**Complexity and uncertainty in geography of health research: incorporating life-course perspectives**

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**Abstract**

Geographers, including those interested in the relationships between health and place, have made important contributions to how, when and where humans are exposed to and influenced by different spatial contexts. Using detailed and sometimes real-time spatial and temporal data, geographers have enhanced our understanding of how people move within and between different social and physical environments, and the implications for health outcomes and behaviours. Yet almost all of this work focuses on spatial temporal mobility over short time periods (e.g. day, week) and there has been little effort to understand the extent to which people are exposed to different types of places and environments over their full lifespan. This paper examines the analytic possibilities of, and technical challenges to, incorporating this uncertainty into a life-course framework to better understand (a) the accumulation of environmental circumstances over life and (b) whether there are critical periods during life when aspects of place is particular pertinent in understanding health. It is argued that this approach not only offers opportunities to understand better the complex relationships between health and place (and other social outcomes) but can also strengthen the evidence for causal relationships between the environment and health. Finally, there is brief discussion of some of our own nascent work considering these issues using longitudinal data collected in the United Kingdom.

**Key words:** health geography; life course; context; uncertainty

**Introduction**

In recent years, geographers have been prominent in international interdisciplinary research endeavours that seek to understand how environmental circumstances are implicated in crucial global health challenges including non-communicable diseases, healthcare provision, infectious disease and health inequalities (Brown et al. 2017). Collectively, this work emphasises places can be healthy and therapeutic as well as pathogenic and degenerative. It is also apparent that addressing these public health priorities require long-term, sustainable, and intersectoral policy approaches that integrate a deep understanding of the ways in which ‘context’ affects different disease vectors. Despite these important contributions from geographers, there are critical conceptual and methodological challenges that are threatening to undermine the discipline’s prominence in global public health research. In particular, it is increasingly apparent that much health geography scholarship is failing to address and embrace key contextual uncertainties that are affecting the assessment and specification of human contextual exposure and experiences of places. There are very few examples of work examining these uncertainties over long time periods including the full duration of life. This concern is problematic because it will almost certainly result in the misspecification of environmental exposures and, potentially, in imprecise assessments of place-based influences and causal processes.

The intention of this paper is to consider various ways in which geographers are beginning to overcome important conceptual and methodological issues that affect contextual uncertainties. The paper goes on to examine some important concerns with respect to contextual uncertainty that have received little attention but are restricting a fulsome understanding of the connections between health and place. Although the focus is on health, the issues discussed are salient across a broader range of concerns where the role of geographic context is important.

**Health and place research: some key challenges**

The principal ambition of health geography scholarship is to understand how, when and for whom place is implicated in understanding aspects of health outcomes, behaviours and related experiences including healthcare. A prominent tradition in the sub-discipline has been to use a conceptual model to establish potentially relevant pathways between health and place and then, using quantitative analyses, identify appropriate place-based factors (e.g. pollution, area level deprivation) to derive indicators of exposure for individuals who reside in that area. These measures can then be integrated with individual-level socio-demographic and health information of the residents (e.g. from health surveys) and approaches such as multi-level modelling used to examine the variation in the health outcomes attributable to the contextual factors. Whilst this body of work has been instructive, significant conceptual and methodological concerns have been identified (Kwan 2012) that are likely to impede further substantive progress in developing and deepening our understanding of health-place relations.

First, in most health geography studies the spatial configuration and delimitation of geographic units is problematic as most studies tend to rely on exposure assessment that is based on conveniently available and static areas usually around residential locations (e.g. census units). This is a concern because these spaces may not represent the full extent of the multiple contexts to which people are exposed, or the results might be sensitive to the design of the spatial units and/or the geographic scale selected for analysis. The influence of the well-established modifiable area unit problem (MAUP) has received much attention in the literature on health and place (Flowerdew, Manley, and Sabel 2008).

Second, better-specified contextual measures should not only recognise issues relating to the geometric construction of contextual units but also that the temporal dimensions matter too. More particularly, people traverse a multitude of residential, work, recreational and other spaces over the course of their daily lives, and their use (and potential use) of places over these short time scales are likely to be significant in understanding their health and related behaviours, as well as inequalities in health (Shareck, Frohlich, and Kestens 2014). Therefore, people’s exposure to and experiences of social, physical and cultural place-based processes that influence their health and wellbeing can fluctuate over time in complex ways. For some people at least, it is likely that key health-related social and physical place-based resources may be distal from their residential neighbourhoods (Shareck, Kestens, and Frohlich 2014). In these circumstances, spatial measures of ‘activity spaces’, usually captured using GPS, may be more appropriate for capturing exposure to local health-related features such as food stores (Zenk et al. 2011), tobacco outlets (Lipperman-Kreda et al. 2015) or healthcare provision (Vallée et al. 2010). Although activity space methods have marked a welcome shift from exclusively residentially-based exposure measures towards complete multi-locational assessment, the approach has been critiqued for potentially adding important bias that may confound health-place relations (Chaix et al. 2013). For instance, health-related behaviours such as diet, physical activity and smoking will affect daily mobility patterns as individuals seek out preferred environmental resources such as food stores, green spaces and tobacco outlets. Failing to exclude the locations visited specifically to perform the activities related to the outcome of concern may lead to biased findings. Methodological innovations that combine GPS data with transport surveys or web mapping applications (Chaix et al. 2012), geotagged social media information (Nguyen et al. 2016), geographic ecological momentary assessment (Kirchner and Shiffmas 2016), or social network and social interactions analyses (Kestens et al. 2017) offer prospects for further enhancing the ways in which context is captured and understood in health research (Kwan 2012).

