From Walkability to Active Living Potential

An "Ecometric" Validation Study

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Background: The purpose of this paper is to establish the reliability and validity of a neighborhood-level measure of active living potential by applying principles of ecometrics.

Methods: Following a 3-day training session, observers ($n=8$) were provided with a map of a predetermined walking route constructed through the joining of ten randomly selected street blocks. Then, using an 18-item observation grid, pairs of observers performed ratings of 112 neighborhoods. Resulting observations produced a hierarchically structured data set including 4032 observations nested within observers, which in turn were nested within neighborhoods. Data from the 2001 Canadian census were linked to the neighborhood data.

Results: Application of ecometric multilevel modeling analyses showed that once interitem and interobserver variability were statistically controlled, about one third of the variability in observations were at the between-neighborhood level. Reliability estimates were 0.78 for items measuring activity-friendliness, 0.76 for safety, and 0.83 for density of destinations. Assessment of the convergent validity of the instrument identified that safety of the environment was positively associated with neighborhood affluence. Density of destinations was negatively associated with affluence and positively associated with higher proportions of persons in the neighborhood walking to work.

Conclusions: The three dimensions of the neighborhood active-living potential measure have good reliability and convergent validity and are able to capture between neighborhood differences. Measurement characteristics would have been difficult to ascertain without the ecometrics methodology.

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Background

Over the past 10 years, there has been a surge of interest in identifying environmental variables associated with physical inactivity and in developing interventions targeting environmental and policy change to reduce the societal burden of sedentary lifestyles.[1–10] This accrued interest coincides with a renewed impetus in public health to study how the environment influences the health of individuals and populations.[11–16] There is consensus that real advances in this area of research will only be achieved if a concerted effort is deployed toward the development of measures that capture properties of the environment.[17,18] Although some initial methodologic work has produced useful knowledge,[19–21] there are concerns that properties of environments cannot be reduced to simply aggregating observations or perceptions of users of the environment.[22,23] A new approach to developing environmental measures called "ecometrics" is arising as a promising approach to validating environmental measures.[23–25] The purpose of this paper is to establish the validity and reliability of a neighborhood-level measure of active living potential by applying principles of ecometrics.

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From Walkability to Active Living Potential

The term "walkability" has appeared increasingly often in the transportation, new urbanism, behavioral medi-

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cine, and public health literatures.[20,21,26–29] Although few formal conceptual definitions have been provided, it is intuitively understood that a walkable environment is one where walking is more readily performed. The term walkability originated from the transportation literature wherein data show that more walkable neighborhood environments are associated with greater residential density, mixed land use, and greater street connectivity.[30–32]

The notion of walkability is inherently appealing and has thus been borrowed by health researchers. However, its current use and conceptualization for the study of active living are wanting in at least two ways. First, walking is not the only human-powered ambulatory activity that is associated with more walkable environments. It may be a misnomer to refer to "walkable" environments when in fact the interest is in environments that sustain a variety of forms of human-powered activity (e.g., cycling, wheelchair use, baby stroller use). Second, it should be recognized that human agency or the capacity to "intentionally make things happen" is a key factor of the outcome of complex interactions among individuals, populations, and environments.[33] As a result, environmental characteristics might best be thought of as "potential" rather than capacity, which is a distinctly human characteristic that centrally features intentionality.

Furthermore, there are three cross-cutting issues that should be addressed in efforts to develop environmental measures. First, there are a variety of settings (schools, workplaces, recreation/fitness centers, and neighborhoods) that may be conducive to engaging in physical activity. These settings differ on a number of characteristics, including size, personal and societal value, and accessibility. Given this diversity, it seems wise to adopt a setting-specific approach. Second, although there is currently a great deal of attention devoted to built form,[34–39] there have been fewer efforts[28] to integrate macrosocial aspects (e.g., social cohesion, area friendliness, social disorder) into any understanding of the links between environment and physical activity involvement. The development of new measures should reflect this concern for incorporating the "social."[40] Finally, there is general recognition now that any attempt to promote greater physical activity involvement must incorporate individual and population perspectives.[41,42] The development of conceptual definitions of the Neighborhood Active Living Potential (NALP) measure was formulated with these concerns in mind.

