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From place-based to people-based exposure measures

Mei-Po Kwan*

Department of Geography, Ohio State University, 1036 Derby Hall, 154 North Oval Mall, Columbus, OH 43210, United States

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An essential task in any study that examines the contextual determinants of health behaviors and outcomes is to identify the appropriate geographic area to be used as the basis for deriving exposure measures. Historically, most studies start from conventional and static notions of place or neighborhood, which is often identified in terms of administrative units such as census tracts, census block groups, or post-code areas. These units are convenient because available data of censuses and surveys that can be used to derive contextual measures are often tied to them.

In their article "Disentangling the relative influence of built and socioeconomic environments on walking: the contribution of areas homogenous along exposures of interest" Riva and colleagues rightly emphasize that how the areal unit is defined will have important implications for studying the contextual determinants of health because the use of wrong areal units may lead to errors "when measuring ecologic exposures and estimating their effects on health" (Riva, Gauvin, Apparicio, & Brodeur, 2009). They also make the important point that the "most appropriate geography may be specific to the epidemiological outcome of interest…and should be considered prior to conducting analyses." The study seeks to address some of the limitations in "using standard administrative spatial units" for disentangling the influence of various physical and social environmental attributes on walking. It is based on the premise that we need to use homogenous areal units because "heterogeneity of exposure within spatial units may lead to errors when measuring exposures" (Riva et al., 2009).

The approach pursued in the study is thus to design "homogeneous zones" in order to maximize within-area homogeneity of an area-level exposure (active living potential in the study area). This would, as the authors argue, minimize measurement error of exposures and non-differential exposure misclassification. The study found that variation in utilitarian walking was statistically significant across zones and across census tracts, while recreational walking did not vary significantly across zones or census tracts. Homogeneous zones used in the study, however, distinguish environments that are conducive to utilitarian walking better than environments that facilitate recreational walking. In light of this the authors suggest that "specific attributes of the built environment have a differential influence on motives for walking" and "zones maximising homogeneity along other attributes of the built environment might have yielded stronger and significant variance estimates for recreational walking" (Riva et al., 2009).

While one may question the study's contribution to advancing new knowledge about the contextual influences on health behaviors, it nonetheless makes an important contribution to addressing some of the methodological issues in research involving the use of area-based data: namely, the modifiable areal unit problem (MAUP). The MAUP is a well known problem in geographic literature and refers to the problem that, in the analysis of area- or zone-based data, the results may be influenced by the definition of the areal units for which data are reported. The MAUP has two components: the scale effect and the zoning effect. The scale effect refers to the variation in results obtained from the same statistical analysis at different levels of spatial resolution. The zoning effect refers to different results arising from the regrouping of zones at a given scale.

* Tel.: +1 614 292 9465.
E-mail address: kwan.8@osu.edu

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There are two different views about how the MAUP should be dealt with. One view holds that the best way to resolve the problem is to identify the best zoning scheme or the scale at which the processes being studied operate (Openshaw, 1996). This paper by Riva and colleagues, through designing and using homogeneous zones, aligns with this view. While Riva and colleagues did not explicitly evaluate how their use of homogeneous zones mitigates the MAUP, a recent study by Mu and Wang (2008) lends some support to Riva and colleagues' argument that the use of homogeneous zones mitigates some of the measurement errors when using area-based data. Through the use of what they called a modified scale-space clustering method that accounts for both attribute homogeneity and spatial contiguity, Mu and Wang (2008) found that the homogeneous zones they created are effective for mitigating the MAUP and reducing model-building errors caused by spatial autocorrelation when using ordinary least square (OLS) regression (since the homogeneous zones created through scale-space clustering exhibit less spatial autocorrelation). They argue that the use of appropriate homogeneous zones renders the use of more complex spatial regression models less critical. Further, as the clustering process merges zones with similar socioeconomic attributes and thus can be used to construct geographic areas with sufficiently large base population, the authors suggest that their method would also help mitigate the "small number problem" (where the small number of subjects in some of the areal units under study renders the results of statistical estimation highly unstable).

There is, however, another view on how the MAUP may be mitigated. It holds that the problem is the result of erroneous analytical measures, which fail to take into account the effect of spatial scale and the zoning scheme (Tobler, 1989). Robust analytical measures should be scale-independent or scale-invariant. In other words, if we have developed and used the proper analytical measures, we should be able to eliminate the effect of the MAUP, and scale or the zoning scheme should not have any effect on our results. Based on my own research on individual access to urban opportunities and human space–time behavior (Kwan, 1998, 1999), I suggest that this is a highly promising direction that deserves far more attention in future research, especially in the context of investigating the contextual determinants of health behaviors and outcomes. As this is also the central concern in Riva and colleagues' paper, I would like to delve into it a bit here through revisiting the concepts of exposure and context in contemporary research.

