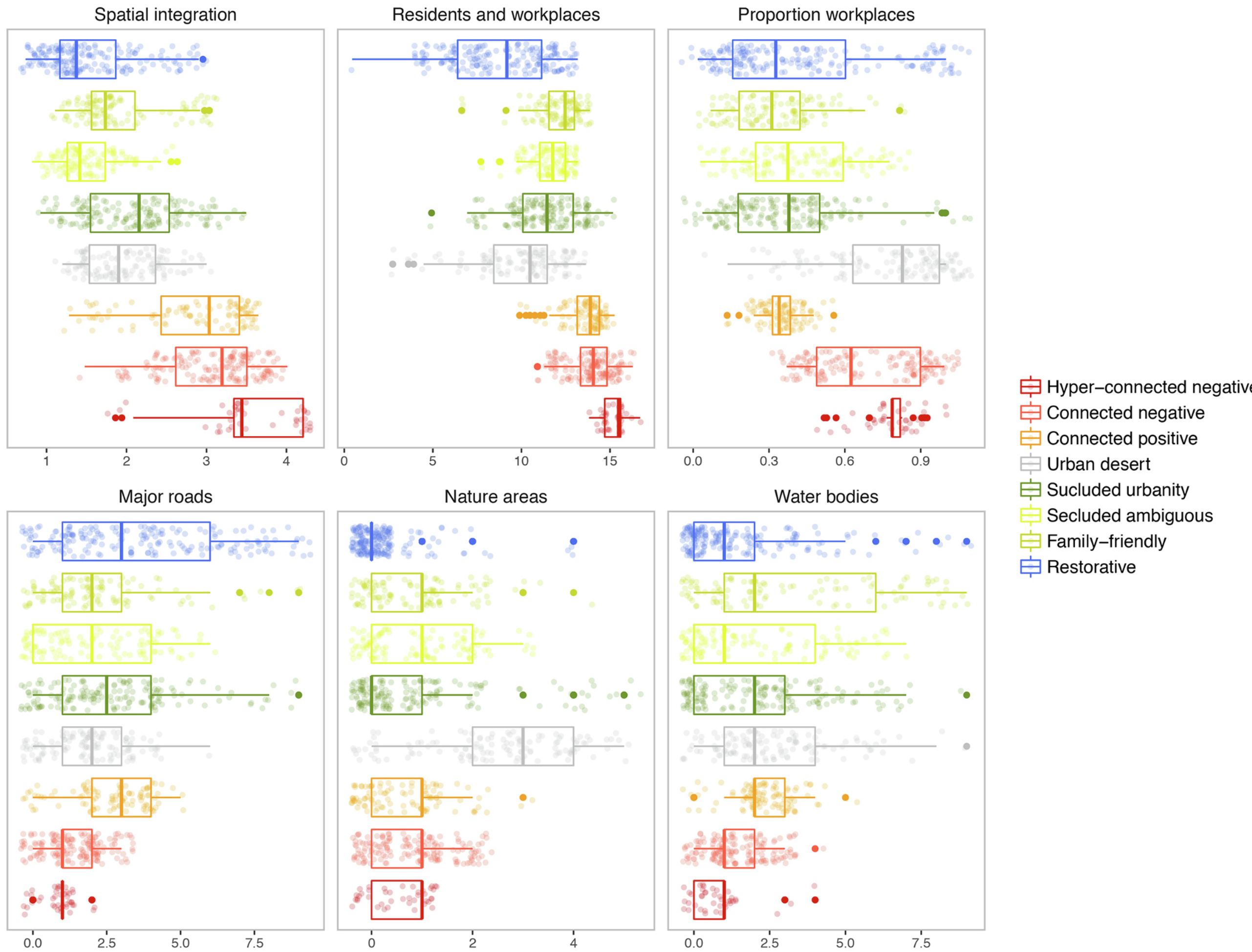

Fig. 5. Distributions of physical variables in different experiential typologies. Spatial integration is measured as is conventional in the space syntax literature (see Bafna, 2003). Residents and workplaces is plotted on a logarithmic scale with base 2 (e.g. 10 means there are roughly 1000 residents and workplaces within walking distance). Major roads, nature areas and water bodies are measured as axial steps. Spatial integration and total population are associated with connectivity of experiences, while proportion workplaces is associated with the proportion of experiences that are positive. Typologies with higher experience diversity tend to have moderate levels of spatial integration and an emphasis on residents over workplaces.

typologies. Moreover, PPGIS surveys risk attracting people with values or preferences that do not represent the public well (Brown, Kelly, & Whitall, 2013). This risk is arguably greater when surveying for example management preferences than everyday experiences, but we cannot rule out the possibility that a random sample would have produced different results in some respects. Another important limitation is that our research design is cross-sectional, meaning that we cannot know how experiences in urban environments influence individuals' wellbeing over time. There are many longitudinal studies on wellbeing impacts of physical factors, such as urban nature (Alcock, White, Wheeler, Fleming, & Depledge, 2014) or noise (Pyko et al., 2017), but to our knowledge no one has yet investigated the interplay between different urban experiences and its influence on wellbeing over time.