Neighborhood Active Living Potential may be defined as aspects of the neighborhood that regulate the likelihood of active living in individuals and populations. Active living, as defined by the Robert Wood Johnson Foundation, is a way of life that integrates physical activity into daily routines. The goal is to accumulate ≥30 minutes of activity each day. Individuals may do this in a variety of ways, such as walking or bicycling for transportation, exercise, or pleasure; playing in the park; working in the yard; taking the stairs; and using recreation facilities. NALP is conceptualized as an ecologic feature of the neighborhood environment that can be associated differentially with individual-level as well as population-level indicators of physical activity. NALP varies on a continuum ranging from very low potential for integrating physical activity into daily routines to very high potential for such integration. NALP consists of three underlying dimensions, namely, activity friendliness (AF), safety (SAFE), and density of destinations (DD). AF is intended to assess the physical characteristics of the neighborhood; low AF hampers human-powered activities such as walking, cycling, skateboarding, and wheelchair use, whereas high AF facilitates engagement in these activities. SAFE is associated with the physical and social characteristics of the neighborhood; low SAFE neighborhoods elicit a sense of threat in people ambulating through the setting, whereas high SAFE neighborhoods elicit a sense of security. DD was developed to assess the physical and social characteristics of the neighborhood; low DD neighborhoods have a restricted number and variety of destinations for engaging in meaningful personal or collective pursuits, such as purchasing consumer goods, working, participating in local community events, using public leisure and recreation facilities, or recreating, whereas high DD neighborhoods offer a wide variety of such destinations. NALP can be achieved through different configurations of AF, SAFE, and DD, and is thus thought of as a latent construct.

Ecometrics: Emergence of a Methodology

In establishing the validity and reliability of measurement instruments, researchers have exploited well-known psychometric methods that generally consist of aggregating items representing constructs. The reliability of a resulting scale is thought to be a function of the number of items and item consistency.[22] Although this strategy has been demonstrated as useful in developing measures of individual skills and attitudes, Raudenbush and Sampson[23] have argued that psychometric techniques have limitations when applied to the development of environmental measures. In particular, psychometric methods do not account for the additional complexities of environmental measures. In developing environmental measures, researchers will often sample a number of users of an environment, ask them to rate a series of items, and then aggregate items to create measures of environmental constructs. Alternatively, several observers might record observations (e.g., presence or absence of walking trails, quality of walking trails) of an environment. These observations are then aggregated across items and observers. Reliability in these cases would not only depend on the number of items and item consistency but also on intersubjective agreement between respondents or observers. This added complexity is not handled by traditional psychometric methods that necessarily create aggregation bias and ignore the nested structure of resulting data sets. Aggregation can lead to under-estimation of standard errors of measurement. As a result, application of psychometric methods can result in inaccurate estimations of reliability and, even worse, in over- or underestimation of associations with other constructs of interest. Ecometrics represents one possible solution to the added complexity of developing environmental measures.[22–25]

Ecometrics refers to the scientific assessment of settings or environments through systematic observation and analysis of resulting data through specialized statistical tools. In an ecometric study, the researcher would collect observational data on numerous items throughout a large sample of settings, and then apply a specific type of multilevel analysis procedure to circumscribe the reliability and validity of resulting scales. Ecometrics resulted from the integration of three well known methodologies, namely, generalizability theory, item-response theory, and multilevel modeling techniques.[22,23] Generalizability theory proposes that any measure includes many sources of error and that validation must commence by the identification of sources of error. Identification of sources of error variance informs the researcher regarding the limits of the measure and optimal conditions for its use. Item-response theory proposes that the probability of a "correct" response on a test including numerous items is a function of the ability of the respondent and the difficulty of the item. A visual inspection of the "difficulty map" allows the analyst to examine whether items of a test are evenly distributed and thus cover the full range of possibilities. Exploration of response patterns as a function of the ability of respondents offers another perspective on the difficulty of an item.

Multilevel modeling techniques allow the analyst to examine different sources of variability in an outcome variable when the data set is organized hierarchically (i.e., subunits nested into larger clusters such as individuals [subunits] nested in a neighborhood [higher-order clusters] or observations [subunits] nested within neighborhoods [higher-order clusters]). Thus, multilevel modeling allows the researcher to decompose the variance between different levels of analysis and to explore the association of predictor variables with dependent variables at each level. The integration of these three methods via ecometric principles allows the researcher to obtain validity and reliability estimates that account for the hierarchical structure of data sets as well as different sources of variability in the data.

