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Measuring the Food Environment State of the Science

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Abstract

The past decades have seen an increased interest in understanding how the environment affects population health. In particular, public health practitioners and researchers alike are eager to know how the food environments of neighborhoods, schools, and worksites affect food choices and, ultimately, population risk for obesity and other diet-related chronic disease. However, the measurement tools for assessing the environment and the employed study designs have limited our ability to gain important ground. The field has not yet fully considered the psychometric properties of the environmental measurement tools, or how to deal with the copious amounts of data generated from many environmental measures. The field is dominated by research using unsophisticated study designs and has frequently failed to see the role of social and individual factors and how they interrelate with the physical environment. This paper examines some of the measurement issues to be considered as public health practitioners and researchers attempt to understand the impact of the food environment on the health of communities and takes a broad look at where the science currently is with regard to how the food environment is measured, thoughts on what issues may benefit from more deliberate inspection, and directions for future work.

Introduction

The past decades have seen an increased interest in understanding how the environment affects population health. Public health has moved from considering environment through the lens of early social psychologists such as Lewin[1] and Bandura,[2] who focused on how one's perception of the environment influenced health-related decisions, to a consideration of how one's physical and social environments affect health, either directly or by providing the context in which important health-related decisions are made. Interest in the environment is reflected in the widespread recognition of the need to use an ecologic framework to understand factors influencing population health[3–5] and in the burgeoning field of social epidemiology.[6] In addition, "upstream approaches," such as policy and legal solutions, are increasingly acknowledged as an essential component of efforts to improve the health and well being of populations.[7]

Despite today's widespread focus on the importance of the environment in influencing behavior, the science of measuring and evaluating it is still in its infancy. McKinnon and colleagues[8] describe the results of a literature search examining published papers on measures

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of the food environment. They document an increase in research related to measuring the food environment in the past decades as well as limitations in the field. The complex and multifaceted factors believed to be related to the epidemic of obesity and other chronic diseases related to diet and physical activity have created urgency for measuring and quantifying the environment and have been instrumental in bringing together a diverse field of stakeholders. Public health professionals have reached out to urban planners, policymakers at all levels, economists, and geographers to better understand what forces shape our environments, how the environment may be influencing health or health-related decisions, and the possible leverage points for making environmental changes that positively affect the health of communities. As diverse fields converge, an examination of measurement issues becomes particularly important.

This paper examines some of the measurement issues to be considered in an attempt to understand the impact of the food environment on the health of communities; it is not meant to review the literature, but rather, to take a broad look at where the science currently is with regard to how the food environment is measured, thoughts on what issues may benefit from more deliberate inspection, and directions for future research. Discussion is limited to measurements of neighborhood, school, and worksite environments and does not review issues related to psychosocial assessments of the environment.

Issues in Measuring the Food Environment

The existence of links between foods available in the environment, food choices of the population, and food-related disease risk makes intuitive sense. Public health professionals interested in preventing obesity and diet-related chronic diseases want to be able to measure aspects of the food environment that are thought to influence foods and calories consumed. However, attempting to measure all aspects of the environment that potentially affect the eating habits of people is a daunting task. At a minimum, the following issues arise:

- To what psychometric standards should measurement tools assessing the food environment be held? Should measurement tools be both reliable and valid? Should measurement tools have utility across populations and different types of nutritional issues?
- How is the obesogeneity or diet-related disease risk of environments quantified? How do researchers reduce the copious amounts of data that are often generated when attempting to assess environments?
- What are the best study designs for assessing the importance of environmental factors?
- How is the food environment assessed in the broader context of an ecologic model? What interactions occur between physical and social environments and individual food choice?

The remainder of this paper explores each of these issues.

To What Psychometric Standards Should Tools That Assess the Food Environment Be Held?

The term *psychometrics* is well known to behavioral scientists as an important consideration of measurement. Nunnally begins his seminal text on Psychometric Theory[9] by describing measurement as consisting of "…rules for assigning numbers to objects in such a way as to represent quantities of attributes."[9] In psychometrics, attributes of interest usually focus at the level of the individual, including perceptions, motivations, attitudes, and beliefs. As the field of behavioral science has expanded to consider measures of the physical and social

environment, the terminology from psychometric theory is beginning to be applied to environmental measures. However, the translation process is incomplete and not well articulated. Raudenbush[10] and others[11] have suggested how issues related to reliability, generalizability and construct validity may translate from the field of psychology and psychometrics to measurement issues that arise when assessing the neighborhood environment. However, to date, their examination has been limited to consideration of levels of potential error when the neighborhoods are observed over time (e.g., the presence/absence of graffiti and loitering) or to evaluating ecometrics, an aggregate measure of community members' perceptions of their neighborhood environment.[11] Table 1 suggests how traditional psychometric terms may be translated to apply to measures of the food environment.

