Day 2−*Tues 5 May*

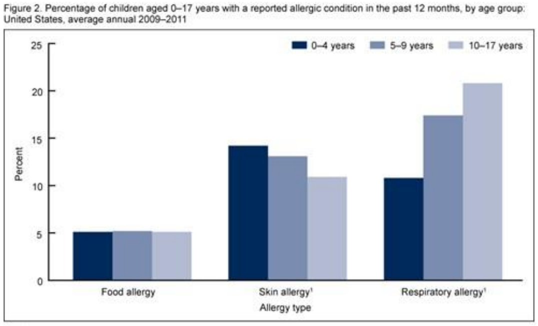
Greenspace and Health

Greenspace and Allergic / Respiratory Disease

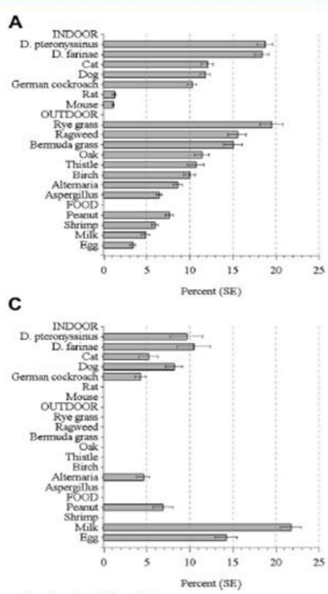
Background: Allergic Disease

- Characterized by specific IgE production against allergens
  - HDM, pets cockroach, *grass, trees, ragweed*
- Runny, stuffy nose, itchy eyes, red/watery eyes, sneezing
- Closely linked to respiratory disease / asthma

Figure 2. Percentage of children aged 0–17 years with a reported allergic condition in the past 12 months, by age group: United States, average annual 2009–2011



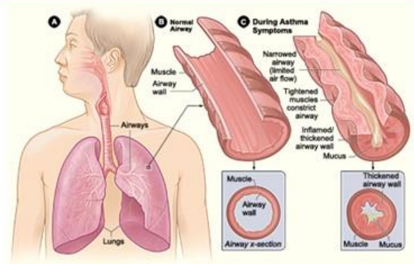
[1]Significant trend by age group.
SOURCE: CDC/NCHS, Health Data Interactive, National Health Interview Survey.



A. Age 6+, C. Age 1-5
Salo et al. J Allergy Clin Immunol. 2014;134:350-9.

Background: Asthma

- Chronic inflammatory disorder of the airways associated with periods of reversible airflow obstruction (i.e. asthma attacks)
  - Airflow obstruction caused by inflammation and airway hyper responsiveness caused by contraction of the airway smooth muscle
  - Wheezing, shortness of breath, chest tightness, and cough
  - Triggers include: tobacco smoke, indoor allergens (e.g dust mites, cockroaches, pets), infections, exercise, weather, *outdoor air pollution, outdoor allergens*
- Prevalence (US: 2008-2010)
  - 0-17: 9.5%
    - Male-11%, Female-8%
    - White-8%, Black-16%
  - 18+: 7.7%
    - Male–6%, Female–10%



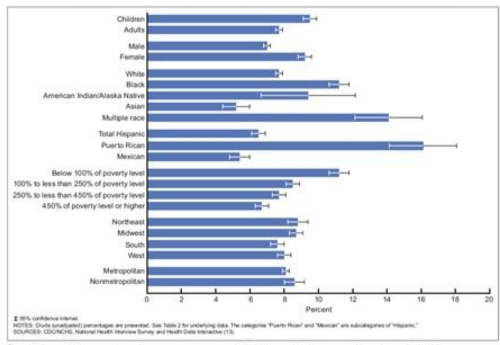
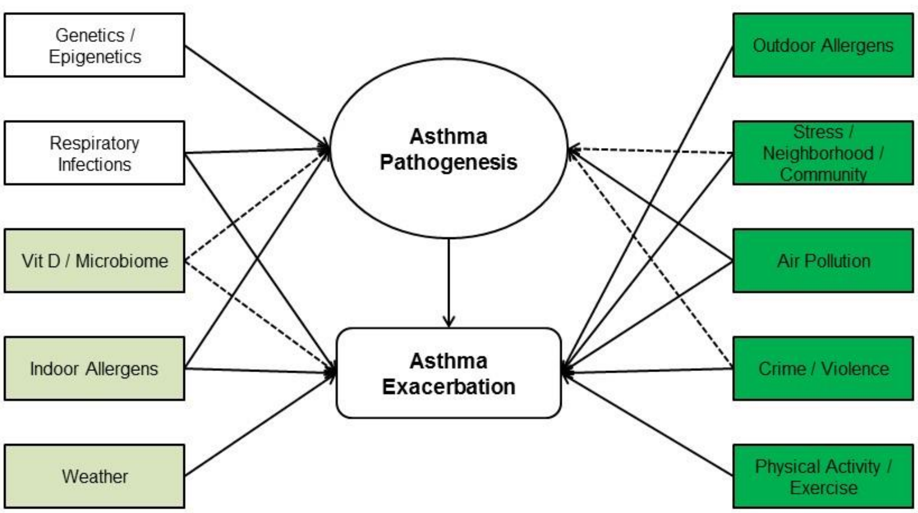


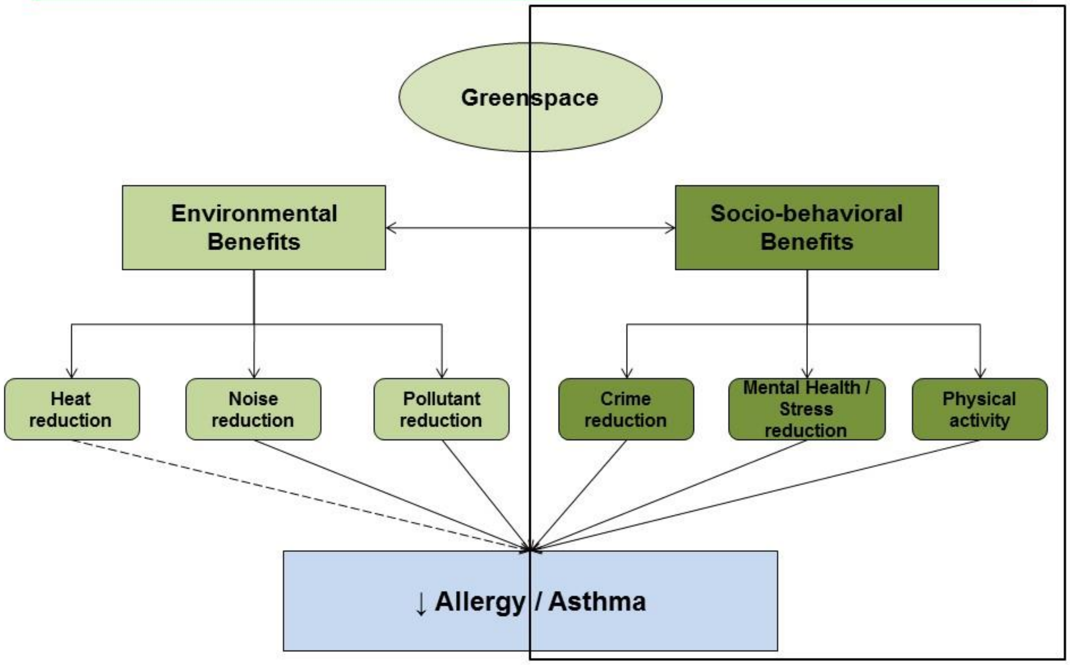
Figure 2. Current asthma prevalence, by age group, sex, race and ethnicity, poverty status, geographic region, and urbanicity: United States, average annual 2008–2010

Moorman JE, et al. National Center for Health Statistics. Vital Health Stat 3(35).2012.