Third, and related, it is increasingly recognised that the most appropriate geographic specification of particular contextual measures may differ between demographic and social groups and across health outcomes and behaviours. Some groups (e.g. young children) may be more contingent on place-based resources in their residential neighbourhood whereas other groups (e.g. those in full-time employment) may draw on resources from a wider range, and more geographically-dispersed set, of locales. Work in New Zealand for example has shown that for individuals who were more reliant on their local neighbourhoods there was a stronger relationship between built environment characteristics (destination density, streetscape attractiveness and street connectivity) and physical activity outcomes (Ivory et al. 2015). This issue emphasises the need for theoretically-informed and bespoke contextual measures that recognise and capture how age, socioeconomic circumstances and other factors affect people’s dependencies on their residential and non-residential spaces.

It is therefore clear that important conceptual and methodological concerns threaten to undermine the identification and specification of causal relationships between health and place. Although these earlier concerns are important, and recent innovative approaches to enhancing measures of contextual exposure are a welcome addition to the literature on health and place, the field continues to overlooks a problem that is vital to understanding contextual uncertainty and generating relevant and reliable knowledge. The issue here is that most work incorporating a temporal dimension has been concerned with spatial temporal mobility over relatively *short time periods* (e.g. day or week); there are few examples of studies attempting to understand the extent to which people are exposed to different types of environmental circumstances *over their full lifespan*. This is important because most work on health and place relies on contemporaneous data that are highly likely to mis-specify an individual’s environmental exposure and may lead to an underestimate of the importance of the accumulative importance of place in understanding health. Related, there is a paucity of work seeking to identify whether there are crucial points in the life course where certain aspects of places are particularly salient for subsequent health outcomes. It is plausible, for example, that environmental circumstances early in life (e.g. pollution exposure during early childhood) have major implications for health in adolescence and early adulthood (e.g. developmental outcomes and respiratory health) as well as towards the end of life (e.g. cognitive ageing). Although concepts such as the ‘exposome’ have emphasised the totality of *individual* environmental exposures (including physical features, personal behaviours and socioeconomic factors) from the prenatal period onwards (Wild 2005; Jacquez et al. 2015), few studies have been able to operationalise these complex spatio-temporal processes.

The remainder of this paper examines the analytical possibilities and technical challenges of incorporating this contextual uncertainty into a life-course framework to better understand (a) the accumulation of environmental circumstances over life and (b) whether there are critical periods during life when place is particular pertinent in understanding health. It is argued that this approach not only offers opportunities to understand better the complex relationships between health and place (and other social outcomes) but can also strengthen the evidence for causal relationships. Finally, there is a discussion of some of our own early work considering these issues using data collected in the UK.

**Health and place over the life course: new opportunities**

Geographic concerns with life-course perspectives are well-established in some parts of the discipline, perhaps most notably in population geography (Bailey 2009). Important themes in human geography such as ageing (Skinner, Cloutier, and Andrews 2015), migration (Findlay et al. 2015), housing and gentrification (Smith and Holt 2007) and family relationships (Feijten and van Ham 2010) have all benefited from engagements with a life-course perspective. This work has shown how early life and/or lifetime accumulations of events, experiences and assets affect subsequent life chances through placing people in advantageous or vulnerable circumstances as well as the extent to which individuals and groups are empowered to alter or develop resilience to these circumstances (Bailey 2009). For example, geographical work on migration and mobility demonstrates how the timing and nature of migration is changing in relation to socio-demographic factors (e.g. changing family structures) and period effects (e.g. housing market geographies) (Thomas, Mulder, and Cooke 2017). These findings not only demonstrate that migration and mobility are explicitly relational processes (individual lives being linked to each other and broad structural conditions) but also that these changes are producing different outcomes (e.g. employment, income) later in the life course (Coulter, van Ham, and Findlay 2016). Similar encounters with life-course frameworks have been fruitful in other disciplines, including perhaps most notably, over two decades of important research in social epidemiology and cognate disciplines revealing how a multitude of health and behavioural outcomes can, in part at least, be dependent on circumstances much earlier in life. Studies adopting a life-course approach have shown for example how physical (e.g. cardiovascular), mental (e.g. anxiety, depression) and behavioural outcomes (e.g. tobacco and alcohol use) in adulthood are affected by factors such as socioeconomic status, nutrition, IQ and health conditions in utero, childhood, adolescence and/or early adulthood (Poulton et al. 2002; Kuh et al. 2003).

