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Issue: *The Biology of Disadvantage***Neighborhoods and health**

Ana V. Diez Roux and Christina Mair

Epidemiology, Center for Integrative Approaches to Health Disparities, University of Michigan, Ann Arbor, Michigan, USA

Address for correspondence: Prof. Ana V. Diez Roux, Epidemiology, Center for Integrative Approaches to Health Disparities, University of Michigan, 3rd Floor SPH Tower, 109 S Observatory, Ann Arbor, MI 48019-2029. adiezrou@umich.edu

Features of neighborhoods or residential environments may affect health and contribute to social and race/ethnic inequalities in health. The study of neighborhood health effects has grown exponentially over the past 15 years. This chapter summarizes key work in this area with a particular focus on chronic disease outcomes (specifically obesity and related risk factors) and mental health (specifically depression and depressive symptoms). Empirical work is classified into two main eras: studies that use census proxies and studies that directly measure neighborhood attributes using a variety of approaches. Key conceptual and methodological challenges in studying neighborhood health effects are reviewed. Existing gaps in knowledge and promising new directions in the field are highlighted.

Keywords: neighborhoods; health; epidemiology

Introduction

Although the study of geographic and spatial variations in health has a long history, only recently have health researchers focused on investigating how spatial contexts, or more specifically neighborhood and community-level-factors, affect the health of residents.¹⁻³ The interest in neighborhoods and health has been driven by several interrelated trends within public health and epidemiology. The first trend is a growing sense that purely individual-based explanations of the causes of ill-health are insufficient and fail to capture important disease determinants. This has been reflected in discussions of the need to consider not only individual characteristics but also characteristics of the groups or contexts to which individuals belong in understanding the distribution of health and disease.⁴⁻⁷ Neighborhoods (or residential areas more broadly) have emerged as potentially relevant contexts because they possess both physical and social attributes which could plausibly affect the health of individuals.

A second trend has been the revitalized interest in understanding the causes of social inequalities and race/ethnic differences in health. Because place of residence is strongly patterned by social position and ethnicity, neighborhood characteristics could be important contributors to inequalities in health. A third trend has been a perception that disease pre-

vention efforts need to consider the health effects of policies which are not traditionally thought of as health policies but that could have important health implications.⁸ Many of these policies (such as housing policy or urban planning policy) could affect health through their impact on the contexts in which individuals live. Thus the study of neighborhood health effects becomes directly policy-relevant. A fourth factor has been the increasing availability and popularity of methods especially suited to the study of neighborhood health effects, first multi-level analysis^{7,9} and more recently the explosion of Geographic Information Systems (GIS) and spatial analysis techniques which allow the examination of space in a much more detailed and sophisticated manner than has been possible in the past.^{10,11}

Figure 1 schematically summarizes the processes through which neighborhood physical and social environments could contribute to health and health inequalities. As can be seen, there are several reinforcing mechanisms. Residential segregation and inequalities in resources across areas mutually reinforce each other: residential segregation can result in spatial inequalities in resources and these in turn can reinforce residential segregation. Neighborhood social and physical characteristics also affect each other: for example, characteristics of the built environment such as the quality of public spaces can affect the nature of social interactions

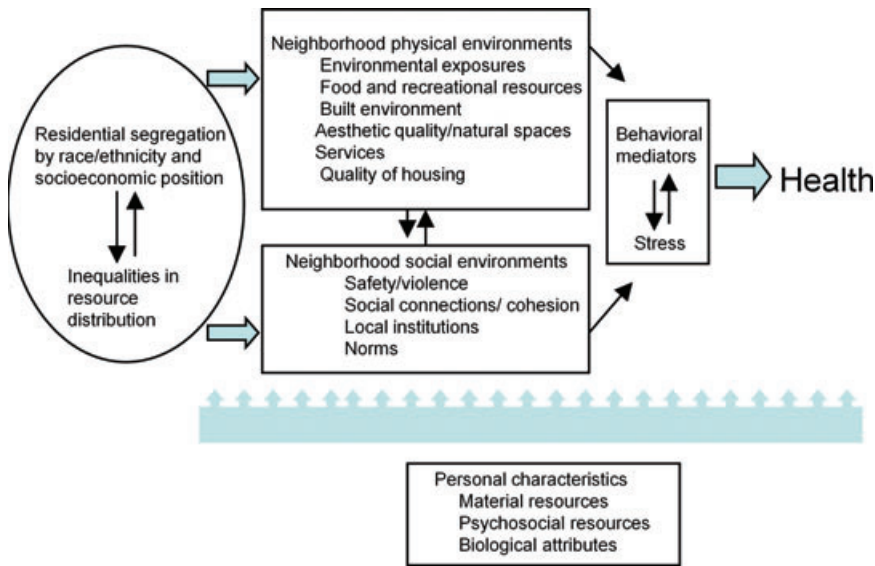


Figure 1. Schematic representation of the contributions of neighborhood environments to health inequalities.

within the neighborhood, which in turn has consequences for the ability of neighbors to advocate for improved public spaces. Finally, behavioral and stress processes operating at the level of individuals are also dynamically related: stress can result in the adoption of unhealthy eating behaviors as coping mechanisms, and some behaviors (such as physical activity) can buffer the adverse effects of stress. Many of the processes illustrated in the figure are amenable to policy interventions. These range from upstream policies that minimize inequalities in social and material resources across areas (such as policies that redistribute resources or reduce residential segregation), to policies that specifically target certain neighborhood-level features (such as increasing the availability of healthy foods). Many of these neighborhood-level factors can operate across the life course. In addition, the impact of neighborhood conditions on health is likely to be modified by individual-level characteristics. For example, some individuals may have characteristics that make them more vulnerable to adverse neighborhood conditions, while others may have the personal and financial resources that allow them to overcome deficiencies or hazards in their neighborhoods.