Nunnally[9] is explicit about the notion of attempting to measure some attribute of an object or an individual, and not the actual object or individual. This distinction is important in considerations related to measuring the food environment; it is the attribute of the environment as it relates to population health that is important, not the environment per se. For example, early work in the field involved measuring shelf space for products that were deemed to be more, or less, healthful, and investigators often based their measurements on a criteria related to the fat content of the food products. Cheadle[12] assessed shelf space related to four product areas in the store (fresh produce, meat, milk, and bread) and Wechsler[13] assessed shelf space related to low-fat milk. The attribute they were both attempting to assess was the availability of a product in a store that they had defined as healthy, with the underlying hypothesis that there would be some association among availability, purchasing behavior, consumption behavior, and health outcome. They also assumed that one might be able to compare stores, or neighborhoods, or communities, on the dimension of the availability of healthy foods. Figure 1 portrays a simple causal model that implies linking an attribute of an environment with a health outcome of interest.

When environmental variables are included as constructs in causal models examining health outcomes, one may expect those environmental variables to be assessed with the same degree of rigor as psychosocial attributes included in the models. One might even expect that because the environment can be more objectively measured (even directly observed) as compared to psychological constructs (such as perceived outcome expectations), that assessment of the environment should be straightforward and that psychometrically sound environmental measures would be readily available. However, measuring the environment is quite complex and very little work has been published on properties of environmental measures.[14] As with the psychological variables, one would expect these measures of the environment to be reliable, valid, and result in a distribution of values, allowing rank ordering of an environmental attribute along some health-related continuum. For public health work, the measures would, ideally, have utility across different populations and, possibly, across health concerns.

In a compilation of the literature assessing the food environment published in this supplement, McKinnon and colleagues[8] report that only 13.1% of the articles mentioned psychometric properties of measures. The most commonly cited psychometric properties of food environment tools are inter-rater and test–retest reliability and internal consistency. Instruments used to characterize food options in a community generally report good to excellent reliability (kappas around 0.70), particularly when documenting the presence of foods in a store or restaurant. For example, one of the earliest published articles of an environmental measure of a neighborhood was Cheadle's[12] work reporting on the reliability of a tool to assess the amount of point of purchase health education information and the proportion of the display of nutritious items in grocery stores. They surveyed specific product areas within grocery stores and recorded whether items such as low-fat milk or whole wheat bread were available. They reported good levels of inter-rater reliability (between 0.73 and 0.78) for assessing healthfulness indices. Good to excellent inter-rater reliability or test–retest reliability (>0.70)

for the presence or quantification of items in stores has been reported by other studies.[13,15–21] However, reliability for instruments judging more subjective attributes, such as the presence of health education or promotional information or the quality of foods, is usually lower.[12,18] Independent observers may differ on their opinion of how fresh produce looks or what they consider to be a health education or promotional message. Other assessments of reliability have been conducted using repeating interviews over time with organizational stakeholders and have shown mixed results.[22–24]

Researchers exploring worksite and school food environments have published results for the internal consistency of items on scales. Ribisl et al.[25] developed a scale to assess the health climate at a worksite that included the presence of health information, and reported that the coefficient alpha for the 6-item scale was 0.84. The Teens Eating for Energy and Nutrition at School (TEENS) study[26–29] reported the internal consistency of scales to describe the school environment with Cronbach's alphas ranging from 0.68 to 0.83.[27,28]

Published research to date rarely addresses validity of environmental instruments. In the articles reviewed by McKinnon and colleagues in this supplement,[8] content, criterion, and construct validity were rarely mentioned. Construct validity is particularly important if environmental measures are expected to demonstrate relationships with other factors in conceptual models or to help contribute to the variance predicting health outcomes in analytic models.

A variety of tools have been developed to describe environments. For example, the School Health Policy and Practices Survey (SHPPS) has been very useful in describing characteristics of school environments such as the prevalence of vending or school policies related to foods used as fundraisers.[24,30–32] Additional research is needed to substantiate its construct and predictive validity. For example, do schools that rank lower on evidence of health-promoting food and activity policies have students with poorer eating or activity patterns or higher BMIs relative to schools with policies and practices that rank higher?

Similarly, the Nutrition Environment Measurement Survey-Stores (NEMS-S)[18] and Nutrition Environment Measurement Survey-Restaurants (NEMS-R)[19] assess the consumer nutrition environment in neighborhoods. NEMS-S was developed as a tool to assess the availability of healthful options, prices, and quality within grocery stores and NEMS-R was developed to evaluate the healthfulness of options in restaurants. Excellent reliability and face validity are reported for both instruments.[18,19] In NEMS-S, construct validity was evaluated by testing the tool's ability to discriminate between types of stores (grocery stores versus convenience stores) and between the healthfulness of foods in stores. The results showed that grocery stores as compared to convenience stores had greater availability for most healthful items. But, how meaningful is that comparison? To what degree do comparisons of grocery stores with convenience stores help in the understanding or ranking of the food environment of neighborhoods? Does the lack of healthful items in a convenience store help predict or explain the risk of obesity or cardiovascular disease for that neighborhood? Likewise, of the 33 characteristics of restaurants assessed in the NEMS-R validation study,[19] 27% of the items scored significantly higher (or were deemed more healthful) for fast-food restaurants as compared to full-service restaurants, calling into question its construct validity. A predominance of fast-food restaurants in a neighborhood is believed to be an indication of fewer healthful restaurant options while full-service restaurants are generally believed to offer more healthful choices.[33,34]

One study that was able to demonstrate construct validity was the TEENS study.[26] TEENS school-environment measures demonstrated a positive and significant association between the leniency of school food policy with regard to food access in schools and the self-reported BMI

of students. The measures also showed an association between the availability of a la carte lines in a school and student-level fruit, fat, and saturated fat intakes.[27,28] Additionally, after a school intervention to improve the availability of healthful foods on a la carte lines, a significant difference was seen for the proportion of healthier foods offered on the a la carte lines between intervention and control schools (p=0.04).[29] This result suggested that the method for assessing foods available on a la carte lines in schools was both sensitive and specific. Other school-based intervention research using a group randomized trial design also has been able to demonstrate adequate construct validity for changes in the school environment.[35–37] However, utility, sensitivity, and specificity of these methods across populations and health behaviors of interest have not been demonstrated.