Using an ecometric approach, the researcher can obtain the following indicators of the validity and reliability of measures: (1) average estimates of constructs that are unbiased by aggregation; (2) an estimate of the intraclass correlation which provides information on the degree of within versus between unit variability in indicators; (3) a difficulty map of the utility of each item on each scale; (4) the intraunit and between-unit reliability (i.e., internal consistency) in the environmental indicators and the sensitivity of the measures in distinguishing units from one another; and (5) estimation of the associations of average unit level scores with other variables of interest for the establishment of convergent validity of measures. There are at least four applications of the ecometric approach in the published literature which provide demonstrations of the application of these principles.[23,27,43,44]

The Current Investigation

The purpose of this study was to establish the reliability and validity of a neighborhood-level measure of active living potential by applying selected principles of ecometrics. Toward this end, data were used from an ongoing project that is designed to examine the association between environmental features of residential neighborhoods and active living among noninstitutionalized seniors living in urban and suburban environments.[45]

Methods

Sampling of Neighborhoods

Montreal is constructed on an island of 485 km^2 and around a mountain of 232 m in altitude. According to the 2001 Canadian Census, the island has a population of 1,812,723 persons but the overall census metropolitan area of Montreal includes a population of 3,426,000, the second largest urban center in Canada. The average household income is about $50,818, slightly below the national average. From a geographic standpoint, the city of Montreal is divided into 27 boroughs and 511 census tracts. In this study, neighborhoods were equated with census tracts. In an effort to obtain a representative sample of neighborhoods, census tracts were sampled within each borough through a two-stage sampling approach. That is, the census tracts in each borough were divided into tertiles based on average family income. Within tertiles, census tracts were then sampled randomly and proportionally to the number of tracts in the borough with the constraint that at least three tracts were sampled within each borough. Ultimately, observations were conducted in a total of 112 census tracts. In the resulting sample, the average family income was $52,894 (median=$40,941), the average population size was 2834 persons, the average percentage of people with low education (i.e., less than high school) was

14.5%, and the average percentage of people walking to get to work was 10.4%.

Sampling of Streets Within Neighborhoods

For each of the 112 neighborhoods, ten street segments were randomly selected using MapInfo 6.5 (MapInfo Corp., Troy NY, 2001) and SPSS 10.0 (SPSS Inc., Chicago, 2001) software. A street segment was defined as a continuous stretch of road that was uninterrupted by an intersection. Sixty meters was set as the minimum length of a street segment for selection. Once the ten street segments in a neighborhood were selected, a research assistant traced a walking route that joined the ten street segments in MapInfo.

Measures

To assess NALP, the 18-item grid developed by Craig et al.[27] was used (see Table 1). Items with face validity for AF, SAFE, and DD (six, four, and eight items, respectively) were taken from the original measure that was previously used unidimensionally. All observations were recorded using a 10-point rating scale, which in some cases were reverse coded, such that higher scores reflect greater active living potential.

Training of Observers

A total of four pairs of observers (n =8) were recruited to perform observations. Half were female and average age was

Table 1. Items tapping into dimensions of NALP and location of items on subscales (from univariate analyses)