This chapter provides an overview of recent work in the area of neighborhoods and health, discusses methodological challenges and research gaps, outlines new directions, and concludes with a discussion of the implications of this work for public health

generally and for the reduction of social inequalities in health. Research on neighborhoods and health is closely connected to work on residential segregation and health¹² and work on housing on health¹³ but these large literatures are not reviewed here. Although neighborhoods have been studied in relation to a number of health-related outcomes we focus specifically on two areas that have received special attention in recent literature. These include neighborhood effects on chronic-disease related outcomes (with a special emphasis on obesity and related risk factors, driven in part by interest in the obesity epidemic) and mental health outcomes (especially depression). A number of reviews of work in these areas have been published;^{14–34} this chapter draws on these reviews as well as on representative recent empirical examples to illustrate key points and highlight challenges and new directions.

Early studies of neighborhoods and health: secondary data analyses and census proxies

Studies attempting to estimate the effects of neighborhood characteristics on health began in to appear in the health literature in the late 1980s and early 1990s, and grew exponentially over the next 10–15 years. The vast majority of early studies consisted of secondary data analyses of individual-level data from cross-sectional or longitudinal health studies

linked to census data on neighborhoods based on the residential addresses reported by study participants. In one of the earliest examples Haan *et al.* used data from the Alameda County study to investigate whether living in a federally designated poverty area was associated with mortality.³⁵ They found that residents of poor areas had a 50% higher risk of death compared to residents of nonpoor areas after statistically controlling for age, race, sex, individual income, and chronic health problems. A number of subsequent studies have followed a similar approach linking various measures of neighborhood socioeconomic position, indices of disadvantage, or summary measures of deprivation to health outcomes measured in individuals.^{14,15} These studies used census-defined areas (such as census tracts or block-groups in the United States or wards in the United Kingdom) to proxy neighborhoods, and census-derived measures constructed by aggregating the characteristics of area residents to proxy the specific neighborhood physical or social features hypothesized to be etiologically relevant to the health outcome being studied. Although many of these studies were cross-sectional analyses, a number of longitudinal analyses linking neighborhood census characteristics to mortality, incident disease, or changes in health have also been published (see for example, Refs. 26, 36–42).

Comparisons of results across studies linking neighborhood census characteristics to health outcomes are rendered complex by the various census proxies for neighborhoods employed, the different census-derived neighborhood measures examined, and the different degrees of adjustment for individual-level characteristics. To the extent that comparisons across studies are possible, reviews of this literature have generally concluded that living in a poor, deprived, or socioeconomically disadvantaged neighborhood is generally associated with poor health outcomes including greater mortality, poorer self-reported health, adverse mental health outcomes, greater prevalence of chronic disease risk factors, greater incidence of diseases such as cardiovascular disease and diabetes, and adverse child health outcomes.^{14–16, 21, 22, 31, 43, 44} However the strength of these associations has varied across studies (with a minority of studies finding no effects) and has often been modest compared to associations observed for individual-level characteristics.^{14–16}

The limitations of studies using neighborhood census proxies in drawing inferences regarding causal effects of neighborhoods on health have been reviewed.^{2, 14, 15, 45, 46} Adjustment for individual-level characteristics related to place of residence (specifically socioeconomic position) is especially challenging in these studies because the neighborhood measure itself is an aggregate measure derived from the socioeconomic characteristics of residents. Because of this, the use of these measures raises methodological questions regarding the extent to which aggregate neighborhood socioeconomic characteristics and individual-level socioeconomic characteristics (key confounders of area or neighborhood effects) can be meaningfully separated empirically.⁴⁵ It may also result in incorrect estimates of neighborhood health effects if neighborhood socioeconomic characteristics are poor proxies for the true neighborhood construct of interest. Most importantly the use of neighborhood socioeconomic characteristics does not allow identification of the specific neighborhood-level factors that are most relevant and therefore does not permit investigation of the causal processes linking neighborhood environments to health outcomes.^{3, 46} The identification of these specific features is fundamental to determine the neighborhood-level interventions which should subsequently be tested in experimental or quasiexperimental designs.

Despite their limitations, early studies on neighborhood census characteristics and health have laid the groundwork and provided justification for more detailed investigations of neighborhood health effects involving more precise measurement of specific neighborhood-level attributes and more nuanced discussion of the relevant neighborhood definitions. They have also stimulated greater methodological sophistication in the identification of neighborhood health effects. These advances have been reflected in a second generation of observational studies of neighborhood health effects designed with much more attention to measurement of neighborhood attributes and greater sophistication in the analytical approaches used.

A note on types of group (or “neighborhood”) effects

In evaluating the results of observational studies of neighborhoods and health, especially those

linking aggregate census characteristics to health outcomes, it is useful to review what exactly is meant by neighborhood health effects. Manski developed a typology of “group” effects which can be adapted to the study of neighborhoods.⁴⁷ In his typology Manski distinguishes three types of group effects (1) effects of aggregate outcomes at the group-level on individual-level outcomes (which he terms “endogenous” effects); (2) contextual effects of group composition; and (3) environmental effects. An example of an endogenous effect is the effect of the prevalence of an infectious disease in the group (or neighborhood) on the probability that a given member of the group (or neighborhood resident) acquires the infection. To the extent that attitudes or behaviors are transmitted from person to person these endogenous effects may also be present for noninfectious health outcomes. Contextual effects of group compositions are present when, for example, the socioeconomic composition of a school affects the educational outcome of students independently of their own socioeconomic characteristics. This may occur if having high socioeconomic status (SES) peers creates a more favorable learning environment. Finally, environmental effects involve the effects of exogenous features of the groups (such as the presence of certain institutions, the built environment of a neighborhood, etc.) on individual-level outcomes.

Manski discusses how endogenous effects are very difficult if not impossible to identify from observational studies. Specifically, in regressions including all three types of group effects (plus any relevant individual-level controls), it is not possible to distinguish endogenous and contextual effects, although in some situations it may be possible to determine whether an overall social effect (defined as endogenous plus contextual effects) is present (for more details see Manski 1995, chapter 7). This has led some critics to question all studies of neighborhood effects.⁴⁵ However, this situation, in which a researcher attempts to separate out endogenous, contextual, and individual-level (or other group-level effects) is not typical of neighborhood effects research to date. In fact, either explicitly or implicitly, even studies using census variables are usually not interested in the causal effects of neighborhood composition per se or in the effects of the prevalence of the outcome, but in the effects of the physical and social environment features which these mea-

asures are proxying. Although processes involving social contagion are sometimes alluded to, for the most part neighborhood health effects researchers are essentially interested in environmental effects. For these reasons more precise definition and measurement of these environmental attributes as exemplified by the second generation of studies of neighborhood health effects is key.

