Neighborhoods and health disparities: old evidence and new directions

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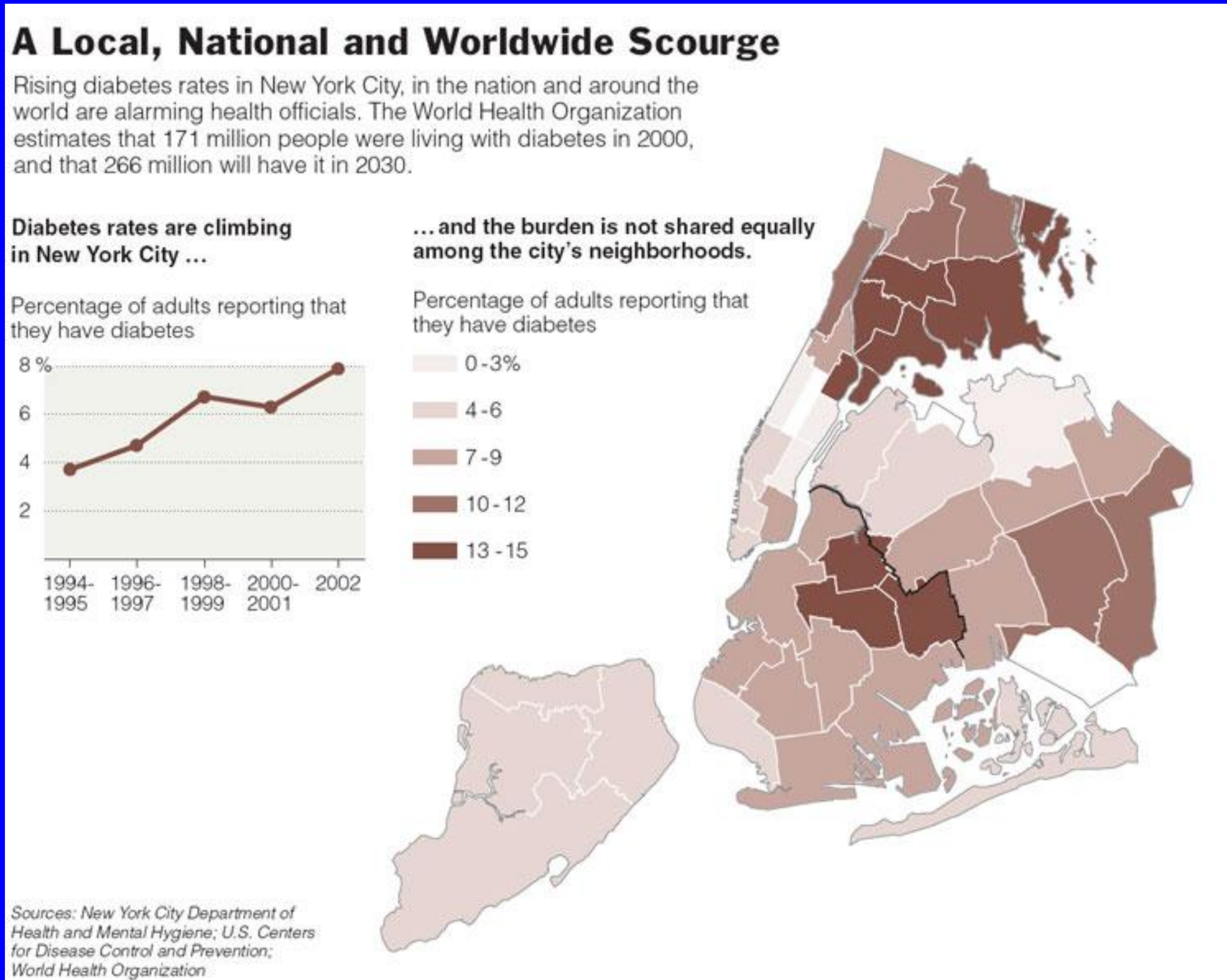
Overview

- Rationale
- Evidence
- Challenges
- Future directions
- Evidence for health disparities

Space (and places) as a key dimension across which health is patterned


A Local, National and Worldwide Scourge
Rising diabetes rates in New York City, in the nation and around the world are alarming health officials. The World Health Organization estimates that 171 million people were living with diabetes in 2000, and that 266 million will have it in 2030.
Diabetes rates are climbing in New York City ...
Percentage of adults reporting that they have diabetes
8 %
6
4
2
1994-1995
1996-1997
1998-1999
2000-2001
2002
... and the burden is not shared equally among the city's neighborhoods.
Percentage of adults reporting that they have diabetes
0-3%
4-6
7-9
10-12
13-15
Sources: New York City Department of Health and Mental Hygiene; U.S. Centers for Disease Control and Prevention; World Health Organization

NYT
Jan 2006

- Residential segregation by socioeconomic/ethnic characteristics predictive of health

- Place-based features as contributors and perpetuators of social differences in health

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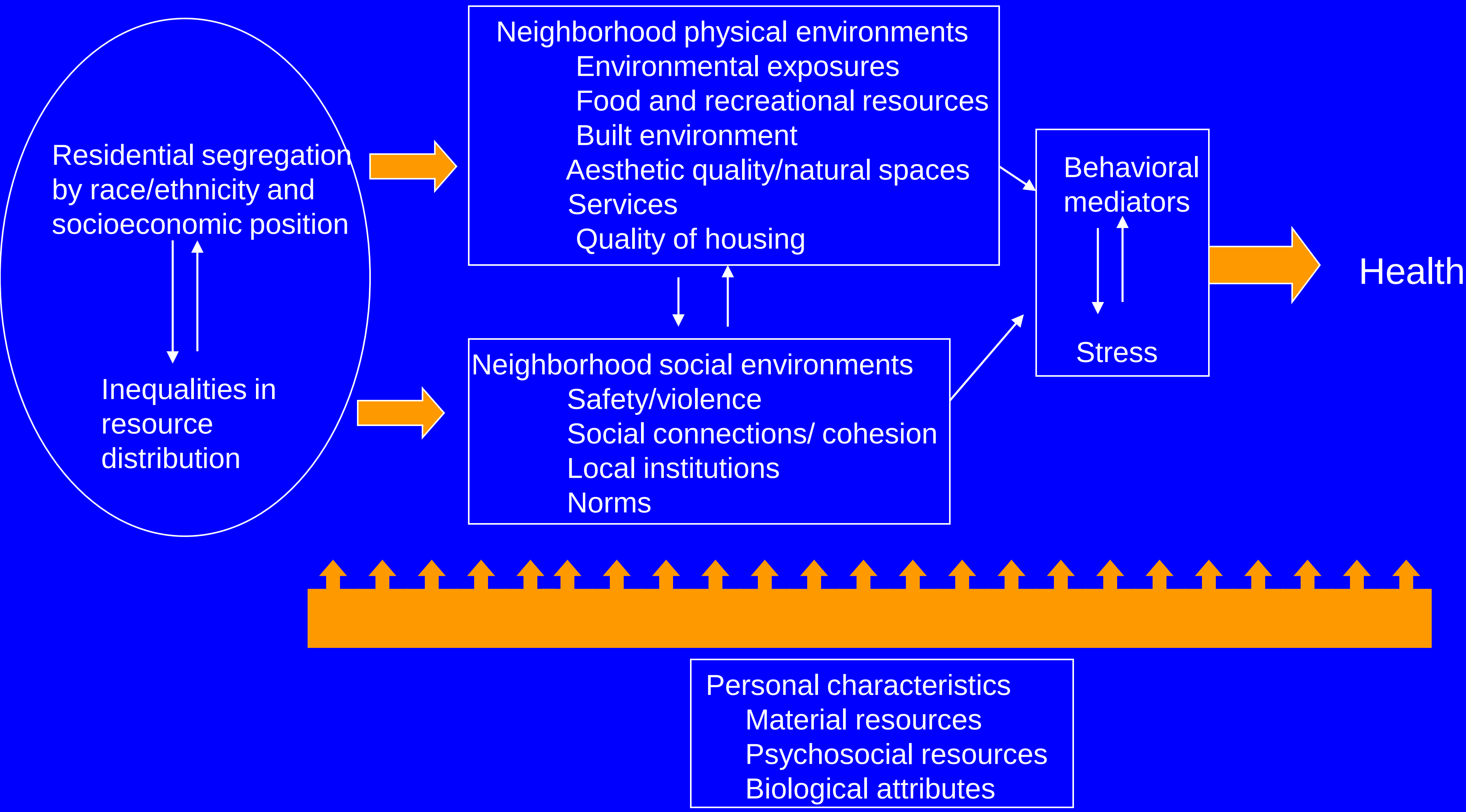
Why focus on places/neighborhoods?

- Mutually reinforcing nature of place –based and individual inequalities
- Neighborhood differences not “naturally” determined, result from specific policies, amenable to intervention
- Causation and facilitation…
- Health impact of non health policies
- Changes in neighborhood environments likely to have multiple health and non health benefits

Odds ratios of hypertension, obesity, and diabetes for Blacks vs Whites in integrated communities and national data

Adjusted for gender, marital status, household income, insurance status, self-ratings of health, weight status, physical inactivity, diabetes, drinking, current, smoking status.