In summary, the state of the science regarding the psychometric standards for environmental measures is in its infancy. The vast majority of articles published using food environmental measures do not mention psychometric properties and the diverse disciplines involved in obesity and diet-related chronic disease research have not had a dialogue about how psychometric properties from psychological roots translate into environmental measurement needs. When properties are mentioned they are most often the reliability of measurement tools or selected measures of validity. The inclusion of environmental measures in analytic and conceptual models of health-related outcomes is an important advancement in the public health research and practice. However, in many cases public health researchers have “put the cart before the horse” and attempted to show the impact of the environment on health without proving the rigor of the environmental measurement tools. It is time to take that important step.

How Do We Quantify the Obesogeneity of Environments? How Do We Make Decisions Related To Data Reduction?

There is much discussion of the obesogeniety (sometimes referred to as toxicity) of food environments, with the assumption that environments differ on their level of obesity-facilitating characteristics.[38–40] Although this assumption has largely been accepted as fact, no empirical work has been conducted to validate it.[41] To document the obesogeniety of an environment requires that data be collected on specific attributes of the environment and then those attributes be reduced into quantifiable measures, and ultimately variables that can be examined in causal models. How to create and test those obesogenic indices has not yet been addressed in the published research, and this task is more complex than the current dialogue suggests. To truly test the obesogeneity of one environment over another, myriad factors would need to be considered that would include both the food and the physical activity environment. Such comparisons are further complicated by how individuals differ in their interactions and reactions to obesogenic environments.

Environmental data from schools can be used to demonstrate the complexities of these data. It is reasonable for researchers and public health practitioners to want to be able to assess foods and beverages to which youth are exposed throughout the school day and, as previous work has demonstrated, to manipulate the environment and assess the impact. In some instances, assessment occurs using a survey or interview with a school principal or a food service worker.[24,28,30,32] Often, though, detail on the types, prices, and quantities of competitive foods available in schools is desired and cannot be obtained through information collected with a school staff member. In that case, data may be collected in a number of objective ways, including tracking products and prices through cash register data[37,42]; creating checklists to document whether types of foods are available in vending, school stores, or on the a la carte line[30,43]; or inventorying all foods available.[29]

The complexity of assessing, reducing, and creating measures of environmental attributes of obesogeneity of schools is further illustrated through the Identifying Determinants of Eating

and Activity in youth (IDEA) study, part of the National Cancer Institute's Transdisciplinary Research in Energetics and Cancer initiative (www.compass.fhcrc.org/trec). This etiologic, longitudinal research program is examining factors that may be related to unhealthy weight gain during adolescence (L. Lytle, University of Minnesota, unpublished observation, 2008). Multiple levels of influence are examined for each member of the cohort, including the child's family, home, neighborhood, and school. For the school level, data were collected on policies and practices related to foods available in the school through a principal survey. In addition, study staff directly observed and documented the number of vending machines and the contents of each machine, as well as the foods available a la carte and in school stores.

The studied cohort attends more than 100 schools, and those schools contain more than 800 vending machines offering more than 13,000 products. Another 1640 items are offered on a la carte lines. The amount of time and cost required to collect data, enter package and nutrient data, and clean and analyze the inventory data is substantial. Once the data are ready for analysis, researchers face many decisions with regard to data reduction. What aspect of the competitive food offerings is most important with regard to obesogeneity? Is it type of food, nutrient, portion size, price or, more generally, the overall cueing to eat in the environment? If nutrients are important to consider, what nutrients are most important on which to classify offerings as more or less healthful? Is it calories, fat, sugar, calcium, or some other nutrient? Or, is the issue less about nutrients and more about the food consumed or the level of processing in foods available?[44]

The purpose in collecting and analyzing these data is to create some index for schools that reflect their degree of obesogeneity, but this raises a number of large questions that are relevant for any investigator attempting to quantify the obesogeneity of environments: Are some aspects of the school environment more important in predicting obesity than others? Will a single variable be able to represent the obesogeneity of a school environment or will several variables be required to capture the complexity of environmental influences? Currently, in spite of the volumes that have been written about obesogenic environments, there is no guidance about how to quantify the attribute of "obesogenic."

To date, the field has largely ignored the issue surrounding data reduction of environmental variables. In this nascent field, a more thorough description of the environmental variables considered as potentially important, data reduction steps taken, any testing and creation of latent variables, and the final environmental data included and excluded would be very useful to other researchers. Lack of transparency with regard to decisions made may misrepresent the challenges in collecting and analyzing environmental data. Articles that simply report that they "…recorded and analyzed the foods available in vending" may lead the inexperienced researcher to believe that this is a simple task and may mask the many decisions that were made in the process of data collection and analysis. By describing the protocol for data collection and the process of data reduction in manuscripts or through methods papers, other scientists can better evaluate potential sources of bias and also learn from others' experiences and approaches.

