RESPONSE: SEGREGATION AND SOCIAL DISTANCE—A GENERALIZED APPROACH TO SEGREGATION MEASUREMENT

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The study of segregation is a fundamentally sociological enterprise, defined by a concern with the social distance between members of different groups. The groups of interest may be categorized by race and ethnicity, by sex, by religion, by income or wealth, or by any number of other social characteristics. Social distance may be based on spatial locations, social institutions—such as schools, organizations, or occupations—social networks, or some other aspect of the social terrain. In any case, however, the motivation behind the study of segregation is generally driven by the understanding that individuals' location in social space is linked to their access to resources of some kind—economic rewards, social networks, cultural capital, political power, physical safety, quality schools and instruction, social status, and so on.

Regardless of the specific segregation phenomenon under examination, however, the sociological study of segregation always depends on two key elements: (1) methods of producing meaningful and analytically useful descriptions of the social distance between groups; and (2) sociological theory that illuminates the relationship between individuals' location in social space to their access to social resources. Our concern in our paper in this volume and in this reply to Grannis's commentary is with the first of these elements, the need for theoretically appropriate and meaningful measures of segregation. This requires the reduction of often massive amounts of information about the location of individuals within the social terrain and about the social distance among them. As in much of sociology, careful measurement of social phenomena is the prerequisite to careful analysis.

The field of segregation research has long been hampered by its general reliance on a set of simple, two-group, aspatial measures of seg-

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regation. Our paper in this volume removes the *two-group limitation* by extending a traditional set of measures of segregation to the case where the population of interest contains more than two mutually exclusive groups (Reardon and Firebaugh 2002, this volume). Grannis (2002, this volume) points out that although we address the two-group limitation, we have ignored the *aspatial* aspect of traditional segregation indices, since the measures we examine do not take into account the spatial location of the organizational units (e.g., census tracts) in which individuals are located. This is true, and Grannis is right in calling for more attention to spatial measures of segregation, particularly in the field of residential segregation. Here we take up Grannis's suggestion that we attend to "the dimension of distance," although we consider the more general notion of "social distance" rather than simply considering spatial distance.

Our response here addresses four main points: (1) We argue that a segregation measure should incorporate a theoretically appropriate social distance metric; (2) we suggest several approaches to developing social distance-based multigroup segregation measures; (3) we discuss the need for criteria against which to evaluate such measures, and present a tentative list of such criteria; and (4) we suggest an agenda for the field of segregation measurement.

1. SOCIAL DISTANCE AND SOCIAL PROXIMITY

The dichotomy between spatial and aspatial indices is a somewhat false one, since both types of measures incorporate implicit notions of social distance. Traditional, "aspatial" measures imply that the social distance between any two organizational units is equal, while "spatial" measures take the social distance between two units to vary according to some function of the spatial location of units. We formalize these notions below.

From the social location information, we must define a social distance metric. More specifically, we must define, for each pair of individuals i and j, the social distance d_{ij} between individuals i and j. (Note that we change notation slightly from our earlier paper; here i, j, and k index individuals, while I, J, and K index organizational units.) Standardizing the social distance metric to range from 0 to 1, we will have $d_{ij} = 0$ if i and j are in the same social location and $d_{ij} = 1$ if i and j are at the maximum possible social distance from one another. From this it follows as well that the social distance metric should give $d_{jj} = 0$ for all j and $0 \leq d_{ij} \leq 1$ for all $i \neq j$. In cases where it is more convenient to use social proximity rather than social distance, we can define the social proximity of individuals i and j as $c_{ij} = 1 - d_{ij}$.

In practice, however, we rarely have the individual-level data that allow us to compute the social distance or proximity of two *individuals*. Instead, we usually have data tabulated by some organizational units (schools, census tracts), among which we may have some measure of social distance/proximity (such as spatial distance, spatial contiguity). Consider the case where the population is divided among discrete organizational units (such as schools or tracts) and individual j is in unit J while individual k is in unit K. Now if we define $d_{ik} = d_{jk} = d_{JK}$ for all j in J, k in K, and $J \neq K$, then d_{JK} is the social distance between units J and K (with $d_{JJ} = 0$ for all J and $0 \leq d_{JK} \leq 1$ for all $J \neq K$). Moreover, for simplicity's sake, we can (though we need not) define $d_{ij} = 0$ for all i and j in the same unit J—when we do this we are in effect saying the organizational units bound social relations in such a way that the effective social distance between individuals in the same organizational unit is negligible.

