Exposure Assessment for Chemical and Non-chemical Exposures for Urban Epidemiology

SOT Risk Assessment Specialty Section (RASS)
- International Society for Exposure Science (ISES) Webinar
February 14, 2018

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Cumulative Risk Assessment (CRA) & Non-chemical stressors

- Recently, growing attention in cumulative risk assessment that most health outcomes are influenced by many exposures (chemical & non-chemical).
  - e.g., solvents & noise => hearing loss
  - Smoking & air pollution => lung cancer

- Non-chemical exposures are tremendously varied:
  - Heat, noise (sound), diet, behaviors (e.g., smoking), greenspace, social/ psychosocial stressors….
  - Exposures may be derived from community or occupational environment
    - & may modify impacts of exposures from other settings.

- => There is a growing need to incorporate multiple exposures derived from multiple environments into CRAs.

  - Several review papers and frameworks have now been offered for integrating various non-chemical stressors into CRA:
    - Alves et al 2012; August et al 2012; Hicken et al 2011; Harper et al 2013; Lewis et al, 2011; McEwen & Tucker 2011; Morello-Frosch et al 2011; Rider et al 2013; Schwartz et al 2011; Sexton & Linder, 2011; Wason et al 2012

  - Though operationalizing these frameworks remains challenging.

Socioeconomic Position (SEP) & Urban Environmental Epidemiology

- Exposures to many exposures (chemical & non-chemical) are often greater in lower-socioeconomic position (SEP) communities.
  - *(i.e., confounding)*

- Susceptibility shown to vary by SEP.
  - Greater *susceptibility* with lower SEP has been shown for: air pollution [Krewski et al, 2000], industrial emissions [Jerrett et al, 2004], agricultural hazards [Griffith 2007], lead (Pb) [Schwartz 1994].
    - *(i.e., effect modification)*

What is SEP-related Susceptibility?

- A rich literature examines efficacy of various SEP indicators (e.g., income, education),
  - though the "causal components" underlying SEP-related susceptibility remain poorly elucidated [Matthews and Gallo 2014].
- Growing evidence suggests that chronic psychosocial stress may partly mediate this susceptibility (Clougherty et al 2014).
- Chronic stress confers broad physiologic changes, known as 'allostatic load' [McEwen 1998], including:
  - HPA-axis function (e.g., cortisol)
  - Glucocorticoid receptor alteration
  - Sympathetic-adrenal-medulary (SAM) axis
  - Early life immune function (e.g., Th-1/ Th-2)
- So, it follows that stress could make one more susceptible to everything else…
  - Incl. pollutants, or the common cold virus [Cohen et al, 1991].

How to account for social & psychosocial stressors

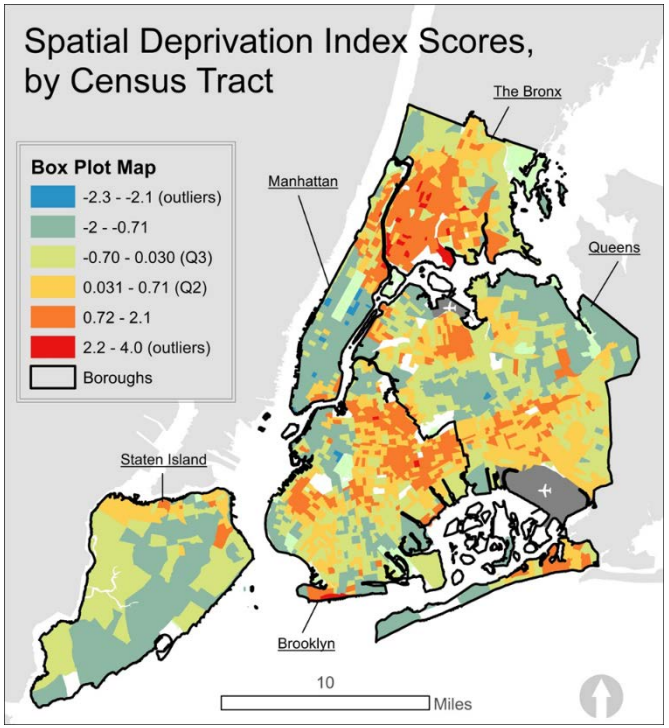
1. Key issues in measuring social constructs and socioeconomic position (SEP).
2. Methods for measuring “stress” and stressor exposures.
3. Incorporating social/ psychosocial data into environmental epidemiology.

Measuring Socioeconomic Position (SEP)

- What do we mean by SEP – and, relatedly, nonchemical stressors?
  - Health care? Diet? Co-exposures? Lifestyle? Social status? Stress?
- Selection of – and misclassification in - SEP indicators:
  - e.g., Income vs. education vs. wealth … or, composite indicators?
- Measurement scale:
  - Community -level processes
    - (e.g., crime rate, social capital, amenities, rituals) = *context*
  - vs. individual characteristics
    - (e.g., individual income, job strain, social support) = *composition*

Measuring SEP: Composite metrics of community-level (material) socioeconomic deprivation