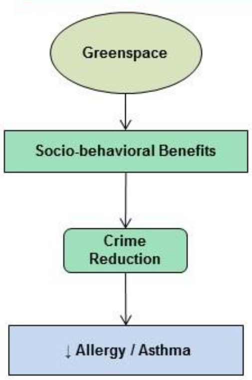
Greenspace and Asthma (Overly Simplified)



Greenspace: Potential Beneficial Pathways for Allergic / Respiratory Disease



Greenspace, Crime, and Allergic / Respiratory Disease



The association between community crime and childhood asthma prevalence in Chicago

Ruchi S. Gupta, MD, MPH*†; Xingyou Zhang, PhD‡; Elizabeth E. Springston, AB†; Lisa K. Sharp, PhD§; Laura M. Curtis, MS*; Madeline Shalowitz, MD, MBA¶; John J. Shannon, MD‖; and Kevin B. Weiss, MD, MPH*#

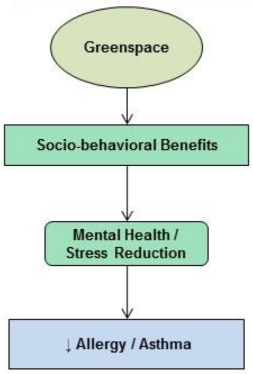
Ann Allergy Asthma Immunol. 2010;104:299–306.

Table 3. Odds of Chicago Schoolchildren Being Diagnosed with Asthma Based on the Incidence of Crime in Their Neighborhood

Variable	Likelihood of Asthma, OR (95% CI)		
	Unadjusted	Adjusted without including race/ethnicity[a]	Adjusted including race/ethnicity[b]
Total crime[c]			
High vs low	1.73 (1.48–2.03)[d]	1.49 (1.26–1.76)[d]	1.16 (0.98–1.37)
Moderate vs low	1.44 (1.28–1.62)[d]	1.33 (1.19–1.48)[d]	1.08 (0.96–1.20)
Violent crimes[e]			
High vs low	2.03 (1.76–2.34)[d]	1.83 (1.52–2.20)[d]	1.27 (1.04–1.55)[f]
Moderate vs low	1.41 (1.26–1.57)[d]	1.35 (1.21–1.51)[d]	1.15 (1.02–1.29)[f]
Property crimes[g]			
High vs low	1.56 (1.32–1.84)[d]	1.37 (1.17–1.60)[d]	1.09 (0.93–1.26)
Moderate vs low	1.45 (1.28–1.63)[d]	1.32 (1.18–1.47)[d]	1.08 (0.97–1.20)
Drug abuse violations[h]			
High vs low	1.81 (1.56–2.11)[d]	1.51 (1.25–1.82)[d]	1.14 (0.96–1.35)
Moderate vs low	1.32 (1.17–1.49)[d]	1.23 (1.08–1.41)[d]	0.11 (0.99–1.24)

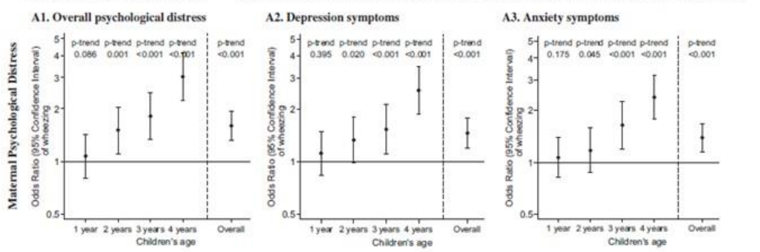
Abbreviations: CI, confidence interval; OR, odds ratio.
[a] Adjusted for age, sex, household member with asthma, and socioeconomic status.
[b] Adjusted for age, sex, household member with asthma, socioeconomic status, and race/ethnicity.
[c] Annual incidence per population of 100,000: high, >6352; moderate, ≤6352 and >3077; and low, ≤3077.
[d] $P<.001$.
[e] Annual incidence per population of 100,000: high, >1772; moderate, ≤1772 and >452; and low, ≤452.
[f] $P<.05$.
[g] Annual incidence per population of 100,000: high, >4766; moderate, ≤4766 and >2440; and low, ≤2440.
[h] Annual incidence per population of 100,000: high, >2707; moderate, ≤2707 and >344; and low, ≤344.

Greenspace, Stress, and Allergic / Respiratory Disease

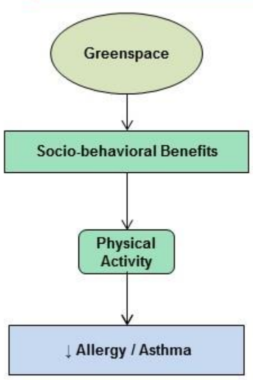


Parental psychological distress during pregnancy and wheezing in preschool children: The Generation R Study

Mònica Guxens, MD, MPH, PhD,[a,b,c,d] Agnes M. M. Sonnenschein–van der Voort, MSc,[a,e,f] Henning Tiemeier, MD, PhD,[f,g] Albert Hofman, MD, PhD,[f] Jordi Sunyer, MD, PhD,[b,c,h] Johan C. de Jongste, MD, PhD,[e] Vincent W. V. Jaddoe, MD, PhD,[a,f,i] and Liesbeth Duijts, MD, PhD[e,f,i] *Rotterdam, The Netherlands, and Barcelona, Spain* Allergy Clin Immunol 2014;133:59-67.)



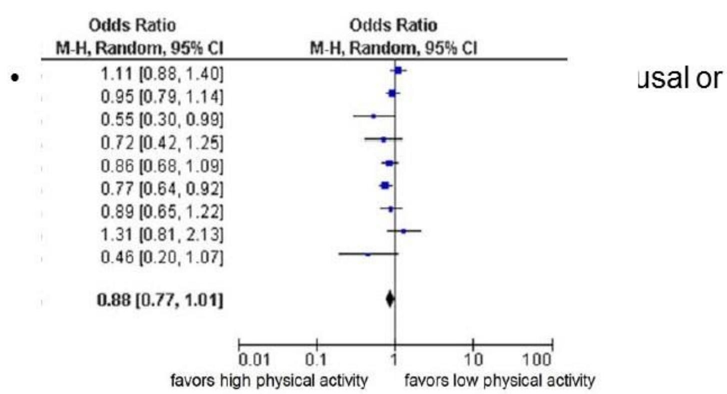
Greenspace, Physical Activity, and Allergic / Respiratory Disease