Finally, a great deal of work is needed to develop and test indices that measure environmental factors that are believed to be obesogenic or carry some other diet-related disease risk. What elements of an environment are most responsible for disease risk and how is that environmental risk accurately and parsimoniously represented in our analytic models? Beyond obesity, environmental measures may need to be developed to assess other specific diet-related risk, such as the availability of fruits, vegetables, and whole grains in the environment and cancer risk or the availability of calcium- and vitamin D–rich foods and the risk of osteoporosis.

What Study Designs are Best at Assessing the Importance of Environmental Factors?

High-quality measures are of limited value in poorly designed studies and, particularly with regard to the study of the food environments in neighborhoods, current study designs are severely limited. To date, the vast majority of research in this area reports on cross-sectional associations among environmental factors, demographic characteristics of the population and, infrequently, health-related outcomes. Most neighborhood research implies causation and does not adequately address important issues of confounding.

The use of longitudinal studies alone will not solve these study design problems because environments, neighborhood characteristics, and the health of the population within those neighborhoods change over time, and not independently. Although group randomized trials that manipulate the environment have occurred in school and worksite settings, helping to demonstrate causality, such examinations are rare in neighborhood food environments and are much more difficult to implement. Only two studies[45,46] have been published that examine how low-income consumers' purchasing patterns change when a full-service grocery store is built in their neighborhood. One study conducted in Leeds, England[45] reported a positive, albeit small, impact of fruit and vegetable consumption when a large supermarket was introduced into the community, but the study design only assessed pre- and post-consumption patterns in one community. Another study that included a control group examining consumer consumption patterns after a large supermarket was introduced to a low-income area[46] found no significant changes in fruit and vegetable consumption or consumption patterns between groups.

Neighborhood-level research is further compromised by confounding. Individuals are not randomly assigned to neighborhoods. Rather they locate in neighborhoods based on their incomes, lifestyles, preferences, proximity to work, and a variety of other factors. Blume and Durlauf[47] discuss this issue as a problem of selection. Individuals select neighborhoods based on their own characteristics as well as those of the neighborhood and, eventually, both "parties" affect each other. In addition, examining the relationships between contextual (e.g., the characteristics of a neighborhood) and endogenous (e.g., factors within the individual, such as food choice) is prone to error from reflection. In other words, the assumption of linear dependence is likely violated because it is nearly impossible to separate out contextual factors from endogenous factors.

To examine the influence of the food environment on health outcomes of interest, the field must move beyond cross-sectional study designs. Although examining correlations and associations is helpful in the early stages of examining relationships and generating hypotheses, they do not serve us well in the stage of hypothesis testing.

How Do We Assess the Food Environment in the Broader Context of an Ecologic Model?

An important contribution of ecologic models is their inclusion of aspects of the physical and social environment that serve as the contexts wherein people make eating- and activity-related decisions. Neighborhoods are recognized in most of these ecologic models as an important community-level context for behaviors. A number of studies have examined the relationship between the availability of food stores and neighborhood characteristics in specific locations.[17,48–50] Notably, using nationally representative data, Powell et al.[51] published the most comprehensive examination of the relationship between neighborhood characteristics and the community nutrition environment. Specifically, this research compared the existence of chain supermarkets, nonchain supermarkets, grocery stores, and convenience stores among high, medium, and low-income neighborhoods, by race and ethnicity of neighborhoods and by urban,

rural, and suburban characteristics. The authors gathered these data by linking commercial food store outlet data by ZIP code to national census bureau population and SES data. The research showed that low-income neighborhoods have fewer chain supermarkets and convenience stores and more nonchain and grocery stores as compared to middle-income neighborhoods. In addition, large disparities by race and ethnicity were seen for the availability of chain supermarkets, and rural areas were shown to have fewer food stores of all types. Others have examined the types of restaurants that are in neighborhoods, and some evidence suggests that lower-income and more racially diverse neighborhoods have more fast-food restaurants as compared to higher-income neighborhoods.[33,34,52,53]

The majority of research on the neighborhood food environment is limited to making associations between stores or restaurants within some geographic or political boundary (such as ZIP codes, census tracts, or postal codes) and the characteristics of the population within that boundary. Most often, the characteristics are demographic in nature with a primary interest in SES or race/ethnicity distributions. The difficulty in defining the geographic space that defines a neighborhood is well recognized and several analytical techniques have been proposed to deal with some of the limitations including spatial analytic methods.[51,52,54]

Neighborhood may seem to be an appropriate context to identify in an ecologic model, but operationalizing the term is much more difficult. Ball et al.[55] outline several important issues that pose challenges to defining neighborhoods, including: (1) people live and function in multiple settings and contexts; (2) people live and work in multiple geographic areas and influential environments are often nested; and (3) single neighborhoods contain multiple types of environments, including physical, social, cultural, and policy environments. Therefore, making associations using one definition of neighborhood (i.e., based on census tract or postal code); the availability of healthful and affordable options in that same census tract or postal code (i.e., inexpensive and quality fresh produce in stores); and some health-related behavior of individuals in the neighborhood (i.e., eating fruits and vegetables) relies on many assumptions about where people shop, how far they are willing to travel, and a host of other individual-level preference, knowledge, and motivational factors.