LaVeist et al Health Affairs 2011


Residential segregation by race/ethnicity and socioeconomic position
Inequalities in resource distribution
Neighborhood physical environments
Environmental exposures
Food and recreational resources
Built environment
Aesthetic quality/natural spaces
Services
Quality of housing
Neighborhood social environments
Safety/violence
Social connections/ cohesion
Local institutions
Norms
Behavioral mediators
Stress
Health
Personal characteristics
Material resources
Psychosocial resources
Biological attributes

Some features of work on residential environments and health

- More than typical “environmental” features ….
- Physical AND social environments
- Multiplicity of ways in which environments can affect health related processes (behaviors, stress)
- Interaction with individual characteristics (moderation and reinforcing loops)

Observational evidence on neighborhoods and health

- Generation 1: Secondary data analysis of health datasets linked to aggregate census measures for administrative areas

- Generation 2: Collection of health data linked to specific features of residential environments using GIS and existing locational data, surveys, and systematic social observation

Early studies of neighborhoods and health

- Secondary data analysis of geographically-linked epidemiologic studies using multilevel analysis

- Census areas as proxies for "neighborhoods"

- Aggregate census socioeconomic characteristics (deprivation) as crude proxies for features of neighborhood social and physical environments hypothesized to be relevant to health

Hazard ratios of incident coronary heart disease by tertiles of neighborhood score before and after adjustment: the ARIC Study 1987-97

	Race-specific tertiles of neighborhood score	Adjusted for age & center	Adjusted for age, center, income, education & occupation
Whites	I (Low)	2.1 (1.6-2.8)	1.7 (1.3-2.3)
	II	1.7 (1.3-2.3)	1.5 (1.2-2.1)
	III (High)	1.0	1.0
	P trend	<0.001	<0.001
African-Americans	I (Low)	1.7 (1.2-2.3)	1.4 (0.9-2.0)
	II	1.4 (1.0-2.1)	1.3 (0.9-1.9)
	III (High)	1.0	1.0
	P trend	0.003	0.1

Diez Roux et al. NEJM 2001

HRs of Cardiac Mortality Associated With Neighborhood SES Categories

Adjustment	Neighborhood SES, HR (95% CI)			
	Lower Tertile (n=362)	Middle Tertile (n=446)	Higher Tertile (n=371)	P for Trend
Cardiac mortality				
Deaths, n	106	85	42	
Unadjusted	2.98 (2.09–4.26)	1.78 (1.23–2.58)	1 (Reference)	<0.001
Age, sex, and origin	2.91 (2.02–4.21)	1.81 (1.25–2.63)	1 (Reference)	<0.001
Model 1	2.09 (1.42–3.05)	1.56 (1.07–2.28)	1 (Reference)	<0.001
Model 2	1.63 (1.09–2.45)	1.41 (0.96–2.07)	1 (Reference)	0.02

Model 1: adjusted for age, sex, origin, CVD risk factors (hypertension, diabetes mellitus, dyslipidemia, smoking, and physical activity), and disease severity indexes (admission to ICU, anterior MI, comorbidity index, Killip class, coronary artery bypass graft within 45 days, percutaneous coronary angioplasty within 45 days, and self-rated health). Model 2: model 1 plus individual-level socioeconomic measures (education, income, pre-MI employment, and living with a steady partner).

Gerber et al Circulation 2010

Limitations

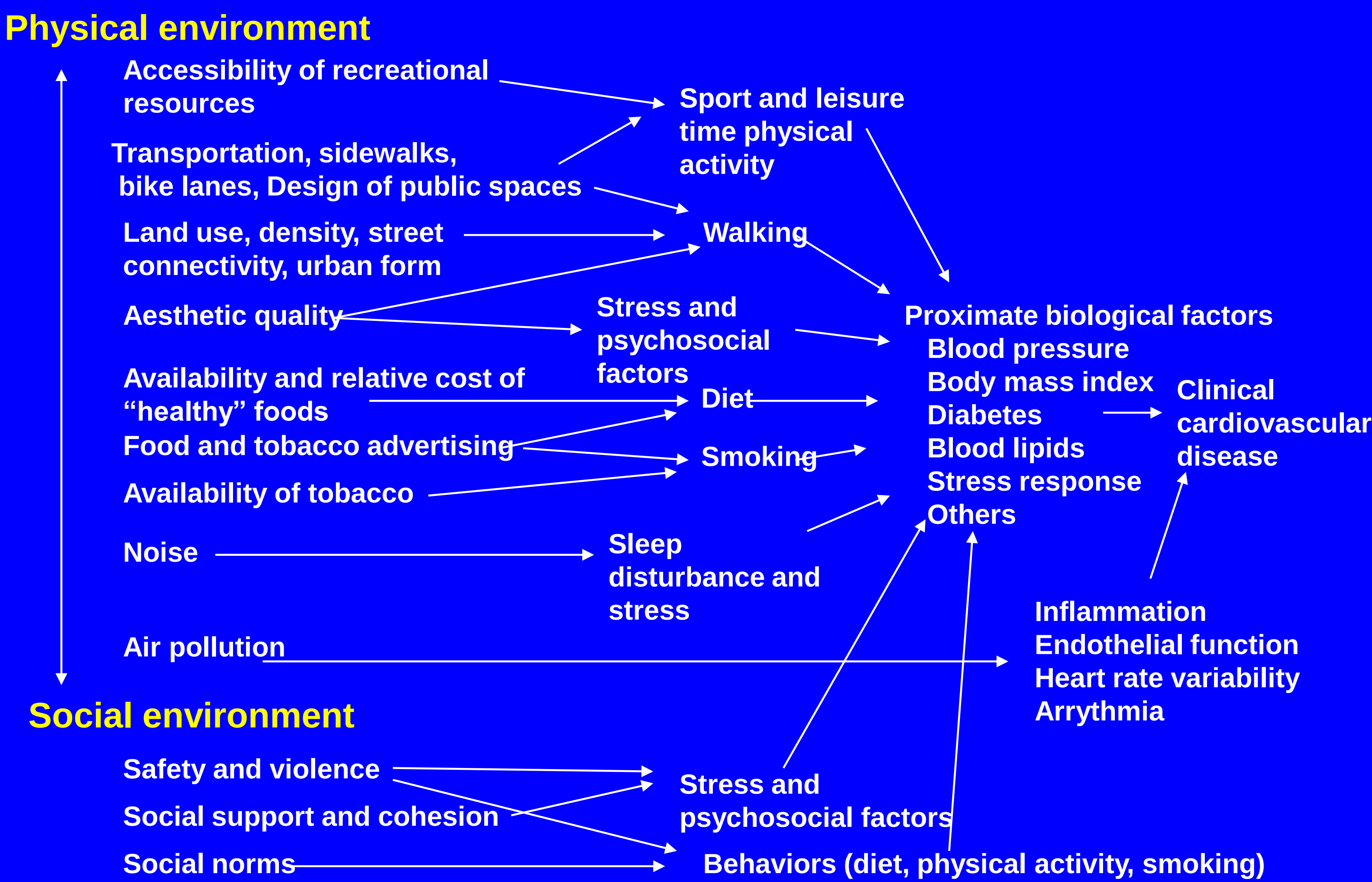
- Separating "context and composition"
  - Residual confounding by individual-level variables/omitted individual-level confounders
  - Extrapolations/off-support inferences
- Aggregate area SES as (very) crude proxy for true relevant constructs
  - Misestimate of causal effect of interest
  - No identification of specific components, processes
- Do associations of area SES with health reflect causal effects of neighborhood "environments" on health?

Advancing knowledge on neighborhood health effects

- What is it about areas that matters?
- How does it matter?
- At what spatial scale do these processes operate?
- With what time scales do these processes operate?
- Can we change these characteristics and show an effect?

More recent studies

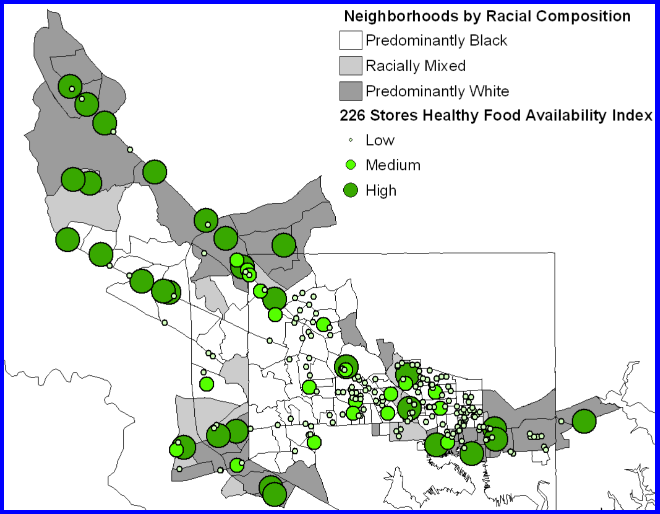
- Direct measurement of health relevant neighborhood attributes
  - Surveys
  - GIS and locational data
  - Systematic social observation
- Cross sectional patterning by area features (usually race and socioeconomic composition)
- Cross-sectional and longitudinal associations with more proximal health related factors (e.g. behaviors, stress biomarkers)



Diez Roux J Urb Health 2003

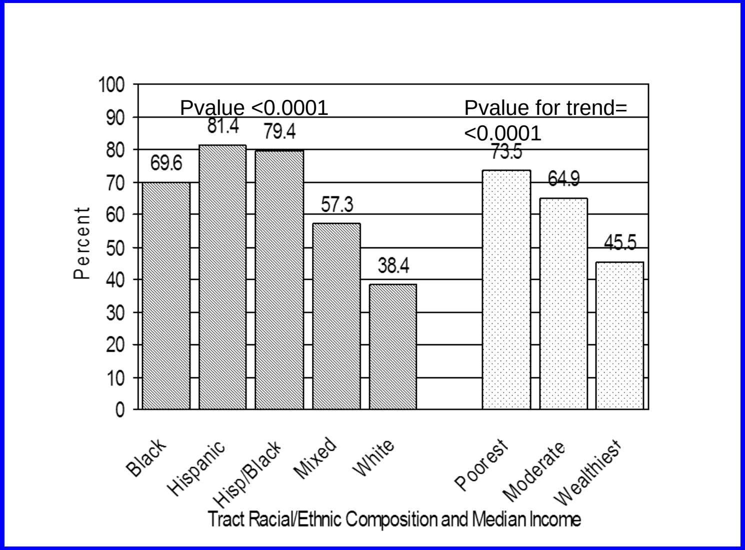
Area features are strongly associated with area SES and race

