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The Examination of Neighborhood Effects on Health: Conceptual and Methodological Issues Related to the Presence of Multiple Levels of Organization

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Over the past few years there has been a resurgence of interest in the social determinants of health (Krieger, 1994; Kaplan and Lynch, 1997). At the same time there has been a move toward rethinking the uses of ecological studies and ecological variables in health research (Schwartz, 1994; Susser, 1994a; Diez Roux, 1998). And there has also been a growing sense that to better understand the causes of ill health, epidemiology needs to grapple with the presence of multiple levels of organization and their implications for both models of disease causation and empirical research (Schwartz et al., 1999). All three interrelated trends have been expressed in the study of neighborhoods and health.

The investigation of neighborhood effects on health raises a series of conceptual and methodological issues related to the presence of observations at a lower level (e.g., individuals) nested within observations at a higher level (e.g., neighborhoods). Many of these issues are generalizable to a broad set of common situations in epidemiology involving nested data structures (for example, patients nested within providers, measurements over time nested within individuals, hospitals nested within a health system, districts nested within countries). The presence of multiple levels of organization (or nested sources of variability) has two important implications (Diez Roux et al., in press). First, the units of analysis (or units for which dependent and independent variables are measured) can be defined at different levels. The units of analysis will de-

terminants may be conceptualized at the group level rather than at the individual level. Here the group-level measures are used not as proxies for individual-level data but because the group-level constructs themselves are hypothesized to be related to the outcome. For example, the construct of neighborhood unemployment is distinct from individual-level unemployment, and both may be important to health. Similarly, inequality in the distribution of income within a group measures a different construct than individual-level income.

Variables that reflect the characteristics of groups have been classified into two basic types: derived variables and integral variables (Valkonen, 1969; Lazarsfeld and Menzel, 1971; Blalock, 1984; Von Korff et al., 1992; Morgenstern, 1995). Derived variables (also termed analytical or aggregate variables) summarize the characteristics of individuals in the group (means proportions, or measures of dispersion; for example, percentage of persons with incomplete high school education, median household income, standard deviation of the income distribution). Sometimes derived group-level variables have an analogue at the individual-level (e.g., mean neighborhood income and individual-level income), but both variables may be tapping into different constructs. The group-level variable may provide information that is not captured by its individual-level analogue. For example, mean neighborhood income may be a marker for neighborhood-level factors potentially related to health (such as recreational facilities, school quality, road conditions, environmental conditions, the types of foods that are available, etc.), and these factors may affect everyone in the community regardless of their individual-level income. Similarly, community unemployment levels may affect all individuals living within a community, regardless of whether they are unemployed or not. A special type of derived variable is the average of the dependent variable within the group. The prevalence of infection in a group, for example, may affect an individual's risk of acquiring infection (Halloran and Struchner, 1991; Koopman et al., 1991a; Koopman and Longini, 1994). Similarly, an individual's likelihood of adopting a certain behavior may depend in part on the prevalence of the behavior in the community.

Integral variables (also termed primary or global variables) describe characteristics of the group that are not derived from characteristics of its members (for example, the existence of certain types of regulations, availability of health care, political systems). A special type of integral variable refers to patterns and networks of contacts or interactions among individuals within groups, which may be important in understanding the distribution of health outcomes (Koopman et al., 1991b; Koopman and Longini, 1994; Koopman and Lynch, 1999). Although these patterns are

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derived from how individuals are connected to one another, they are more than aggregates of individual characteristics. They can be summarized in the form of group-level attributes such as network size or structure (Lazarsfeld and Menzel, 1971; van den Eeden and Huttner, 1982). Although derived and integral variables are sometimes presented as conceptually distinct, they are closely interrelated. Derived variables operate by shaping certain integral properties of the group. For example, the composition of a group may influence the predominant types of interpersonal contacts, values, and norms or may shape organizations or regulations within the group that affect all members (Valkonen, 1969).