Although the macro-level associations among food availability, neighborhood characteristics, and racial and ethnic disparities seem apparent (at least in the U.S.; the picture is not so clear outside of the U.S.[56]) an important consideration in assessing the food environment in the context of an ecologic model is how the individual chooses to behave in the environment. What is known about where people shop? Do they shop within their home ZIP codes or within the ZIP code of their place of employment or where their children go to school? How far are they willing to travel to get the food that they want? How many and at what kinds of stores do they usually shop? What factors influence where they shop? Only limited qualitative work has examined these questions and major knowledge gaps remain.[57]

A study by Giskes and colleagues[20] provides some insight into the importance of understanding how individuals intersect with their environment. As part of the Brisbane Food Study, these investigators examined the relative contribution of perceived and objective price and availability of recommended, or healthful versions of foods in stores (such as whole grain bread as compared to refined wheat bread) to food purchasing by household income. The important contribution of this research is that it included both individual and environmental-level data-collection methods, asking people in 50 different census tracts where they usually shop, what they usually buy, and their perceptions of availability and pricing of recommended foods. Objective in-store audits in those 50 census tracts were conducted to assess actual availability and pricing of specific food groups.

Their results showed that 14.4% of respondents shopped outside their census tract areas and documented that lower-income people were less likely to buy the recommended or more nutritious versions of the items despite the fact that almost all the stores in the census tracts offered the recommended choices. In addition, for the most part, participants believed that the recommended items were available in the store in which they shopped. An important finding of the Giskes article[20] was that people's perceptions of availability and price were associated with their reported food purchases, while the availability and prices documented through the store audits were not related to their purchasing patterns. In the words of the authors, this finding "…raises the issue of whether the singular focus on the objective environment is really improving our understanding about the relationship between the environment and health-related behaviors."[20]

The intersection between the individual and the environment is critically important and not being studied to the extent needed.[39,55,57] Cummins[57] suggests that the deprivation-amplification model (the belief that poorer and minority neighborhoods tend to have fewer health-promoting resources compared to their wealthier and whiter counterparts) that leads most of the neighborhood environmental research may be insufficient and inaccurate. He writes:

> Current theories which form the basis of increasingly sophisticated empirical investigations of environmental influences on diet often do not take into account the social processes and symbolic relationships between individual and their environments. Without a deeper and more complex understanding of how "environment" gets into the "body," interventions based exclusively upon existing theoretical models will never be able to fulfill their public health potential.[57]

Very little work has been done on the social environment and how it influences food and eating decisions.

Discussion and Recommendations

Attempting to understand and positively influence what people choose to eat is amazingly complex. Eating is required for life and is an important part of all cultures. People make decisions about whether, what, and how much to eat throughout every day. It is one of the most personal, and potentially private, health behaviors in which humans engage. Being able to assess with any precision how the surrounding environment affects food and dietary-related decisions will be a very complicated, and likely, impossible task. A reductionist approach to understanding food choices will likely be of limited value. Still, as the field moves forward, we might consider the following recommendations:

> 1. Pay more attention to the psychometric properties of food environment measurement tools, including validity, and address more directly the utility of instruments across populations and diet-related issues

If environmental measurement tools are expected to be useful in describing attributes of environments related to population health, ranking environments along some continuum of obesogeneity or disease risk, and predicting some health behavior or outcome of populations, then measurement tools must have adequate psychometric properties. Beyond reliability, tools should demonstrate construct validity, adequate variability, sensitivity, and specificity to be able to detect change. In addition, the field needs to consider and debate the expected utility for food environment measurement tools. Should we expect that one tool can be used across a wide range of communities, neighborhoods, and cultures to characterize some aspect of the food environment (such as availability of fruits and vegetables)? Can a single tool be created that validly and reliably assesses "a healthy diet" or do tools need to be tailored to assess foods specific to disease states? Perhaps rather than developing a compendium of food-environment

tools that can be recommended broadly, we should be developing and promoting a process for how communities or researchers might evaluate aspects of their local food environment.

2. Be more transparent about data-reduction decisions and begin to describe the development of testable obesogenic indices

At the very least, research should describe the process and rationale for data-reduction methods. In the absence of that information, sources of bias are not apparent and advancements in the field are delayed as investigators may underestimate the complexities of environmental data. Several potential approaches might be useful in purposively guiding the types and quantities of data that are collected and in making decisions about data reduction. Defined and testable conceptual and causal models with clearly defined endpoints related to health behavior or health outcome may help provide clearer focus for the environmental aspects that are important to assess[55,57]. In addition, research that compares different ways to assess the same environmental attributes is needed. For example, is an inexpensive checklist instrument that identifies foods available (*yes/no*) in schools as useful for ranking schools on some measure of obesogeniety as a more expensive inventory approach where all foods available are catalogued, categorized, and used to rank schools (M. Hearst, University of Minnesota, unpublished observation, 2008)? As investigators devise ways to measure the environment and reduce the data so that it can be examined in causal models, methods papers that describe how obesogenic indices were created and demonstrate the construct validity of those indices would be helpful.

