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Creation of synthetic homogeneous neighbourhoods using zone design algorithms to explore relationships between asthma and deprivation in Strasbourg, France

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ABSTRACT

The concept of 'neighbourhood' as a unit of analysis has received considerable research attention over the last decade. Many of these studies raise the question of the influence of local characteristics on variations in health and more recently, researchers have sought to understand how the neighbourhood can influence individual health through individual behaviour. Relatively few studies discuss the question of the borders and definition of a neighbourhood but we know that the results from health or population datasets are very sensitive to how zones are constructed – part of the Modifiable Areal Unit Problem (MAUP). In reality, we know that neighbourhoods are not constrained by artificial statistical boundaries, but rather exist as complex multi-dimensional living communities. This paper tries to better represent the reality on the ground of these communities to better inform studies of health. In this work, we have developed an experimental approach for the automated design of neighbourhoods using a small tessellated cell as a basic building block. Using the software AZTool, we considered population, shape and homogeneity constraints to develop a highly innovative approach to zone construction. The paper reports the challenges and compromises involved in building these new synthetic neighbourhoods. We provide a fully worked example of how our new synthetic homogeneous zones perform using data from Strasbourg, France. We examine data on Asthma reported through calls to the emergency services, and compare these rates with an index of multiple deprivation (NDI) which we have constructed and reported elsewhere. Higher correlations between Asthma and NDI were found using our newly constructed synthetic zones than using the existing French census areas of similar size. The significance of our work is that we show that careful construction of neighbourhoods – which we claim are more realistic than census areas – can greatly aid unpacking our understanding of neighbourhood relationships between health and the social and physical environments.

Introduction

The last decade of research in the environment and health field has seen the emergence of the concept of neighbourhood (Diez Roux, 2003; Kawachi, 2003; Pickett & Pearl, 2001) as a unit of analysis. Many of these studies raise the question of the influence of local characteristics on variations in health (Macintyre, Ellaway, & Cummins, 2002; Pickett & Pearl, 2001). For instance, the effects of proximate exposure to environmental stressors such as local ambient air pollution gave rise to a body of literature linking air pollution to several health outcomes, including asthma exacerbation (Samet & Krewski, 2007; Ward & Ayres, 2004). Most studies use average citywide ambient pollutant concentrations in order to estimate exposure, although these concentrations often vary spatially and strongly within cities (Jerrett et al., 2005). The social gradient for asthma is also well established; the most deprived being more at risk (Laurent, Bard, Filleul, & Segala, 2007). An effort has then been made to explore the influence of socioeconomic factors on the above associations (Lin, Chen, Burnett, Villeneuve, & Krewski, 2003) again with a low spatial resolution. Our group carried out studies on this topic using a small area design for assessing both exposure to air pollutants and socioeconomic status (Laurent, Filleul, et al., 2008, Laurent et al., 2009).

Paralleling work in Anglo-Saxon countries, here has been some early work investigating definitions of neighbourhood in France by

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Tonnellier (1992). More recently, French researchers have sought to understand how neighbourhood can influence individual health through individual behaviour, in particular as regards risk factors for ischaemic cardiac disease (Chaix et al., 2008). Studies have used multilevel analysis as a tool (Diez Roux, 2003; Diez Roux, Link, & Northridge, 2000; Wright & Subramanian 2007) to document how neighbourhood effects modulate the relation between exposure to environmental stressors and individual health.

Environment, social and individual factors all play a role in an individual's health and wellbeing (Dahlgren & Whitehead, 1991; McLeroy, Bibeau, Steckler, & Glanz, 1988). Linking social and health data to a particular place is important because where we live can and does influence our health. Health outcomes are related to an individuals' environment, including factors such as water, soil and air content, exposure to hazardous materials, tobacco smoke, occupation, marital status, social support, characteristics of the home, in addition to the composition of the local built environment (Marmot, 2000; Pickle, Waller, & Lawson, 2005).

Here it is useful to acknowledge the 'context verses composition' debate (Macintyre et al., 2002). Debates on how big or small a neighbourhood should be, and how it shapes health are often set within the wider question of which is more important in terms of shaping health – the area in which people live (context) or the people who make up the inhabitants of that area (composition)?

Local spatial units, variously referred to as community (Wright et al., 2004), place (Macintyre et al., 2002) or residential environment (Bonaiuto, Fornara, & Bonnes, 2003; Diez Roux, 2003; Mares, Young, McGuire, & Rosenheck, 2002; Wright, 2008) are often the units of analyses used to investigate its different aspects: noise or the presence of green space (van den Berg, Maas, Verheij, & Groenewegen, 2010; Maas, Verheij, Groenewegen, de Vries, & Spreeuwenberg, 2006), physical environment (Niemann et al., 2006; Van kempen et al., 2006; Willich, Wegscheider, Stallmann, & Keil, 2006), living conditions such as the indoor physical environment, availability of and accessibility of healthcare, transportation networks (Forsyth, Schmitz, Hearst, & Oakes, 2008; Lee & Moudon, 2008; Nagel, Carlson, Bosworth, & Michael, 2008), or food stores (Moore & Diez- Roux, 2006; Powell, Auld, Chaloupka, O'Malley, & Johnston, 2007; Sturm & Datar, 2005), but also the social environment, by studying, for example, violence and stress in the neighbourhood (Clark, Benkert, & Flack, 2006; Suglia, Ryan, Laden, Dockery, & Wright, 2008; Sundquist et al., 2006; Wright et al., 2004) as well as aspects of social cohesion or social capital (Ikeda et al., 2008; Lett et al., 2005; Sundquist, Lindstrom, Malmstrom, Johansson, & Sundquist, 2004).