Whilst this work has significantly enhanced the epidemiological literature, with some notable exceptions (Curtis et al. 2004; Murray et al. 2013; Lekkas et al. 2017), few geographers and others with interests in health and place have successfully adopted a life-course perspective. This omission is problematic because many disease and behavioural outcomes, as well as the antecedents of health inequalities, have long response lags and it is feasible that environmental exposure early in life (e.g. childhood) may also have life-long implications for health. Therefore, the lack of conceptualisation and operationalisation of contextual exposure assessment over people’s lives has added further analytic uncertainty. People are not only highly mobile in their activity spaces across the course of the day but they are also increasingly itinerant through their lives as they respond to a host of factors relating to employment opportunities, housing markets, family responsibilities and other life events. Importantly, these migration flows are often highly health selective as migration events can often be promoted by health-related outcomes (Tunstall et al. 2015). Previous work has found that people with similar levels of health and well-being tend to congregate over time, leading to greater spatial inequalities in health outcomes across cities, regions or countries (Pearce and Dorling 2010; Gatrell 2011; Tunstall et al. 2014). Further, not only do people migrate between different social and physical milieu during their lives, it is also apparent that places can be highly dynamic and change rapidly over short and medium periods of time, or remain highly stable, with implications for environmental exposures of local residents and ultimately their health (Pearce, Mitchell, and Shortt 2016). Understanding these placed-based trajectories and the movement of people through and within these different social contexts may be important in explaining diverse health outcomes across populations. Not only have these difficulties resulted in a weak conceptual understanding of connections between health and place but it is likely that researchers have mis-specified – and likely underestimated – how place matters for health, which in turn has undermined the identification of causal relationships.

The few studies attempting to capture contextual measures over the life course and relate these to health are mostly limited to studies of the social environment (often using census-based indicators). The evidence tends to suggest that residing in disadvantageous social circumstances (e.g. captured using measures of area-level deprivation or unemployment) detrimentally influences subsequent health trajectories (e.g. physical capabilities or disease outcomes), sometimes much later in life (Curtis et al. 2004; Hystad et al. 2013; Murray et al. 2013). Although these findings have been significant in developing causally relevant contextual measures, the reliance on census-based information is problematic because they are usually poorly specified proxies for other place-based processes. Beyond this work on area-level social characteristics, the only other studies to examine the relationships between health and place across the life course has been work on the influence of air pollution (Elliott et al. 2007; Hansell et al. 2016) and living in a rural area (Jokela et al. 2009; Patterson et al. 2017).

The obstacles to operationalising research on health and place across the life course are non-trivial. Answering such questions requires the integration of longitudinal information about people and places over long periods. Data relating to people’s geographic mobility across their lives coupled with detailed information about the social, demographic and health characteristics are limited. Even rich data resources such as the British Birth Cohorts are restricted in the detail collected about participants’ residential addresses over time. Even more significantly, obtaining longitudinal place-based data stretching back over a number of decades is challenging as it is rare that historical environmental data are readily available in a format suitable for research use. Collecting and collating these data can be expensive and time consuming, requiring extensive searching across a multitude of archival sources that are often located in different settings with various restrictions on access and use. Further, the data that it is possible to collect may be limited due to non-availability at particular time points or produced at an inconsistent spatial resolution. Environmental information may be unavailable for critical windows such as during the period of childhood. Related, there may be varying data collection strategies over time that restrict the comparability of environmental measures between different junctures in the life course. It is also likely that while some information may be readily available at regular time points (e.g. area-level socioeconomic measures from the census, or estimates of pollution estimates from air quality monitors) other aspects of place that have been related to health (e.g. local social capital) may not be obtainable for multiple time points over the life course. Nonetheless, despite these technical challenges, there remains a significant opportunity in integrating longitudinal health and environmental data to enhance understanding of environmental exposure over the life course. The final section of this paper looks at some of the opportunities for geographers interested in the relationships between health and place over the life course, and briefly examines some emerging research in this area.