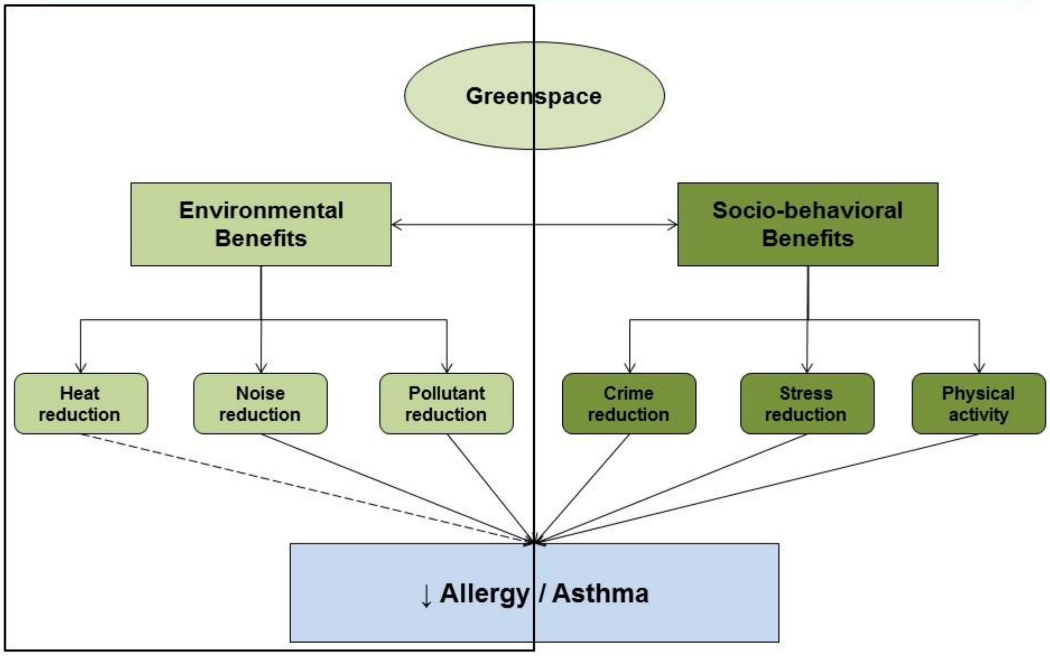
Physical Activity and Asthma: A Systematic Review and Meta-Analysis

Marianne Eijkemans[1,2]*, Monique Mommers[2], Jos M. Th. Draaisma[1], Carel Thijs[2], Martin H. Prins[2]

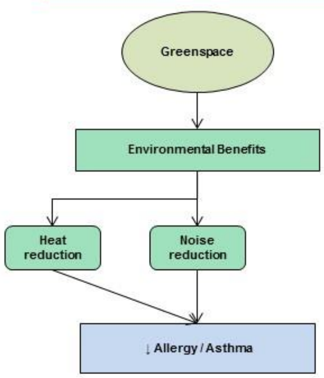
Citation: Eijkemans M, Mommers M, Draaisma JMTh, Thijs C, Prins MH (2012) Physical Activity and Asthma: A Systematic Review and Meta-Analysis. PLoS ONE 7(12): e50775. doi:10.1371/journal.pone.0050775



Greenspace: Potential Beneficial Pathways for Allergic / Respiratory Disease



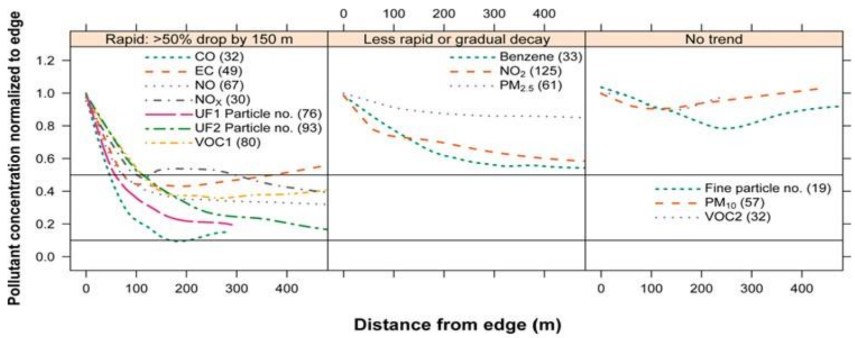
Greenspace, Noise, Heat, and Allergic / Respiratory Disease



- Noise and asthma
  - Greenspace (trees and shrubs) may reduce noise by 5-10 db / 30m
  - Lack of studies designed to examine noise associated with asthma
    - Activation of stress pathway?
- Heat and asthma
  - Greenspace ↓ temperatures
  - Heat – asthma link less clear
    - Indirect pathway through ozone production

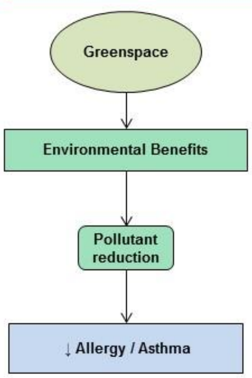
Greenspace, Air Pollutants, and Allergic / Respiratory Disease

- Traffic-Related Air Pollution (TRAP)
  - PM, NOx, PAHs, EC, Metals
  - Significantly elevated near roadways
- Traffic-related air pollutants causally associated with asthma exacerbation
  - Hospitalization, medication use, symptoms, lung function
- TRAP ‘usually’ associated with new-onset asthma



Karner et al. 2010

Greenspace and Air Pollutants



Surrounding Greenness and Exposure to Air Pollution During Pregnancy An Analysis of Personal Monitoring Data

Payam Dadvand,[1,2,3] Audrey de Nazelle,[1,2,3] Margarita Triguero-Mas,[1] Anna Schembari,[1,2,3,4] Marta Cirach,[1] Elmira Amoly,[4] Francesc Figueras,[5] Xavier Basagaña,[1,2,3] Bart Ostro,[1,6] and Mark Nieuwenhuijsen[1,2,3]

VOLUME 120 | NUMBER 9 | September 2012 • Environmental Health Perspectives

Table 2. Regression coefficients (95% CIs) of change in personal exposure and microenvironmental pollutant levels (μg/m³) associated with an IQR[a] increase in the average NDVI within the buffers of 100 m, 250 m, and 500 m around maternal residential addresses.

	Surrounding greenness					
	100-m buffer		250-m buffer		500-m buffer	
Measurements	Regression coefficient (95% CI)	*p*-Value	Regression coefficient (95% CI)	*p*-Value	Regression coefficient (95% CI)	*p*-Value
Personal (unadjusted)						
$PM_{2.5}$	–5.2 (–9.4, –0.9)	0.02	–2.4 (–5.0, 0.1)	0.06	–2.8 (–5.8, 0.3)	0.08
NO_x	–2.6 (–15.3, 10.1)	0.68	–2.3 (–9.7, 5.1)	0.54	–3.2 (–12.4, 6.0)	0.49
Personal (adjusted)[b]						
$PM_{2.5}$	–5.9 (–10.0, –1.8)	< 0.01	–2.4 (–4.8, 0.0)	0.05	–2.3 (–5.1, 0.5)	0.11
NO_x	–5.1 (–18.6, 8.4)	0.45	–3.0 (–10.7, 4.6)	0.43	–3.6 (–12.9, 5.7)	0.44
Home-indoor[c]						
$PM_{2.5}$	–6.1 (–10.6, –1.6)	< 0.01	–1.9 (–4.6, 0.8)	0.17	–2.3 (–5.5, 0.9)	0.15
NO_x	–9.5 (–24.4, 5.3)	0.20	–4.5 (–13.3, 4.2)	0.31	–6.7 (–17.3, 3.9)	0.21
Home-outdoor[d]						
$PM_{2.5}$	–4.4 (–9.5, 0.7)	0.08	–3.2 (–6.6, 0.2)	0.07	–5.5 (–10.5, –0.4)	0.04
NO_x	–5.8 (–17.6, 6.0)	0.33	–5.3 (–14.0, 3.4)	0.23	–5.6 (–19.5, 8.3)	0.43

[a]0.049 for 100 m buffer, 0.031 for 250 m buffer, and 0.042 for 500 m buffer. [b]Adjusted for the time spent at home (sum of time spent at home-indoor and home-outdoor), smoking (active and passive), use of gas-cooking appliances, time spent in transfer, and MEDEA index of neighborhood deprivation. [c]Adjusted for the temperature at home-indoors on the first day of sampling round, the use of gas-cooking appliances, smoking (active and passive), the number of inhabitants, and MEDEA index of neighborhood deprivation. [d]Adjusted for the traffic intensity in the buffer of 100 m around maternal residential address, the height of the monitor, and MEDEA index of neighborhood deprivation.