Food stores and healthy food availability indices in Baltimore



Franco, Diez Roux et al AJPM 20009

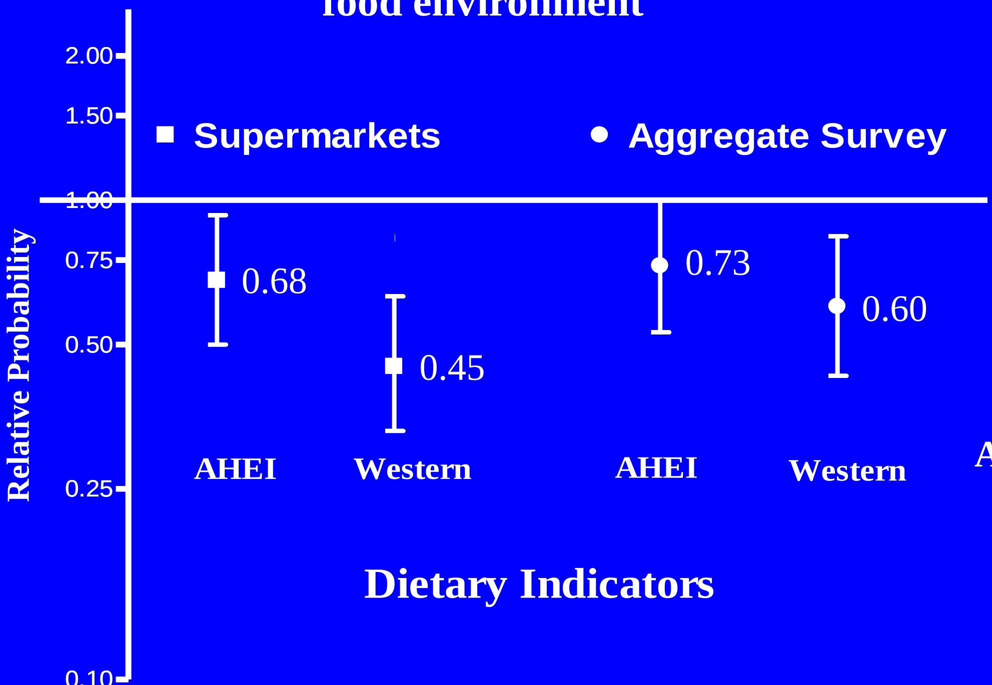
Percent of tracts without a recreational facility by racial/ethnic composition and median income adjusted for tract area*



Moore, Diez Roux et al 2008

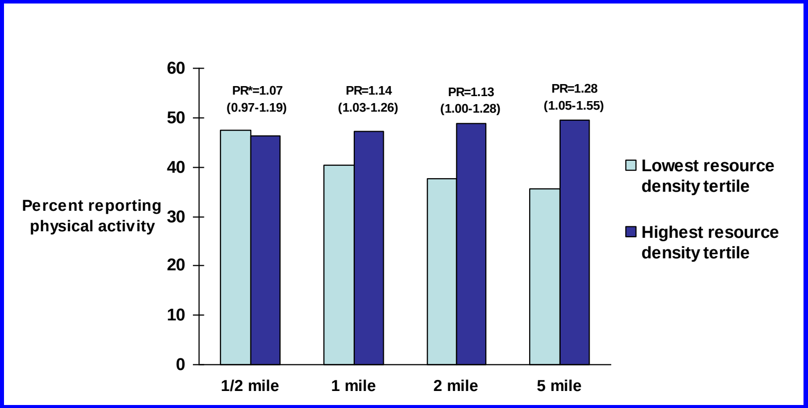
Area features are cross-sectionally associated with behaviors

Adjusted relative probability (95% CL) of having a good diet for "worst" vs. "best" food environment



Moore et al. AJE 2008

Percent of participants reporting physical activity and prevalence ratios (PR) of activity by resource densities for windows of varying size*



Diez Roux et al 2006

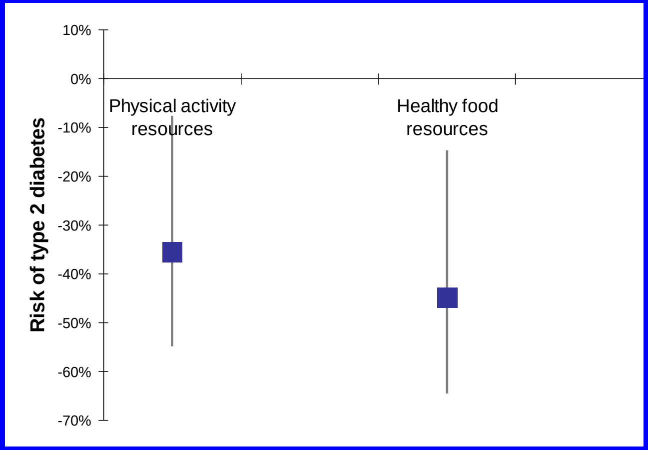
Associations of land use measures with walking >90 min/w

	Walking to places OR [95% CI]
Density (hundreds of persons/hectare)	1.41 [1.21,1.65]
Entropy (0-1)	2.24 [1.43,3.51]

Rodriguez et al 2009

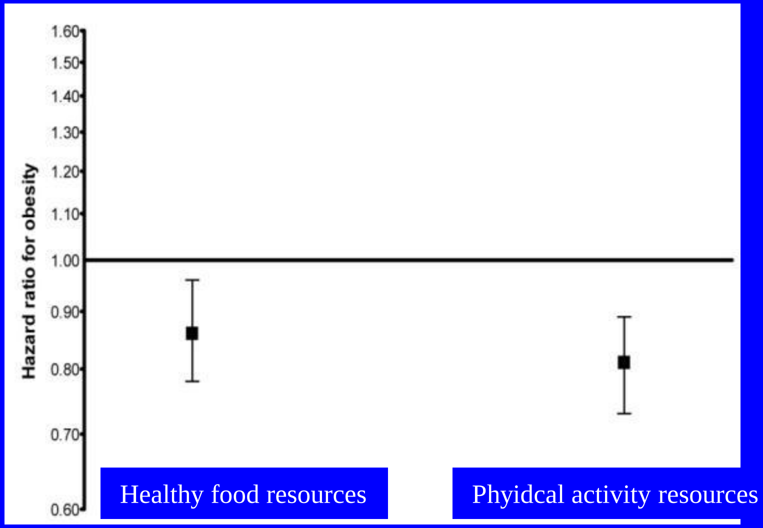
Area features are (sometimes) predictive of incident disease

Incident diabetes



Auchincloss et al Arch Int Med 201(

Incident obesity



Auchincloss et al Obesity in press

Changes in CES-D

Change in environment	Change in CES-D
Aesthetic Environment	-3.61 (-6.08, -1.14)**
Social Cohesion	-2.89 (-6.05, 0.27)*
Safety	-1.81 (-3.77, 0.15)*

Mair et al unpublished

Associations of within-person increases in supermarket density around the home with within-person changes in diet, the CARDIA Study

Men

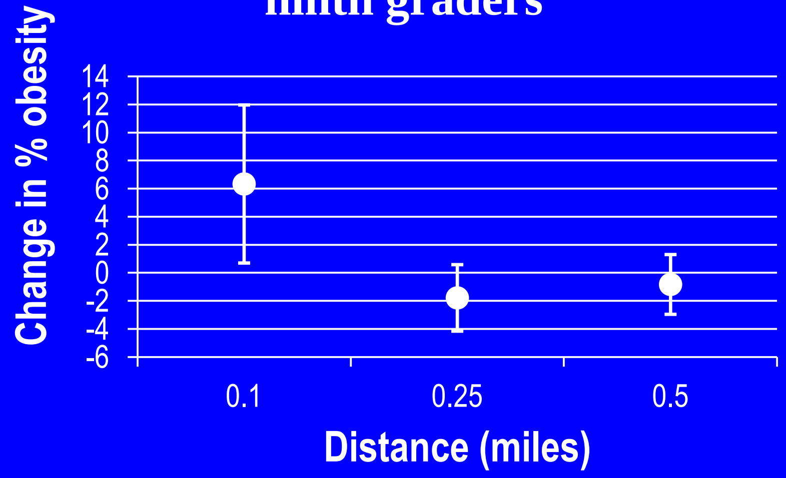
Distance from home (km)	Change in diet quality [mean: 46.5]	Relative odds of meeting fruit & vegetable recommendations [overall : 5.6%]
<1	**-0.1** (-0.6, 0.5)	**1.1** (0.8, 1.5)
1-2.9	**-0.4**(-1.2, 0.4)	**2.1** (1.2, 3.8)*
3-4.9	**-0.0** (-1.0, 1.0)	**1.0** (0.5, 2.0)
5-8.05	**0.6** (-0.5, 1.7)	**0.6** (0.3, 1.2)

Women

Distance from home (km)	Change in diet quality [mean: 53.0]	Relative odds of meeting fruit & vegetable recommendations [overall: 8.7%]
<1	**-0.2** (-0.7, 0.3)	**0.9** (0.8, 1.1)
1-2.9	**-0.3** (-1.1, 0.5)	**0.8** (0.6, 1.1)
3-4.9	**-0.4** (-1.3, 0.5)	**0.9** (0.6, 1.3)
5-8.05	**0.6** (-0.4, 1.6)	**1.5** (1.0, 2.2)

Boone-Heinonen et al 2011

Change in fast food availability and change in obesity among ninth graders



*Currie, J., et al. The effect of fast food restaurants on obesity and weight gain. American Economic Journal: Economic Policy 2: 32-63