Note that the social distance metric need not be defined by *spatial* distance, though there are clearly cases where spatial factors may play a role in social distance. The concept of social distance (or proximity) is more general than that of spatial distance. Consider, for example, the following different ways of conceptualizing and operationalizing social distance.

Social Distance and Residential Segregation. As Grannis and others have pointed out, in the study of residential segregation, distance matters. It matters because greater spatial proximity is assumed to mean greater social proximity, a greater probability of social interaction. However, scholars have suggested a variety of ways of operationalizing a social distance metric based on spatial distance or proximity.

One common way of doing this is to define the social distance matrix—as Grannis does in this volume—as based on contiguity of residential areas (tracts, block groups), so that $d_{ij} = d_{IJ} = 0$ for all i in I and j in J if $I = J$ or if I is adjacent to J, and $d_{ij} = 1$ otherwise (Morrill 1991). Wong (1993) suggests refining this so that d_{ij} depends on the length of the shared boundary between I and J or on the area and perimeter of the two areas, since these factors may influence the probability of interaction among members of adjacent areas. Grannis, however, suggests that social distance may be in part a function of the presence of connecting tertiary street networks; this would lead to defining d_{ij} as a function of street networks connecting I and J (Grannis 1998). Another approach is to define the social distance matrix as some function of the spatial distance between individuals. For example, if r_{ij} is the spatial (Euclidean) distance between i and j, we might define $d_{ij} = ar_{ij}$, where a is some standardizing constant, so that social distance increases linearly as a function of spatial distance (Jakubs 1981; Morgan 1983a). Other scholars have suggested $d_{ij} = 1 - e^{-r_{ij}}$, so that social proximity decays exponentially with spatial distance (Massey and Denton 1988; Morgan 1983b; White 1983).

One potential problem with contiguity-based distance metrics is that they will generally result in cases where $d_{ij} + d_{jk} < d_{ik}$ for some i, j, and k, which may lead to somewhat uninterpretable results (e.g., negative segregation). However, it is not our goal in this paper to discuss the merits or flaws of these different approaches to measuring social distance based on spatial distance. Rather, we wish to point out the need to use segregation measures that capture a theoretically appropriate dimension of social distance.

An additional point merits attention here. Because studies of residential segregation are generally based on data aggregated by tracts or blocks, measured levels of segregation may be confounded somewhat by the somewhat arbitrary definition of the size and boundaries of the areal units employed. This issue is known as *the modifiable areal unit problem* (MAUP) in the literature (Openshaw and Taylor 1979). Although Grannis claims that using segregation indices that incorporate a spatial distance metric "allows one to deal with" MAUP issues (page 82, this volume), this is not necessarily so. In our framework, MAUP arises not from the aspatial nature of traditional segregation indices but from the assumptions that $d_{ij} = 0$ for all i and j in J and that $d_{jk} = d_{JK}$ for all j and k in $J \neq K$. This assumption is valid only to the extent that it is reasonable to assume that all individuals in a given areal unit are located at the same place in the social/spatial geography. The smaller the areal units, and the more closely boundaries between units correspond to real social barriers, the more reasonable this assumption. Nonetheless, we should keep in mind that spatial measures are not immune from MAUP, though they may be less sensitive to MAUP-induced measurement error than aspatial measures.

Social Distance and School Segregation. In describing school segregation, there is little justification for attending to the physical distance between two schools, since school boundaries circumscribe social relations and the provision of resources and instruction far more clearly than spatial distance among schools. Conversely, school segregation research has rarely attended to differences in levels of social distance among different pairs of students within schools—all students within a school are assumed to be in the same social location. While this may seem an oversimplification in a school with substantial grade and curricular differentiation (since a pair of students in kindergarten and twelfth grade, for example, presumably have far less social interaction than a pair of students in the same grade and classroom), it makes sense from the point of view of the allocation of school resources, policies, curricula, and so on, since many such aspects of schooling operate at the level of the school rather than the level of the classroom or grade.