Dimension of NALP	Item	Scale	Score	Coefficient	SE
Activity friendliness (six items)	Intercept			**6.00*****	0.16
	Pedestrian system has limits to pedestrians	Not at all to Very limited	−	**0.58*****	0.08
	Effort to walk around	Very low effort to Very high effort	−	**0.48*****	0.09
	Bicycle system has limits to cyclists' needs	Not at all to Very limited	−	0.16	0.08
	Pedestrian system addresses pedestrian needs (Reference item)	Not at all to Very well	+	0	
	Effort to cycle around	Very low effort to Very high effort	−	**−0.17***	0.08
	Bicycle system addresses cyclists' needs	Not at all to Very well	+	**−0.32*****	0.08
Safety (four items)	Intercept			**6.41*****	0.17
	Safety/feeling threatened with the potential for crime	Not at all threatening to Very threatening	−	**0.37*****	0.09
	Threat of traffic to pedestrians	Not at all threatening to Very threatening	−	**0.25****	0.09
	Safety/feeling comfortable with the potential for crime (Reference item)	Not at all comfortable to Very comfortable	+	0	
	Threat of traffic to cyclists	Not at all threatening to Very threatening	−	**−0.45*****	0.09
Density of destinations (eight items)	Intercept			**5.34*****	0.17
	Exclusive of people	Not at all exclusive to Very exclusive	−	**1.52*****	0.10
	Inclusive of people	Not at all inclusive to Very inclusive	+	0.03	0.10
	Number of people-oriented destinations (Reference item)	No people oriented destinations to Very many people-oriented destinations	+	0	
	Environmental stimuli	Simple to Complex	+	−0.07	0.10
	Socially dynamic/static	Static to Dynamic	+	−0.08	0.10
	Visual interest	Low visual interest to High visual interest	+	**−0.31*****	0.10
	Variety of destinations	Homogenous to Highly mixed	+	**−0.34*****	0.10
	Overwhelming	Not at all to Very	+	**−1.10*****	0.10

*p<0.05; **p<0.01; ***p<0.001.
NALP, Neighborhood active living potential; SE, standard error.

22.9 years (range=17–29). Educational achievements of observers ranged from 1 year of junior college to completed undergraduate training in a variety of disciplines including communications, education, architecture, geography, and public health. This diversity was actively sought to test the viability of training persons with varied experience. Observers participated in a 3-day training seminar wherein they were provided with (1) background information regarding the built environment and involvement in physical activity; (2) a description and illustrated examples of each observation item; and (3) some guidelines for avoiding drift and redefining of observation items. Observers participated in classroom as well as field trial-and-error observations. Training finished once all eight observers were able to repeatedly achieve consensus on all NALP ratings. Halfway through data collection, all observers conducted an evaluation of the same neighborhood to ensure that no drift had occurred in observations.

Procedures

Pairs of observers were provided with maps of the two neighborhoods that they had been assigned for the day. Upon arrival in the neighborhood, members of each pair of observers commenced their evaluations at opposite ends of the walking route, and recorded their overall neighborhood ratings independently at the end of their route. Typically, observations in one neighborhood required about half a day. Thus, each pair of observers completed two neighborhoods per day. Observations were recorded between May 2003 and September 2003, on weekdays between 9 AM and 5 PM, and when there was no precipitation. For security reasons, observers were provided with an identification card, and local police stations were informed of the presence of observers. Once observations were completed for the day, observers signed off by telephone. Given that data were collected in public places and that there was no collection of data from individuals, the Research Ethics Board deemed that ethical approval was not required.

Statistical Analyses

Following descriptive analyses, multilevel modeling was applied to the data. Multilevel modeling is a generalization of the general linear modeling used in regression that allows researchers to account for the hierarchical structure of a database. The technique also allows for the specification of random as well as fixed effects in the model.[46] In this application of multilevel modeling, observations ($n=4032$) were conceptualized as being nested within observers ($n=2$), who in turn were nested within neighborhoods ($n=112$). The multilevel analysis for each dimension of NALP proceeded in four steps: (1) partitioning of variance into interitem, interobserver, and interneighborhood sources by running a null model prior to controlling for known sources of variance; (2) partitioning of variance while controlling for known interitem variance (through the addition of $n\text{L}-1$ dummy variables accounting for items on subscales where n was equal to the number of items on a scale) and interobserver variance (through the addition of seven dummy variables accounting for identity of observers); (3) examining the location of items on the latent dimension by comparing item coefficients in models controlling for interitem and interobserver variance; and (4) estimating the internal consistency of the scale once known sources of variance were controlled. In a final step, convergent validity of the subscales was established by examining intercorrelations of dimensions of NALP, and the influence of average income in the neighborhood and proportion of people walking to work in the neighborhood. This last phase of analysis was performed by running a multivariate multilevel model with no intercepts.[46] All analyses were conducted using HLM 5.04 (Scientific Software International,Chicago IL, 2001) software.[47] For purposes of comparison, psychometric analyses were also performed consisting of computation of internal consistency indicators for subscales, correlations between aggregated subscale scores, and correlations with average family income and percentage of people walking to work.