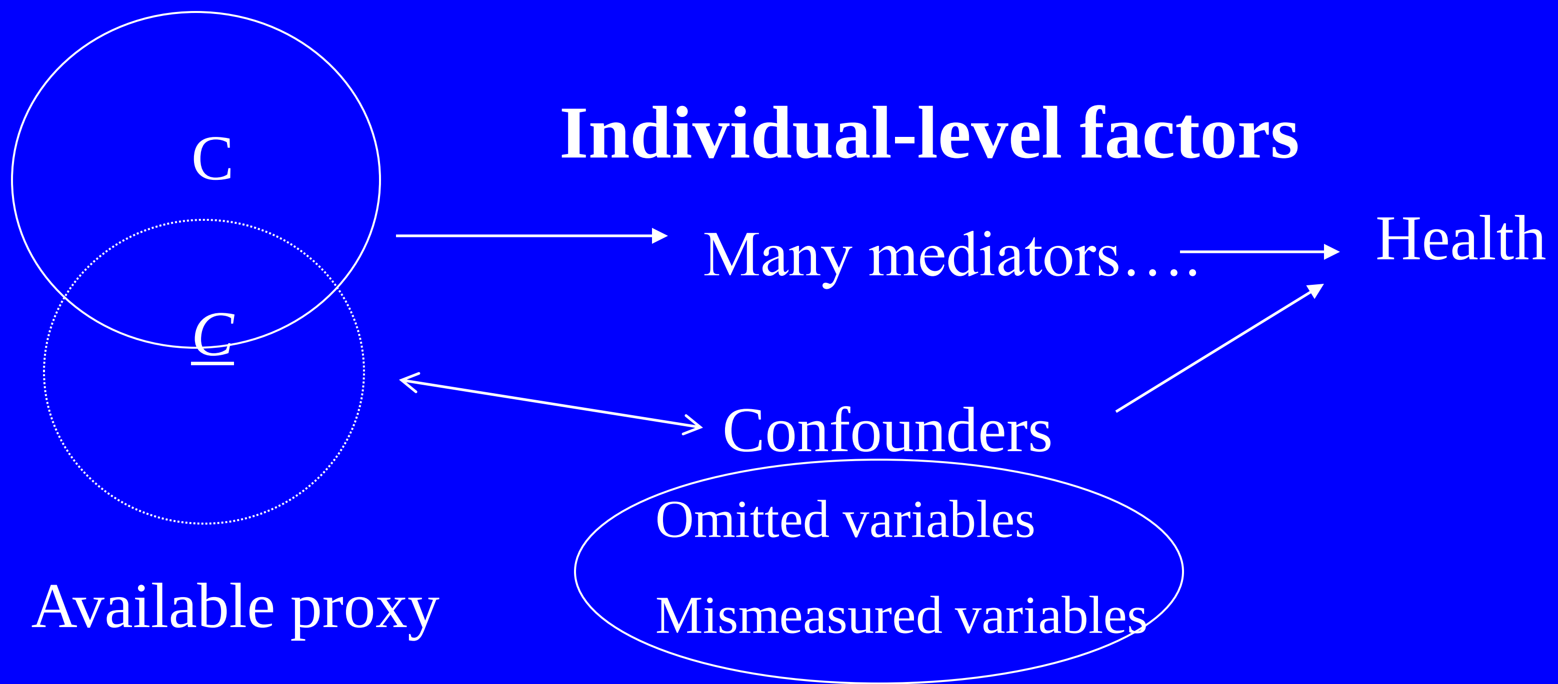
Change in housing density and change in utilitarian and exercise walking

Change in housing density	Change in utilitarian walking		Change in exercise walking	
	Increase	Decrease	Increase	Decrease
No change	1	1	1	1
Increase ≥1 quintile	1.23 (0.98, 1.55)	1.09 (0.86, 1.36)	1.26 (1.05, 1.52)	1.31 (1.09, 1.56)
Decrease ≥ 1 quintile	1.00 (0.83, 1.21)	1.36 (1.14, 1.62)	0.97 (0.85, 1.12)	1.04 (0.91, 1.19)

*Coogan, P.F., et al. Prospective study of urban form and physical activity in the black women's health study. Am J Epidemiology 2009; Vol 170 (9): 1105-1117

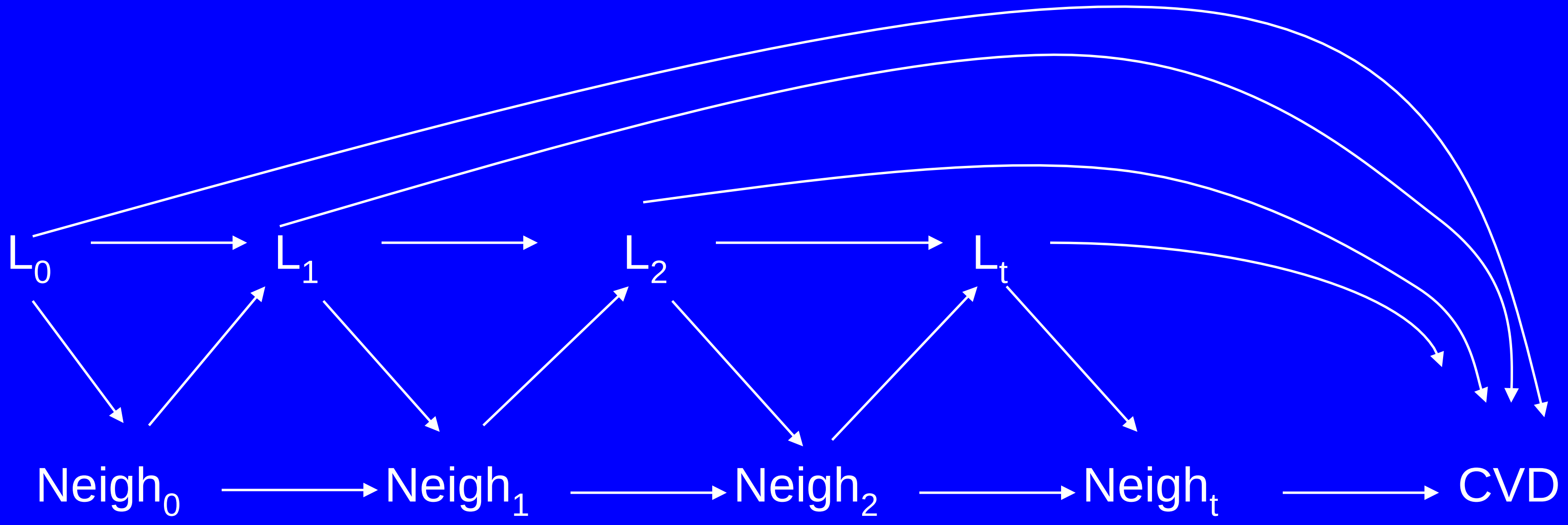
Contextual factors

“True” relevant spatial context



Contexts mis-specified
Long (complex) causal chains
Confounders

Time-varying confounding/mediation



L_0: Age, race, gender, education

L_x: Income, BMI, smoking, physical activity

Associations of neighborhood poverty at time t-1 with alcohol behaviors at time t, the CARDIA Study

	Traditional adjustment for time varying covariates	Marginal structural model
Odds ratio of binge drinking	1.47 (0.96-2.25)	1.86 (1.14-3.03)
Relative rates of weekly drinks consumed	1.09 (0.81-1.47)	1.29 (0.92-1.80)

Estimates correspond to a 1 unit increase in census tract proportion below poverty.

Cerda et al Epidemiology 2010

Limitations

- Residual confounding/selection
- Measurement
- Highly correlated “exposures”
- Long causal chains/moderators
- Few longitudinal, change vs change
- Lags, habituation, limited environmental changes

Experiments

What most experimenters take for granted before they begin their experiments is infinitely more interesting than any results to which their experiments lead.

Norbert Wiener

There is no result in nature without a cause; understand the cause and you will have no need of the experiment.

Leonardo da Vinci

Neighborhoods, Obesity, and Diabetes — A Randomized Social Experiment

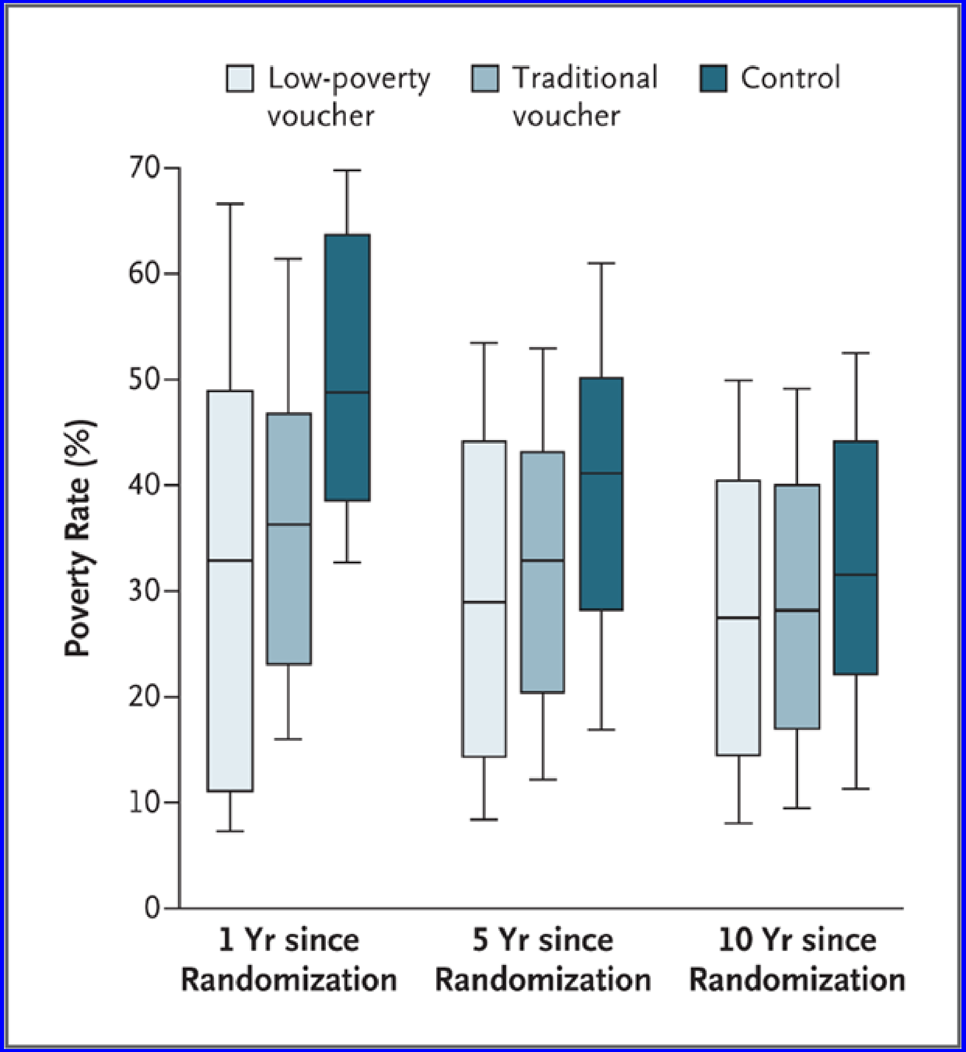
Ludwig J et al. N Engl J Med 2011;365:1509-1519

Baseline Characteristics of the Study Population.