Candidate SEP variables (n = 20) *Source: US Census American Communities Survey (2005-2009)*	***PCA first-component solution***	
	Spatially-Stratified	***City-wide***
Education (among adults aged > 25)		
% < High School		
% BA or more	X	
Employment (among adult labor force, aged 20-64)		
% unemployed	X	X
% males in labor force		
% females in labor force		
Housing		
% renter occupied (among occupied units)		
% vacant housing units (among total housing units)		
% crowded (> 1 occupant per room, among occupied housing units)	X	X
Occupation (among full-time, year-round civilian employed population)		
% adults in management or professional occupations	X	
Income		
% households in poverty (< 200% Federal Poverty Line)	X	
% Families w/ annual income < $35,000 (2009 inflation-adjusted)		
% female householders with children aged < 18		
% households w/ public assistance income	X	
% households w/ Food Stamp benefits (in past 12 months)		
Median household income (in the past 12 months)		
% renter or owner housing costs in excess of 30% household income (in past 12 months)		X
Racial composition		
% African American (non-Hispanic)		X
% non-white (calculated as inverse of non-Hispanic white population)	X	
% Hispanic		
Language		
% speak English less than "very well" (among pop > 5 years old who speak a language other than English at home)		



NIH 5 R01 ES19955-3 (Savitz)

Shmool et al., *Am J Epidemiol 2015*

Measuring *Psychosocial* Stress

- Stress Process Paradigm (Lazarus 1984; Cohen 1995)

- Need select measures according to hypothesized pathway.
  - e.g.: sound (physical) vs. noise (annoyance)

Methods for Measuring "Stress"

Optimally at individual level, captures perception/ mental well-being:

- Perceived stress (Cohen et al. 1983)
- Affect (i.e., optimism, trait anger) (Scheier et al. 1984; Spielberger et al. 1995)
- Mental health (i.e., anxiety, depression) (Butcher et al. 1989; Radloff et al. 1977; Irwin et al. 1999)

Or, measure a key stress*or*.

- Major life events (Attar et al. 1994; Kessler et al. 1998)
- Chronic condition (e.g., caregiver stress (Shankardass et al. 2009)
- Strong negative stressor (e.g., exposure to violence) (Clougherty et al., 2007)

Biomarkers? (NIH Biomarker Network: http://gero.usc.edu/CBPH/network/)

- Allostatic load (McEwen 1998) & metabolic risk
- Impacted by multiple agents (i.e., markers of inflammation)
- Physiology of acute vs. chronic stress
  - Cumulative acute <> chronic (i.e., hair cortisol)

Many of these not feasible for population-level studies:

- Administrative *stressor* indicators (e.g., crime, poverty rates) (Hajat et al. 2014; Shmool et al. 2014)

NIH Stress Measurement Network: https://stresscenter.ucsf.edu/

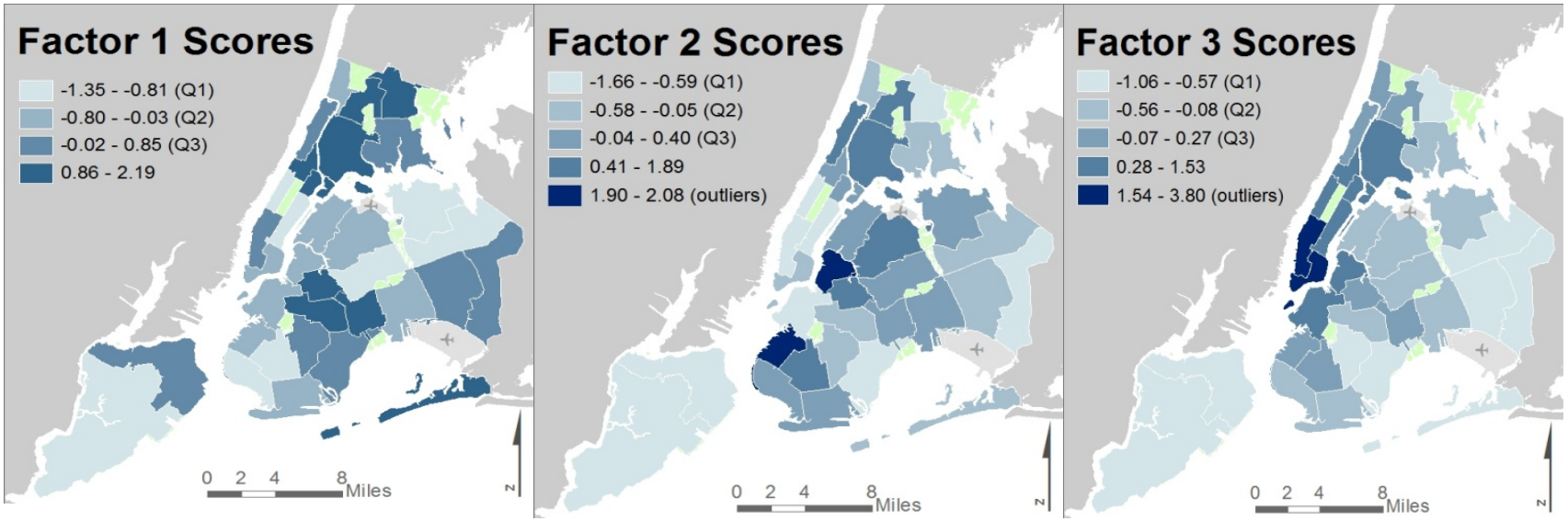
Selection of (Community) Stressor Indicators