In considering the use of group-level variables in epidemiology as well as in interpreting the results of studies that use ecological, or group-level variables, it is crucial to differentiate group-level and individual-level constructs and specify the types of constructs the variables included in the analyses are purported to be measuring. In some cases this distinction may be complex. On one hand, individual-level variables can be used to categorize people into groups, such as age groups. However, age itself remains an individual-level attribute. Of course, it is possible that age groups themselves may have emergent group-level properties (related, for example, to the types and patterns of interactions between individuals), which may be related to the outcome being studied. Another issue is that many variables measured at the individual-level (such as individual social class or race–ethnicity) may be meaningfully understood only in the context of how individuals are related to one another in groups or societies. Although they derive their meaning (and implications for health) from how individuals are related to one another in society (or groups), they remain individual-level constructs (although they are not individually determined). Thus, there is no direct correspondence between "group-level" variables and "social" variables on the one hand, and "individual-level" variables and "biological" variables on the other hand.

STUDIES WITH GROUPS AS THE UNITS OF ANALYSIS: ECOLOGICAL STUDIES

Ecological studies are studies in which groups are the units of analysis. Both independent and dependent variables are measured for groups, and variability in outcomes across groups is examined as a function of group-level variables. Ecological studies have often been used to investigate the relation between area characteristics and morbidity and mortality rates. The sizes of the areas investigated have ranged from relatively large (e.g.,

Wing et al., 1992; Tyroler et al., 1993; Raleigh and Kiri, 1997) to small (e.g., Briggs and Leonard, 1977; Paul-Shaheen et al., 1987; Townsend, 1988; Eames et al., 1993). The group-level variables most commonly investigated have been derived variables constructed by aggregating the socioeconomic characteristics of individuals living within areas.

Ecological studies are most appropriate when investigators are interested in explaining variation among groups (i.e., drawing inferences regarding the causes of intergroup variability in the outcome), and the constructs of interest can be conceptualized as group-level properties. Because of the unavailability of information on the cross-classification of individual-level exposures and outcomes within groups, ecological studies are limited in their ability to examine the role of individual-level constructs as confounders, mediators, or effect modifiers of the relation between group-level variables and the outcomes. For example, ecological studies documenting a relation between area deprivation and mortality are unable to determine whether this is confounded by individual-level characteristics of the persons living in different areas, how it is mediated by individual variables, or whether the effect of area deprivation varies by individual characteristics. The absence of individual-level data also makes it impossible to differentiate the contextual from the compositional effects of derived variables (a variant of the more general problem of absence of information on individual-level confounders) (Duncan et al., 1998). Both the contextual and the individual-level effects are confounded in the ecological association. For example, a study documenting associations between measures of area deprivation and mortality cannot determine whether the association is due to the contextual effect of living in a deprived area or to the fact that many deprived individuals live in deprived areas. Of course, from a public health perspective, the ecological association may itself be of interest, regardless of whether it is confounded by individual-level variables or whether it results from contextual or compositional effects.

The methodological problem inherent in drawing inferences regarding individual-level associations based on group-level data (the ecological fallacy) is well known and often discussed in epidemiology (Piantadosi et al., 1988; Greenland and Robins, 1994; Morgenstern, 1995). The absence of information on individual-level confounders or effect modifiers (which may vary from group to group) is one of the sources of the ecological fallacy. Another source (which is less often highlighted in discussions of the ecological fallacy because of the implicit assumption that all disease determinants are individual-level constructs) is the presence of contextual effects of derived variables (an effect of the aggregate measure over and above the effects of its individual-level namesake). Even in

the absence of individual-level confounders or effect modifiers that differ from group to group, associations at the group and individual level may differ because the group variable (e.g., area deprivation) and the individual level variable (e.g., individual-level deprivation) are tapping into different constructs.