Results

Initial descriptive statistics showed that items on the NALP measure were normally distributed. Multilevel models for continuous data were therefore used. Running of the null model showed that between 26.8% and 31.3% of the variance was at the between neighborhood level (see Table 2). Once interitem and interobserver variability were controlled for, however, this proportion of variance increased to about one third of the total variance, which underscored the utility of controlling for these sources in attempting to measure NALP. Interestingly, examination of these data showed

Table 2. Variance estimates (proportions) for NALP dimensions before and after controlling for interitem and interobserver variability

	Between neighborhoods	Between observers	Between items
Before controlling for known source of variance			
Activity friendliness	0.43 (26.9%)	0.24 (14.8%)	0.92 (58.2%)
Safety	0.48 (31.3%)	0.09 (5.6%)	0.96 (63.1%)
Density of destinations	0.62 (26.8%)	0.10 (4%)	1.59 (68.8%)
After controlling for known sources of interitem and interobserver variance			
Activity friendliness	0.44 (32.5%)	0.12 (8.8%)	0.80 (58.7%)
Safety	0.45 (33.3%)	0.08 (5.7%)	0.83 (61.0%)
Density of destinations	0.63 (34.6%)	0.13 (7.1%)	1.06 (58.2%)

NALP, Neighborhood active living potential.

that residual interobserver variability was relatively small, at most 8.8%, suggesting that observer idiosyncrasies were not clouding the data.

Examination of the location of items on underlying dimensions of NALP (see Table 1) showed appropriate variability around reference items for constructing latent indices. For AF, for example, the reference item ("pedestrian system addresses pedestrian needs") was rated 6.00 on average. Other items were rated as systematically higher (e.g., "pedestrian system not having limits to pedestrians," "lack of effort to walk around") or systematically lower (e.g., "bicycle system addresses cyclists needs," "lack of effort to cycle around"). For SAFE, similar dispersion was evident. "Feeling comfortable with the potential for crime" (the reference item) had an average score of 6.41 across neighborhoods, but "not feeling threatened by the potential for crime" and "pedestrians not being threatened by traffic" were rated higher, although "cyclists not feeling threatened by traffic" was rated lower. For DD, the reference item ("number of people-oriented destinations") had a score of 5.34, whereas the reverse-coded "exclusive of people" was rated much higher. "Variety of destinations," "overwhelming stimuli," and "visual interest" were systematically lower. Internal consistency of NALP dimensions was also high once inter-item and interobserver variability were controlled. The average reliability indices across neighborhoods were 0.78, 0.76, and 0.83, for AF, SAFE, and DD, respectively, suggesting good internal consistency. Traditional psychometric analyses showed that internal consistency estimates were slightly higher at 0.80, 0.77, and 0.87, respectively.

Finally, findings from the multivariate multilevel model showed that AF and SAFE were positively correlated ($r=0.71$) and that SAFE and DD were negatively correlated ($r=-0.78$). AF and DD shared a small negative correlation ($r=-0.31$). Parallel intercorrelations between aggregate subscale scores were lower at 0.63, −0.54, and −0.24, respectively. Furthermore, examination of the influence of two other variables characterizing neighborhoods, namely average family income and percentage of people walking to work (Table 3) on dimensions of NALP, revealed interesting patterns. In particular, as average family income in the neighborhood increased, density of destinations decreased whereas safety increased. In addition, as the percentage of people walking to work increased, density of destinations increased, whereas safety and activity friendliness decreased. A similar pattern of findings emerged in examining correlations between aggregate subscales scores.

Discussion

The purpose of this paper was to establish the reliability and validity of a neighborhood-level measure of active living potential by applying selected principles of ecometrics. Examination of the data showed that by training observers to rate aspects of the neighborhood environment, it is possible to reliably detect between-neighborhood differences. In particular, examination of results pertaining to decomposition of variance indicated that about one third of the variance in observations can be ascribed to between-neighborhood differences. Without controlling for known sources of variance (i.e., between item and between observer), this proportion of variance was smaller (about 26% to 30%), suggesting that teasing out sources of variance is a useful exercise with this measure. In addition, only a limited percentage of the variance was associated with idiosyncratic observer variations (at most 8.8%), which suggests that it is feasible to train observers to detect various features of the neighborhood environment.