Unadjusted		− 8.1 (− 13.6, −2.6)	<0.01	− 13.9 (− 19.4, −8.4)	<0.01
Adjusted[d]		− 9.0 (− 13.8, −4.1)	<0.01	− 14.6 (− 19.4, −9.8)	<0.01
Black carbon ($\mu g \cdot m^{-3}$)	1.2 (0.8)				
Unadjusted		− 0.27 (− 0.45, −0.08)	<0.01	− 0.47 (− 0.65, −0.28)	<0.01
Adjusted[d]		− 0.30 (− 0.44, −0.16)	<0.01	− 0.46 (− 0.60, −0.32)	<0.01
Traffic-related $PM_{2.5}$ ($\mu g \cdot m^{-3}$)	5.0 (4.8)				
Unadjusted		− 1.2 (− 2.3, 0.0)	0.05	− 2.4 (− 3.6, − 1.2)	<0.01
Adjusted[d]		− 1.5 (− 2.5, −0.4)	<0.01	− 2.7 (− 3.9, − 1.6)	<0.01

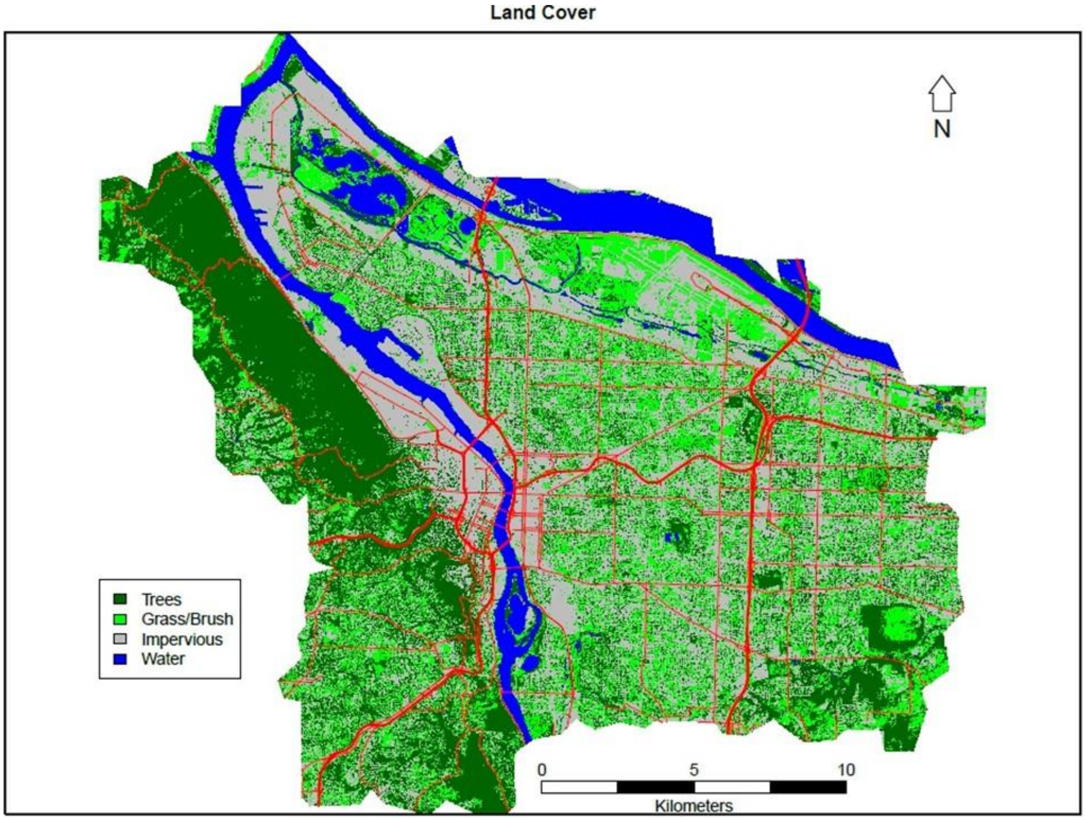
[a] 0.087 and 0.144 for greenness within and surrounding school boundaries respectively.

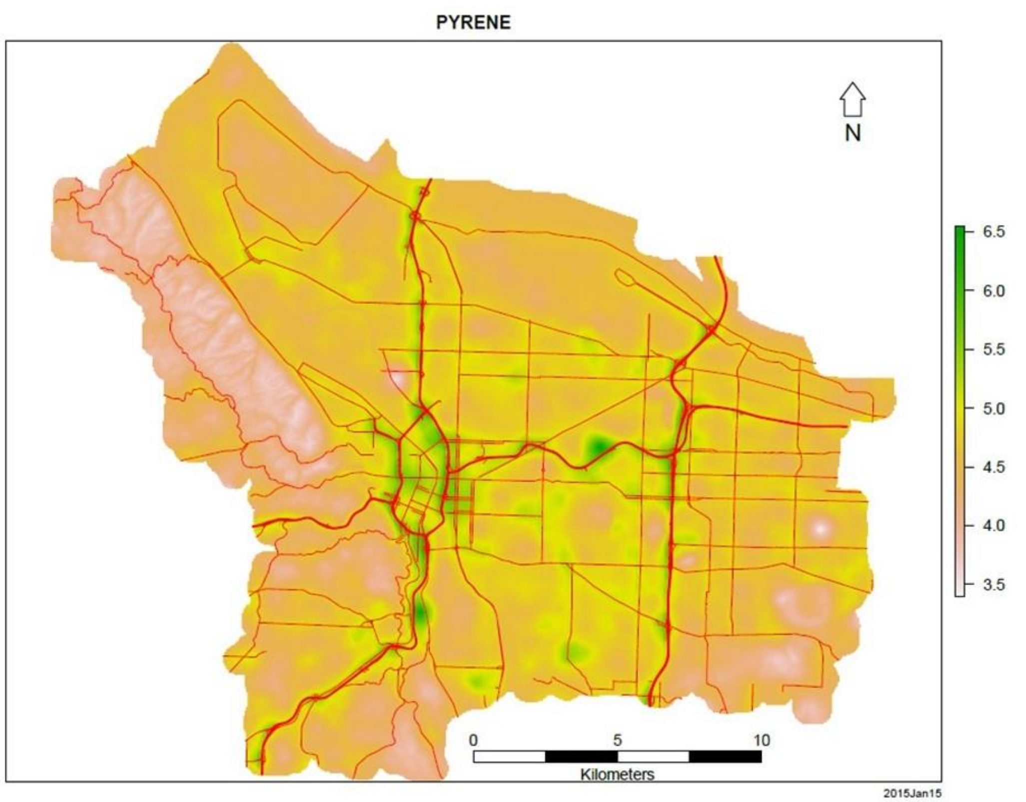
[b] Adjusted for weekly average of background level of that pollutant, meteorological indicators (temperature, humidity, and precipitation), monitor placement (floor and orientation), and school characteristics including building age and ventilation.