In considering the inferences that can be drawn from ecological studies, it is important to bear in mind that characteristics of individuals may be important even in drawing inferences regarding variability in the outcomes across groups (i.e., variables defined at a lower level may be important in explaining variability at a higher level). Ignoring the role of individual-level variables in explaining group-level associations may lead to what some have called the sociologistic fallacy (Riley, 1963). For example, suppose a researcher finds that communities with higher rates of transient population have higher rates of schizophrenia and then concludes that higher rates of transient population lead to social disorganization, breakdown of social networks, and increased risk of schizophrenia among all community inhabitants. However, suppose that schizophrenia rates are only elevated for transient residents (because transient residents tend to have fewer social ties, and individuals with few social ties are at greater risk of developing schizophrenia). That is, rates of schizophrenia are high for transient residents and low for nontransient residents, regardless of whether they live in communities with a high or a low percentage of transient residents. If this is the case, the researcher would be committing the sociologistic fallacy in attributing the higher schizophrenia rates to social disorganization affecting all community members rather than to differences across communities in the percentage of transient residents.

STUDIES WITH INDIVIDUALS AS THE UNITS OF ANALYSIS: INDIVIDUAL-LEVEL STUDIES

In individual-level studies both dependent and independent variables are measured for individuals, and the causes of interindividual variation are examined. These studies are most appropriate when investigators are interested in explaining variation among individuals (i.e., drawing inferences regarding the causes of interindividual variability). When studies with individuals as the units of analysis are limited to individuals from a single "group," they cannot examine the role of group-level constructs in causing individual-level outcomes (or as effect modifiers of individual-level predictors), because group-level characteristics are obviously invariant within groups (Schwartz and Carpenter, 1999). Although studies

of individuals sometimes pool individuals across potentially meaningful "groups," they often lack information on the groups to which individuals belong. Thus, they cannot examine the role of group-level constructs as antecedents of individual-level variables, as independent predictors of outcomes, or as confounders of individual-level associations. They cannot determine whether the effect of a given individual-level variable is present only in certain group contexts or varies from group to group as a function of group characteristics.

Just as ecological studies are limited in their ability to draw inferences regarding variability across individuals in the outcomes (individual-level inference), studies of individuals are limited in their ability to draw inferences regarding group to group variability in the outcomes. The methodological problem inherent in drawing inferences regarding intergroup variability based on individual-level data has sometimes been called the atomistic fallacy (the counterpart of the ecological fallacy). It arises because individual-level measures do not necessarily measure the same construct as their group-level analogues and because information on potentially important group-level confounders or effect modifiers is often unavailable (or cannot be examined) in studies of individuals, either because individuals are drawn from a single group or because information on group-level variables is not collected.

In addition, just as individual-level variables may be important in explaining variability across groups, group-level variables may be important in explaining variability in the outcomes across individuals. The failure to consider important group-level factors in drawing individual-level inference has been termed the psychologistic (or individualistic) fallacy (Riley, 1963; Valkonen, 1969). (The term *psychologistic fallacy* is not the most appropriate because the individual-level factors used to explain the outcome are not always exclusively psychological. Other authors have used the term *individualistic fallacy*, [Valkonen, 1969], but this term has also been used as a synonym of the *atomistic fallacy* described above [Alker, 1969; Scheuch, 1969]). For example, a study based on individuals might find that immigrants are more likely to develop depression than are natives. However, suppose this is true only for immigrants living in communities where they are a small minority. A researcher ignoring the contextual effect of community composition might attribute the higher overall rate in immigrants to the psychological effects of immigration per se or even to genetic factors, ignoring the importance of community-level factors and thus committing the psychologistic fallacy (Riley, 1963; Valkonen, 1969). The potential fallacies in ecological and individual-level studies are summarized in Table 3–1.

TABLE 3–1. Types of Fallacies

Unit of Analysis	*Level of Inference*	*Type of Fallacy*
Group	Individuals	Ecologic
Group (relevant individual-level variables excluded)	Groups	Sociologistic
Individual	Groups	Atomistic*
Individual (relevant group-level variables excluded)	Individuals	Psychologistic*

*Also called individualistic by some authors.

Source: Diez-Roux (1998).