Given the assumption that all students within a given school occupy the same location in the social geography of schooling, and that all schools are equally distant from one another, we get a social distance metric that has $d_{ij} = 0$ if i and j are in the same school, and $d_{ij} = 1$ otherwise. (Note that in the school segregation literature, there is no concern with MAUP, since the assumption that all students within a school are located in the same place in the social geography of schools is fairly reasonable.)

Social Distance and Social Network Segregation. Suppose we are interested in measuring the segregation of social or friendship networks. We might define social proximity based on the "degrees of separation" between individuals. For example, suppose we have a population of adolescents, each of whom identifies their five "best friends" in the population. From this information, we may draw a social network map (e.g., see Coleman 1961), with "best friends" indicated by (one- or two-way) links. From this network, we can define some measure of the social distance d_{ij} between i and j as a function of the number, length, and directionality of the network path(s) connecting i and j. For example, let n_{ij} be the length of (the number of links in) the shortest path connecting individual i to j and then define $d_{ij} = 1 - a^{-n_{ij}}$, where a is some constant greater than 1. More complex measures of social distance might incorporate information on the number of distinct paths connecting i and j, as well as information on whether friendship links are mutually nominated or not. Again, our goal here is not to evaluate the merits of different definitions of social distance within friendship networks, but only to point out (1) that "social distance" may apply to other dimensions of distance than spatial distance; and (2) the need for careful attention to how social distance is operationalized.

Social Distance and Occupational Segregation. As a final example of social distance, consider the study of occupational segregation. In the occupational segregation literature, occupations are generally thought of in the same way as schools are in the school segregation literature—as distinct organizational units, each equally socially distant from one another (e.g., see Charles and Grusky 1995; Watts 1992; Watts 1997). In our notation, the social distance between occupations is $d_{JK} = 1$ for all occupations $J \neq K$, and the social distance within an occupation J is $d_{ij} = 0$ for all i and j in J. In some cases, this may be a somewhat unreasonable assumption. It may make sense to define d_{JK} to account for the fact that professional occupations are more similar to one another ("closer" in social distance) than a professional occupation is to a service or labor occupational category. The exact definitions of social distance one might employ should derive from theoretical understandings of the occupational structure and social relations among members of different occupations.

In each of these examples, the exact definition of "social distance" should follow from theoretical consideration of the social processes of interest. Grannis and others who have argued against the use of aspatial measures of residential segregation do so because sociological theory suggests that the probability of social interaction decreases with spatial distance. In order to provide the basis for meaningful analysis of segregation and its processes, segregation measures must incorporate an appropriate metric of social distance.

2. INCORPORATING SOCIAL DISTANCE INTO SEGREGATION MEASURES

Even given a theoretically appropriate social distance matrix, we still require a mathematical formulation for computing segregation levels based on this social distance matrix. Although a complete derivation and evaluation of segregation indices that incorporate notions of social distance or proximity is beyond the scope of our comments here, we nonetheless wish to suggest several approaches that might profitably lead to useful measures of segregation.

2.1. *Segregation Measures Using Proximity-Weighted Group Proportions*

Think of segregation as a measure of the extent to which the composition of each individual's social environment deviates from the composition of the average social environment of the total population. We can formally define the composition of the social environment of individual k as follows. Suppose m is one of M distinct groups (e.g., race/ethnic groups) in the population. Let k and j index individuals, and define $c_{kj} = 1 - d_{kj}$ as the "social proximity" of individuals k and j. Let $x_{jm} = 1$ if individual j is in group m and $x_{jm} = 0$ otherwise. Then define

$$\tilde{\pi}_{km} = \frac{\sum_j x_{jm} c_{kj}}{\sum_j c_{kj}}. \tag{1}$$

Now $\tilde{\pi}_{km}$ is the proximity-weighted proportion of members of group m in the social environment of individual k. Likewise, the average proximity-weighted proportion of members of group m in the social environment of the population is $\tilde{\pi}_m$, which is simply the average of the $\tilde{\pi}_{km}$ over all individuals.