[c] Adjusted for weekly average of background level of that pollutant, meteorological indicators (temperature, humidity, and precipitation), monitor placement (floor and orientation), and traffic indicators (squared distance to the nearest major road, product of traffic intensity on the nearest road and inverse of distance to the nearest road, and total length of roads (all types) in a 1000 m buffer around the school).

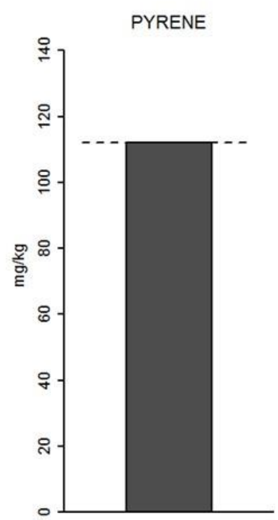
[d] Adjusted for weekly average of background level of that pollutant, meteorological indicators (temperature, humidity, and precipitation), monitor placement (floor and orientation), and traffic indicators (the product of traffic intensity on the nearest road and inverse of distance to the nearest road and total traffic load (all road types) in a 50 m buffer around the school).

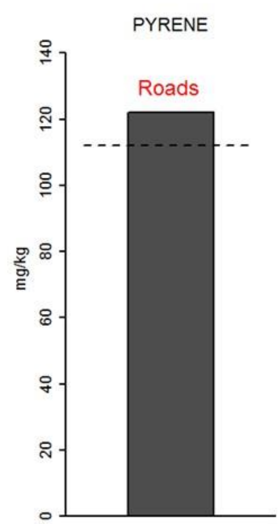
Day 2- Respiratory effects



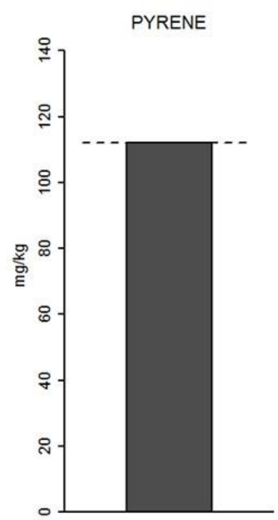


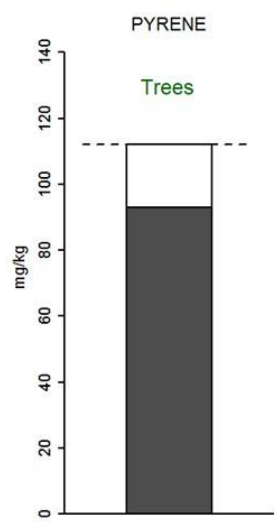
Day 2- Respiratory effects



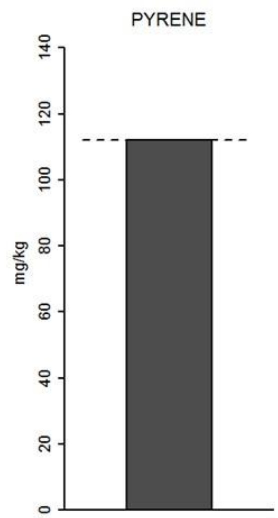


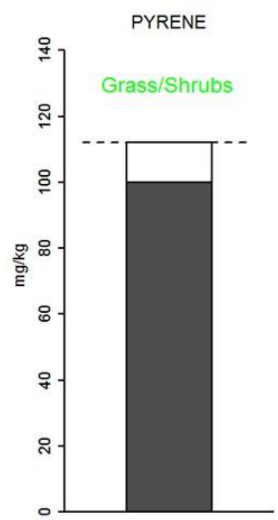
Day 2- Respiratory effects



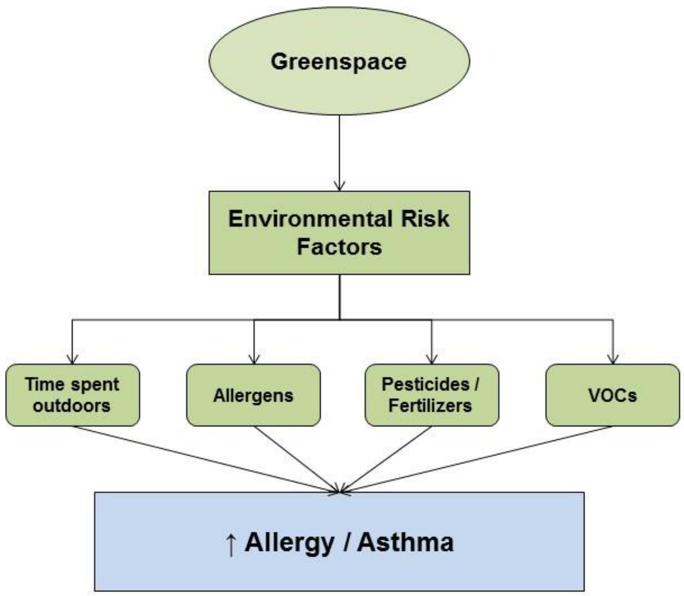


Day 2- Respiratory effects





Potential Deleterious Effects of Greenspace



Urban Tree Canopy and Asthma, Wheeze, Rhinitis, and Allergic Sensitization to Tree Pollen in a New York City Birth Cohort

Gina S. Lovasi,[1] Jarlath P.M. O'Neil-Dunne,[2] Jacqueline W.T. Lu, [3] Daniel Sheehan,[1,4] Matthew S. Perzanowski,[5] Sean W. MacFaden,[2] Kristen L. King,[3] Thomas Matte,[6] Rachel L. Miller,[5] Lori A. Hoepner,[5] Frederica P. Perera,[5] and Andrew Rundle[1] VOLUME 121 | NUMBER 4 | April 2013 · Environmental Health Perspectives

- Birth cohort (n = 288 – 427)
- Tree canopy characterized by LiDAR and multispectral imagery < 0.25 prenatal address

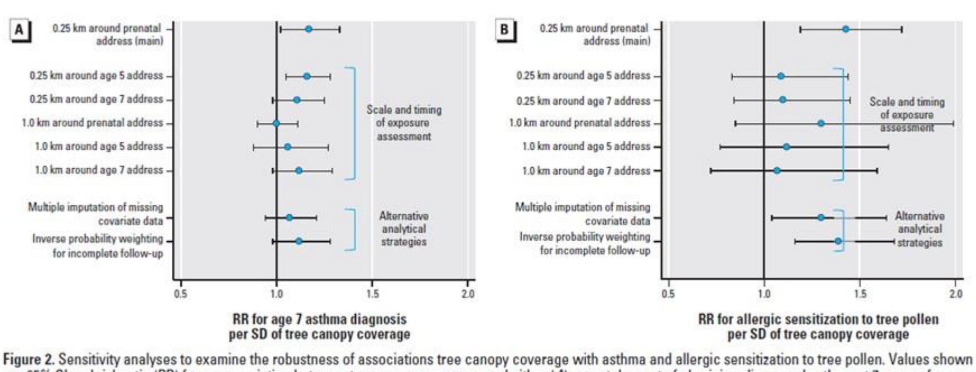


Figure 2. Sensitivity analyses to examine the robustness of associations tree canopy coverage with asthma and allergic sensitization to tree pollen. Values shown are 95% CI and risk ratio (RR) for an association between tree canopy coverage and either (*A*) parental report of physician-diagnosed asthma at 7 years of age or (*B*) allergic sensitization to tree pollen based on IgE testing from sensitivity analysis models adjusting for the following covariates: sex, age at the time of outcome measurement, ethnicity, maternal asthma, previous birth, other previous pregnancy, Medicaid enrollment, tobacco smoke in the home, active maternal smoking, and the following characteristics of 0.25-km buffers: population density, percent poverty, percent park land, and estimated traffic volume.