A second generation of neighborhood health effects studies: from census proxies to direct measurement of neighborhood physical and social environments

Improving causal inference in studies of neighborhood health effects requires not only greater methodological sophistication but also much more attention to the theoretical models underlying the research questions. It requires developing conceptual models and testable hypotheses about the causal processes involved with attention to how specific neighborhood attributes may be related to specific health-related processes and outcomes. The specification and measurement of the specific neighborhood-level attributes is a key requisite for more rigorous inference. Investigations into neighborhood health effects have identified two broad domains of neighborhood attributes that may be relevant to health: features of the neighborhood physical environment and features of the neighborhood social environment. The physical environment includes not only traditional environmental exposures such as air pollution but also aspects of the man-made built environment including land use and transportation, street design, other features of urban design and public spaces, and access to resources such as healthy foods and recreational opportunities. The social environment includes the degree and nature of social connections between neighbors, the presence of social norms, levels of safety and violence, and various features of the social organization of places. Physical and social features of neighborhoods may affect health through constraints on, or enhancements of, health-related behaviors or through mechanism involving the experience of stress and the buffering effects of social support and social connections. Emerging research on the relation of neighborhood physical and social environments to various chronic disease and mental health outcomes is briefly reviewed below.

Neighborhood physical environments and health

A growing body of work has examined features of neighborhood built environments such as land use patterns, density, and access to destinations; street connectivity and transportation systems; features of urban design; and access to healthy food and recreational resources in relation to the behaviors of diet and physical activity and related health outcomes of obesity, diabetes, and hypertension. Other work has examined associations of neighborhood physical environments such as physical decay and other aspects of the built environment in relation to mental health outcomes such as depression.

Physical activity

Transportation planners have long studied the connection between the built environment and travel behavior.⁴⁸ More recently public health researchers have partnered with urban planners to examine effects of the built environment on walking and other forms of physical activity, leading to an exponential growth of work in this field. Features of the built environment are usually assessed using participant reports,⁴⁹ GIS-based measures⁵⁰ and, less commonly, systematic social observation by trained raters or reports of other neighborhood informants.⁵¹ A recent systematic review of prior reviews and original articles published between 2002 and 2006 concluded that there was consistent evidence that greater population density, more land use mix, and proximity of nonresidential destinations are linked to more walking for transportation.²⁴ Walking for recreation appears to be associated with better pedestrian infrastructure, aesthetics, safety, and land use mix, although associations are less consistent for the latter two domains.

Features of the built environment are also associated with other types of physical activity: a review of 50 articles published between 1998 and 2005 reported that most (80%) studies showed some significant positive relationships between the presence of physical activity resources in parks and recreation settings and physical activity levels of residents.¹⁸ For example, in the Multiethnic Study of Atherosclerosis (MESA) Neighborhood Study, the density of recreational resources in windows of 1–5 miles around each participant's home was associated with greater probability of being physically

active after adjustment for a variety of individual-level sociodemographic characteristics.⁵² In general, reviews have concluded that there is sufficient evidence on the link between physical environments and physical activity to recommend the implementation of design and land use policies which support physical activity within urban areas, as well as policies that create or increase access to places for physical activity.^{53,54}

Diet

Another research area of exponential growth has been the study of the relation between local food environments and the dietary behaviors of residents. Because in many contexts (especially in the United States) supermarkets tend to offer a greater variety of health foods at a lower cost than other types of stores,^{55,56} many studies have used the presence of supermarkets as a proxy measure of healthy food availability. A recent systematic review concluded that the majority of studies investigating links between presence of food stores and diet found that neighborhood residents with better access to supermarkets and other retail stores that provide access to healthful food products tend to have healthier food intakes.¹⁷ Results appear to be consistent when other approaches are used to characterize healthy food availability. For example, a recent analysis of the MESA Neighborhood Study found that greater neighborhood availability of healthy foods as assessed by greater supermarket density, participant reports, or informant reports was consistently associated with a better quality diet as assessed by two different indicators of overall dietary quality.⁵⁷

More recently, studies have begun to characterize not only the types of stores present but also the actual foods available in stores using validated instruments.⁵⁵ A recent review concluded that of five studies on the relationships between the actual availability of healthy food products in local stores and the diet of residents, four reported that greater availability was associated with either higher intake or greater home availability of the same foods.¹⁷ Recent analyses of one site of the MESA Neighborhood Study also found that greater healthy food availability as determined through the systematic assessments of local stores by trained raters was associated with a better quality diet, although results were not robust to adjustment for race/ethnicity possibly due to the strong confounding of race/

ethnicity and healthy food availability in these data.⁵⁸ Recent work in the MESA Neighborhood Study has also shown that proximity to fast food restaurants (as assessed by GIS or survey measured) is associated with a worse quality diet.⁵⁹

Obesity, diabetes, and hypertension

A number of studies have begun to investigate associations of the built environment with health conditions likely to occur at least in part as a consequence of environmental constraints on physical activity and diet. The majority have focused on body mass index and obesity.^{17,19,20} A review of 20 studies investigating links between the built environment and body mass index published between 2002 and 2006 found that 17 of the 20 reported a statistically significant association between some aspect of the built environment and body mass index (Papas 2007). The features of the built environment investigated varied widely, although access to recreational resources and walkability measures were more commonly investigated than food access measures. Of the 15 studies investigating some aspect of the physical activity-related built environment and obesity, 11 found an association between greater walkability or greater access to recreational resources and lower BMI.¹⁹ A more recent review of neighborhood food environments and BMI¹⁷ found that out of six studies that focused on the link between retail food access and BMI⁶⁰⁻⁶⁵ four reported that poor access to supermarkets was associated with greater BMI.⁶⁰⁻⁶³ Another recent review of neighborhoods and obesity also concluded that there was generally consistent evidence that physical activity environments are related to obesity, but generally less data (and more inconsistent findings) regarding the impact of the local food environment.²⁰