3. Improve the rigor of the study designs and the analytic techniques used to assess the importance of the food environment on health outcomes

A recent review of papers examining the associations between environmental factors and energy and fat intakes among adults characterizes the state of the science.[41] Of 21 papers meeting inclusion criteria, fewer that half (*n*=9) assessed an environmental factor objectively, all were cross-sectional study designs, and only one[58] used multilevel analysis.

Although developing measures that are useful in describing environments may be an important first step, as public health researchers we cannot deny that we are interested in causal inferences and in developing and testing hypotheses. To that end, psychometrically sound measures used with rigorous study designs that allow the examination of all the elements of causality and minimize threats to internal validity are needed. Oakes and Kaufman remind the field that "… causal inference requires a strong theoretical foundation to justify assumptions of causal order, of no bias due to omitted covariates, and of effect homogeneity"[6] and suggest that lack of theoretical justification is particularly common in social epidemiology. The impact of measurement error on establishing causality between the environment and dietary intakes is largely unexplored.[59]

The cost and complexity of RCTs, especially where entire communities or neighborhoods are the unit of randomization, call for alternative, creative approaches. More attention should be paid to examining the behavioral and health effects of natural experiments. For example, a chain restaurant moving into a disadvantaged neighborhood or the influence of the U.S. Department of Agriculture wellness-policy mandates on the types of foods offered in schools and what students eat in schools could be the impetus for a useful analysis.[60] Funders and researchers will need to develop more expeditious systems for proposal generation and review to take advantage of naturally occurring experiments and be open to less tightly controlled experimental conditions. In addition, pilot or effectiveness studies where the environment is manipulated and individual reaction to that environmental change is assessed would be helpful.

There is also a need to advance the analytical tools for testing ecologic models. Few studies to date have assessed environmental change as mediators or moderators in a hypothesized causal

model that links the environment to individual behavior change or a health-related outcome. The use of analytic techniques from psychology and social psychology may have great utility in helping us to create classes of latent variables that represent the environmental attribute being assessed, and the use of latent class analysis may lead to a better understanding of patterns of environmental exposures.[61,62] These latent variables are a data-reduction approach and also help create variables that can represent the environment in more complex analytic models. Multilevel modeling that reflects an ecologic approach is needed. Finally, supporting secondary data analyses, especially in instances where an environment was manipulated and environmental- and individual-level factors assessed, may be useful.

4. Put the individual back into the equation

It would be useful to conduct additional studies like the Giskes study,[20] in which the intersection among people's purchasing behaviors, perceptions of the availability and prices of foods, social or normative perceptions, and measures of the actual physical environment are considered. A better understanding of what influences the choices people make within their food environments is greatly needed.

Examining the influence of the environment on individuals' food choices may benefit from a realization that, across populations or communities, the physical environment, the social environment, and personal choice may have differential influences on the foods that people choose to eat. I hypothesize that the more restricted an environment is with regard to availability and accessibility of healthy, inexpensive options, the more influence the physical environment may have with regard to food choices that are made. As availability and accessibility increase, the influence of the physical environment may decline and the influence of personal choice and social influence may increase. Figure 2 shows a schematic of these posited relationships.

As an example, access and availability of low-cost healthful food options may be severely limited in areas of extreme poverty, very rural or isolated communities, or areas experiencing natural disasters. Similarly, restriction may occur in areas limited by public transportation, higher expense of nutritious foods, or where fast-food restaurants or convenience stores dominate.[63] Access to healthful options may be restricted by where one spends the day and one's ability to choose foods freely during the day. For example, schools and worksites may represent restricted environments if school or work campuses are closed, if there is insufficient time to leave for lunch, or if resources for storing or preparing foods are inadequate.

At the other end of the spectrum are the least-restrictive environments, in which healthful foods are abundant at prices that the population is willing and able to afford. Although most suburban and urban areas in the U.S. have an abundance of convenience stores and fast-food restaurants, they also have excellent access to supermarkets and restaurants that serve a range of healthful foods. In less-restrictive environments, personal choice and social influence are likely to be influential in determining what a person chooses to eat.

Figure 2 may be useful as a conceptual model proposing how individual factors and the social and physical environments interact and may provide some guidance with regard to the utility and economy of spending resources assessing each of these three factors. Assessing social and individual factors may be a lower priority for explaining what people eat when they are in very restricted environments, and resources should focus on examining the physical environment. On the other hand, when trying to understand the food choices of individuals in nonrestricted environments, it may be a poor use of resources to accurately or comprehensively assess what is available in the physical environment.

Conclusion

As measures of the food environment continue to be developed, the field should focus on purpose and continually check the direction of the research by asking: How will this environmental information be used to improve the health of populations? The measures must be rigorous and shown to be related to health outcomes of interest, have an eye toward parsimony in data collection and be transparent with regard to data reduction. The study designs must be rigorous and move from cross-sectional descriptive work to testing hypotheses while minimizing threats to internal validity.

The goal should be an increased understanding of how environment influences the food choices that individuals make while acknowledging that a wide variety of factors, both proximal and distal to the individual, influence those choices. As a field, we need to maximize our capacity to see the importance of both the distal and proximal factors that influence what, when, and how much people eat and to foster an approach that allows us to telescope between distal and proximal causes facilely and confidently, back and forth from the individual to environmental elements, depending on the question, population, and setting.