Whilst the term neighbourhood is frequently examined in the literature, as a concept it is difficult to define objectively. For reasons of practicality and data availability, most studies examining asthma as an outcome use predefined geographic areas, associated with already available geographic data, especially those designed by the collection and output of census data. These include US census tracts (Juhn et al., 2005; Liu & Pearlman, 2009), US census block groups (Saha, Riner, & Liu, 2005; Shankardass, Jerrett, & Milam, 2010), the US Postal Service ZIP code (Litonjua, Carey, Weiss, & Gold, 1999), the census output area or ward in Great Britain (Burr, Verrall, & Kaur, 1997), meshblocks in New Zealand (Salmond, Crampton, Hales, Lewis, & Pearce, 1999) and in France, the IRIS census block (Laurent, Filleul, et al., 2008; Laurent, Pedrono, et al., 2008). Among conceptual models of neighbourhood definition, Wright and Subramanian (2007) proposed a theoretical framework of neighbourhood definition, which may influence asthma outcome.

Relatively few studies discuss the question of the borders and the definition of neighbourhood, but we know that the results from health or population datasets are very sensitive to how zones are constructed – part of the Modifiable Areal Unit Problem (MAUP). In reality, we know that neighbourhoods are not constrained by artificial statistical units, but rather exist as complex multi-dimensional living communities. We acknowledge the contestability around the concept of place. Here we are not just interested in capturing sterile spaces of habitation, but rather places where, to paraphrase (Agnew, 1987), social interactions and relations occur, where people have emotional attachment and moreover, have a sense of place.

This paper tries to better represent the reality on the ground of these communities to better inform studies of health. In this work, we have developed an approach for the automated design of neighbourhoods using a small tessellated cell as a basic building block without the constraints of pre-existing zone boundaries.

MAUP

We know that the borders of study areas, both their shape and size influence results (Gehlke & Biehl, 1943). This is a component of the modifiable areal unit problem (MAUP) well known to geographers (Fotheringham & Wong, 1991; Openshaw, 1984). Fotheringham and Wong (1991) defined MAUP as the 'sensitivity of analytical results to the definition of units for which the data are collected' (p. 1025). Its essence is that analytical results for the same data in the same study area can be different – in some cases wildly different – if aggregated in different ways.

The MAUP is often described as having two aspects—the scale and the zonation effects (Fig. 1). The scale effect is the tendency, within a system of modifiable areal units, for different statistical results to be obtained from the same set of data when the information is grouped at different levels of spatial resolution. The aggregation or zoning effect is the variability in statistical results obtained within a set of modifiable units as a result of alternative combinations of areal units of the same size (Openshaw, 1984).

These two phenomena are often taken into account in geographical studies (Unwin, 1996), but only rarely in spatial or geographic epidemiology, even when exposure is estimated on an

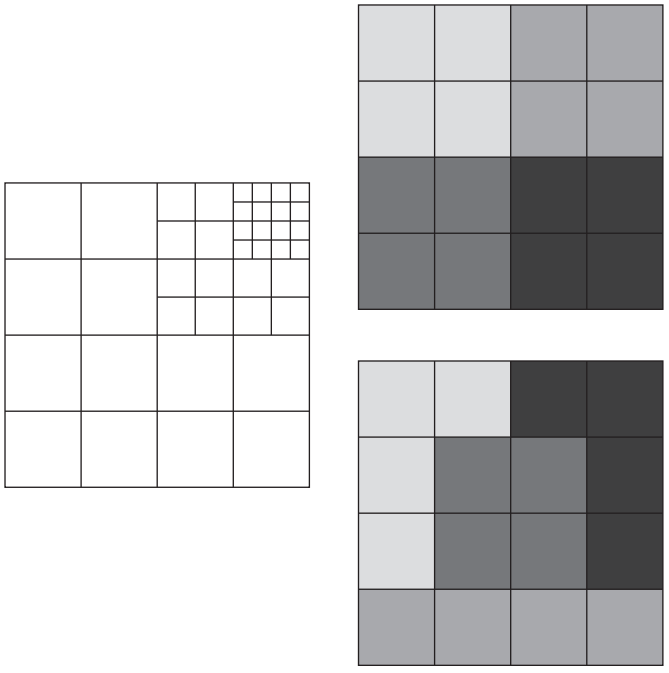

Fig. 1. Illustration of the scale (left) and zonation (aggregation) (right) effects in MAUP.