Some studies have begun to examine the combined effects of physical activity and food environments. For example, a recent cross-sectional analysis of the MESA Neighborhood Study using informant-reported measures of physical activity and food environments found that better neighborhood physical activity and food environments were associated with significantly lower BMI after adjustment for multiple measures of socioeconomic position and race/ethnicity.⁶⁶ Longitudinal analyses of the effects of the food and physical activity environments on BMI are beginning to emerge. For example, a longitudinal study of children found that lower prices

of fruits and vegetables predicted lower 3 year gains in BMI.^{65,67} In a recent study, neighborhood green space was prospectively associated with smaller increases in BMI in children.⁴¹ Recent analyses have also linked proximity of fast food restaurants to schools to greater increases in body mass index in children over time.⁶⁸

A small but growing literature has begun to examine associations of neighborhood physical environments with other conditions linked to diet and physical activity such as diabetes and hypertension. The MESA Neighborhood Study has shown that better access to neighborhood physical activity and food resources as estimated through spatial interpolation of survey and GIS measures is associated with lower levels of insulin resistance and diabetes in a large population-based sample.^{69,70} Recent work has also linked better physical activity and food environments to lower incidence of type II diabetes in this sample.⁷¹ Informant-reported access to physical activity resources and healthy foods was also cross-sectionally associated with hypertension although the strong patterning of both neighborhood characteristics and neighborhood resources by race/ethnicity made it difficult to determine whether these associations were independent of race.⁷²

Depression and other mental health problems

Depression has been the mental health outcome most commonly studied in relation to neighborhood characteristics.²¹⁻²³ The physical environment characteristics examined have included physical disorder or decay, other general measures of the quality of the built environment, and the presence of problems in a variety of domains (traffic, noise, access to resources, transportation, services, etc.). Perceptions of neighborhood environments as disordered were found to be associated with increased levels of depressive symptoms in six out of seven studies.⁷³⁻⁷⁹ Poor quality neighborhood and home built environments as assessed by independent raters or census and housing data were associated with depression two studies,^{80,81} but studies investigating features of the service environment found mixed results.^{82,83}

Neighborhood problems, including those related to traffic, public transportation, green space, and services, were associated with increased levels of depression in four of four studies⁸⁴⁻⁸⁷ and one study has suggested that better neighborhood walkability

is linked to decreased levels of depressive symptoms in the elderly.⁸⁸

Summary

Although studies are often difficult to compare because of the varying physical environment measures used, there is generally good evidence that better access to physical activity resources and healthy foods are cross-sectionally associated with greater physical activity and better diets. Evidence regarding physical environments in relation to BMI is more mixed because of the wide variety and nonoverlapping measures investigated although the preponderance of the evidence seems to suggest that poorer physical activity and (to a lesser extent) poorer food environments are associated with greater BMI. A small number of studies have also begun to report suggestive associations of physical environments with diabetes and hypertension. Longitudinal observational studies are beginning to emerge. Identifying associations of neighborhoods with BMI, diabetes, and hypertension is more difficult than identifying associations with behaviors because of the more distal nature of these outcomes and the many other factors affecting their development. Features of the physical environment have also been linked to mental health outcomes, especially depressive symptoms. However, several (but not all) of these studies are cross-sectional and rely on participant perceptions of their neighborhoods which could lead to important bias.

Neighborhood social environments and health

Although the social environment is often mentioned in discussions of the pathways through which neighborhoods may affect health, investigations of neighborhood social environments are less common than investigations of neighborhood physical environments. Features of the neighborhood social environment hypothesized to be relevant to health include social norms, social stressors, and aspects of social connections including social cohesion and related constructs, which may facilitate the transmission of behaviors, enforce norms and social control, and reduce or buffer stress. Neighborhood social environments have been measured using census characteristics such as socioeconomic or race/ethnic composition or predominant family structure (as

crude proxies for a variety of social characteristics),⁸⁹ crime statistics (as indicators of safety or violence),⁹⁰ and surveys (e.g., measures of social cohesion, collective efficacy, or disorder).^{76,91} The majority of studies of neighborhood social environments and health have focused on mental health outcomes (primarily depression or depressive symptoms), although a number of studies have begun to focus on behaviors such as physical activity and alcohol consumption and physical health outcomes including body mass index, self-rated health, and cardiovascular outcomes.

Depression and other mental health problems

The key social environment measures investigated in relation to depression have included social cohesion, social capital and related domains; informal social control; safety/violence; residential stability; and various measures of demographic composition including population density, ethnic density and family structure.^{21–23} Overall, 11 out of 16 studies have found that social connections between neighbors including greater social cohesion, social capital, and reciprocal exchanges between neighbors are protective against depression.^{21,73,75,76,81,86,89,92–96} Exposure to violence and hazardous conditions have been associated with increased depression and depressive symptoms in 6^{77,89,92,93,97,98} of 12 studies.²¹ Residential instability, which has been hypothesized to reduce the number and strength of informal social ties, has also been linked to depression in four^{76,99–101} out of eight studies.²¹ The literature on neighborhood race/ethnic composition and depression is mixed and difficult to summarize because of the varying positive and negative aspects of neighborhoods that these measures may be proxying.²¹ In recent analyses of the MESA Neighborhood Study, lower levels of social cohesion and aesthetic quality and higher levels of violence were associated with higher levels of depressive symptoms in a large sample of adults.⁹¹

Physical health outcomes and behaviors

Relatively few studies have investigated associations of features of neighborhood social environments with physical health outcomes. The two social environment measures most commonly investigated have been social cohesion/social capital and measures of safety and violence. Self-reported health has been the most common outcome investigated,

followed by mortality. A recent review found that of 17 studies that investigated the relationship between neighborhood-level social capital or cohesion and self-rated health, 10 found that lower social capital or cohesion was associated with worse health.³³ Studies of mortality were less common and quite mixed: only one of three found that lower social capital/cohesion was associated with greater mortality.³³ Greater neighborhood social cohesion and social capital have been linked to lower cardiovascular disease (CVD) incidence or mortality in two out of three studies.^{102–104} Less safety, greater violence, and greater levels of social disorder have also been linked to worse self-reported health or higher mortality in a small number of studies.^{78, 102, 105}