Table 3: Community stressor constructs, indicators, source agencies, and date

Stressor Construct	Indicator and Administrative Scale	Data Source and Date
Crime & Violence	Murder and non-negligent manslaughter per 10,000 (PP)	NYPD (FY 2009)
	Felonious Assault per 10,000 (PP)	NYPD (FY 2009)
	Robbery per 10,000 (PP)	NYPD (FY 2009)
	Burglary per 10,000 (PP)	NYPD (FY 2009)
	Felony Larceny thefts per 10,000 (PP)	NYPD (FY 2011)
	% Perceptions of Neighborhood Safety (self-report) (UHF)	DOHMH CHS (2010)
Mental and General Health Status	% Depression diagnosis ever (self-report) (UHF)	DOHMH CHS (2009)
	% Mental health treatment in past year (self-report) (UHF)	DOHMH CHS (2009)
	% Fair or Poor general health (self-report) (UHF)	DOHMH CHS (2009)
Physical/Built Environment	% Small parks not acceptably clean (CD)	NYC Parks (FY 2009)
	% Sidewalks not acceptably clean (CD)	MOoO (FY 2009)
	Serious housing violations per 1,000 Rental Units (CD)	HPD (2009)
	Air Quality complaints per 10,000 residents (CD)	DEP (FY2009)
	% Residential Crowding (>1 occupant/room) (USCBG)	US Census ACS (2005-09)
Access to Healthcare	% With no type of insurance coverage (self-report) (UHF)	DOHMH CHS (2009)
	% Went without needed medical care (self-report) (UHF)	DOHMH CHS (2009)
	% Without a personal care provider (self-report) (UHF)	DOHMH CHS (2009)
	Public Health Insurance enrollment per 10,000 (CD)	MOO (FY 2009)
Noise disruption	% Frequent noise disruption (3+ times/wk over 3 months) (self-report) (UHF)	DOHMH CHS (2009)
	% Noise disruption, by noise sources (i.e. neighbors, traffic) (self-report) (UHF)	DOHMH CHS (2009)
Childhood-specific stressors	% Students in schools exceeding capacity (SD)	NYC DOE (SY 2006-07)
	% School buildings in good to fair condition (SD)	NYC DOE (SY 2006-07)
	% Average daily student attendance (SD)	NYC DOE (SY 2008-09)
	Substantiated cases of Child Abuse/Neglect per 10,000 (CD)	NYC ACS (2008)
Socioeconomic Position (SEP)	% Living below 200% federal poverty line (USCBG)	US Census ACS (2005-09)
	% Delayed rent or mortgage payment in past year (self-report) (UHF)	DOHMH CHS (2009)
	Food Stamp program enrollment per 10,000 (CD)	MOO (FY 2009)
	% Less than high school education (self-report) (UHF)	DOHMH CHS (2009)
	% Unemployed for less than 1 year (USCT)	US Census ACS (2005-09)

Carr Shmool et al., *Environ Health* 2014

Spatial correlation among social stressors



Extreme deprivation & violence

Deprivation & inadequate housing

Property crimes & perceived poor air quality

EPA RD-83457601-1

Carr Shmool, *Environ Health* 2014

Validating GIS-based stressor indicators: *Content* and *Scale*

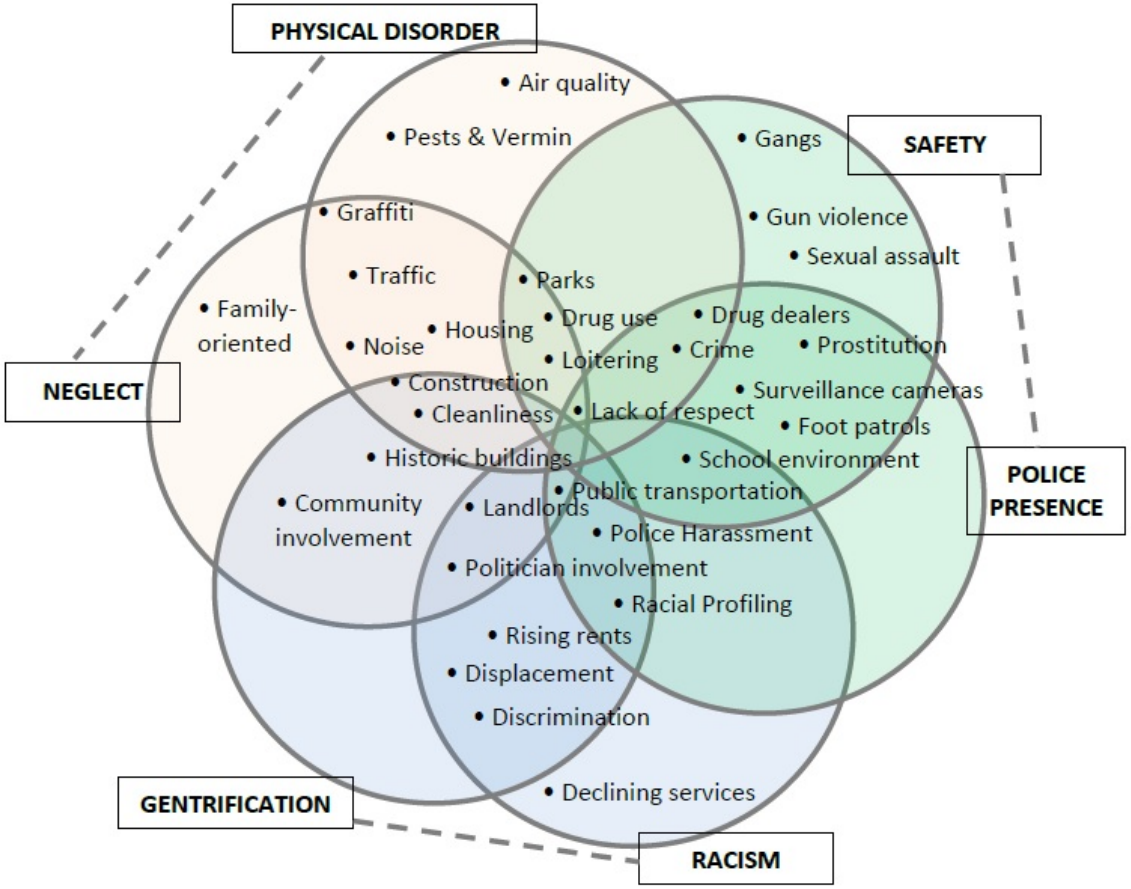
(1) Content:

- Focus Groups (n = 14)
  - e.g., Which stressors most affect people in *your community*?
- Systematic Spatial Survey (n = 1,589)
  - To validate relationship between areal stressors (e.g., poverty rate) and individual stress.
  - e.g., Where do you live, and are you stressed?

(2) Scale:

- Do administrative units really resemble 'neighborhoods'?
- How to merge/ compare data reported at different scales ?

(1) Validating Content: Systematic content analysis of qualitative focus group data to derive over-arching themes



Identify Proxy Measures

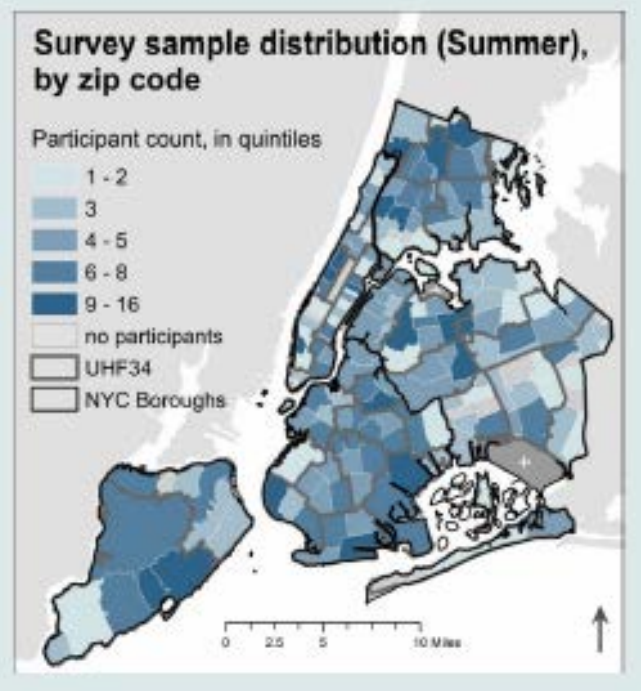
Community-identified Stressors	# of groups
Safety (violence, crime)	14
Drugs (dealers, use)	9
Sanitation (trash, rats, pests)	9
Police presence (Stop-and-Frisk)	9
Public transportation	7
Lack of involvement from city officials	6
Gang activity	6
Gentrification	6
Lack of community pride, unity, involvement	6
Poor housing conditions, inadequate housing	6
Disrespect, harassment among community members	5
Diminishing services, funding cuts	5
Traffic	4
Noise, raised voices, loud music	4
High cost of living	4
Lack of emergency services, hospitals	3
Sexual assaults	3
Schools	3
Prostitution	2
Construction	2
Guns	2
Pollution	2
Lack of grocery stores	2

Stressor Construct	Indicator and Administrative Scale
Crime & Violence	Felony Larceny Crimes per 10,000 (PP) Murder and non-negligent manslaughter per 10,000 (PP) Felonious Assault per 10,000 (PP) Robbery per 10,000 (PP) Burglary per 10,000 (PP) % Perceptions of Neighborhood Safety (self-report) (UHF)
Mental Health	% Depression diagnosis ever (self-report) (UHF) % Mental health treatment in past year (self-report) (UHF)
Physical/Built Environment	% Small parks not acceptably clean (CD) % Sidewalks not acceptably clean (CD) Serious housing violations per 1,000 Rental Units (CD) Air Quality complaints per 10,000 residents (CD) % Crowding (>1 occupant/room) (USCT)
Access to Healthcare	% With no type of insurance coverage (self-report) (UHF) % Went without needed medical care (self-report) (UHF) % Without a personal care provider (self-report) (UHF) Public Health Insurance enrollment per 10,000 (CD)
Noise disruption	% Frequent noise disruption (3+ times/wk over 3 months) (self-report) (UHF) % Noise disruption, by sources (i.e. neighbors, traffic) (self-report) (UHF)
Childhood-specific stressors	% Students in schools exceeding capacity (SD) % School buildings in good to fair condition (SD) % Average daily student attendance (SD) Substantiated cases of Child Abuse/Neglect per 10,000 (CD)
Socioeconomic Position (SEP)	% Living below 200% federal poverty line (USCBG) % Delayed rent or mortgage payment in past year (self-report) (UHF) Food Stamp program enrollment per 10,000 (CD) % Less than high school education (self-report) (UHF) % Unemployed for less than 1 year (USCT)