Table 1. Baseline Characteristics of the Study Population.*

Characteristic	Low-Poverty Voucher (N=1425)	Traditional Voucher (N=657)	Control (N=1104)
		number (percent)	
Age†			
≤35 yr	196 (14.6)	94 (13.5)	163 (14.7)
36–40 yr	310 (21.5)	156 (23.9)	253 (23.3)
41–45 yr	347 (23.5)	143 (21.7)	257 (23.2)
46–50 yr	273 (18.6)	124 (20.5)	194 (17.1)
>50 yr	299 (21.7)	140 (20.4)	237 (21.7)
Race or ethnic group‡			
Black	973 (65.0)	393 (63.9)	706 (66.1)
Other nonwhite	339 (28.1)	194 (27.6)	288 (26.8)
White	92 (8.5)	52 (7.1)	88 (6.9)
Hispanic	404 (31.5)	235 (33.0)	346 (30.3)
Never married	874 (62.6)	395 (63.5)	692 (64.3)
Age <18 yr at birth of first child	347 (25.1)	163 (28.0)	265 (25.0)
Employed	368 (27.1)	176 (26.0)	258 (23.9)
Enrolled in school	216 (16.0)	113 (17.7)	172 (16.9)
Received high-school diploma	565 (38.3)	233 (34.3)	407 (35.9)
Received certificate of General Educational Development (GED)	235 (16.2)	124 (18.7)	204 (19.9)
Receives Supplemental Security Income§	221 (15.9)	107 (17.1)	171 (16.3)

Census-Tract Poverty Rate According to Study Group and Years since Randomization.



Ludwig J et al. N Engl J Med 2011;365:1509-1519

The NEW ENGLAND JOURNAL of MEDICINE

Body-Mass Index (BMI) and Glycated Hemoglobin Level at Follow-up, According to Study Group.

Table 3. Body-Mass Index (BMI) and Glycated Hemoglobin Level at Follow-up, According to Study Group.*

Variable	Control	Low-Poverty Voucher			Traditional Voucher		
	Prevalence (%)	Intention-to-Treat Estimate (95% CI)†	P Value	Prevalence (%)	Intention-to-Treat Estimate (95% CI)†	P Value	Prevalence (%)
BMI‡							
≥30	58.6	−1.19 (−5.41 to 3.02)	0.58	57.5	−0.14 (−6.27 to 5.98)	0.96	58.4
≥35	35.5	−4.61 (−8.54 to −0.69)	0.02	31.1	−5.34 (−11.02 to 0.34)	0.07	30.8
≥40	17.7	−3.38 (−6.39 to −0.36)	0.03	14.4	−3.58 (−7.95 to 0.80)	0.11	15.4
Glycated hemoglobin§							
≥6.5%	20.0	−4.31 (−7.82 to −0.80)	0.02	16.3	−0.08 (−5.18 to 5.02)	0.98	20.6

* The analysis sample consisted of women with a valid BMI measurement (for the BMI analysis) or a valid glycated hemoglobin measurement (for the glycated hemoglobin analysis) in the long-term follow-up data collection. See the Supplementary Appendix for the sample sizes used.

† Intention-to-treat estimates compare the average outcomes for all participants assigned to an intervention group with the average outcomes for controls, with adjustment for the set of baseline covariates shown in Table 1 and indicators for survey-sample release and random-assignment periods. The effects are calculated with the use of logistic regression and are presented as average marginal effects.

‡ BMI (the weight in kilograms divided by the square of the height in meters) was calculated from measured height and weight for most adults as part of the long-term follow-up data collection. Self-reported values were used for 23 observations in the low-poverty–voucher group, 22 observations in the traditional-voucher group, and 21 observations in the control group.

§ Glycated hemoglobin (HbA_{1c}) was assayed from dried blood spots collected as part of the long-term follow-up data collection.

Ludwig J et al. N Engl J Med 2011;365:1509-1519

Conclusions

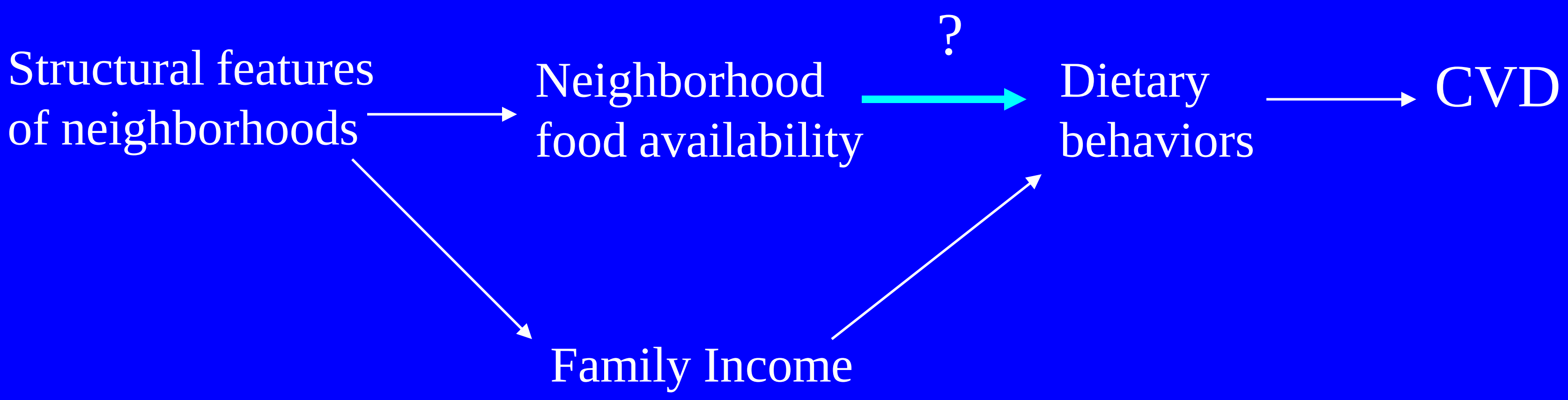
- The opportunity to move from a neighborhood with a high level of poverty to one with a lower level of poverty was associated with modest but potentially important reductions in the prevalence of extreme obesity and diabetes.
- The mechanisms underlying these associations remain unclear but warrant further investigation, given their potential to guide the design of community-level interventions intended to improve health.

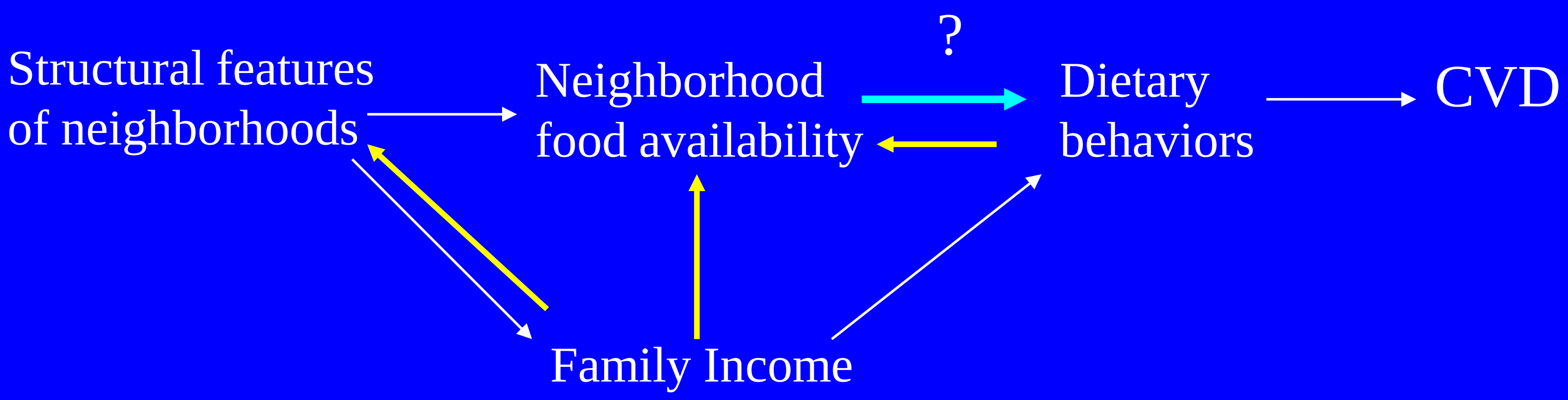
Limitations

- Mechanism?
- Most “relevant” treatment?
- Time lag/ lifecourse
- Generalizability

Multilevel dynamic processes

Structural features of neighborhoods → Neighborhood food availability $\xrightarrow{?}$ Dietary behaviors → CVD