A growing number of studies have investigated neighborhood social environments in relation to health behaviors such as physical activity, smoking, and alcohol use. Although it has often been hypothesized that poorer safety and greater crime would lead to less physical activity, a recent review concluded that existing evidence of these relationships was inconsistent, possibly due to measurement limitations.³² Several newer studies using more sophisticated measurement strategies (including the inclusion of both objective and perceived measures) have supported the presence of a link between neighborhood safety and physical activity.^{106–112} Evidence regarding associations of neighborhood social capital/social cohesion with physical activity has been limited and mixed.^{87, 113, 114}

Results of studies linking smoking and heavy drinking to neighborhood social cohesion, violence/safety, and/or disorder have also had mixed results.^{115–118} A small number of studies have investigated neighborhood social environments in relation to BMI.^{66, 119–123} Three studies have found that greater neighborhood collective efficacy or some aspect of social cohesion were associated with lower BMI after adjusting for individual-level characteristics,^{122, 124, 125} although two of these studies measured social cohesion at the individual-level only.^{124, 125} Another study reported that greater neighborhood safety was associated with lower BMI but collective efficacy was not.¹²³ Greater neighborhood psychosocial hazards, poor aesthetic quality, and crime have also been associated with BMI and obesity.^{119–121} In contrast, greater neighborhood safety and social cohesion were not associated with lower BMI in the MESA Neighborhood

Study; in fact, paradoxical positive associations of social cohesion and safety with BMI were observed in men.⁶⁶

Summary

Evidence linking specific features of neighborhood social environments to health outcomes is more sparse and difficult to summarize than evidence for the effects of physical environments. Features of the social environment are even more complex to measure than features of the physical environment. The best studied social environment features are safety/violence, social cohesion and related constructs, and various measures of disorder. The most evidence linking neighborhood social environments to health is present for mental health outcomes (specifically depression). However, studies of depression are limited by cross-sectional designs and possible same-source bias. In studies of health behaviors and related physical outcomes, the possibility of confounding by physical environment measures remains a challenge.

Future research directions

Improved causal inference from observational studies

The many challenges involved in drawing causal inferences from observational studies of neighborhood health effects have been repeatedly noted.^{2, 45, 126, 127} These are no different from the difficulties inherent in inferring causation from observational studies generally, although there are a number of issues which are especially salient in neighborhood health effects research. Chief among these is the difficulty in fully accounting for individual-level characteristics (such as income, education, or occupation) known to be predictive of health that are also related to the sorting of individuals into neighborhoods. The most common strategy used to address this problem has been the use of regression methods (such as multilevel analysis) to statistically control for these individual-level characteristics.¹²⁶ As in any application of statistical adjustment, inferences will be limited if important individual-level variables are omitted, if adjustment variables are mismeasured, or if limited overlap in distributions of individual-level variables makes generalization to nonoverlapping areas questionable. Greater attention to these methodological

difficulties through sensitivity analyses (to evaluate robustness of results to omitted or mismeasured confounders of varying strength) and through the use of alternatives to regression adjustment such as propensity score matching (in order to restrict comparisons to areas with overlapping distributions) is an important need in future work.^{2,128,129}

It has also been argued that individuals may select (or be selected into) their place of residence (or neighborhood) based on their health or based on their predisposition to certain behaviors. For example, mental illness may result in downward social mobility and may ultimately cause depressed persons to live in neighborhoods with greater physical disorder. Persons who are more inclined to be physically active may choose to live in areas with better physical activity resources. This creates an obvious threat to causal inferences in observational cross-sectional analyses, which still constitute a large part of work on neighborhoods and health. Longitudinal designs relating neighborhood characteristics to changes in outcomes over time (combined with statistical control for baseline characteristics) as well as longitudinal analyses relating changes in outcomes to changes in predictors (sometimes referred to as difference-in-difference models)¹³⁰ are an important need. Because they remain observational, longitudinal designs obviously do not guarantee unbiased causal inference but they are an improvement over cross-sectional analyses and are necessary to build a case for experimental studies (when feasible) or for rigorously evaluated interventions.

Further complexity in controlling for individual-level variables results from the fact that many individual-level characteristics may be simultaneously mediators and confounders of neighborhood health effects. For example, individual-level socioeconomic position may be simultaneously a confounder and a mediator of the causal effect of cumulative exposure to neighborhood disadvantage on mortality. This occurs because neighborhood disadvantage early in life may affect access to education or to occupational opportunities later in life (education and occupation are mediators); in turn education and occupation may also determine subsequent exposure to neighborhood poverty (education and occupation are confounders). Under these circumstances traditional regression adjustment will yield biased estimates of the effects of cumulative expo-

sure to neighborhood disadvantage. Methods such as marginal structural models can be used to arrive at more valid causal inferences.^{131,132} However the application of these methods requires longitudinal datasets with multiple repeat measures, and the extent to which these methods will yield different results than the naïve approach will depend on the strength of the time dependent confounding and mediation. More generally, careful attention to the hypothesized causal structure through, for example, the use of directed acyclic graphs, is important to better guide future analyses of neighborhood health effects and the variables that should and should not be controlled for.¹³³

There are clearly many limitations to causal inference from observational studies of neighborhood health effects, as there are to causal inference from observational studies generally. The key issue is determining how important these challenges are in real-life studies rather than in hypothetical situations. For these reasons, hypothetical statements which imply important challenges to causal inference (e.g., physically active people tend to choose to live in neighborhoods with more physical activity resources, persons select neighborhoods based on their prior health, generalizations to areas of little overlap in adjustment variables are always invalid) need to be subject to empirical inquiry so that their true magnitude, and consequently their actual implication for causal inferences regarding neighborhood effects can be gauged (see for example, Ref. 134). In addition, it is important to contrast results obtained using more sophisticated methods (such as marginal structural models, propensity score matching) with traditional approaches in real-life scenarios in order to determine the circumstances under which these more complex approaches do and do not make a difference.

