



Conceptualization and measurement of environmental exposure in epidemiology: Accounting for activity space related to daily mobility

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ABSTRACT

A considerable body of literature has investigated how environmental exposures affect health through various pathways. These studies have generally adopted a common approach to define environmental exposures, focusing on the local residential environment, using census tracts or postcodes to delimit exposures. However, use of such administrative units may not be appropriate to evaluate contextual effects on health because they are generally not a 'true' representation of the environments to which individuals are exposed. Recent work has suggested that advances may be made if an activity-space approach is adopted. The present paper investigates how various disciplines may contribute to the refinement of the concept of activity space for use in health research. In particular we draw on seminal work in time geography, which provides a framework to describe individual behavior in space and time, and can help the conceptualization of activity space. In addition we review work in environmental psychology and social networks research, which provides insights on how people and places interact and offers new theories for improving the spatial definition of contextual exposures.

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1. Introduction

A considerable body of literature in social science and population health research has investigated the field of contextual effects over the past two decades. Despite ongoing discussions on the best way to define geographic context (Bernard et al., 2007; Cummins et al., 2007; Daniel et al., 2008; Macintyre et al., 2002), ecologic and multilevel analysis have generally adopted a common approach based on the notion of "neighborhood". Most studies focus on the residential neighborhood and used local administrative units, such as census tracts, as spatial delimitations (Diez Roux, 2001). Such choices are primarily based on the availability of routine administrative data rather than on the theoretical underpinnings concerning the appropriate spatial scale at which environmental exposures are meant to affect individuals. Census tracts, block groups, or postal units provide a readily usable spatial delimitation for the assessment of social or built characteristics of local areas. Nevertheless, administrative units are probably ill-suited to represent the appropriate space to

evaluate environmental effects on health, as they generally do not represent the potentially accessible environment of an individual nor the true experienced exposure (Lee et al., 2008). Prior research on environment-health relationships has observed a relatively marginal effect of neighborhood factors (Adams et al., 2009; Diez Roux, 2001; Oakes, 2004; Pickett and Pearl, 2001). However, a misspecification of contextual boundaries could explain the weakness of such observed associations (Spielman and Yoo, 2009). Until now, social and spatial epidemiology have not fully integrated individual space-time behavior, even if fixed residential spatial units may not be the most relevant way to account for environmental exposure in epidemiologic research.

By reviewing the concept of space and mobility in the fields of epidemiology, geography, transportation research, and environmental psychology, the present article aims to help refine the conceptual and operational elements for environmental exposure assessment in epidemiological research. First, we question the relevance of routinely using administrative units. Second, the role of mobility is explored in relation to the current focus on residential exposure in aetiological studies. Given the transdisciplinary nature of research on mobility and exposure, the present article performs a scoping review in various disciplines in order to explore how notions of mobility and activity spaces may contribute to a refinement of contextual exposures in health research.

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2. Measuring exposure: The limits of a static approach to neighborhood

2.1. The neighborhood: A static definition of context

2.1.1. Residential neighborhoods as fixed spatial units

Several literature reviews (Chaix, 2009; Cummins et al., 2007; Leal and Chaix, 2010; Riva et al., 2007; Schaefer-McDaniel et al., 2010a) have questioned the legitimacy of using fixed spatial units such as census tracts, census block groups, postal codes, voting precincts or administrative unit clusters as geographic boundaries to investigate social and physical influences. Relationships between neighborhood residential environments and various health behaviours and outcomes have traditionally been investigated using such an approach. This choice is justified, in part, by the homogeneity criterion (related both to the physical and socioeconomic environments) that is generally used to establish these spatial delimitations (Diez Roux, 2007), the availability of routine data describing such administrative units, and use of some statistical methods that require hierarchical data such as multilevel modelling.

Such definitions of context have conceptual and methodological limitations for environmental exposure assessment in epidemiology. Whereas administrative or historically inherited delimitations of neighborhoods may have true sociological and collective meanings (Lebel et al., 2007), they are not necessarily representative of each individual's unique spatial experience. Due to individualized patterns of mobility around the residence, there is often a mismatch between the experienced or perceived residential neighborhood and its administrative definition. Perceptions of neighborhood limits will vary between individuals, even among those residing in the same building (Coulton et al., 2004, 2001; Duncan and Aber, 1997; Schaefer-McDaniel et al., 2010b). Furthermore, the characteristics of a given unit are potentially less adequate in representing the exposure of individuals living near the boundaries of the unit than of individuals located near the center of the unit (Chaix et al., 2005). The currently rigid and uniform approach that nests individuals within fixed spatial units generates a common spatial definition of context and thus attributes similar levels of exposure to all individuals living in the same administrative territory (Leal and Chaix, 2010).

