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Toward dynamic urban environmental exposure assessments in mental health research

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ABSTRACT

It is increasingly recognized that mental disorders are affected by both personal characteristics and environmental exposures. The built, natural, and social environments can either contribute to or buffer against metal disorders. Environmental exposure assessments related to mental health typically rely on neighborhoods within which people currently live. In this article, I call into question such neighborhood-based exposure assessments at one point in time, because human life unfolds over space and across time. To circumvent inappropriate exposure assessments and to better grasp the etiologies of mental disease, I argue that people are exposed to multiple health-supporting and harmful exposures not only during their daily lives, but also over the course of their lives. This article aims to lay a theoretical foundation elucidating the impact of dynamic environmental exposures on mental health outcomes. I examine, first, the possibilities and challenges for mental health research to integrate people's environmental exposures along their daily paths and, second, how exposures over people's residential history might affect mental health later in life. To push the borders of scientific inquiries, I stress that only such mobility-based approaches facilitate an exploration of exposure duration, exposure sequences, and exposure accumulation.

1. Urban environments and mental health

Mental health is an integral aspect of people's capacity to live a fulfilling life (World Health Organization, 2013). However, mental disorders (e.g., anxiety, depression) are exceedingly prevalent (Wittchen et al., 2011): On a global scale, one out of five adults suffered from a mental disorder within the past year (Steel et al., 2014). With a lifetime prevalence of two out of seven adults, mental disorders make a significant contribution to the number of healthy years lost due to mental ill-health (Steel et al., 2014). Mental disorders not only have devastating consequences for people's quality of life, but also present striking challenges for health systems and cause significant economic losses (Bloom et al., 2011). Both research and policymakers have therefore identified the reduction of mental disorders as a key priority (World Health Organization, 2013; Wittchen et al., 2011).

Public concerns about mental health have prompted a large number of researchers to disentangle the underlying risk and protective factors. It seems that the predisposition of people toward mental disorders consists of genetic factors, demographic characteristics, socioeconomic conditions, traumatic events, lifestyle habits, etc. (Cairns et al., 2014; Franklin et al., 2017; Hawton et al., 2013; Lorant et al., 2003; Meng et al., 2017). It turns out that these individual factors are not the sole health influencing factors (Kestens et al., 2017). According to the socio-ecological model of health (Sallis et al., 2008), people's mental health behavior also shapes, and is shaped by, the socio-environmental context in which they live and/or are born and raised (Riva et al., 2007; Diez Roux and Mair, 2010; Mair et al., 2008; Blair et al., 2014; Tost et al., 2015). The socio-ecological model furthermore suggests that the environment – subsuming built, natural, and social environments – serves as a background factor that can trigger, reduce, or amplify the risk of suffering from a mental disorder. More recently, significant conceptual and methodological progress has been made concerning the role of place in general (Riva et al., 2007; Diez Roux and Mair, 2010; Blair et al., 2014), and how the urban environment affects the brain in particular (Tost et al., 2015). Along with this renewed interest in the urban environment, a differentiated understanding of environmental exposures emerged, namely that places constitute different physical environments while being shaped by social interaction (Kestens et al., 2017).

Whereas the aforementioned risk and protective factors are relatively well understood, how the built, natural, and social environments together affect mental disorders remains less clear (Tost et al., 2015; Stickley et al., 2017; Adli et al., 2017; Heinz et al., 2013; Peen et al., 2010; Prüss-Üstün and Corvalán, 2006; Nieuwenhuijsen, 2016). There

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is increasing evidence that the built environment (e.g., urban morphology, land use, and street layout) might be a determinant of mental health (Rao et al., 2007; Sarkar and Webster, 2017). Although the existing knowledge is inconclusive, and the individual environments were frequently studied in isolation (Mair et al., 2008; Weich et al., 2002; Evans, 2003; Saarloos et al., 2011; James et al., 2017), it seems that, for example, higher urban densities increase social interactions that may decrease the risk of psychotic disorders (Kawachi and Berkman, 2001). Neighborhoods with well-connected streets benefit from good neighborliness, thus increasing community ties and enhancing the degree of acquaintanceship (Duncan et al., 2013). Similarly, land-use diversity ensures that there are more destinations nearby (Miles et al., 2012). Both factors encourage active travel, which has antidepressant effects (Teychenne et al., 2008). Others have reported the opposite effect, namely that, for example, walkable neighborhoods increase depression risk, but variations across population groups are possible (James et al., 2017). The natural environment (i.e., green space and blue space) has received attention in the mental health literature, and accumulated findings suggest that greenness reduces stress and has restorative effects (Gascon et al., 2015; Hartig et al., 2014; Völker and Kistemann, 2011). There is evidence that strong social ties, a close family, etc. reduce the risk of mood disorders at the individual level (Mair et al., 2008; Hawton and van Heeringen, 2009), and that overcrowded places characterized by stressful urban living contribute to psychological stress (Tost et al., 2015; Berry, 2008).

Although these explanations seem intuitively plausible, empirical models utilizing either cross-sectional or longitudinal study designs are still controversial. The partly contradictory results might be traced back to the static conceptualizations of how place and environmental exposures are integrated, which is primarily done by means of administrative units thought to represent neighborhoods (Kwan, 2012, 2013; Van Ham and Manley, 2012). Such static environmental exposure assessments are undoubtedly inappropriate, however, as they misleadingly assume that people do not move in space–time throughout a day or over their life course.