Defining relevant spatial contexts

A recurring issue in the study of neighborhood health effects is the definition and operationalization of a “neighborhood.” Neighborhoods can be defined in multiple ways and the relevance of different definitions to health depends on the causal processes hypothesized to be operating.¹³⁵ For example, small areas may be relevant to processes involving social interactions between neighbors, whereas larger areas may be relevant for food shopping behaviors. In some cases, the spatial context

relevant to a particular process and outcome may not be commonly thought of as a “neighborhood” by residents. In addition, spatial contexts other than residential such as work contexts may also be relevant. Thus, the study of neighborhood health effects is really a subset of the more general study of spatially defined contexts on health.

Ideally, researchers should define the spatial context relevant to the health outcome being studied based on theory about the processes involved.^{1,135} Unfortunately, we still have little information on which to base such theories. Qualitative studies that shed light on how persons relate to and interact with varying spatial contexts, as well as information on the links between daily activities and space are key to the development of better theories. In the meantime, sensitivity analyses to varying definitions of neighborhoods or spatial contexts, guided by theory and prior knowledge to the extent possible, will be important. The ability to carry out these sensitivity analyses has been greatly enhanced by the advent of GIS which, if combined with the right data, allow estimation of measures and associations for varying spatial contexts. It is important to recognize that the search for the “perfect” definition of a neighborhood is likely to be futile and that the spatial contexts relevant to health are likely to have fuzzy boundaries. For practical purposes, the relevant question in interpreting the results of studies becomes not whether the definition of neighborhood used in the research is the right one, but whether the measure for the spatial context available is likely to be a reasonable proxy for, or highly correlated with, the true causally relevant spatial context.

Another important issue pertains to the need to consider not only how local areas or neighborhoods affect health but also how the broader spatial context within which neighborhoods are situated may add to or modify the effects of local areas. For example, resource poor areas surrounded by other resource poor areas in highly segregated contexts may have very different implications for health than resource poor areas situated close to resource rich areas. Thus, areas that are spatially proximate to each other may affect each other with implications for health. A growing body of work has begun to use spatial methods to account for spatial dependencies between areas and examine these spill-over effects.^{43,136–138} More sophisticated analyses of spatial dependencies and how varying defined spatial

contexts affect health will help identify the kinds of interventions which it may be useful to implement and evaluate in future work.

Measurement of spatial contexts

A major challenge in the study of neighborhood health effects has been the measurement of the specific neighborhood-level attributes hypothesized to be relevant. The field has advanced substantially in this area over the past few years. The new measurement strategies employed (many of them borrowed from other fields) have included systematic social observation by trained raters¹³⁹ as well as the use of surveys to health study participants or other residents.⁷² New methodological approaches have been employed to aggregate or interpolate the responses of raters or survey respondents in order to characterize an area^{69,140} and to properly estimate the health effects of these measures in regression models.¹⁴¹ In addition, GIS approaches combined with other sources of data have been used to calculate a variety of distance and density measures in order to assess spatial access to resources as well as other measures related to the built environment such as street connectivity and land use mix.^{24,52,142} A major advantage of the new measures has been the use of raters, separate surveys, or other sources of objective data in order to avoid biases that may occur when self-reported perceptions of neighborhood characteristics are examined in relation to self-reported outcomes that could affect the reports (such as mental health or behavioral outcomes).

The explosion of measurement techniques and measures has been a major advance. However, the multiplicity of different measures employed often makes it difficult to compare results across studies and draw general conclusions. Replication of analyses using similar measures in different samples, as well as greater systematization and consistency in the measures used would facilitate our ability to draw general conclusions. As previously noted, stronger links to theories articulating the ways in which different spatial contexts may affect health will also strengthen the informativeness of analyses using improved measures.

Life course processes and residential mobility
It is well established that factors operating early in life may have implications for disease outcomes in adulthood.¹⁴³ It is therefore natural to think that

neighborhood environments early in life may be of special relevance. However the complexities of characterizing neighborhood environments in life course studies has limited work in this area. The few existing studies of area or neighborhood life course effects are limited to the use of census proxies.^{144–146} The development of strategies that will allow linkage of cohort data to meaningful historical neighborhood data is therefore an important need.

Life course and longitudinal studies also need to track the mobility of individuals over time. This is important in order to create cumulative measures of neighborhood exposures and to examine effects of changes in neighborhoods on changes in outcomes. In addition, because accounting for selection of persons into neighborhoods is such an important methodologic challenge in neighborhood health effects research, the study of predictors of mobility, and of mobility into different types of neighborhoods, is itself important. A better understanding of the predictors of mobility will help identify improved strategies (such as propensity score matching on predictors of mobility) to account for these factors in observational studies. It will also allow more realistic assessments of the conditions under which selection factors invalidate inferences drawn from observational studies. Recent work has begun to incorporate factors predictive of mobility and residential preferences in empirical studies of neighborhood effects.¹⁴⁷

Synergistic effects

Although it is often hypothesized that the health effects of neighborhood contexts may vary depending on individual-level characteristics such as age, sex, and socioeconomic position efforts to detect such interactions have not always yielded consistent results.^{148–151} The most common approach to detecting these interactions has been the inclusion of interaction terms in regression models. Many studies test for interactions, and a wide variety of interactions with age, sex, race/ethnicity and socioeconomic position have been reported, but the direction of the interactions documented has not always been consistent. *Post hoc* theorizing is sometimes used to explain the results but the varying and often contradictory theoretical explanations offered have made these results not very compelling or conclusive.

Methodologic issues such as sample size limitations and insufficient variation in individual-level characteristics within neighborhoods may have seriously hampered the ability to detect interactions in prior work. The testing of interactions requires substantial variation in individual-level characteristics within neighborhoods. In addition, it is possible for selection factors to mimic statistical interactions. For example, low income residents who live in wealthy neighborhoods may be different from low income residents who live in poor neighborhoods, making it appear as if the effect of low income on health varies by neighborhood characteristics. It may be possible to design studies in ways to maximize the ability to detect these interactions through appropriate sampling and measurement strategies. In addition, more sophisticated a priori theorizing about how personal and neighborhood characteristics may act synergistically is needed.