A modeling study of the impact of urban trees on ozone

David J. Nowak[a,*], Kevin L. Civerolo[b], S. Trivikrama Rao[b], Gopal Sistla[b], Christopher J. Luley[c], Daniel E. Crane[a] Atmospheric Environment 34 (2000) 1601–1613

- Trees produce VOCs, which can in turn increase ozone.
  - Varies by species (sweet gums are bad, for example) but minor compared to anthropogenic sources

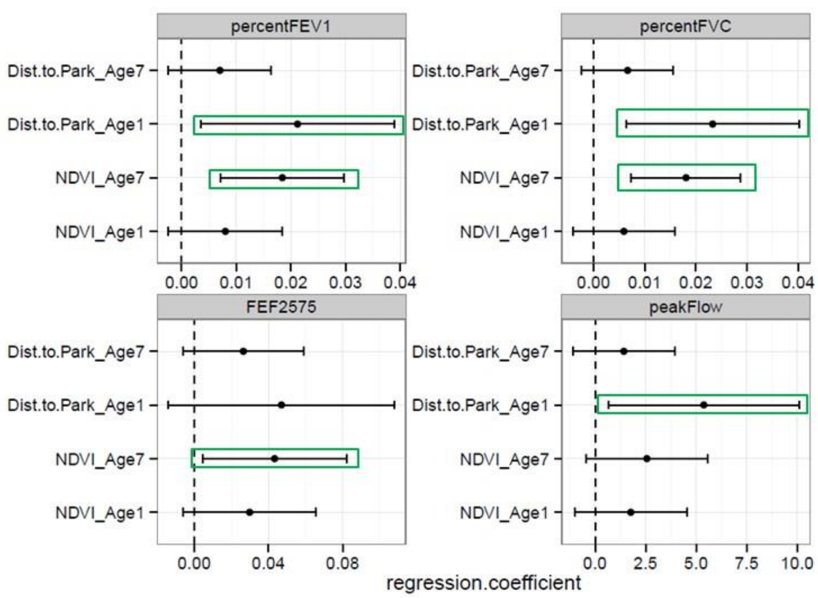
Greenspace and Allergic / Respiratory Disease in the CCAAPS Cohort

- Cincinnati Childhood Allergy and Air Pollution Study (CCAAPS)
  - Objective: Determine if children exposed to traffic-related air pollution, specifically diesel exhaust particles, are at increased risk for developing allergic diseases, asthma, and impaired neurobehavioral development
  - Longitudinal birth cohort study of infants born 2001-2003 in greater Cincinnati region
    - Eligibility: Birth record address < 400 m major road or > 1500 m from major road
    - Enrolled – 762; Age 7 – 617; Currently ongoing Age 12 - ~500

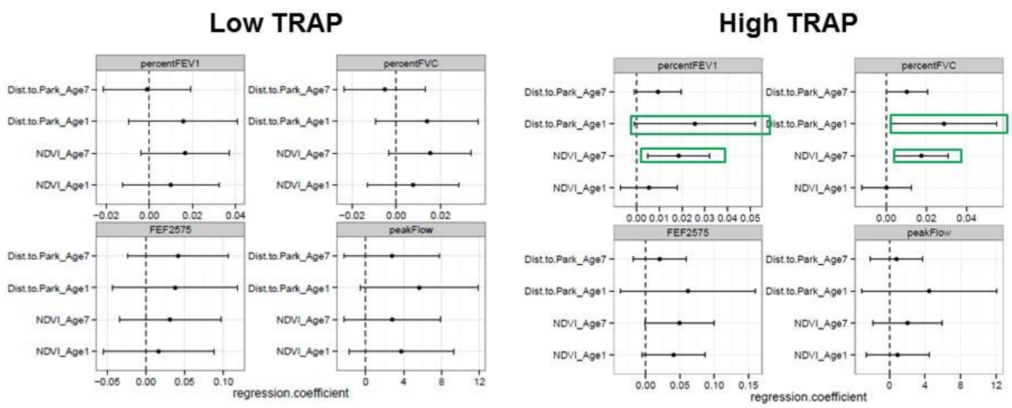
CCAAPS Methods

- Clinical evaluations
  - 1-4: Questionnaire, SPT, physical exam, hair, saliva, blood, eNO, spirometry
  - 7: All above + behavior
  - 12: All above + intelligence, reading ability, attention/inhibition, memory, executive function, neuromotor function, behavior, anxiety/depression, MRI (structure, organization, and function)
- Indoor exposure (1,7)
  - Walk-through, dust (allergens, mold, endotoxin)
- Outdoor exposure
  - PM2.5, EC
  - Land-use regression model

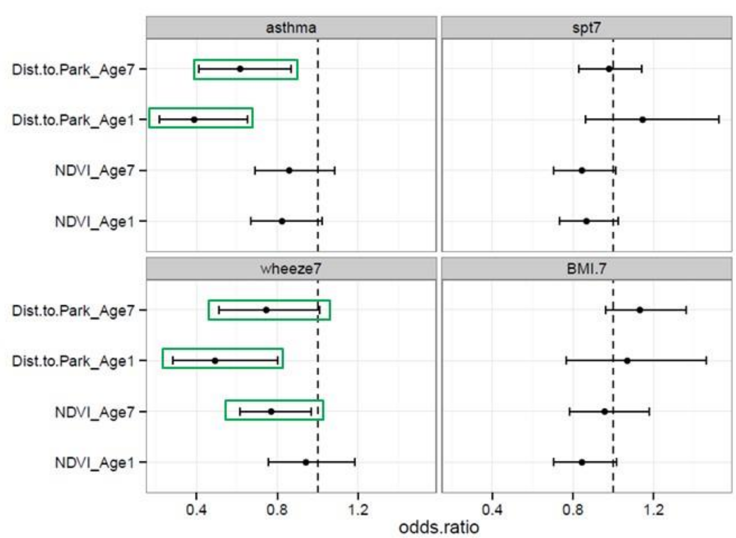
Greenspace and Parks and Lung Function in the CCAAPS Cohort



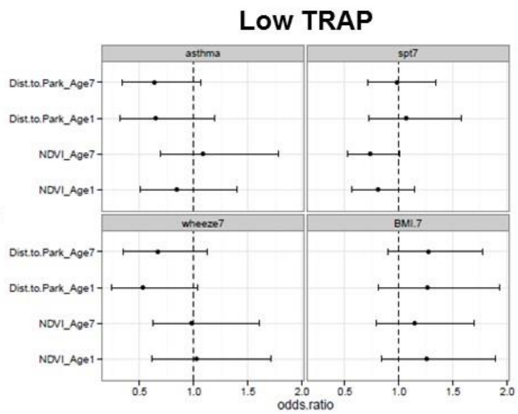
CCAAPS Preliminary Data: Greenspace, Traffic, and Lung Function