CONTEXTUAL ANALYSIS

When studies of individuals include individuals from several meaningful groups, characteristics of the groups to which individuals belong can be examined in individual-level analyses by appending the group characteristic to each observation. For example, group-level variables can be included in regression equations with individuals as the units of analysis. These types of analyses have been called contextual analyses (Blalock, 1984; Iversen, 1991). Contextual effects models can include multiple group-level and individual-level variables as well as their interactions. Special methods may be necessary to account for residual correlation between outcomes within groups that may persist after accounting for individual-level and group-level variables included in the analyses. The residual correlation violates the assumption of independence of observations and may lead to incorrect standard errors and inefficient estimates (Diggle et al., 1994). With the exception of recent work on neighborhood effects, contextual analysis is still uncommon in epidemiology, perhaps because the prevalent assumption is that all relevant disease determinants are reducible to individual-level constructs and can be measured at the individual level.

Several studies have investigated the contextual effects of neighborhood environments by including neighborhood characteristics (usually derived variables) in individual-level equations and examining associations between neighborhood characteristics and the outcomes before and after controlling for individual-level variables (Anderson et al., 1997; Robert, 1998; Waitzman and Smith, 1998; LeClere et al., 1998; Slogget and Joshi, 1998; Yen et al., 1998; Davey Smith et al., 1998: Elreedy et al., 1999; Diez-Roux et al., 2001). Because it allows the investigation of neighborhood effects after controlling for individual-level variables, contextual

analysis can be used to separate out the effects of group context and composition. It can also be used to examine interactions between group-level and individual-level variables. However, the unit of analysis remains the individual, and only interindividual variation is examined. In contrast to modern multilevel analysis methods (see below), contextual analysis does not allow examination of group-to-group variability per se or of the factors associated with it.

Multilevel Analysis

Recently, multilevel analysis has emerged as a new analytic strategy in several fields, including education, sociology, and public health (see Chapter 4, as well as Mason et al., 1983; Hermalin, 1986; Bryk and Raudenbush, 1992; Von Korff et al., 1992; DiPrete and Forristal, 1994; Paterson and Goldstein, 1995; Wu, 1995; Rice and Leyland, 1996; Duncan et al., 1998; Kreft and de Leeuw, 1998). Although the terms contextual analysis and multilevel analysis often have been used synonymously (Van den Eeden and Hutner, 1982; Hermalin, 1986), today's multilevel models are more general than were early contextual models in that they allow examination of intergroup as well as interindividual variability. Multilevel analysis simultaneously examines groups (or samples of groups) and individuals within them (or samples of individuals within them). Variability at both the group level and the individual level can be examined, and the role of group-level and individual-level constructs in explaining variation among individuals and among groups can be investigated. For example, a study may have information on a sample of neighborhoods and on the individual-level characteristics of a sample of individuals within each neighborhood. Researchers may be interested in investigating how neighborhood-level and individual-level factors are related to health outcomes, as well as the extent to which between-neighborhood and between-individual variability in the outcomes are explained by variables defined at both levels. Multilevel analysis methods allow the simultaneous investigation of both types of research questions. Thus, multilevel analysis allows researchers to deal with the microlevel of individuals and the macrolevel of groups or contexts simultaneously (Duncan et al., 1998). Multilevel models can be used to draw inferences regarding the causes of interindividual variation and the extent to which it is explained by individual-level or group-level variables, but inferences can also be made regarding intergroup variation, whether it exists in the data, and to what extent it is accounted for by group- and individual-level characteristics. The statistical details as well as advantages and limitations of multilevel

models are discussed in Chapter 4 and in other published papers (Bryk and Raudenbush, 1992; DiPrete and Forristal, 1994; Goldstein, 1995; Duncan et al., 1998; Kreft and de Leeuw, 1998; Snijders and Bosker, 1999; Diez-Roux, 2000).