4.2. Experiences as mediators between environment and wellbeing

In Stockholm, places with high spatial integration are disproportionately experienced as hectic or unsafe. Based on previous findings (Pain & Townshend, 2002), we were not surprised to find this. In addition, these places harbour many negative experiences related to difficulties to socialise or go shopping. This is more surprising, because shops and cafés cluster in spatially integrated places (Hillier et al., 1993), also in Stockholm. One plausible explanation for this result is the ratio of workplaces to total population. Areas with many workplaces change the most over the course of a day. Crowding during the day might negatively affect possibilities to enjoy the company of friends or family, while a feeling of desolation outside workhours is equally uninviting for socialising. These findings point in a perhaps surprising direction: if Stockholm's central parts were to become less spatially integrated and had offices converted into housing, experiences that hinder wellbeing might be curbed. They also show that the current treatment of connectivity in the urban resilience literature as something where more is always better (Ahern, 2011; Jabareen, 2013) needs to be critically assessed. In ecosystems, studies show that habitat connectivity may occur at the expense of easier spread of disturbances, such as invasive species or fires. Compartmentalized structures in ecosystems may increase stability by isolating and retaining the impacts of a perturbation within a single module (May, 1972). These insights may inform the building of more resilient street networks in a city. The fundamental and empirically supported idea here is that urban street grids often are constituted by a "foreground network" that provides high accessibility throughout the urban system, facilitating high socio-economic exchange and social interaction, and a "background network" that in patches throughout the system creates secluded and undisturbed spaces, facilitating socio-cultural continuity and transmission as well as reproduction of specific types of experiences (Hillier, 2009). Hence, and as we argue herein, an experientially attractive city should strive to avoid over-connected street networks.

Three typologies – *Secluded urbanity, Secluded ambiguous* and *Family-friendly* – are very similar concerning connectivity, diversity and proportion of positive experiences. However, the kinds of experiences that are most common differ between them. Comparing them, experiences related to shopping or socialising occur where spatial integration is higher, corroborating the literature (Hillier et al., 1993). However, where the population is greater, there is a tendency towards less experiences related to shopping or socialising. In other words, whether there are people on the streets or people inside buildings might not always matter for the connectivity or diversity of experiences, but it matters for what kinds of experiences there are. Because people on the streets and people inside buildings are best captured by different variables, this points to the inadequacy of density alone as a proxy for how urban space is experienced and used.

Our analysis showed that the most common typology is *Restorative*. Experiences in this typology mainly relate to escaping one's routine or taking care of the place. *Restorative* is a suitable name for this typology because escape from one's routine is a main quality of restorative experiences (Korpela et al., 2001), while taking care of the place might reflect the quality of involving activities with matching support in the environment. What defines areas within this experience typology is vicinity of nature, supporting previous research (Korpela et al., 2001; MacKerron & Mourato, 2013). This typology has the lowest connectivity of experiences, being located in places with little spatial integration. This indicates that the experiences, despite belonging to the most common typology, are likely not part of people's everyday routine, but instead analogous to the "background network" previously referred to. In terms of experiential composition, *Restorative* is the least diverse and the most different from other typologies. We think that these findings together speak to the importance of restorative experiences as an almost universal counter-balance to the rest of urban life, highlighting the need for urban planning to account for them in any attempt to safeguard the wellbeing of urban dwellers.

Apart from the *Restorative* typology, *Secluded urbanity* also contains many experiences that are close to nature. However, in this typology, respondents report restorative experiences less often than across the city as a whole. This begs the question whether experiences of nature in *Secluded urbanity* entail the same restorative benefits as those in *Restorative.* We see two possibilities. The first is that people have other motivations for seeking out places with nature in *Secluded urbanity,* e.g. meeting friends, and thus do not report their experiences as restorative even when they are. The second is that nature in *Secluded urbanity* is qualitatively different from nature in *Restorative.* Restorative effects of urban nature mainly depends on size but also vegetation cover (Nordh, Hartig, Hagerhall, & Fry, 2009). Whether one, the other, or a combination of both possibilities is true is important for future work to address, because it can provide insight into how cities could be designed for people that do not actively seek out restorative environments.