As we noted above, however, in practice we rarely have the individual-level data that allow us to compute the social proximity of two *individuals*. To compute $\tilde{\pi}_{km}$ in the case where we have data tabulated by some organizational units (schools, census tracts), among which we may have some measure of social proximity (distance, contiguity), consider individuals j and k in organizational units J and K, respectively. Now if c_{jk} is equal to some constant c_{JK} for all j and k in J and K, then c_{JK} is the social proximity of unit J to unit K (with $c_{JJ} = 1$ for all J and $0 \le c_{JK} \le 1$ for all $J \ne K$). From this, we get

$$\tilde{\pi}_{km} = \tilde{\pi}_{Km} = \frac{\sum_J t_J \pi_{Jm} c_{KJ}}{\sum_J t_J c_{KJ}}, \tag{2}$$

where t_J is the number of individuals in unit J and π_{Jm} is the proportion of J made up of group m (for example, proportion Latino in census tract J). Now $\tilde{\pi}_{km}$ is constant for all individuals k in K, and this constant can be computed from the sizes, compositions, and proximities of each of the units relative to K.

Now consider the special case where each organizational unit has no social proximity to any other unit—as in the case where the organizational units are schools. In this case $c_{JJ} = 1$ for all J and $c_{KJ} = 0$ for all $J \neq K$. From this, we get $\tilde{\pi}_{Km} = \pi_{Km}$, where π_{Km} is the proportion of unit K in group m. In other words, if we assume that all individuals in a given unit have maximum social proximity to each other and minimum (zero) proximity to individuals in other units, then the composition of the social environment of individual k is simply the composition of his or her organizational unit.

If we return to our definition of segregation above—a measure of the extent to which the composition of each individual's social environment deviates from the composition of the total population—we can use equation (2) to extend the set of multigroup segregation indices in Reardon and Firebaugh (2002, this volume) to a more general set of indices that can accommodate any number of forms of social proximity. To do this, we simply replace π_{jm} and π_m with $\tilde{\pi}_{jm}$ and $\tilde{\pi}_m$ in Table 2 in Reardon and Firebaugh (2002, this volume). A note of caution regarding this approach is warranted however; it is not immediately clear whether constructing social distance-based segregation measures in this way leads to mathematical difficulties. However, we leave the evaluation of these and all measures suggested here to future consideration. Our goal here is simply to suggest different possible approaches to incorporating social distance into measures of multigroup segregation.

2.2. *Segregation Measures as Distance-Weighted Average Differences in Group Proportions*

A second possible approach to constructing segregation indices that incorporate a social distance metric is to take the sum, over all groups and all pairs of organizational units, of a measure of the difference in group proportions between units, weighted by the size of the group, the size of the units, and the social distance between the units. This gives

$$W = \sum_{m=1}^{M} \pi_m \sum_J \sum_K \left[\frac{t_J t_K}{T^2} \cdot f(r_{Jm}, r_{Km}, d_{JK}) \right], \tag{3}$$

where $f(r_{Jm}, r_{Km}, d_{JK})$ is a function that measures the difference between r_{Jm} and r_{Km} as an increasing function of d_{JK} with $f(r_{Jm}, r_{Km}, d_{JK}) = 0$ if $r_{Jm} = r_{Km}$. Following our approach in deriving the disproportionality-based segregation indices described in our paper in this volume, we then divide W by its maximum possible value (obtained in the case of complete segregation) to get plausible distance-weighted measures of segregation. For example, if $f(r_{Jm}, r_{Km}, d_{JK}) = d_{JK}|r_{Jm} - r_{Km}|/2$, we get a distance-weighted Gini index. Similarly, if $f(r_{Jm}, r_{Km}, d_{JK}) = d_{JK}(r_{Jm} - r_{Km})^2$, we get a distance-weighted squared coefficient of variation index. In the case when $d_{JK} = 1$ for all $J \neq K$ (which is the case when we think of all organizational units as equally distant from one another, as is the case with aspatial segregation measures), these two distance-weighted measures reduce to the G and C we define in our paper in this volume. The spatially adjusted versions of the dissimilarity index suggested by Morrill (1991) and Wong (1993) can also be derived from this approach, if we define $f(r_{Jm}, r_{Km}, d_{JK}) = (|r_{Jm} - 1| + |r_{Km} - 1| - (1 - d_{JK})|r_{Jm} - r_{Km}|)$ and use $d_{JK} = 1 - W_{JK}$ (where W_{JK} is Wong's boundary weight term—a measure of social proximity in our terminology). In the aspatial case (where $W_{JK} = 0$ for all $J \neq K$), these indices reduce to D.