Structural features of neighborhoods
Neighborhood food availability
?
Dietary behaviors
CVD
Family Income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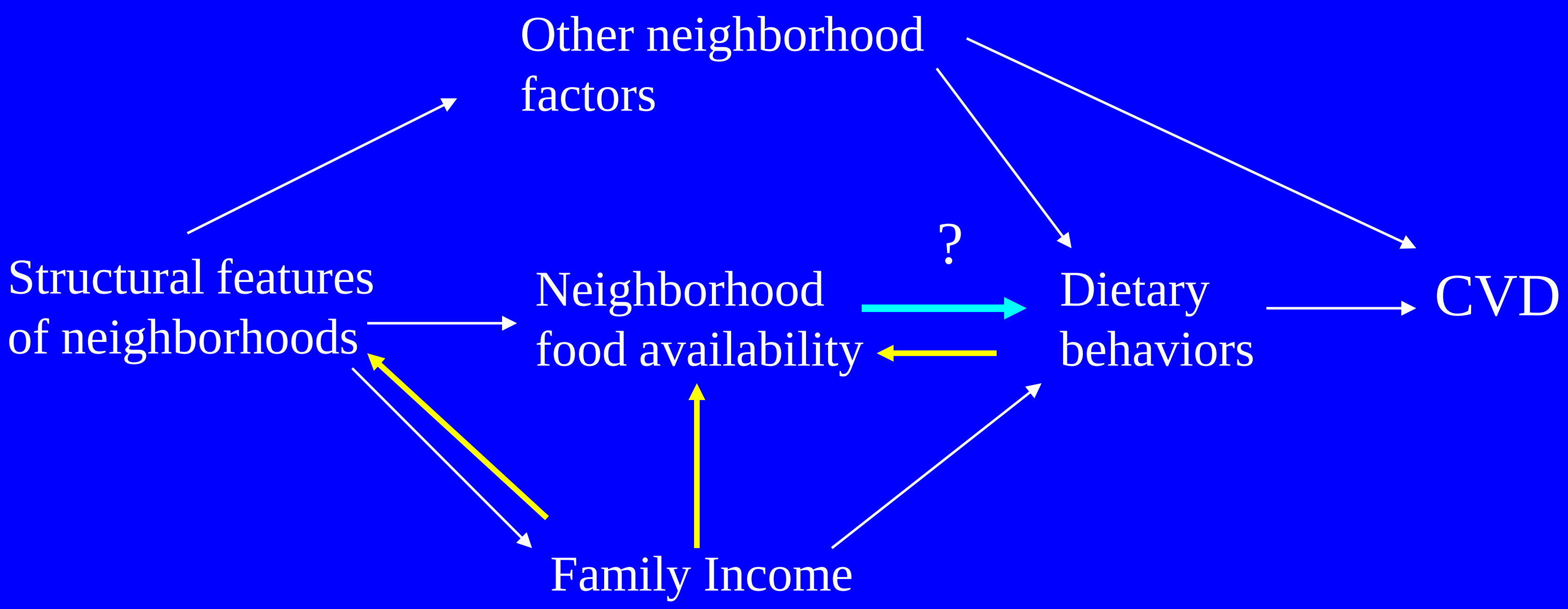
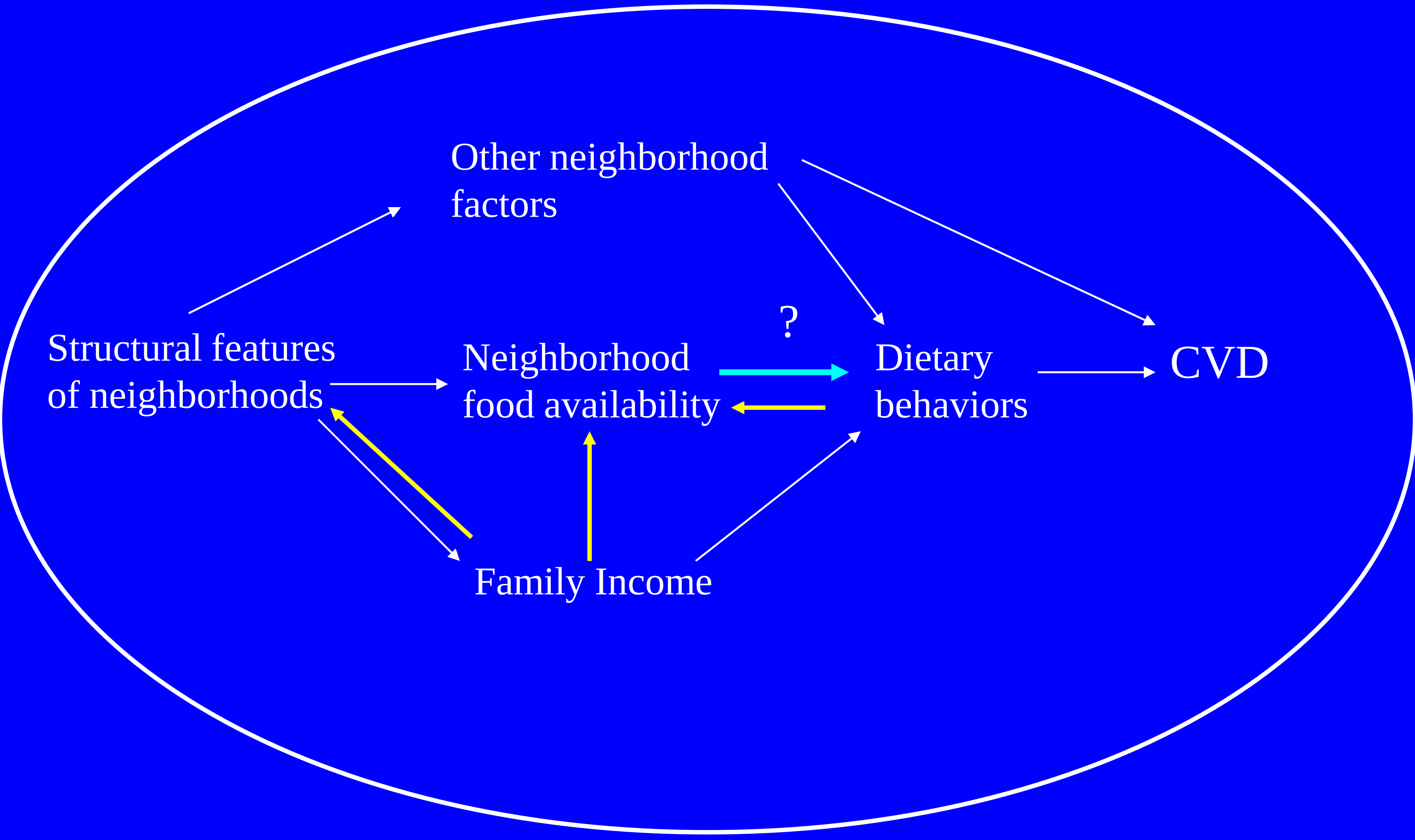

Other neighborhood
factors
?
Structural features
of neighborhoods
Neighborhood
food availability
Dietary
behaviors
CVD
Family Income



Society-wide food production factors

General Process	Example neighborhood differences in physical activity
I. Health is affected by features of neighborhood	Availability of places to be physically active promotes physical activity
II. Persons are sorted into neighborhoods based on individual attributes	Persons of lower income and minorities live in neighborhoods with less resources

General process	**Example neighborhood differences in physical activity**
III. Persons select neighborhoods based on preferences for certain attributes	Physically active persons choose to live in neighborhoods with more PA resources
IV. People change their behavior in response to the behavior of others around them	Seeing more people walk in the neighborhood stimulates individuals to walk
V. Neighborhoods change in response to the behavior of residents	The presence of more physically active residents increases the availability of recreational resources

The focus of regression approaches……

General Process	Example neighborhood differences in physical activity
I. Health is affected by features of neighborhood	Availability of places to be physically active and promotes physical activity
II. Persons are sorted into neighborhoods based on individual attributes	Persons of lower income and minorities live in neighborhoods with less resources

Spatial patterning of health emerges from the functioning of a system:

- individuals interact with their environment
- individuals interact with each other
- individuals and environments adapt and change over time.

Five features of dynamic systems

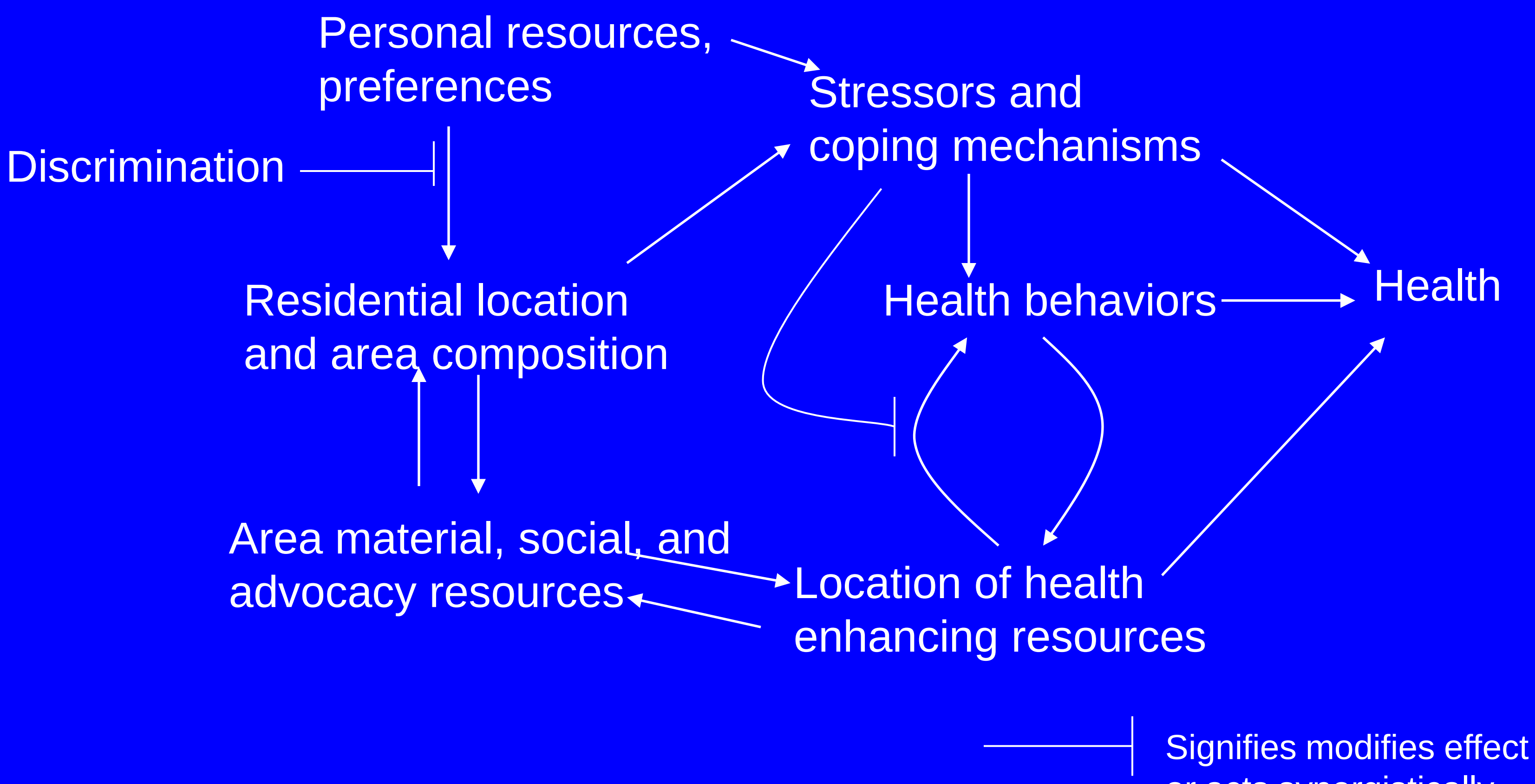
- Factors at multiple levels
- Heterogeneous and interdependent units
- Recursive relationships and feedback loops
  - Endogeneity
- Non linear effects/Dynamic response→ effects at other locations and other times
- Unanticipated effects

Policy resistance

“the tendency for interventions to be defeated by the system’s response to the intervention itself”

“obvious solutions fail or even worsen the situation”

Sterman, AJPH 2006



Dynamic relations between area factors, personal factors, health behaviors, and health outcomes

Processes resulting in spatial health inequalities

- Feedbacks (positive or negative), adaptation over time
- Dependencies across people/places, interaction between people/places
- Effects distant in space and time
- Multiple paths to same outcome, similar distal causes of multiple different outcomes
- Emergent patterns not easily reducible to “independent effects”

What is a “systems” approach?