In this article, I therefore argue for a dynamic conceptualization of environmental exposures when exploring environment–mental health relations. Further, I stress the significance of advances in geotechnologies as well as the availability of register data with respect to the implementation of dynamic exposure assessments. As health policies are increasingly grounded in evidence-based research, dynamic exposure assessments that focus on people's daily mobility and residential trajectory are necessary as they may prevent a misspecification of the health-influencing context across space and over time (Park and Kwan, 2017).

The rest of the article is structured as follows. Section 2 promotes a switch from neighborhood-based conceptualizations of environmental exposures to mobility-based exposure assessments; Section 3 deals with the benefits of dynamic context specifications; Section 4 outlines challenges related to space–time exposure assessments; and Section 5 presents the conclusions.

2. From static to dynamic exposure assessments

2.1. Area-based exposure assessments

Although not consistently confirmed, urban living seems to affect mental health (Tost et al., 2015; Heinz et al., 2013; Gruebner et al., 2017a). For example, a meta-analysis confirmed that urbanization is a risk factor for several psychiatric disorders (e.g., mood and anxiety disorders) (Peen et al., 2010). However, research (Blüml et al., 2017; Helbich et al., 2015) remains on a coarse analytical scale focusing on intra-regional differences, which is too crude to explore how area-level urban environmental exposures correlate with mental health. As residential neighborhoods matter for health outcomes (Diez Roux and Mair, 2010; Macintyre and Ellaway, 2000; Sampson et al., 2002), it is reasonable to analyze mental health within cities on a detailed scale beyond the crude urban–rural dichotomy (Peen et al., 2010; Liu et al., 2015; Helbich et al., 2017). Inter-urban study designs markedly increase the conceptual and methodological complexity of analyses, as environmental exposures not only directly affect people's mental health, but also moderate other risk and protective factors.

Methodological advances in spatial analytics within the field of statistics and geographic information science have created new possibilities to link health data with environmental exposures by means of people's residential location. Here, it is traditionally assumed that the residential location and the surroundings affect people's mental health (Kwan, 2013). Administrative units thought to represent neighborhoods are frequently used to define the influential neighborhood by attaching aggregated environmental conditions to individuals (Riva et al., 2007; Diez Roux and Mair, 2010; Mair et al., 2008; Blair et al., 2014; Owen et al., 2016). Through the correlations between people nested within the same spatial unit, multilevel models are the gold standard when simultaneously examining the association between individual and area-based exposures on health outcomes, otherwise resulting in biased inference (Owen et al., 2016; Diez-Roux, 2000). Despite this progress in modeling, the area-level approach misleadingly indicates that the environmental context is static following a well-defined spatial extent. At least the following criticisms have been put forward concerning such a procedure: a) Administrative units are not intended to capture health exposures meaningfully (Flowerdew et al., 2008; Wheeler et al., 2012); b) it is assumed that people in a neighborhood have similar exposures, independent of their daily mobility patterns (Kwan, 2012; Chaix et al., 2013); and c) people living close to a neighborhood boundary are possibly more exposed to the neighboring context than to their own (Van Ham and Manley, 2012).

To circumvent the rigidity of administrative units, more individualized or eco-centered representations of environmental exposures have been proposed (Meng et al., 2017; Kestens et al., 2017; Berke et al., 2007). The geocoding capabilities of geographic information systems (GIS) can be used to pinpoint people's exact residential locations. Well-established procedures to delineate the health-influencing spatial environmental contexts are circular buffers centered on people's actual place of residence, or on accessibility measures reflecting areas that can be reached within a given walking or driving time along the street network (Helbich et al., 2017). Although this context operationalization added important details compared to neighborhoods, ignoring exposures beyond the residential location is regarded as problematic, as short- or long-term locational immobilities of people are still postulated (Cummins, 2007). This probably induces inaccuracies and a systematic bias in exposure assessments (Kwan, 2012; Hurvitz and Moudon, 2012).

Whereas area-based research was insightful in addressing the role of place within the constellation of health, static approaches gave impetus for dynamic individual assessment methods that consider exposures during people's day-to-day traveling (Kestens et al., 2017; Chaix et al., 2013; Perchoux et al., 2013; Sarkar et al., 2013) and changing exposures over their life course (Ben-Shlomo and Kuh, 2002; Lynch and Smith, 2005) due to residential moves (Leyland and Næss, 2009; Miltenburg and van der Meer, 2016; Musterd et al., 2012; Sharkey and Faber, 2014; Browning et al., 2016).

2.2. Exposures along people's daily activity places and their mobility path

As most of daily life takes place at different places outside the home, people experience numerous exposures during their daily trajectories (Fig. 1A). From a theoretical view point, thinking of people's activity spaces – namely the multiple places people visit for their daily activities (e.g., work, leisure) (Schönfelder and Axhausen, 2003) and their daily paths connecting these activity places – offers a comprehensive framework to assess the mobility of individuals and their spatiotemporal exposure to environments (Dijst, 2009). The latter approach is rooted in