2.3. *Segregation Measures as Average Social Proximity Ratios*

A third general approach to developing segregation measures that incorporate a social distance metric is to compute a set of average within- and between-group social proximity measures and then to define segregation as some appropriate function (most likely a ratio) of these average social proximities. White (1983) was the first to take this approach, applying it to the measurement of spatial segregation.

In this approach, for each pair of groups m and n, we compute the average social proximity of a member of group m and group n. In particular, the average social proximity of two individuals of groups m and n is

$$C_{mn} = \sum_J \sum_K \frac{t_J t_K \pi_{Jm} \pi_{Kn}}{T^2 \pi_m \pi_n} (1 - d_{JK}). \tag{4}$$

Similarly, the average social proximity of any two individuals is

$$C_{tt} = \sum_J \sum_K \frac{t_J t_K}{T^2} (1 - d_{JK}). \tag{5}$$

Grannis, following White in his comment, suggests a segregation measure based on these measures. His multigroup spatial proximity index is simply

$$SP = \sum_{m=1}^{M} \pi_m \frac{C_{mm}}{C_{tt}}, \tag{6}$$

which is a multigroup extension of White's two-group proximity statistic P (White 1983). One potential disadvantage of this measure, however, is that it is not bounded between zero and one, as are other segregation measures. Instead, it is bounded between 0 and $1/C_{tt}$, where $0 < C_{tt} \leq 1$. A value of SP greater than 1.0 indicates that individuals have a greater social proximity, on average, to members of their own group than to other groups; a value of 1.0 indicates zero segregation; and a value less than 1.0 indicates that individuals have a greater social proximity, on average, to members of other groups than to their own (a result that can arise if the social distance metric is defined in a way that allows cases where $d_{ij} + d_{jk} < d_{ik}$ for some i, j, and k).

A related index can be constructed if we simply replace C_{mm} and C_{tt} by D_{mm} and D_{tt} in equation (6) and subtract the resulting ratio from 1. This index measures the ratio of the average social distances among members of the same groups to the average social distance among the population. One advantage of this index over Grannis's is that it is normally bounded between 0 and 1 (although negative values, indicating negative segregation, are possible if the social distance metric is not defined so that $d_{ij} + d_{jk} \geq d_{ik}$ for all i, j, and k). Finally, other approaches to deriving multigroup segregation indices that incorporate measures of social distance are possible (e.g., see Jakubs 1981; Morgan 1983a; Morgan 1983b), but we leave a fuller discussion of these for another time.

3. EVALUATING MEASURES OF SEGREGATION THAT INCORPORATE SOCIAL DISTANCE

Grannis implies that the appropriateness of a segregation index can be reasonably inferred based on its "functional inputs"—the information used to compute it. "Indices can best be understood in terms of the variables they are functions of," he argues (page 70, this volume), but never makes clear the justification for this statement. While true at a relatively crude level—an index that does not use information on the spatial location of census tracts cannot be said to be a spatial measure—this method of analyzing segregation indices seems to miss key issues in the measurement of segregation, notably the need for segregation measures that allow mathematically valid comparisons among different populations.

We agree with Grannis that a segregation measure must rely on an appropriate social distance metric, yet, given a definition of social distance, a variety of measures of segregation are possible. We have suggested several general approaches to deriving segregation indices that incorporate a social distance metric. Each of these approaches yields multiple potential indices that derive from different functional definitions of segregation and different operationalizations of the concept of "social distance." In addition, there are at least several other measures of spatial segregation in the literature that we have not discussed and that do not fall under these general types (e.g., see Jakubs 1981; Morgan 1983a; Morgan 1983b). In all, we are presented with a wide array of apparently meaningful segregation measures that incorporate a social distance metric, each of which is potentially a useful measure of spatial segregation. All of the indices we have described above include information on social distance; and all allow for multiple groups. How are we to decide which to use?

To see if an index permits mathematically valid comparisons among different populations, we must determine whether the index responds appropriately to changes in the distribution of individuals across social space. That insight is the basis for the criteria we established for evaluating the aspatial multigroup indexes in our earlier paper. As we show there, not every mathematical operationalization of the concept of segregation possesses the mathematical properties to allow meaningful comparisons among different populations and useful segregation decomposition analyses.