A possible fruitful area for research is the interaction between stressors operating at the individual level and environments. For example, personal stressors may lead persons to engage in coping behaviors related to eating and smoking. These behaviors may in turn be facilitated and reinforced by neighborhood environments resulting in synergistic effects of personal stressors and neighborhood features such as access to high calorie fat foods and tobacco. In addition, personal psychosocial resources may buffer the adverse health effects of neighborhood environments.⁷⁹ Efforts to operationalize these theories and test them empirically would be an important advance in the field and may help it move beyond the current impasse in the study of interactions. Another promising area is the inclusion of neighborhood environment measures in studies of gene environment interactions, although the very distal nature of these exposures (which must necessarily operate through more proximal individual-level factors such as behaviors or the stress response) may make the identification of these interactions challenging. Nevertheless, detailed environmental assessments such as those promoted in many neighborhood studies may be a sine-qua-non for understanding the role of genes and their interactions with environments in shaping the distribution of many health outcomes.

A relatively unexplored area is the synergistic effect of neighborhood physical and social environments. Most research has tended to treat both

domains as independent although they are clearly closely related and may have synergistic effects on health. For example, a stressful social environment may potentiate the health effects of exposures such as air pollution, or neighborhood safety may modify the effects of street connectivity on walking behavior. Although these kinds of interactions are often hypothesized they have been rarely empirically tested. As in the case of interactions between neighborhood environments and personal characteristics, methodological factors such as high correlation between both domains as well as sample size issues may limit the ability to detect these interactions unless studies are designed with this purpose in mind. Improved measurement of neighborhood social and physical environments is also likely to enhance the ability to detect synergistic effects.

Nonbehavioral mechanisms linking neighborhoods to health

As reflected in this review, a large portion of the work linking neighborhoods to health has focused on behaviors (such as diet and physical activity) as key mediators. Although psychosocial processes are often hypothesized to play a role, their examination is much less common. There are a number of mechanisms through which psychosocial or stress-related factors may contribute to the relationship between neighborhoods and health. Features of neighborhoods (such as the presence of violence) may themselves be stress-inducing. Neighborhoods may also serve to buffer or enhance the consequences of other sources of stress. For example, neighborhoods characterized by pleasant natural environments may have stress reducing properties, whereas those characterized by disorder and lack of social connections may enhance adverse consequences of other sources of stress. In addition, as noted above, features of neighborhood physical environments may promote or discourage unhealthy strategies to cope with stress, such as smoking or eating energy-dense foods.

Additional work is needed to better understand the role of stress and psychosocial processes in neighborhood health effects. This includes studying the relationship between various neighborhood attributes and biological markers of stress or the metabolic consequences of stress.^{152,153} It also includes investigating the dynamic processes through which behavioral and

psychosocial processes interact and affect each other, to shape differences in health across neighborhoods.

Experiments and quasi-experiments

Experimental approaches to the study of neighborhood health effects would clearly allow firmer causal inferences than observational studies. Very few studies experimental studies of neighborhood health effects have been conducted, and the little information available comes from experimental studies which were not designed specifically to examine health outcomes. A major recent example is the Moving to Opportunity Study (MTO), which randomized families (mostly female-headed households) living in high poverty neighborhoods to receiving vouchers to enable them to move into nonpoor neighborhoods.¹⁵⁴ A few health related measures including measures of mental health, physical health (including BMI), and risky behaviors were included in the study. Although the study found no effects on most physical health outcomes in adults, moving to a nonpoor neighborhood was associated with lower BMI and better mental health outcomes. Results for youth were mixed, with girls experiencing positive effects on physical health and risky behavior but boys showing adverse effects.

An important limitation of the MTO design is that the intervention tested was moving poor families out of areas of concentrated poverty and into nonpoor neighborhoods, rather than intervening directly on the neighborhood attributes hypothesized to be important. For the point of view of improving population health, it may be more relevant to identify the most effective neighborhood-level interventions rather than to determine the effect of moving families out of poor neighborhoods. This is because a variety of different neighborhood-level attributes (which vary in their correlation with neighborhood poverty) may be relevant to health. Identifying which interventions are most effective in changing these attributes, and which have the expected health consequences, is the crucial policy question. Aside from methodological issues related to the interpretation of the MTO results,¹⁵⁵ investigating the health consequences of moving out of a poor neighborhood, although of interest, is not the main question of interest in neighborhood health effects research.

Although desirable, the experimental testing of neighborhood level interventions is complex and may not be feasible for a number of reasons. The design of such an experiment would necessitate sampling multiple distant neighborhoods (to avoid issues of spatial spillover effects). The need for large numbers of neighborhoods would make the study logistically complex and expensive. Most fundamentally, it is not clear that there is sufficient consensus in the literature on what interventions would be the best candidates for experimental testing. It is under these circumstances that rigorously designed and analyzed observational studies, especially longitudinal studies, may still be of considerable utility, despite their known limitations for causal inference.

Another fruitful area for research is the evaluation of natural experiments. Neighborhoods are constantly changing, for reasons often unrelated to health. Capitalizing on these changes in order to evaluate their health consequences would allow researchers the opportunity to provide valuable information on the consequences of neighborhood change. For example, two recent studies in the UK have used quasi-experiments to evaluate the dietary impact of changes in the local food environment.^{156,157} To the extent that reasonably valid instruments can be identified, the use of instrumental variable approaches (which essentially approximate a natural experiment) can also help resolve issues of residual confounding in observational analyses.^{158,159} For example, a recent paper has used proximity to highways as an instrument for exposure to restaurants.¹⁶⁰ However, there are many challenges to the identification of valid instruments suitable to address the questions of interest in neighborhood health effects research. As is often the case for health outcomes, it may be necessary to act and intervene on neighborhoods using the best available observational evidence rather than wait for true experimental evidence. However, it is important to rigorously evaluate these interventions so that their effectiveness can be established and future interventions can be improved.