**Advancing our understanding of health and place: the life course of place approach**

Although, there are technical challenges in integrating longitudinal environmental data with longitudinal health and demographic information, the research opportunities are significant for researchers interested in developing richer understandings of how place-based processes operate to affect health through life. In nascent work in the UK we have been attempting to overcome some of the technical challenges noted above to examine how places matter for health over the life course, and, in particular, whether the influences of place are accumulative and/or if there are critical periods during the life course which are particularly salient for health. To consider these questions, we have proposed a framework that we have called the ‘life course of place’ (Pearce 2015). The life course of place approach is designed to simultaneously understand the co-evolution of people and places and the significance of these dynamic and reciprocal relationships over time. We have been using this framework to guide the methodological development for ‘reconstructing’ the health-related characteristics of places across the Lothian region of Scotland to examine how places have evolved over the past 100 years (Pearce et al. 2016). Longitudinal information on features of the neighbourhood environment including green space, social deprivation, pollution as well as alcohol and tobacco outlets have been collected from various archival resources. This environmental information was then integrated with data from participants of a birth cohort who were born in 1936 (the Lothian Birth Cohort 1936) (Deary et al. 2012) using residential information gathered using a “life grid” questionnaire when the participants were aged 78 (Cherrie et al. 2017). Analyses of this innovative dataset have provided novel insights into the role of place across the life course. For example, the findings demonstrate that greater provision of local parks (defined as the percentage of park area that intersected with a 1,500m buffer zone surrounding the participant’s address) in mid adulthood and particularly childhood seems be related to slower cognitive ageing in later life (between the ages 70 and 76) (Cherrie et al. 2017) and, for those residing in the most socially disadvantaged neighbourhoods, better mental health at the age of 70 (Pearce et al. 2017).

Whilst the integration of longitudinal environmental and health data provides analytic promise, it is also apparent that it is operationally challenging. More specifically, the procurement and integration of environmental data over time can be a significant and for some environmental characteristics an impossible task. It is unusual for longitudinal area-level data on green space, pollution, housing and so on to be collected and archived, particularly in digitised form. Therefore, new methods are required to make use of those resources that are available. Many of these historical resources remain in paper-based format (e.g. maps, newspapers, reports) and therefore methodological developments are needed to enable automated extraction techniques for large geographical areas that coincide with available health data. Procedures such as automated map extraction methods that identify, enter and geo-reference features recorded on historical maps (e.g. green spaces, industrial facilities) (Chiang, Leyk, and Knoblock 2014) and Geographical Text Analysis which recognises and classifies geo-referenced textual data are examples offering methodological promise (Porter, Atkinson, and Gregory 2015).

**Conclusion**

As geographers and epidemiologists have argued, linking information on the places where people have lived across their lives with data on their health, socio-demographic circumstances and residential history in a key research priority with a host of analytic possibilities for a better understanding how health unfolds (Diez Roux and Mair 2010; Pearce 2015). Integrating dynamic conceptualisations of place with new methods for collecting and analysing data on human mobility will enable a richer understanding of how people’s movement between, or entrapment within, evolving (or static) geographic contexts is implicated in their health trajectories.

One of the constraints of most current health-environment work, including empirical studies using cohort data, is the lack of information on whether and how people use and engage with their local environments (e.g. visits to, and activities in, local parks). Most existing studies rely on residential location as a proxy for environmental exposure, yet studies using GPS technology emphasize that individual ‘activity spaces’ are often far more geographically dispersed and complex. Further, the range of available longitudinal environmental data is often restricted to data extracted from population censuses. Advances in individual-level data capture such as through mobile technology and social media offers the potential to prospectively acquire longitudinal information about an individual’s mobility patterns at different stages of the life course. This information alongside data on their wellbeing, behaviours, perceptions of the spaces they occupy and other social, genetic, cultural and environmental factors offer new possibilities for charting an individual’s exposome (Jacquez et al. 2015).

A life course of place approach incorporating longitudinal data on the totality of an individual’s exposure and experiences offers the potential for new and historically informed insights into how some of the most important concerns in health geography emerge from ‘complex systems’ (e.g. economic, transport, food) (Curtis and Riva 2010). This includes the spatial and temporal dynamics of how people’s social and physical milieu across life operate to affect their health and wellbeing. It is argued that moving away from traditional linear cause and effect models to embrace complex systems approaches are vital for understanding multilevel and context-driven public health challenges and in developing effective policy responses (Rutter et al. 2017).

Whilst the technical impediments to this research agenda are not to be underestimated, identifying and extracting the data required for developing measures of the ‘life course of places’ and then integrating the geographic measures with longitudinal health data offers new opportunities to better understand the pathways linking health and place either accumulatively or in time-limited windows during the life course. Such an approach would allow novel insights into the whether there are critical junctures when the connections between person and place are life altering due to the person’s life stage or due to events that transform the individual’s environment such as natural disaster, economic crisis or large-scale migration. Further, in doing so, studies of health and place over the life course will be better able to understand, address and incorporate an aspect of contextual uncertainty that is currently largely missing from the literature. Future work in other settings could usefully adopt the life course of place framework to provide a richer and more nuanced comprehension of the relationships between place and health over people’s lives and a better understanding of the causal relationships between the two.

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