In the investigation of neighborhood effects on health, multilevel analysis has been used with the two purposes outlined above. On one hand, multilevel analysis has been used to examine between-neighborhood and within-neighborhood variability in outcomes and the degree to which between-neighborhood variability is accounted for by neighborhood-level and individual-level variables (Humphreys and Carr-Hill, 1991; Duncan et al., 1993; Jones and Duncan, 1995; Ecob, 1996; Gould and Jones, 1996; Shouls et al., 1996; Hart et al., 1997; Boyle and Willms, 1999; Duncan et al., 1999). Another related objective of the use of multilevel analysis in the investigation of neighborhood effects has been to estimate associations of neighborhood characteristics with individual-level outcomes after adjustment for individual-level confounders, usually individual-level measures. Thus, for example, neighborhood characteristics such as deprivation or other indicators of socioeconomic context have been found to be associated with adverse health outcomes after accounting for individual-level indicators of social class (Humphreys and Carr-Hill, 1991; Kleinschmidt et al., 1995; Ecob, 1996; Shouls et al., 1996; O'Campo et al., 1997; Diez-Roux et al., 1997; Matteson et al., 1998; Duncan et al., 1999; Yen and Kaplan, 1999). In deriving these estimates, multilevel models are used chiefly as a way to account for residual correlation between outcomes within neighborhoods, an objective that can also be achieved using contextual analysis and accounting for residual intraneighborhood correlation in other ways, as noted above. The types of study designs based on unit of analysis, level at which variability is examined, and constructs most appropriately investigated are summarized in Table 3–2.

THEORETICAL AND METHODOLOGICAL CHALLENGES IN MULTILEVEL ANALYSIS

In allowing the simultaneous examination of between-group and within-group variability and the contribution of individual-level and group-level factors to both sources of variability, multilevel analysis provides a link between ecological and individual-level studies and resolves many of the limitations of these study designs. However, although the last few years have witnessed an explosion of the statistical methods of multilevel analysis, the use of multilevel analysis (and contextual analysis generally)

TABLE 3–2. Types of Study Designs Based on Unit of Analysis, Level at Which Variability Is Examined, and Constructs Most Appropriately Investigated

Type of Study	*Unit of Analysis*	*Level at Which Variability Is Examined*	*Constructs Investigated as Potential "Causes" of Variability*	
			Group Level	*Individual Level*
Ecologic	Groups	Groups (utility for interindividual variability limited)	Yes	Only group-level proxies
Individual level	Individuals	Individuals (utility for intergroup variability limited)	No (Yes in contextual)	Yes
Multilevel	Groups and individuals	Groups and individuals	Yes	Yes

Source: Diez Roux et al. (2002).

raises a series of important conceptual and methodological challenges. Many of these challenges are closely linked to the need to develop theoretical models of the ways in which constructs defined at different levels influence individual-level outcomes. In the absence of this theoretical development, multilevel analysis runs the risk of being reduced to the investigation of meaningless groups or of finding associations and patterns that are difficult to interpret or understand. Although common to multilevel analysis generally, many of these challenges can be illustrated with the example of the investigation of neighborhood effects of health.

DEFINING RELEVANT "GROUPS" AND GROUP-LEVEL VARIABLES

A key issue in multilevel analysis is defining the relevant "groups" to be included in the analysis. The definition of *groups* is closely linked to the theoretical model underlying the research and the research question being investigated. In the investigation of neighborhood effects, defining the relevant "groups" implies deciding how *neighborhoods* (or other geographic areas relevant to the outcome) should be defined. The definition of *neighborhoods* is no simple task. Many different criteria can be used to define *neighborhoods*, including historical criteria, geographical criteria, residents' perceptions, and administrative boundaries. Definitions based on these different criteria will not necessarily overlap. Moreover, the size and definition of the relevant geographic area may differ based on the outcome being studied and the processes presumed to operate (Furstenberg and Hughes, 1997; Gephart, 1997). In some cases these areas may not be thought of as neighborhoods in the traditional sense at all. The definition and operationalization of relevant areas (or neighborhoods) based on the underlying processes presumed to operate is a key challenge in the investigation of neighborhood effects on health (Diez-Roux, 2001).