Thus, while Grannis's suggestion of a multigroup spatial proximity index is a useful contribution to the field of residential segregation research, his index, as well as all of those we have suggested above, should be carefully evaluated according to some theoretically appropriate set of mathematical criteria to ensure that they allow meaningful comparisons among populations. This task is well beyond the scope of our discussion here, however. We would like to suggest that researchers take up in the future the task of both specifying an appropriate set of criteria—as James and Taeuber (1985) and we have done for aspatial measures—and evaluating the many social distance-based measures of segregation against these criteria.

As a start toward this goal, we present here a tentative list of appropriate criteria to use for evaluating social distance-based segregation measures. Although Grannis states that the four James and Taeuber (1985) criteria that we use in our paper "concern only the racial populations of each neighborhood and thus have no meaning for indices that include other variables" (like a social distance metric), we fail to see the rationale for this statement. Even in the case of spatial segregation indices, we would still like an index to remain invariant under a doubling of the population in every neighborhood, for example. While some criteria may require a more general statement in the case of social distance-based indices, the idea that indices ought to respond in conceptually appropriate ways to changes in the population distribution among organizational units remains valid. Finally, the criteria we present here are meant as a starting place for discussion; more thorough consideration than we can give them here is necessary before setting them in stone.

Nonspatial Analog. If $c_{ij} = 1$ for all i and j in the same organizational unit, and $c_{ij} = 0$ for all i and j in distinct units, then a segregation measure should reduce to a meaningful aspatial measure. Traditional aspatial measures of segregation are a special case of social distance-based measures, defined as the case where the social proximity of any two distinct units is zero.

Definitions of Minimum and Maximum Segregation. Though arguable, we suggest the following definitions of maximum and minimum segregation. A spatial segregation index should be bounded between 0 (obtained only in the case of no segregation) and 1 (obtained in the case of complete segregation). Segregation should be zero when the group proportions are the same at all points in the social terrain. This means that segregation is zero if either of the following conditions are met, and greater than zero otherwise: (a) if $\pi_{Jm} = \pi_{Km} = \pi_m$ for all J, K, m, regardless of the distances among the units; or (b) if $c_{ij} = 1$ for all i, j, regardless of the group proportions in the units. Segregation is maximized if there is no social proximity between any members of different groups. That is, for any pair of individuals i and j who are members of different groups, the social proximity c_{ij} equals zero.

Note in particular that these definitions appear to be invalid for the social proximity measures we describe above, because these measures allow measured segregation to be negative, at least given certain definitions of social distance. What it means for segregation to be negative, and whether a meaningful measure should allow such a result, merit further consideration.

Social Distance Scale Invariance. If the social distance between each pair of units is multiplied by a constant, then segregation is unchanged. This criterion is debatable, however, as it views segregation as a measure of the relative distribution of individuals across social space. In this perspective, a street with all whites at one end and all blacks at the other end would be as segregated as a metropolitan area with all whites on one side and all blacks on the other. There may be cases where such a result is inappropriate, however. More generally, a segregation index should respond appropriately to a change in the social distance scale, though the definition of "appropriate" must derive from some theoretical understanding of the social processes of interest.

Organizational Equivalence. If $\pi_{Jm} = \pi_{Km}$ for all m, $c_{JK} = 1$, and $c_{JI} = c_{KI}$ for all I, then segregation is unchanged if units J and K are combined into a single unit. Likewise, if a unit is divided into two units J and K such that $\pi_{Jm} = \pi_{Km}$ for all m, $c_{JK} = 1$, and $c_{JI} = c_{KI}$ for all I, then segregation is unchanged.

Size Invariance. If the number of members of each group m in each unit J is multiplied by a constant p, then segregation is unchanged.

Transfers, Exchanges, and Mobility. A key criterion for a segregation measure is a definition of how segregation should change in response to the movement of individuals (or units) in social space. Transfers and exchanges, as we define them in our paper in this volume, are a specific type of movement of individuals within the social space. In the case of more generalized social distance-based measures of segregation, however, it is not exactly clear what should be the appropriate formulation of these criteria. We suggest the following formulations as a starting point, though more careful thought needs to be given to this issue.

Transfers. If a member x of group m is transferred from unit J to K, such that the average distance of x from all other members of group m is increased while the average distance of x from members of other groups is unchanged or reduced, then segregation is reduced.

Exchanges. If a member x of group m from unit J is exchanged with a member y of group n from unit K, such that the average distance of x from all other members of group m is increased and the average distance of y from all other members of group n is increased while the average distance of x and y from members of groups other than their own is unchanged or reduced, then segregation is reduced.