- A systems approach “…does not investigate individual genes or proteins one at a time, as has been the highly successful mode of biology for the past 30 years. Rather, it investigates the behavior and relationships of all the elements in a particular biological system while it is functioning.”
  - » Ideker et al 2001

- A “systems” approach to the study of health would not investigate individual risk factors (or individuals) one at a time, rather it would investigate the behavior and relationships of multiple factors and multiple elements in a particular population system while it is functioning .

A “systems” approach

- Define the components of the system and compile information on them: dynamic conceptual models
  - Abstract the “essential” elements
  - Set bounds
  - Question specific
- Develop a formal model in order to:
  - Explore the functioning of the system
  - Answer fundamental questions about dynamics
  - Obtain predictions under specific perturbations
- Draw conclusions regarding drivers of patterns and plausible impact of interventions

Agent-based models

- Computer representations of systems: “agents” that interact in space and time
- “Agents” defined at multiple levels (persons, businesses, governments etc.)
- Agents change or take actions in response to:
  - their own attributes
  - interaction with other agents
  - the environment
  - prior experience
- Use simulation to observe how macro patterns emerge from agent interactions and adaptations
- Contrast the impact of different “interventions” in the context of this virtual system

Example of types of ABMs

Abstract, highly stylized

Hypothesis generating, can enhance intuition

Sophisticated, modular models that incorporate more complexity.

Begin simple, add on, and add on.

Highly detailed, 'realistic' => approaches prediction

Depends on high resolution data

Auchincloss 2009

An application to the study of the spatial patterning of health

Utility of agent-based models to to neighborhood effects research

- Bidirectional person-environment relations
  - Selection
  - Endogeneity

- Interactions between agents
  - Networks/norms

- Interrelations/interactions between environments
  - Physical- social

- Spatial patterning (segregation) of individual and environmental characteristics

Auchincloss AH, Diez Roux AV. A new tool for epidemiology: the usefulness of dynamic-agent models in understanding place effects on health. *Am J Epidemiol* 2008;168:1-8.

An Agent-Based Model of Income Inequalities in Diet in the Context of Residential Segregation

Amy H. Auchincloss, PhD, MPH, Rick L. Riolo, PhD, Daniel G. Brown, PhD, Jeremy Cook, BA, Ana V. Diez Roux, MD, PhD

Background: Low dietary quality is a key contributor to obesity and related illnesses, and lower income is generally associated with worse dietary profiles. The unequal geographic distribution of healthy food resources could be a key contributor to income disparities in dietary profiles.

Purpose: To explore the role that economic segregation can have in creating income differences in healthy eating and to explore policy levers that may be appropriate for countering income disparities in diet.

Methods: A simple agent-based model was used to identify segregation patterns that generate income disparities in diet. The capacity for household food preferences and relative pricing of healthy foods to overcome or exacerbate the differential was explored.

Results: Absent other factors, income differentials in diet resulted from the segregation of high-income households and healthy food stores from low-income households and unhealthy food stores. When both income groups shared a preference for healthy foods, low-income diets improved but a disparity remained. Both favorable preferences and relatively cheap healthy foods were necessary to overcome the differential generated by segregation.

Conclusions: The model underscores the challenges of fostering favorable behavior change when people and resources are residentially segregated and behaviors are motivated or constrained by multiple factors. Simulation modeling can be a useful tool for proposing and testing policies or interventions that will ultimately be implemented in a complex system where the consequences of multidimensional interactions are difficult to predict.
(Am J Prev Med 2011;40(3):303–311)

Background

- Income differences in diet well established →potential contributor to health disparities
- Spatial segregation of healthy foods repeatedly documented
- Questions regarding causality (selection) and policy implications

Two exploratory questions

- Does spatial segregation contribute to income disparities in diet absent price or preference differentials?
- How do price and preference manipulations (both possible interventions) affect these disparities?

Households

Households shop every 2-3 days, select store based on price, distance, habitual behavior, and preference for healthy foods (utility function plus random noise)

Stores

- Income (bin)
- Healthy food preferences (cont)
- Distance to store
- Diet score

Household diet changes as a function of the store they shop at

- Price of food (bin)
- Healthy or unhealthy food at store (bin)
- Number of customers (store profits)
- Stores go out of business; a new store opens (with some probability of change in food type sold)

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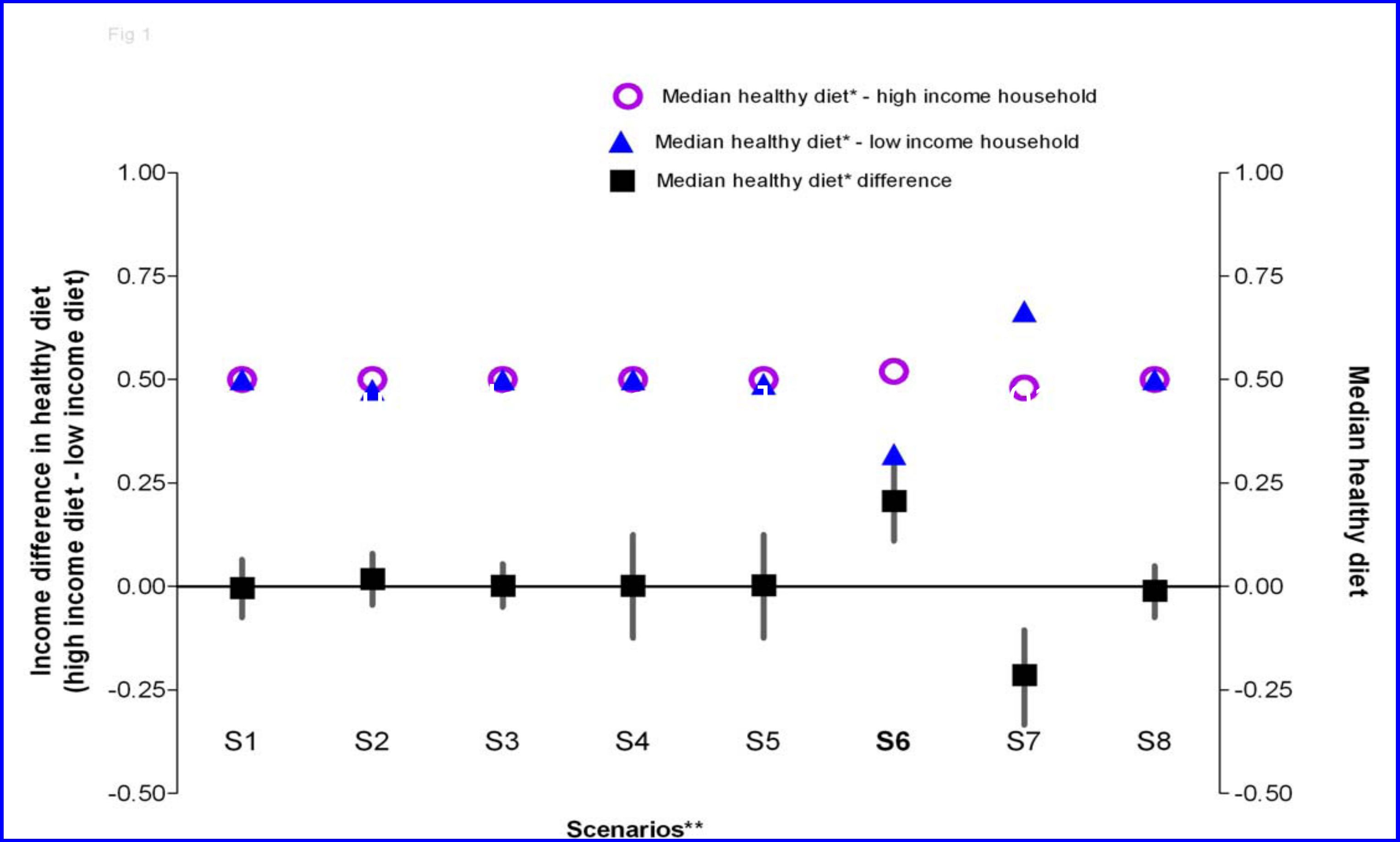
- Compare income differentials under various spatial segregation scenarios (assuming constant price and preferences)

- Compare income differentials holding segregation constant but varying price and preferences

Income differentials in diet and absolute diet levels under various segregation scenarios