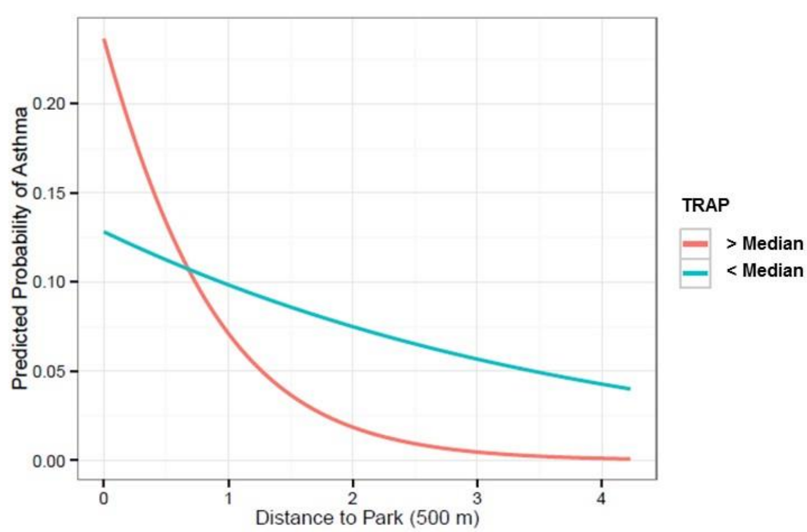
CCAAPS Preliminary Data: Greenspace, and Allergic / Respiratory Disease



CCAAPS Preliminary Data: Greenspace, Traffic, and Allergic/Respiratory Disease



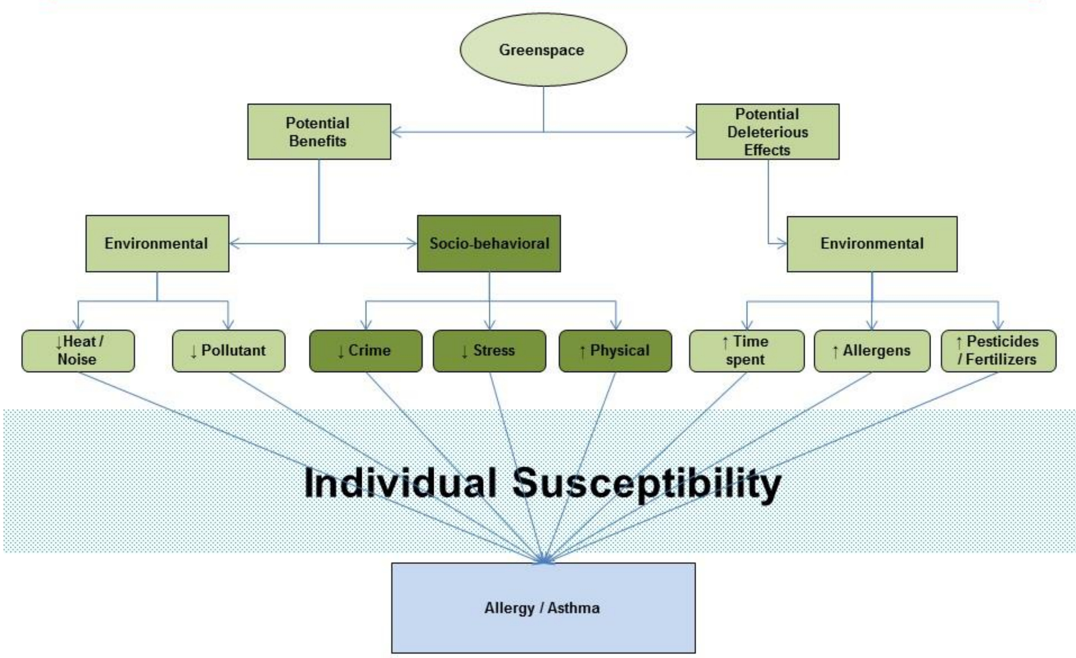
CCAAPS Preliminary Data: TRAP and Park Distance



Susceptible Populations

- Children
  - More time spent outdoors
  - More active → ↑ ventilation rates
  - Respiratory / immune system development begins prenatally and continues through adolescence
    - Prenatal - ~1-2 years especially important
- Elderly
  - Pre-existing conditions
- Socioeconomically disadvantaged
- Black / Puerto Rican
  - ↑ asthma prevalence and morbidity / mortality

Summary



Driving Questions

- How should cumulative risk assessment frameworks consider greenspace as it relates to respiratory health?
- What greenspace elements and metrics are relevant to respiratory health?
- What are the specific known or presumed mechanisms of respiratory health, and can this be used to inform biologic plausibility of reported associations with greenspace?
- Consideration of "active" vs. "passive" exposure pathways and health impacts—e.g. outdoor exercise (active) vs. visible greenspace around residence (passive)
- Considerations of community and individual level outcomes and specific populations

Reproductive Health

Reproductive Health

- Birth weight a major cause of neonatal and infant morality and influences health across the life course.
- Birth weight (and preterm birth and SGA) have been associated with several social and environmental exposures that may be related to greenspace.
  - Air pollution
  - Noise
  - Heat
  - Stress/depression
  - Social capital,
  - Etc…

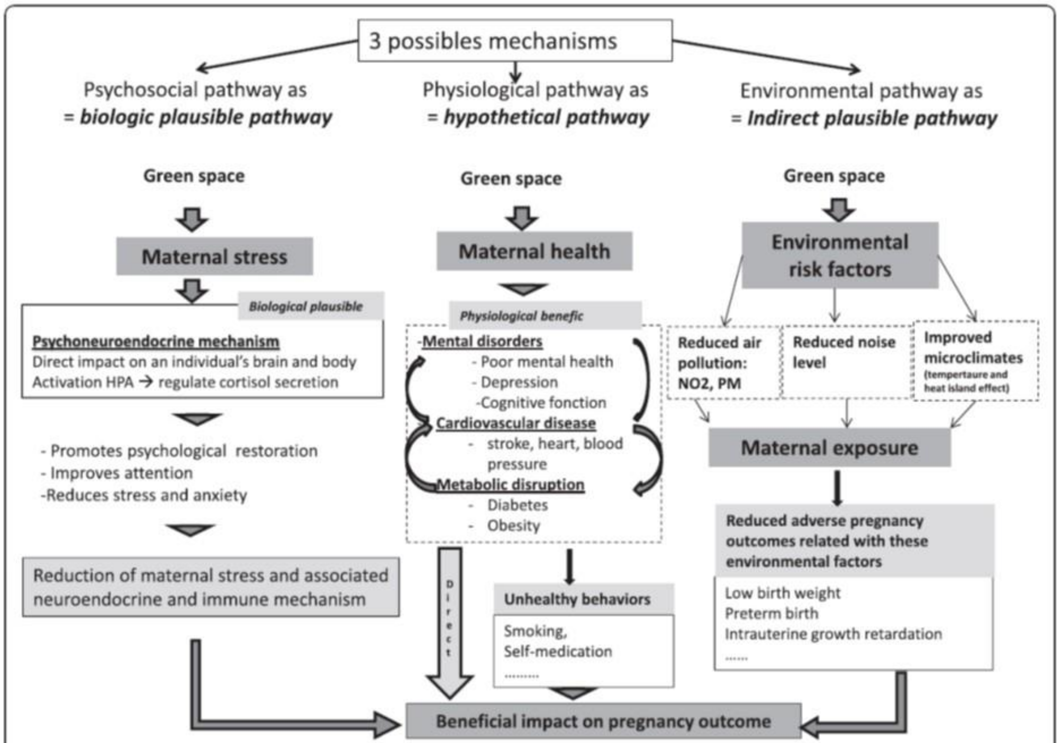


Figure 3 A conceptual model of mediating variables and their hypothesized association with pregnancy outcomes.