Mobility. An appropriate mobility criterion should describe what happens if the social distance between two organizational units is changed while their social distances from all other units are unchanged. It seems that the effect of moving units J and K should depend not only on the change in d_{JK}, but also on the group proportions in J and K. In particular, if each group m is either overrepresented in both J and K or underrepresented in both J and K, then segregation should be increased if d_{JK} is reduced. Conversely, if each group m is overrepresented in one of J and K and underrepresented in the other, then segregation should be decreased if d_{JK} is reduced.

Additive Grouping Decomposability. If M groups are clustered in N supergroups, then a segregation measure should be decomposable into a sum of independent within- and between-supergroup components.

Additive Spatial Decomposition. A segregation measure should be decomposable into a sum of independent within- and between-cluster components.

4. AN AGENDA FOR FUTURE DEVELOPMENTS IN SEGREGATION MEASUREMENT

The field of segregation research has long been hampered by an inappropriate reliance on a limited set of two-group measures that lack explicit attention to theoretically appropriate social distance metrics. And while Grannis is not the first to suggest the need for more attention to spatial dimensions of segregation, he is right to reiterate the point, since much work remains to be done in developing appropriate spatial measures, particularly multigroup spatial measures. Here we would like to suggest an agenda for future developments in segregation measurement.

First, segregation measures must be developed that appropriately incorporate a social distance metric. This requires careful attention to the theoretical processes that define the appropriate social distance metric. Grannis's taxonomy of segregation measures illustrates the aspatial nature of many indices, but a focus on functional inputs alone is insufficient for developing theoretically valid segregation measures. In addition, the functional form of both the social distance metric and the segregation measures must be conceptually appropriate to the phenomenon under examination.

Second, a set of criteria describing the appropriate mathematical behavior of the social distance-based measures is needed. We have suggested some tentative criteria above, but these need more careful consideration and formulation in some cases. A full discussion of the criteria is beyond the scope of our comments here. These criteria can then be used to evaluate the many social distance-based segregation measures available in the literature.

Careful development and evaluation of social distance-based segregation measures will go a long way toward improving the field of segregation research. There are, however, several other areas where further work is needed. In particular, all existing segregation measures require that the groups of interest be mutually exclusive and unordered. Third, then, work is also needed in the development of segregation indices for groups that are not mutually exclusive. Given the new procedures for racial and ethnic classification (in the United States), which allow respondents to identify themselves as members of multiple groups, segregation measurement must be extended to allow the measurement of segregation among members of overlapping groups. No work that we are aware of has addressed this issue, though it is clearly one of growing importance in the United States.

Fourth, the field needs segregation indices—both aspatial and social distance-based—that measure segregation among ordered groups, such as groups defined by income categories or educational attainment, for example. Grannis suggests that multigroup measures, such as his multigroup spatial proximity index, can be used to measure segregation among groups defined by income or educational level, but this ignores the ordered nature of these groups. Grannis is not alone in missing this point, however; studies of socioeconomic segregation have often ignored the ordering of income categories in measuring segregation (e.g., Fong and Shibuya 2000; Telles 1995). Jargowsky (1997) develops a measure of income segregation that respects the ordered nature of income categories, but his measure is aspatial. However, measures of spatial autocorrelation—such as Moran's *I* and Geary's *c* (Cliff and Ord 1973; Cliff and Ord 1981; Odland 1988)—and Chakravorty's *NDI* (1996) provide useful approaches to measuring spatial segregation among ordered income groups.

A final set of issues that we would like to see addressed concern the need to think about the implications of data collection and aggregation approaches for segregation measurement. As we have argued above, the aggregation of data generally necessitates that we treat all individuals within an organizational unit (especially a census tract or block group) as located at the same point in the social geography. This assumption gives rise to MAUP issues and leads to an unknown amount of error in segregation computations.

Gathering social location data at an individual level would alleviate these problems, and allow more precise measurement of segregation. Particularly in residential and social network research, more fine-grained, individual-level data would be useful. A major obstacle to using individual-level data, however, is that segregation measurement relies on having data on the full population under examination, since little or nothing is known about the sampling properties of segregation measures. It would be very useful to examine these properties, to determine whether it might be feasible to get measures of individual-level segregation from a population sample.

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