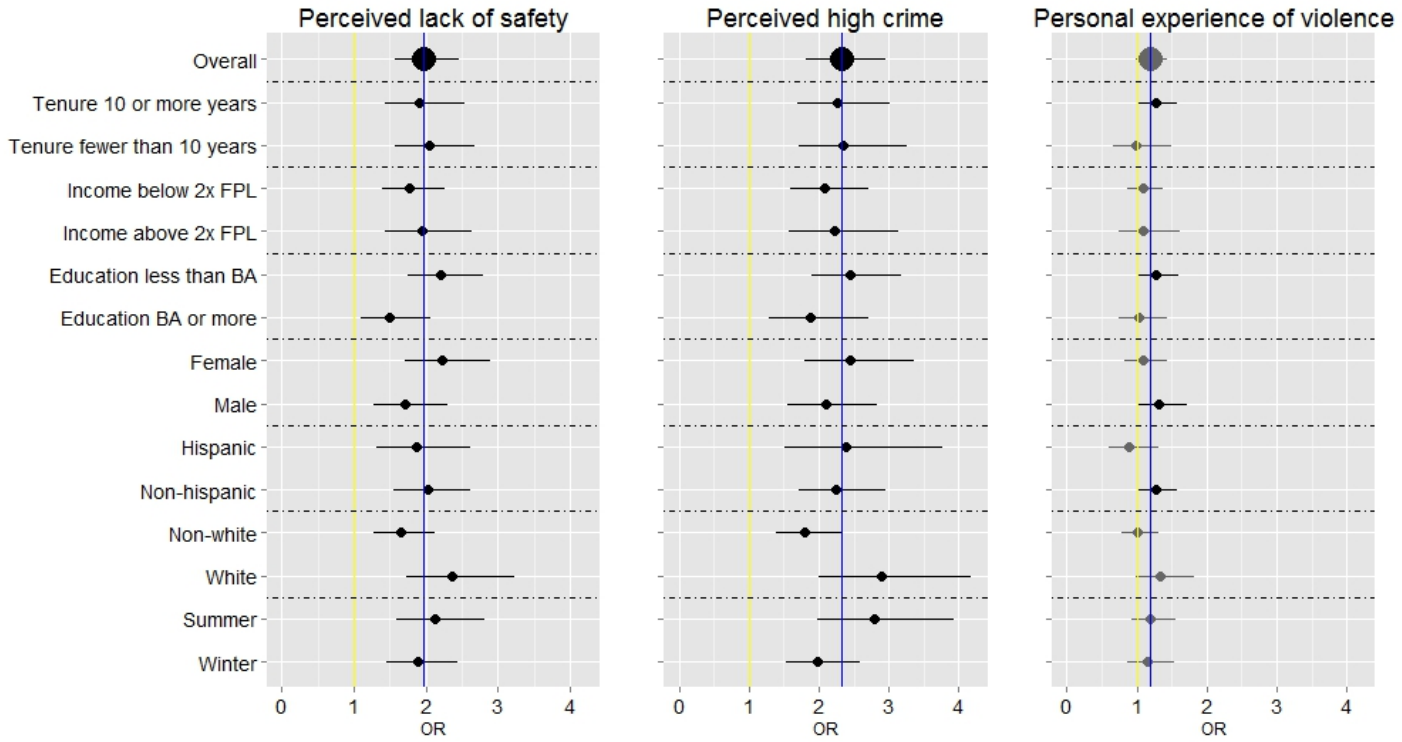
(1) Validating Content: Citywide survey (n = 1,549)

- Triple frame
  - RDD landline (n=539), cell phone (n=164), online (n=846)
- English & Spanish; Summer 2012, Winter 2013

Sample population:	
Mean Age (years)	45 (SD 17)
Race / Ethnicity	
White	49%
African American	31%
Asian	6%
Hispanic	19%
Unemployed	11%
Education < High School graduate	4%
HH income < 2x federal poverty line	24%
Residential tenure > 10 years	60%