A related issue is identifying the group-level variables to be investigated. As in the case of the definition of the relevant "group," the group-level variables selected should be based on the theoretical model and the specific hypothesis being tested. The key issue becomes specifying the relevant group-level constructs and developing operational definitions and measures of them. Here it is crucial to distinguish measures of true group-level constructs from group-level proxies of unavailable individual-level data. Failure to distinguish conceptually group-level properties from individual-level properties leads to confusion regarding the interpretation of any group effects observed. The specification of relevant constructs and the levels at which they are defined and measured is a key challenge to multilevel analysis. Most existing quantitative research on neighborhood effects has examined the effects of neighborhood socioeconomic context

(constructed by aggregating the characteristics of individuals within neighborhoods) on individual-level outcomes after controlling for the socioeconomic position of individuals (Robert, 1999). Neighborhood socioeconomic context may serve as a proxy for a variety of neighborhood characteristics that vary across neighborhoods. However, there has been little examination of the specific attributes of neighborhoods that are relevant or of the processes involved (MacIntyre et al., 1993; see also discussion in Chapters 2 and 15). Specifying the relevant neighborhood properties and processes as well as developing operational measures that can be examined in quantitative studies is an important need in this field. The examination of specific neighborhood factors also raises additional methodological issues derived from the fact that many neighborhood properties are interrelated and may influence one another, making the isolation of their effects difficult.

Specifying the Role of Individual-Level Constructs

Another important challenge to multilevel analysis is specifying the role of individual-level constructs both in the theoretical model and in the specific hypotheses being tested. This will, in turn, determine how individual-level variables will be incorporated into the empirical analyses. Because disease is expressed in individuals, group-level effects ultimately will be mediated through individual-level processes (just as the effects of individual-level variables ultimately will be mediated through cellular and molecular processes). Strictly speaking, therefore, group-level attributes cannot affect individuals "independently" of all individual-level attributes, but this does not imply that group-level constructs are reducible to individual-level constructs. The extent to which an individual-level variable is conceptualized as a confounder or a mediator depends on the particular research question and its underlying theoretical model. A large part of quantitative research on neighborhood effects has examined the effects of neighborhood socioeconomic characteristics after controlling for the socioeconomic position of individuals in an attempt to separate out context from composition (Duncan et al., 1998). Although analytically useful, this approach is also artificial because neighborhood context may influence the socioeconomic trajectories of individuals, and living in disadvantaged neighborhoods may be one of the mechanisms leading to adverse health outcomes in persons of low socioeconomic position. Group-level and individual-level constructs may also interact. For example, the effects of neighborhood environments may differ by individual-level attributes such as age or socioeconomic position. Although a few studies have investigated interactions between neighborhood socioeco-

nomic context and individual-level indicators of social position, results have not been entirely consistent regarding the types of interactions that occur (Robert, 1999). The investigation of interactions is promising in terms of elucidating the processes through which neighborhoods may affect health but is also challenging from a methodological point of view, as it requires sufficient sample size as well as variability in individual-level indicators within neighborhoods.

In addition, multilevel models generally do not allow examination of the full range of complex and reciprocal interrelationships among group-level and individual-level variables (Blalock, 1984). For example, multilevel models do not model the possibility that individual-level properties (or individual-level relations among variables) may influence group characteristics (Mason, 1991; DiPrete and Forristal, 1994), and, vice versa, that group characteristics may shape individual-level independent variables. This is pertinent to the investigation of neighborhood effects on health because many neighborhood and individual characteristics are likely to be interrelated. Individuals may shape the neighborhoods in which they live, and neighborhoods may, in turn, affect individuals within them. A simple example can be found in the examination of dietary patterns. The dietary habits of individuals may influence food availability in their neighborhoods, and neighborhood food availability may, in turn, influence the dietary preferences of individuals. Although modifications to multilevel models to allow the examination of some of these types of reciprocal relations have been proposed (Entwisle, 1991; Mason, 1991), they may be better addressed using other methodological approaches.