Dynamic models and simulation

An important challenge in estimating the causal effects of neighborhood characteristics on health is that the spatial patterning of health emerges from the functioning of a system in which individuals interact with each other and their environment and in

which both individuals and environments adapt and change over time. Thus, the neighborhood patterning of health results from a web of conditions and feedback loops including multiple related processes.

Table 1 illustrates some of these dynamic processes for the case of the spatial patterning of a behavior like physical activity. Persons are sorted (or selected) into neighborhoods based on external constraints related to socio-economic resources and discrimination as well as preferences for neighborhoods with particular features. These selection processes lead to spatial clustering by individual-level attributes (e.g., income) that are related to health behaviors. Health behaviors are in turn affected by features of residential environments such as whether the environment has recreational resources and places to purchase healthy foods. Norms may emerge in the context of places as a result of the predominant health behaviors in the area and individual health behaviors may in turn change in response to these norms. Neighborhoods also change in response to residents' characteristics and preferences, and in response to the features of surrounding or related neighborhoods. Neighborhood differences in health behaviors (and health more generally) emerge from the simultaneous operation of all these processes making it challenging to empirically isolate one from the other.

In general, regression approaches (including multilevel analysis) are not well suited to investigate processes embedded in complex systems characterized by dynamic interactions between heterogeneous individuals and interactions between individuals and their environment with multiple feedback loops and adaptation.¹⁶¹ Aside from logistical difficulties, experimental approaches (which attempt to isolate the effect of changing a single factor while holding all other features of the system constant) may not yield easily generalizable results in the context of dynamic interactions and feedback loops. Identifying the interventions most likely to be effective under different circumstances requires understanding the processes involved. Experiments and their observational approximations yield little insight into these processes particularly when they involve feedback loops and adaptation, yet understanding these processes may be important for predicting the effects of the intervention under other scenarios, and for identifying alternate interventions that may achieve the desired effect.

Table 1. Selected processes generating place differences in health behaviors and examples from the study of neighborhood patterning of physical activity

	Processes generating place differences in health behaviors	Example for being physically active
1	Person-level health is affected by features of the residential neighborhood	Availability of places to be physically active promotes physical activity
2	Persons are selected into residential neighborhoods based on their person/household-level attributes	Individuals are sorted into neighborhoods based on income and race/ethnicity. These characteristics are potentially related to being physically active
3	Persons select their residence based on their preferences for features of residential neighborhoods	Neighborhoods that have safe and aesthetically pleasing places to be physically active, attract persons who prefer to be physically active
4	Persons adapt their behaviors in response to collective behaviors within their spatial (and social) network and wider geographic area	Seeing more bicycle riders may increase the likelihood of commuting to work via bike
5	Neighborhoods change in response to residents' characteristics	Gyms are more likely to locate in areas where individuals are known to be physically active, or in wealthier areas where individuals have greater purchasing power, or in areas where physically active residents advocate for them
6	Neighborhoods adapt in response to features of other neighborhoods or more distant places	Regional transport infrastructure affects the availability of public transportation and automobile restrictions in local neighborhoods

Source: Auchincloss and Diez Roux. *Am. J. Epidemiol.* 2008; 168(1): 1–8.¹⁶¹

For these reasons it has been argued that complex systems methodologies such as agent-based models¹⁶² may be a useful complement to existing observational and experimental studies.¹⁶¹ Systems methodologies raise their own sets of nontrivial challenges.¹⁶¹ Nevertheless, a key advantage is that they force investigators to specify and model processes. Aside from the utility of these models in simulating outcomes under different scenarios, the simple formulation of these models may yield new insights into what is known and unknown about the processes involved and point to the need for new types of data. The use of these methodologies as a complement to existing approaches is an exciting new direction in this field.

Conclusion

Although there is substantial evidence that health is spatially patterned, questions remain regarding causal importance and the health effects of chang-

ing neighborhood factors through direct intervention or more distal policy changes. Given strong evidence of the patterning of residential environments by social class and race/ethnicity,^{25,163–165} these factors may contribute to the development and maintenance of health inequalities,^{166–168} especially through their interaction with other socially patterned individual-level characteristics including personal and family material resources, psychosocial stressors, and coping strategies. This, plus the fact that many neighborhood characteristics are eminently modifiable through policy, makes these factors especially attractive points of intervention for policies aimed at reducing social and racial/ethnic inequalities in health.

It is also important to note, however, that the social patterning of residential environments is not invariant and there are exceptions to the general rule. For example, many wealthy suburban areas have built environment features related to street connectivity and land use which make them less

walkable than inner city areas. However, the residents of wealthy areas have the resources that allow them to achieve physically active lifestyles in other ways, and many “walkable” areas in poor neighborhoods are unattractive to walk in at best, or even dangerous to walk in at worst. In some cases, these complex patterns may yield novel opportunities for intervention. For example, some studies have shown that although poor and minority neighborhoods in the United States often lack supermarkets, they sometimes have a wealth of small stores¹⁶⁹ and these small stores may have the capacity to offer healthy options.¹⁷⁰ Taking advantage of these smaller stores to enhance their ability to offer healthy foods may offer multiple benefits including increased walkability and social connections and interactions within the neighborhood. Thus, there may be imaginative ways to intervene on neighborhoods and communities, sometimes capitalizing on existing resources, to promote changes with the potential for affecting many health related outcomes.

The complexity of the topic is such that a combination of strategies will be necessary to understand the myriad of ways in which neighborhood environments (together with other environments such as work, family, or school) may affect health and to determine the most promising interventions or policies. These include rigorous observational studies, natural experiments or experiments (when feasible), simulation studies, and careful evaluation of pilot interventions implemented based on the best available evidence. Fundamentally, work on neighborhoods and health highlights the potential health impact of policies often thought to be unrelated to health, such as community development policies, urban planning, zoning, and transportation policies. It also highlights the broader role of a continuum of interacting environmental determinants in shaping behaviors and biology through dynamic interactions with the characteristics of individuals. Greater understanding of the role of these environments as well as identifying the most effective ways to intervene on them to improve health will require partnerships between researchers, communities, and policy makers.

Conflicts of interest

The authors declare no conflicts of interest.

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