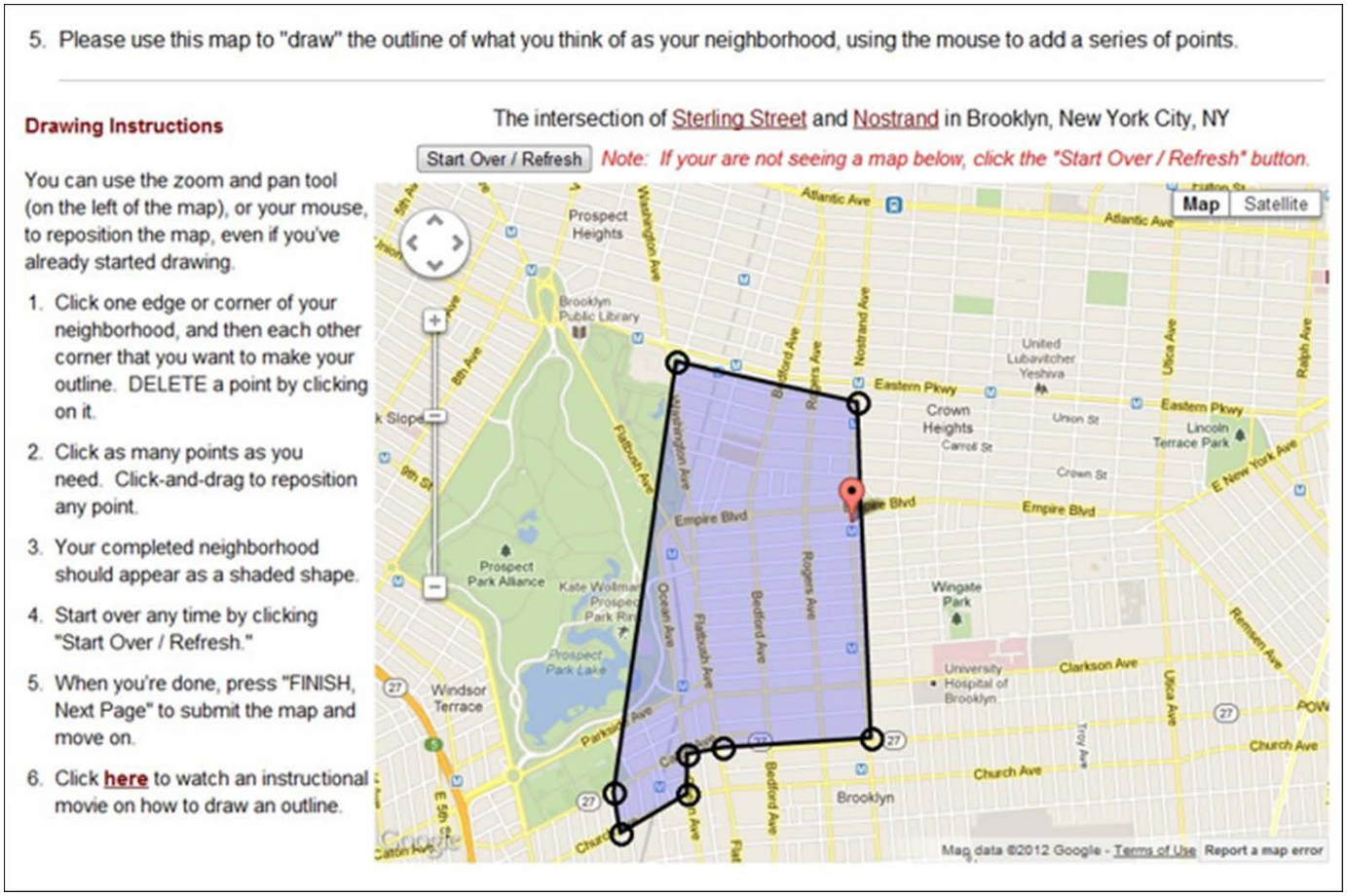


(1) Validating Indicator Content
(Effects per IQR increase in area **Assault Rate)**



Models adjusted for age, sex, residential tenure, season, sampling frame, and nesting of participants within administrative areas (random intercept); except for models stratified by sex, tenure and season.

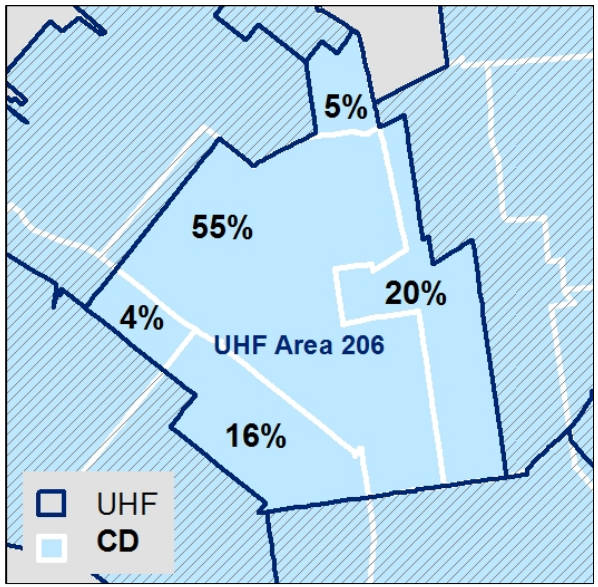
(2) Validating *scale* for "neighborhood" indicators