4.3. Resilience at eye level: A guiding heuristic for urban development

How can resilience principles help us understand how urban environments structure human experiences? By applying them, we found consistent patterns in how experiences are distributed across space in Stockholm. We found a trade-off between connectivity and the proportion of positive experiences, and that this pattern correlates with spatial integration. We also found the greatest diversity of experiences at intermediate levels of connectivity. Interestingly, these findings resonate with the intermediate disturbance hypothesis as developed by Connell (1978), which proposes that ecosystem resilience is maximized when disturbance is neither too rare nor too frequent (Colding, Elmqvist, & Olsson, 2003). Our results suggest that the rationale behind the intermediate disturbance hypothesis may have an important analogue regarding people's experiences in cities. In addition, the greatest diversity of experiences often occurs in neighbourhoods with a few thousand residents and workplaces within walking distance, a ratio of workplaces below 50% and easily accessible nature areas. These features are largely in line with how many urban scholars describe socially and economically vibrant neighbourhoods (e.g. Jacobs, 1961). Our findings show that resilience principles can also be useful as heuristics for urban environments' potential to afford experiences contributing to people's wellbeing.

How should urban environments be structured and configured to afford experiences that promote urban dwellers' wellbeing while undergoing urbanisation? We find that many kinds of environments seem to afford experiences promoting wellbeing, while some hinder it. Successfully navigating urbanisation is a question of avoiding constructing environments hindering wellbeing. The typologies *Connected positive* and *Secluded urbanity* provide an idea of how this could be done. Their experiential compositions are similar. However, *Connected positive* has greater spatial integration and populations, and also higher connectivity between experiences. These high-density connected environments that retain possibilities for a diversity of experiences promoting wellbeing balance residents and workplaces, avoid extreme spatial integration or total population numbers and have accessible nature. Guided by these heuristics, neighbourhoods that undergo densification could possibly move from being more like *Secluded urbanity* to being more like *Connected positive*. That is not to say that all neighbourhoods should be like *Connected positive* – an experientially attractive city still requires a diversity of experiential typologies catering to different kinds of people.

Several questions central to building resilience at eye level remain open. This is a cross-sectional study, so we cannot discuss how experiences in the urban environment affect an individual's wellbeing over time. However, it is possible that diversity of experiences within the same person contributes to that person's wellbeing through an enriched meaning-making of the world. By way of analogy, we constantly use memories of previous experiences to interpret current experiences, as well as augment our accumulated experience to make future analogies more fine-grained (Bar, 2007). Do environments that provide possibilities for experience diversity also lead to a diversity of experiences within the same individual? Another important question is whether environments that support resilient wellbeing outcomes also are resilient from other perspectives. Human-environment relations have been suggested as a suitable heuristic for facilitating sustainable behaviour in cities (Kaaronen, 2017). Can synergies be found between experiences supporting wellbeing and behaviour supporting the biosphere, and how could these synergies inform design of urban spaces?

5. Conclusion

As the rate and scale of urbanisation increases, it is critical to develop heuristics that work as tools in urban planning and design, and operate at the 'eye-level scale' that makes sense for urban dwellers. Cities can achieve very different effects on human wellbeing in navigating urbanisation. Our study shows that some high-density neighbourhoods in Stockholm display a diversity of positive experiences while others suffer from issues of e.g. crowding and feelings of unsafety. While negative experiences will always be part of urban life, environments that continuously expose inhabitants to these should be considered for re-design. We conclude that an experientially attractive city should provide the conditions for a diversity of positive experiential typologies at city level by avoiding over-connected street networks or mono-functional high-density environments. It should also be creative with the "background network" in nurturing secluded or nature-rich spaces of mixed functions and intermediate levels of density. Achieving resilience at eye level requires a shift in urban planning practice that in many cases still suffers from a view of the city as a collection of compartmentalised functions, rather than one emphasising relations between spaces and between places and people (Marcus, Giusti, & Barthel, 2016). It requires more effort than solely focusing on density. Yet, if it opens up the prospect of cities decreasing metabolism while not eroding capacities for generating and sustaining inhabitants' wellbeing, it seems to us as an effort well worth making.

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