The heterogeneity of geographic units of analysis in research makes comparisons across studies difficult. For example, the mean number of inhabitants per geographic unit often varies from one study territory to the other (Diez Roux and Mair, 2010; Lee et al., 2008). Furthermore, multilevel studies usually analyze administrative units as independent and isolated areas (Chaix et al., 2005), as opposed to various types of spatial hierarchical models (Anselin, 2009). This practice ignores resources located in adjacent units (Coulton et al., 2001) that could potentially affect health (Morenoff, 2003). In other words, using administrative units imposes excessive simplifications and a fragmentation of space that leads to potential misestimation of interactions between space, its resources and individual spatial behavior (Diez Roux, 2008).

2.1.2. Shifting to an ego-centered definition of place

Geographic Information Systems (GIS) enable to circumvent the use of routine administrative units as proxies for neighborhoods. As recommended by several authors (Chaix et al., 2009; Lee et al., 2008; Miller, 2007), an ego-centered definition of the residential “neighborhood” may reflect more accurately the local exposure area related to the personal experience of the residential space (Nemet and Bailey, 2000). An ego-centered neighborhood corresponds to a local area which is centered on an individual – typically his/her home – and whose boundaries are generally defined by a given distance threshold.

Different types of buffers have been used, such as circular or elliptic zones, and road network buffers (Oliver et al., 2007). Various distances have been experimented with, but authors have generally used a threshold distance that is easily walkable from home, so as to represent the distance people are willing to walk from home to reach basic utilitarian destinations—though there is limited empirical data to support the choice of buffer size. A number of authors have, for example, used half a mile radius circular buffers around each individual's home (Berke et al., 2007; Leal et al., 2011; Tilt et al., 2007). A study in Seattle, Washington, evaluated that most home and routine destinations were between 0.2 and 0.4 miles apart (Moudon et al., 2007). Some authors (Chaix et al., 2009) also emphasized the use of home centered buffers with fuzzy boundaries, which account for the often smooth transition between the inner and the outer neighborhood space. Similarly, person-focused exposure areas should be specific to the individual rather than universally applied to study participants, and may be defined as oriented rather than isotropic (i.e., distorted in a certain direction according to familiar places, street networks, shops, transport stations and obstacles such as railroads or rivers). Nonetheless, as emphasized by Leal et al. (2011), the choice of the spatial scale is intimately related to the study territory, type of contextual factors, and outcomes of interest and should be driven by these factors.

Yet, administrative and ego-centered neighborhoods are often exclusively home-centered and do not take into account that individuals move around and do not stay in one unique location over the course of their daily activities (Rainham et al., 2010).

2.2. From a static to a dynamic approach of exposure

2.2.1. The neighborhood: an incomplete unit of analysis

Defining the context of exposure using residential areas has been criticized from different perspectives including that of the “local trap” (Cummins, 2007) and the “residential trap” (Chaix, 2009). According to the concept of the local trap, the local scale is not the only meaningful unit of interest in environmental health research; as a result context should not be exclusively defined as a local area (Purcell and Brown, 2005). The residential trap refers to the danger of reducing the influence of context solely to residential environments. Measuring exposure only at one's place of residence ignores non-residential locations visited during daily activities, such as the work place and school, and may thus misrepresent ‘true’ environmental exposures (Matthews, 2011; Setton et al., 2011). Kwan and Lee (2004) emphasized that households did not limit their use of contextual resources to their local neighborhood, but accessed facilities like shops or health-care services in places other than the local areas. The choice of where resources are accessed and used depends on their specific location but is also motivated by individual spatial trajectories, and life situation (Kwan, 1999). Moreover, some authors have shown that there are weak correlations between residential exposures and non-residential environments (Hurvitz and Moudon, 2012; Zenk et al., 2011). This entails that individuals have significantly different residential and non-residential exposures, and accounting for multiple place exposures would avoid individual exposure misclassification.

Most contextual studies in epidemiology have ignored exposure to activity spaces outside of the residential environment (Chaix, 2009). The amount of time spent at home and the fundamental importance of one's residence may be seen as a justification of the fact that contextual epidemiologic research has relied on residential neighborhood in order to assess environmental exposure. Moreover, limiting exposure to the residential neighborhood may be less misleading for specific groups such as young children (Inagami et al., 2007; Pearce et al., 2009) and older people, whose spatial

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