S6: segregation of low inc hh w/unhealthy foods and high inc hh w/healthy foods

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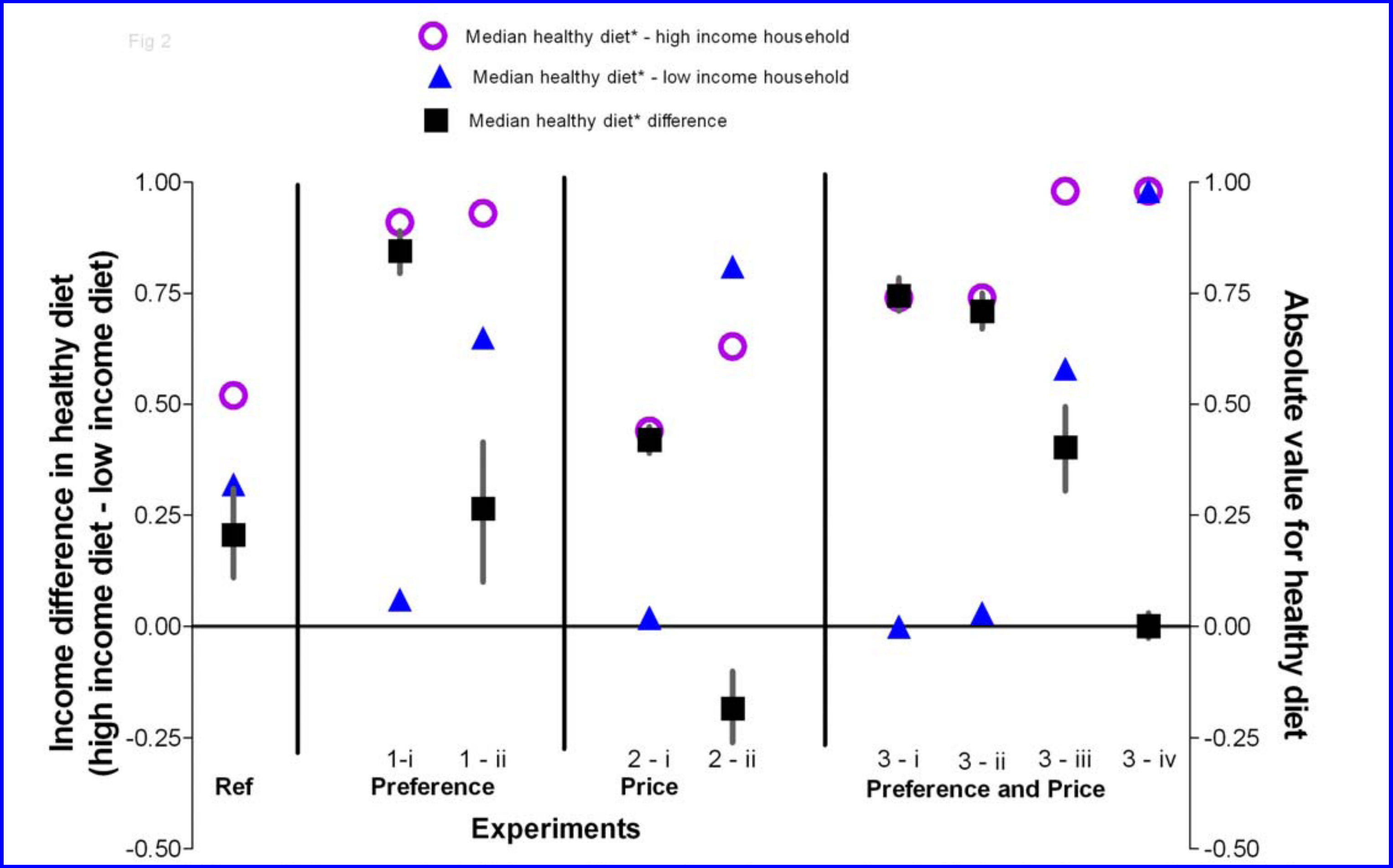
- Income differentials emerge in the presence of co-segregation of low income and unhealthy stores (or high income and healthy stores) even when food preference and price are held constant

- What happens when we manipulate price and preferences?

Income differentials in diet for different manipulations of preference and price for the scenario involving co-segregation of low income and unhealthy stores



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What have we learned?

- Segregation can create disparities in diet even in the presence of no differences in preferences or price
- Changing preferences not enough
- Price manipulation seems to have a stronger impact than preference manipulation, but price and preferences reinforce each other
- Store dynamics….
- We thought about the processes….
- Ideas for new data collection……empirical studies
  - E.g. shopping behavior, store dynamics, networks

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Benefits

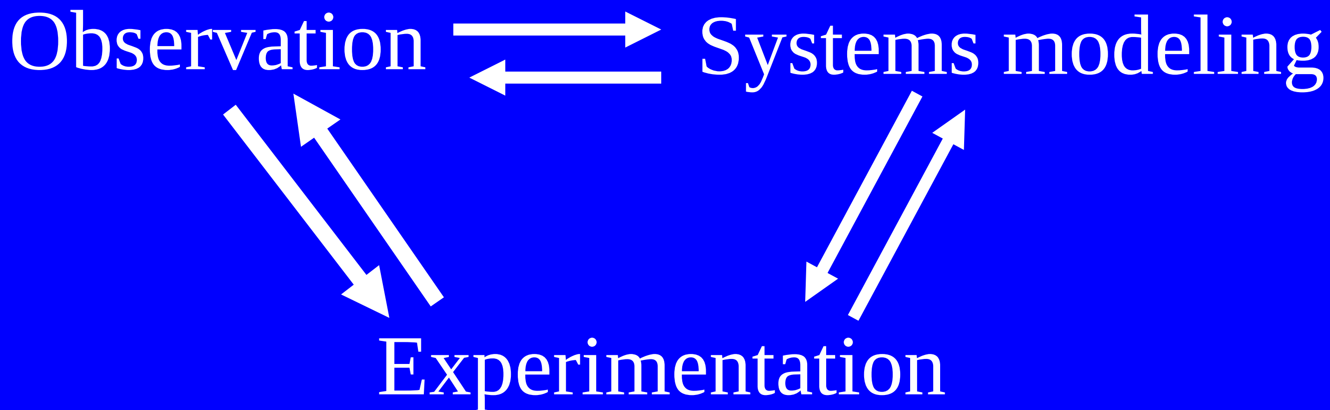
- Dynamic conceptual models
  - Force investigators to think about processes: from describing associations to modeling the processes that generate them
  - Explicitly account for the interrelatedness of people and environments
- Tools
  - Thought experiments and evaluate the effects of hypothetical interventions in the context of SYSTEMS
    - Under conditions different from those observed in real world
    - Accounting for feed back loops and adaptation of people and environments over time
- Data
  - Integrates various sources of data
  - Identifies gaps and data needs

Caveats…

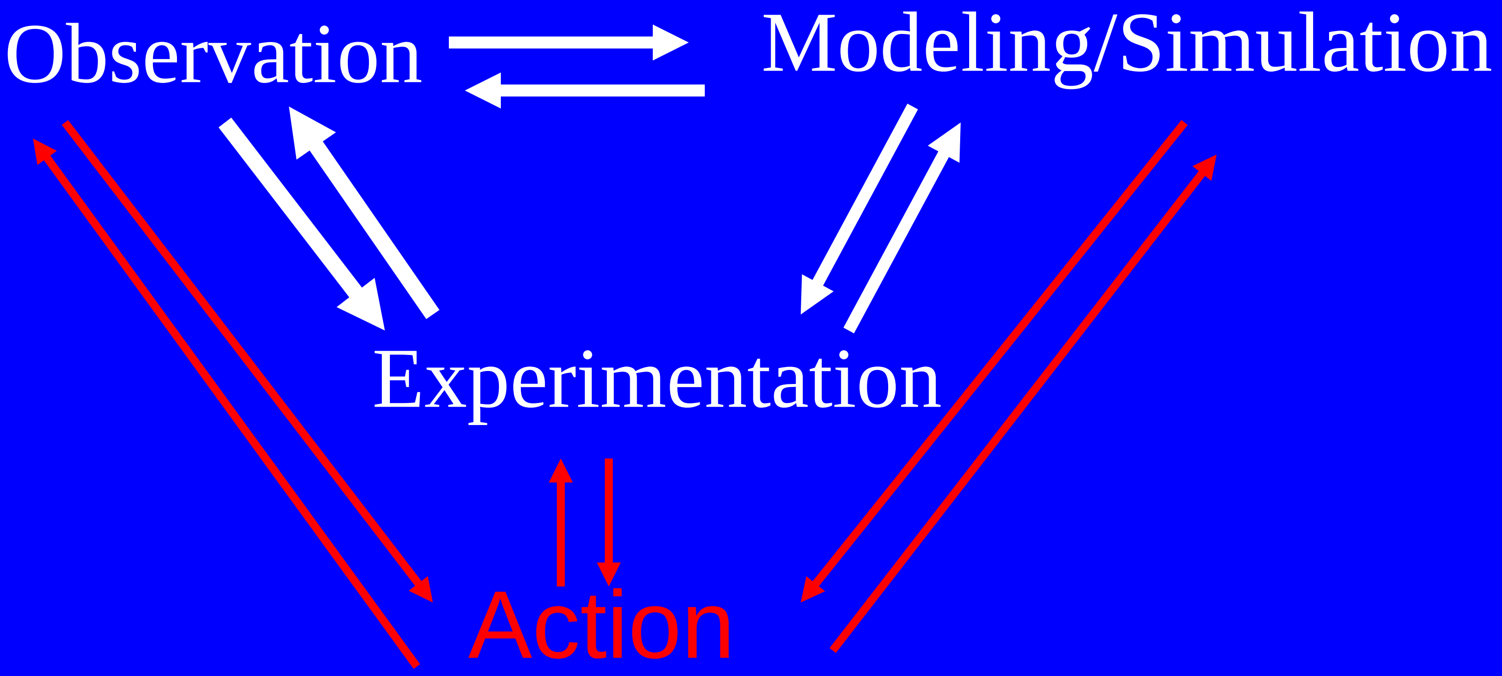
- Keeping it simple but relevant…
  - Boundaries and level of detail (intelligent abstraction)
  - Thought experiments/proof of principle vs. prediction
- Assumptions, Where is the data?
  - Justify modeled processes
  - Calibrate parameters
  - Validate the model
- Arduous process….
- Transparency and communication
- WHEN DOES IT MAKE A DIFFERENCE???

- Spatial differences in health (healrth disparities) emerge from the functioning of a “system”
- “Systems” can be investigated using a variety of approaches
- Methods can constrain our thinking

Knowledge generation and evidence for population health (and health disparities)



Evidence-action system



A few concluding thoughts..

- Mutually reinforcing nature of place –based and individual inequalities
- Complementarity of different types of evidence- including evaluation of action
- Not letting the methods we are used to constrain the questions that we ask
- Systems thinking: implications for conceptual models, evidence and action
- Complexity should not be paralyzing

In the complex system…causes are usually found, not in prior events, but in the structure and policies of the system…”

Forrester 1969

"…the burden of disease on a human population is part of an environmental system and the interrelatedness of the components of the system cannot be understood by pursuing research whose rationale is to divide and isolate the components in ever greater detail."

" If we consider disease to be embedded in a complex network in which biologic, social, and physical factors all interact, then we are impelled to develop new models and adopt different analytic methods."

R. Stallones, 1973

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