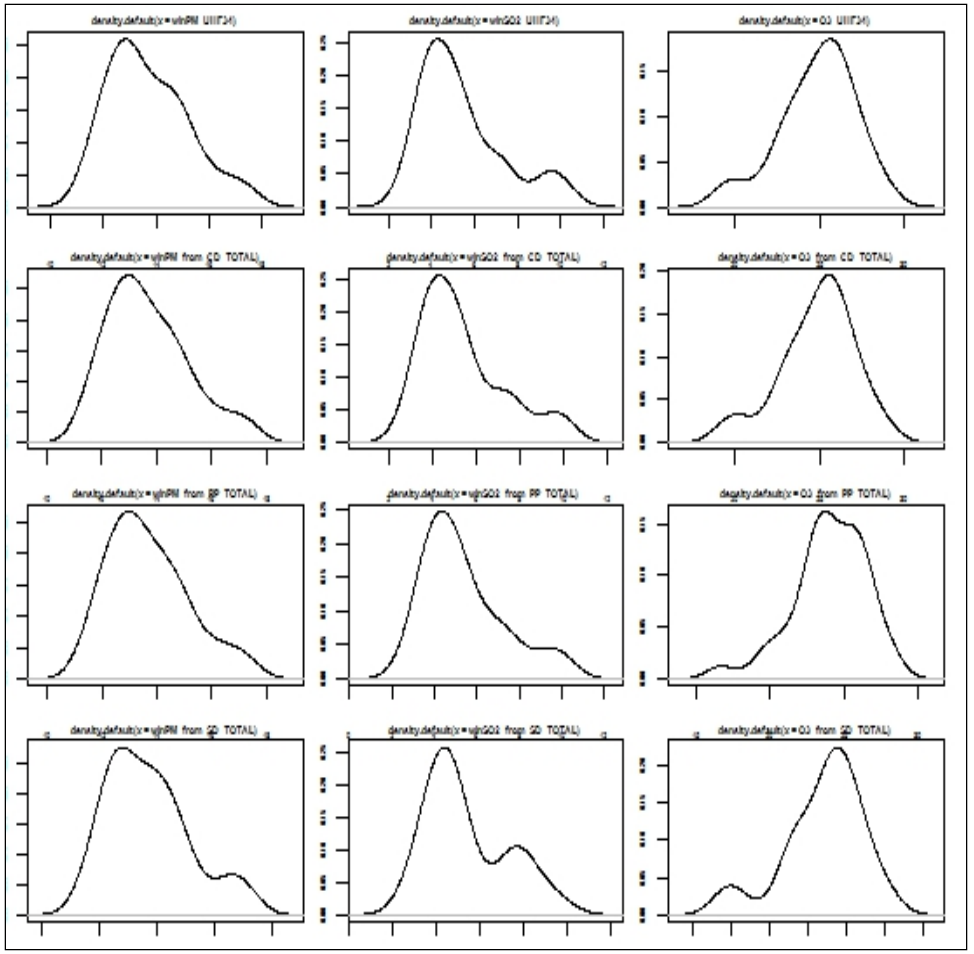


Shmool et al, *The Professional Geographer, in press.*

Areal Reformulation

- Proportional weights
  = % overlap between areas
- Reformulate to common unit
- Validate w smooth surfaces
  (± 5% error tolerance).
- Unknown within-area variation

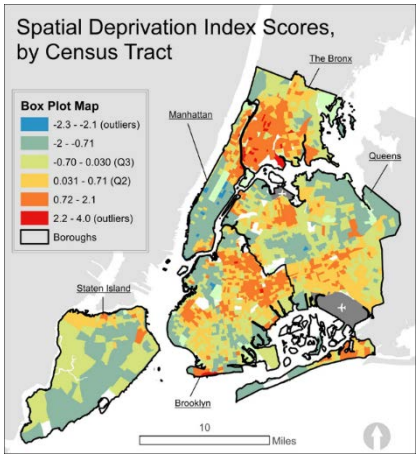


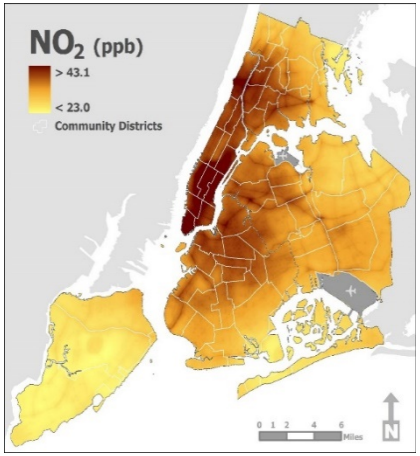


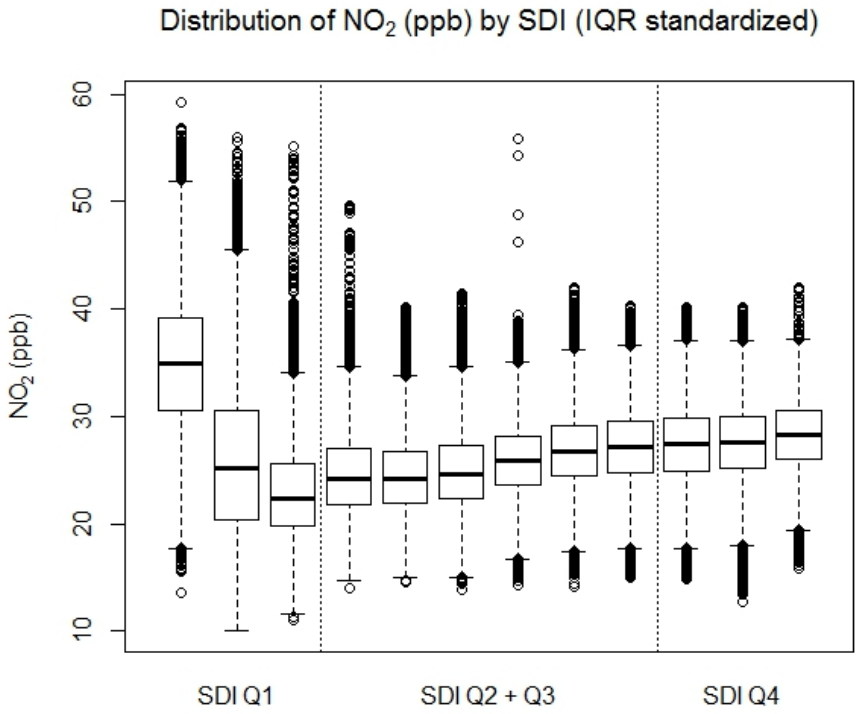
Incorporating Social/ Psychosocial Measures into Environmental Epidemiology