Examination of the location of items on the subscales suggested that a broad spectrum of the content of NALP had been tapped, as there were systematic variations in items across neighborhoods. For example, the average score of the items "overwhelming" and "visual interest" on the DD subscale were systematically lower across neighborhoods, suggesting that these aspects of density of destinations are not redundant with the reference item (number of people-oriented destinations).

Finally, examination of correlations between dimensions of NALP suggests that although the activity friend-

Table 3. Selected fixed effect estimates from the final multivariate multilevel model

Fixed Effects	Influence of . . .	Coefficient	SE	*t* ratio	*p* value
Density of destinations		5.36	0.15	35.20	**0.001***
	% Walking to work	0.05	0.01	8.77	**0.001***
	Average neighborhood income	−0.01	0.00	−3.59	**0.001***
Activity friendliness		5.99	0.16	37.56	**0.001***
	% Walking to work	−0.02	0.01	−3.66	**0.001***
	Average neighborhood income	0.003	0.003	1.11	0.27
Safety		5.99	0.16	37.56	**0.001***
	% Walking to work	−0.04	0.01	−7.90	**0.001***
	Average neighborhood income	0.01	0.00	5.07	**0.001***

*$p \leq 0.001$ (bolded).
SE, standard error.

liness and safety co-occur in this sample of neighborhoods, their shared variance is about 50%, which suggests uniqueness in each concept. More interestingly, the density of destinations dimension, which may be the central aspect of active living potential, is only mildly correlated with safety and activity friendliness. This pattern of relationships suggests that each of the proposed dimensions of NALP, although intercorrelated, explains unique aspects of the neighborhood environment. It should be noted that traditional methods seemed to marginally over-estimate the internal consistency of the subscales and underestimate their intercorrelations. The presence of these discrepancies underscores the contribution of an ecometric approach in disentangling diverse sources of variance.

In terms of convergent validity, one of the provocative findings originates from the fact that the percentage of persons in the neighborhood walking to work was positively associated with density of destinations and negatively associated with safety and activity-friendliness. A reverse pattern was observed for the association with average income in the neighborhood. These findings are consistent with other data.[5,48] However, further research into the association between dimensions of NALP and involvement in physical activity is warranted. What is especially needed is a more in-depth examination of the motives associated with engagement in activity. As suggested by others,[48] it may be that the environmental correlates of walking to work differ substantially from the correlates of physical activity for leisure and cycling for running errands. Similarly, data on proportion of people walking to work are ecologic population-based indicators. There is certainly a need to decipher whether relationships observed at one level (i.e., neighborhood or population level) are paralleled by similar relationships at another level (i.e., individual level).

Limitations

The current study includes several limitations. First, in terms of the ecometric method, the current set of analyses did not fully exploit its potential. That is, although attempts were made to control for different sources of variance and to account for the hierarchical structure of the data, principles of item-response theory were not applied. In the most simple example of item-response theory (a Rasch model),[49] items would have been dichotomized representing correct or incorrect answers. There would also have been a determination of whether selected items were better at discriminating some neighborhoods from others and whether selected items were poorly performing on the scale. This application awaits further attempts at validation. Another limitation pertains to specific definitions of neighborhood. As noted by Galster,[50] using census tracts is likely inappropriate for capturing the full diversity of the concept of neighborhood. However, given that census tracts are the most frequently used operationalization in the literature, this choice still appears appropriate. The extent to which the reliability and validity of the NALP measure varies according to definitions of neighborhoods awaits further empirical work. Furthermore, it should be noted that the focus of the current investigation is methodologic and descriptive. Any inferences about the value of the data for development of interventions seem premature. Moreover, it should be noted that the use of the NALP measure is quite labor-intensive. More widespread use may require simplification of measures or training procedures. Finally, all neighborhoods were from the same urban center, and therefore likely to reflect the cultural and societal influences in this specific city.

Conclusions

There is general consensus regarding the need to develop reliable and valid environmental measures associated with physical activity. In this study, data supporting the reliability and convergent validity of one such measure were provided along with cautions to potential users for the need for further replication. More interestingly, application of the novel approach to validation called ecometrics allowed for an exploration of the measurement characteristics of the observational tool. Substantial advances in this important area will ensue only to the extent that researchers follow the lead proposed by Raudenbush[22] and Raudenbush and Sampson[23] and ecometrically validate environmental measures.

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