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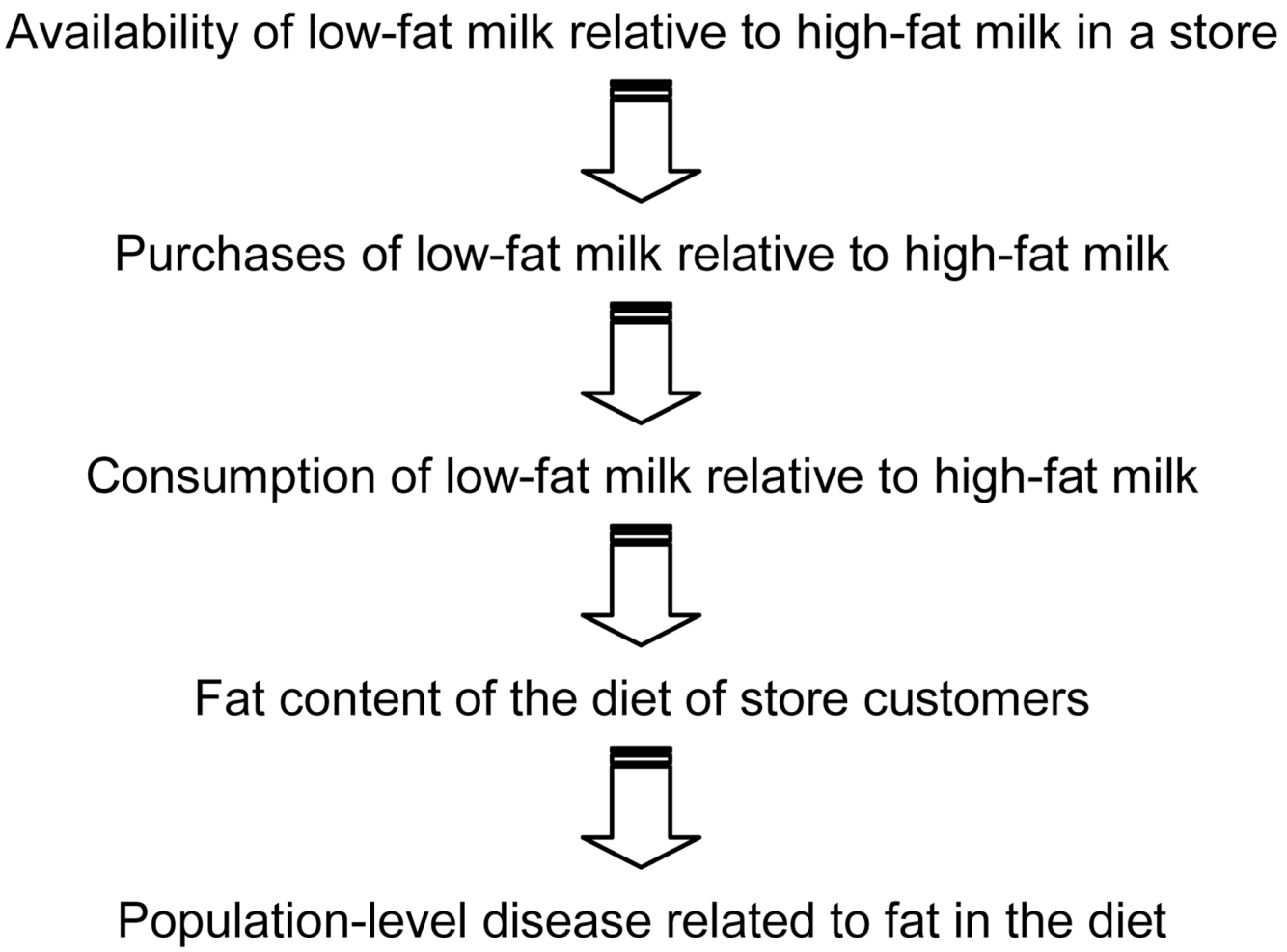

Figure 1.
Example of causal model linking an environmental attribute with population-level disease