- Differential misclassification
  - Annual-average social indicators vs. daily air pollution
  - Different spatial resolution (e.g., near-roadway vs. community)
- (Non-linear) joint distributions
  - Complicates interactions/ interpretability
- Pollutant sources as stressors (Forsberg 1997)
- Relative Temporality:
  - Modifier needs to precede pollutant exposure, to alter effects.
  - Perception-based stress measures may vary with prior stress.

Joint Distribution between SEP and pollution



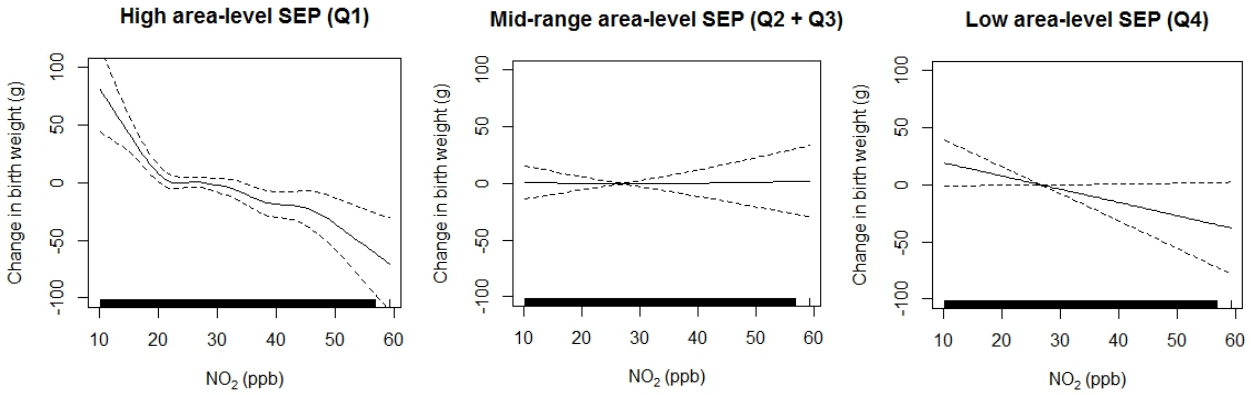




Map credit: Grant Pezeshki, NYCCAS team,
New York City Department of Health and Mental Hygiene

Shmool et al., *Environ Health* 2014;
Environ Res 2015

Modification in NO_2-birth weight association by SEP (deprivation)



Shmool et al, *Environ Res, 2015*

Acknowledgments

SOT Risk Assessment Specialty Section (RASS)
International Society for Exposure Science (ISES)

Collaborators & Contributors:

- Harvard T.H. Chan School of Public Health:
  - LD Kubzansky, JI Levy, JD Spengler
- Mt. Sinai School of Medicine: P Sheffield
- University of Pittsburgh/ UPMC:
  - F Holguin
- WE ACT for Environmental Justice NYC:
  - P Shepard, O Dotson-Newman, E Joseph
- Clougherty lab (Drexel & University of Pittsburgh):
  - Jessie LC Shmool, MPH, DrPH
  - S Gillooly, MPH
  - Isaac Johnson
  - Ellen Kinnee, MS MPH
  - Sheila Tripathy, DrPH

- Health Effects Institute (HEI): Susceptibility to Multiple Air Pollutants in Cardiovascular Disease (Clougherty)
- NIH 1R01HL114536-01: Validating GIS-based methods to address spatial uncertainty in clinical trials (Clougherty/ Holguin)
- EPA-G2009-STAR-E-2: Community Stressors and Susceptibility to Air Pollution in Urban Asthma (Clougherty)
- NIH 1 R21 ES021429-01: Children's Health and Vulnerability to Heat and Ozone in New York City (Sheffield/ Clougherty)
- NIH 5 R01 ES19955-3: Air Pollution and Pregnancy Outcomes in New York City (Savitz)
- UCSUR Manners Faculty Development Award: Social Stressors, Air Pollution, and Cancer across Allegheny County, PA (L Robertson)
- CRDF Faculty Development Award 2011: Developing a GIS-based survey instrument to examine multiple exposures in neighborhood health research (Clougherty)
- UCSUR Manners Faculty Development Award 2011: A novel geospatial modeling technique to predict individual-level chronic stress in urban communities (Clougherty)

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Thank you!

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