As mentioned in the beginning of this commentary, an essential task in any study that examines the contextual determinants of health behaviors and outcomes is to identify the appropriate geographic area to be used as the basis for deriving exposure measures. Exposure measures in most studies to date, however, have been derived based on notions of context, neighborhood or place that conceive them as static and administratively bounded areal units within which all relevant contextual influences are found (Kwan et al., 2008; Matthews, 2008). These units are often operationalized as census units or, in Riva and colleagues' paper, as homogeneous zones constructed based on census units. A common assumption underlying these conventional notions is that the neighborhood of residence is the most relevant area affecting behavioral outcomes or environmental exposure, and that neighborhood effects operate only through connections that exist among those residing in the same area. Further, individuals who live in the same areal unit are assumed to experience the same level of exposure or contextual influences, regardless of where they live within the area or how much time they spend in the neighborhood of residence. Thus most area-based analyses of the contextual determinants of health behaviors and outcomes face the well known problem of ecological fallacy: erroneously ascribing attributes of an aggregate unit (the neighborhood of residence) to individuals.

It is rather puzzling: (1) why studies would start from some arbitrary definitions of place or neighborhood instead of considering the actual geographies through which individuals experience the kind of exposure in question; (2) why the point of departure for deriving ecologic exposure measures should be administratively bounded spatial units or their derivatives (whether small or large, and whether homogeneous or not); and (3) why relevant exposures to environmental risks or resources should be represented by static, bounded areal units containing subjects' residences without considering the actual spatial and temporal "configuration" of exposure – that is, where and when people are actually exposed to the environmental or contextual influences in question as their everyday lives unfold (Kwan et al., 2008; Matthews, 2008).

The most important determinants of exposure are where and how much time people spend while engaged in their daily activities (Kwan et al., 2008). People's activities (and thus exposure), however, do not take place at one time point and wholly within any static, administratively bounded areal unit. Residential location is but one place where people spend their time and the residential areal unit does not capture the majority of their activities or the locations of these activities (Matthews, 2008). For instance, the relevant context or neighborhood for the study of drug use and abuse should take into account: (1) how much time people actually spend in their residential communities; (2) where else they go, how much time they spend there, and what activities they are involved in when they travel outside of their neighborhoods; (3) what types of areas other residents or peers travel to and how prevalent and time-extensive these extra-community activities are; and (4) what types of non-residents regularly spend time within the borders of a given local area and what activities they are engaged in while there (Kwan et al., 2008). All of these aspects of people's uses of and movements across space and time constitute the relevant context of exposure to a range of drug use risk and protective factors.

New conceptualizations of exposure and context that takes the actual spatial and temporal "configuration" of exposure into account not only would allow us to measure exposure more accurately for each individual subject, but also can go a long way in addressing the MAUP. Because where and when people spend their time differ from individual to individual, these new notions of context need to be operationalized through individualized measures that allow exposure level to vary even for individuals within the same neighborhood or place. They should align well with each person's activity space and include the locations they frequent. Riva and colleagues recognize the potential of this approach, which was characterized as creating "bespoke areas around individuals' residential location using computerised techniques."

The space–time accessibility measures I have been working on in the past 15 years seem quite promising for this purpose. These individual measures attempt to reflect each person's use of and movement across space and time based on detailed data of the person's daily activities and trips. They were implemented with geocomputational algorithms in a geographic information system (GIS) (Kwan, 1998, 1999). Two subsequent articles found that analytical results obtained with these measures were not affected by either the zoning scheme or spatial scale (Kwan & Weber, 2008; Weber & Kwan, 2003). This brings us back to Tobler's (1989) controversial suggestion that the MAUP is the result of erroneous analytical measures that fail to take into account the effect of spatial scale and the zoning scheme, and that we should be able to eliminate its effect if the proper analytical measures are used.

Unfortunately few scholars have recognized the immense theoretical and methodological potential of Tobler's view, and there

has been little work undertaken along this line of thinking to date. But as detailed digital geographic data become more available, real-time tracking technologies (e.g., GPS) make it possible to collect high resolution movement data of individuals, and unprecedented computational power allows us to operationalize measures that capture the complexities of human spatial behavior, it is time to attempt to go beyond methods developed under the limitations of the spatial and temporal frameworks of conventional exposure measures (Kwan & Weber, 2003). We should now seriously begin to explore new notions that move us beyond the conventional place-based understanding of exposure and context. As we identify neighborhood and place based on where and when people actually undertake their daily activities and trips (instead of starting from static, administratively bounded spatial units or their derivatives), we will be moving toward a people-based understanding of exposure and context. I believe that people-based measures would provide much more accurate representations of the contextual determinants of health behaviors and outcomes.

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