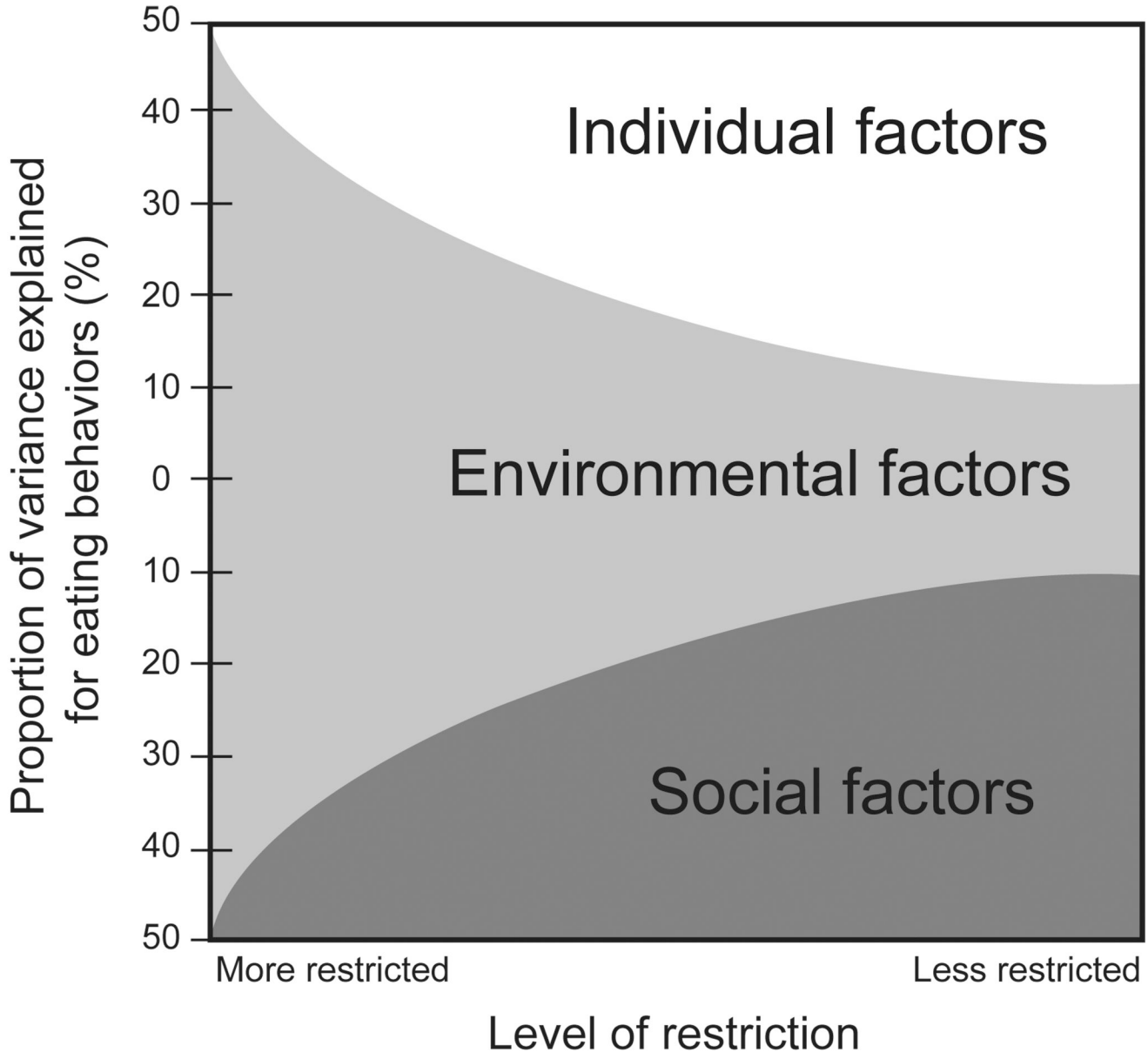

Figure 2.
The relationship among individual, environmental, and social factors

Table 1

Psychometric terms applied to environmental measures and examples from the food environment

1. Reliability
Inter-rater reliability: The extent to which measurements are repeatable between two or more evaluators
If two data collectors use the same protocol to measure shelf space devoted to lower fat milk, what is the level of agreement between their data?
Test–retest reliability: The extent to which measurements are repeatable over time
If shelf space devoted to low fat milk is assessed in January, how similar are the results of the same store and shelf in February?
Item reliability: The extent to which items within a scale are correlated
What is the internal consistency of a set of questions designed to evaluate school-level policy related to accessibility of healthy foods in a school?
2. Validity
Face validity: The extent to which the instrument appears to be measuring what it is supposed to measure
Does amount of shelf space in inches represent availability? Is the ratio of shelf space devoted to lower and higher fat milk products a more accurate representation of availability?
Content validity: The extent to which an instrument samples items from the full breadth of content desired
Is the availability of skim/lower fat/full fat milk a strong predictor of total fat in the diet? Is fat in other dairy products such as cheese, yogurt and ice cream required to explain fat content of the diet?
Criterion validity: The extent to which the measure agrees with an external standard measure or a more accurate (and usually more expensive) instrument (the criterion)
Is there a more accurate assessment of availability of skim/lower fat/ full milk in a store that can be used as a criterion?
Construct validity: The extent to which the measure “behaves” in a way consistent with theoretical hypotheses.
Is shelf space or the ratio of availability lower fat to higher fat milk products related to either the consumption of fat by customers or to fat-related disease in consumers?
3. Other related measurement qualities
Variance: The extent to which the measure results in a distribution of values
When the measurement tool is used across multiple stores, is there a distribution of values related to shelf space or ratio of lower/higher fat milk? Can an ordinal or categorical value be assigned to grocery stores that show their differences on the availability of shelf space or ratio of lower/higher fat milk?
Utility across populations: The extent to which the tool is useful in a wide range of communities, settings, and population groups.
Will this tool be reliable, valid, and show meaningful variance with regard to the availability of lower fat milk products in all regions of the country or across different cultures? Will it be useful in large grocery stores as well as convenience stores? Is milk an important source of fat in all populations and cultures?
Utility across health concerns: The extent to which the tool is useful in providing an assessment of a dietary concern for a variety of diet and disease connections.
Will this tool be reliable, valid and show meaningful variance for all diseases related to fat content? To what extent will it be useful for assessing food intake related to other diet-related diseases, such as calcium intake, fiber intake or fruit and vegetable intake?