SOURCES OF DATA AND STUDY DESIGN

To date, most empirical applications of multilevel analysis have relied on existing data sources. For example, in the examination of neighborhood effects, studies have generally linked data on individuals to census data for the census-defined areas in which they live. An important strength of this approach is the availability of standardized data for a wide range of areas. Disadvantages include possible limitations of the census areas used to proxy "neighborhoods" as well as limited information on measures of neighborhood attributes that may be more directly relevant to understanding the processes underlying neighborhood effects. A better understanding of whether and how neighborhoods are important to health may require new data collection on specific neighborhood attributes and studies specially designed to test hypotheses regarding the processes through which neighborhood effects could be mediated. Although ideal, the col-

lection of new data on theoretically defined areas is complex and may be impractical over a broad range of areas. Strategies that combine the use of existing standardized data on a broad range of areas with new data collection on a subset of areas (as in the West of Scotland Twenty-07 Study) (MacIntyre et al., 1989) are a promising alternative. In addition, more qualitative approaches may also be useful in understanding some of the processes linking neighborhood environments to health. Qualitative research may contribute to the development of hypotheses that can be tested in large, quantitative datasets and may be of help in understanding the results of quantitative studies. The integration of quantitative and qualitative approaches would constitute a major innovation in epidemiology generally.

An additional dimension that has yet to be fully incorporated into investigations of neighborhood effects on health is the longitudinal dimension. Although several longitudinal studies have related neighborhood characteristics to mortality or incidence over time (Haan et al., 1987; Anderson et al., 1997; Waitzman and Smith, 1998; Davey Smith et al., 1998; Yen and Kaplan, 1999), neighborhood characteristics have generally been assessed at one point in time. The investigation of the effects of neighborhood environments over the lifecourse as well as the impact of moving from one neighborhood to another or changes over time in neighborhoods themselves will require study designs that follow both neighborhoods and individuals over time. The analysis of this type of longitudinal data also implies increasing methodological complexity. A final caveat is that observational studies are inherently limited in their ability to conclusively identify causal neighborhood effects on health. The use of experimental designs (Katz et al., 2001) and the evaluation of neighborhood-level interventions may help strengthen inferences regarding the presence neighborhood effects.

Conclusion

The recognition in public health and epidemiology that factors defined at multiple levels may be important in understanding the causes of ill health has stimulated thinking on the implications this has for study design and empirical research. Multilevel analysis has emerged as an analytical technique that allows the examination of both intergroup and interindividual variability in the outcomes as well as how group-level and individual-level constructs are related to variability at both levels. Research on neighborhood effects on health is one substantive area in which this analytical approach has been applied. Despite the advent of sophisticated statistical models, important challenges remain. Many of these stem from the

need to articulate theories that specify the processes through which group-level (i.e., neighborhood-level) and individual-level factors jointly influence health outcomes, theories that can be operationalized and tested. Like other statistical methods, multilevel analysis will help describe, summarize, and quantify patterns present in the data, but it will not explain these patterns; explanation will emerge from reciprocal interplay between theory formulation and empirical testing.

In considering alternative study designs it is important to emphasize that multilevel analysis is not necessarily the "ideal" analytical technique for all research questions. The selection of the appropriate study design should be based on the specific research question to be investigated, including the level of organization for which inferences are to be drawn, as well as the levels of organization of the constructs of interest. For many research questions studies with groups or individuals as the units of analysis may be perfectly appropriate. In addition, when examining the effects of group-level variables on individual-level variables, traditional contextual effects models with appropriate adjustment for residual correlation may be a simpler and adequate alternative to the more complex multilevel models, if estimating between-group variability is not of specific interest.

Finally, in investigating neighborhood effects (or the effects of any given "group" or context), it is important to remember that the continuum of levels of organization does not end with neighborhoods (or with the group being examined). For example, neighborhoods themselves exist within the broader social, economic, and policy "contexts" of states, regions, countries, and social systems. Factors defined at these levels generate differences among neighborhood environments and may also contribute to enhancing or buffering the impact of these neighborhood differences on health. In addition, neighborhoods are only one of the many "groups" or "contexts" to which individuals belong. For some people, and for some outcomes, other contexts (such as, for example, the work context) that may or may not be geographically defined may be more relevant to health than "neighborhood" or area of residence. Broadening discussion, theorizing, and empirical research on the causes of ill health to incorporate these multiple levels and multiple contexts is likely to enhance our understanding of the causes of ill health generally and will help generate more effective actions to reduce health disparities.

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