Green space, social inequalities and neonatal mortality in France http://www.biomedcentral.com/content/pdf/1471-2393-13-191.pdf

All *EHP* content is accessible to individuals with disabilities. A fully accessible (Section 508–compliant) HTML version of this article is available at http://dx.doi.org/10.1289/ehp.1308049.

Research | Children's Health

Residential Greenness and Birth Outcomes: Evaluating the Influence of Spatially Correlated Built-Environment Factors

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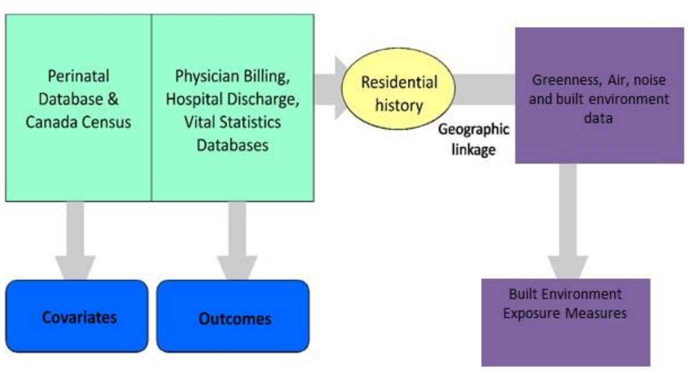
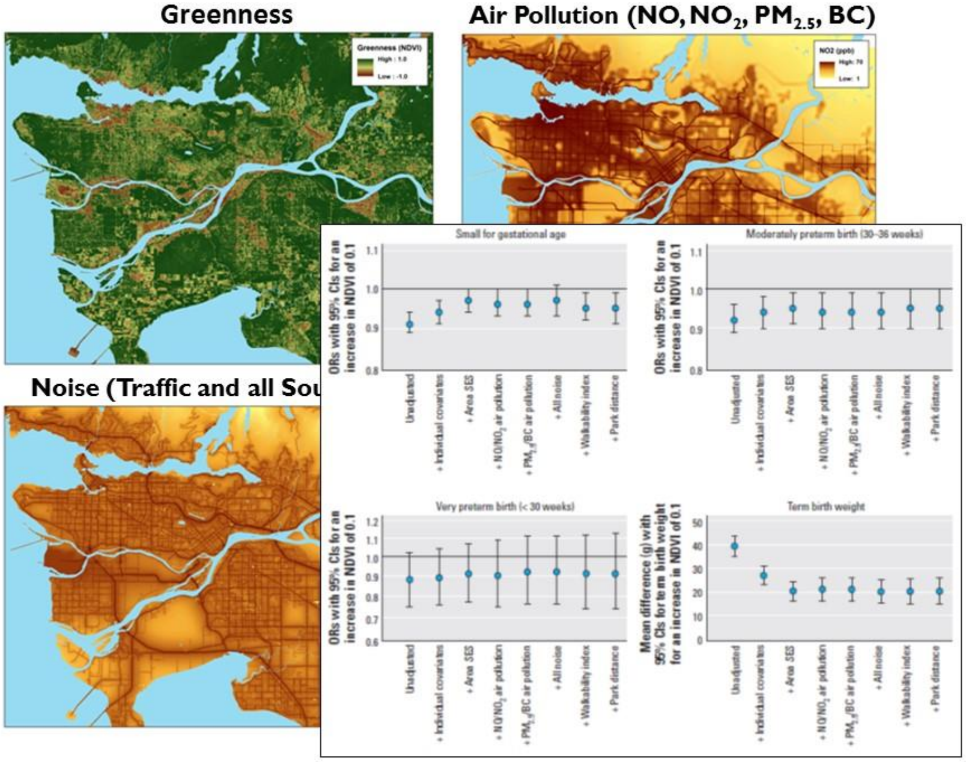
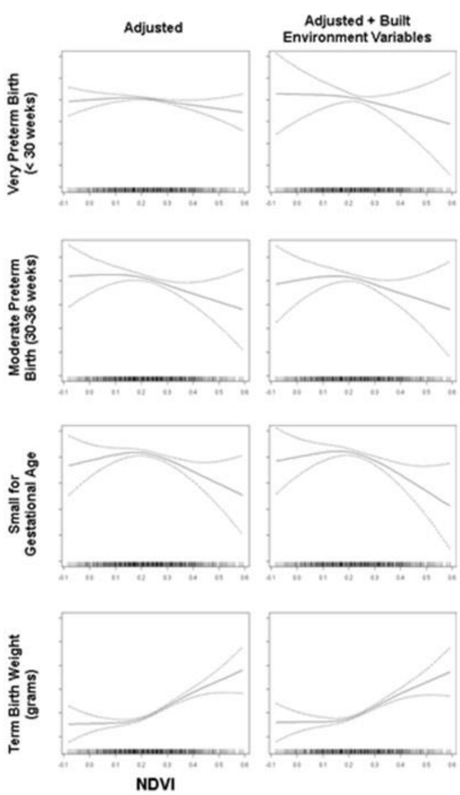
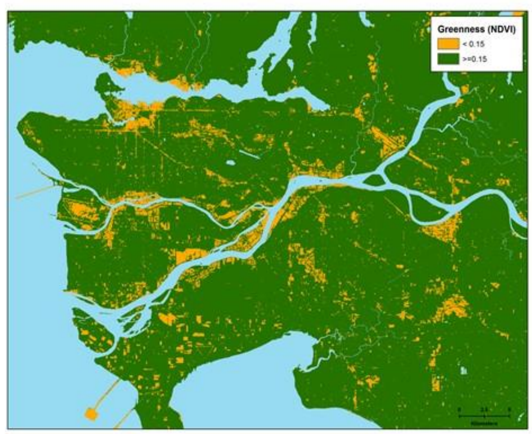


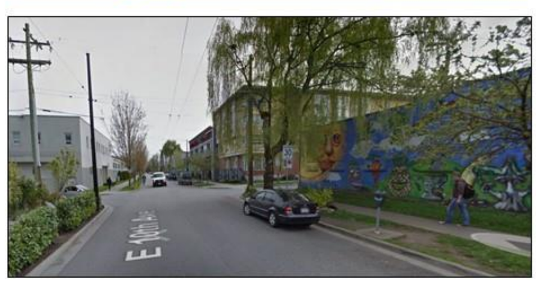
Birth cohort identified 92,158 children born in the Vancouver metropolitan area from 1999–2002.

Day 2- Reproductive effects









Urban trees and the risk of poor birth outcomes

Table 2
Multiple logistic regression of small for gestational age births (Portland, Oregon, 2006 and 2007, $n = 5295$).

Variable	Odds ratio	95% CI	*p*-value	Marginal effect per 1000 births
Total births	0.8466	0.7611–0.9418	0.0022	−10.3
Mother has no college education	1.4424	1.1267–1.8465	0.0037	25.3
Mother non-Hispanic white	0.6941	0.5580–0.8633	0.0010	−24.4
Percent canopy cover within 50 m	0.9902	0.9811–0.9993	0.0343	−1.42*
Distance to private open space (m)	1.0001	1.0000–1.0001	0.0178	−1.85**
McFadden *R*-squared	0.01853			

* For a 10% increase in canopy cover.
** For a 500 m reduction in distance (private open space consists of cemeteries, golf courses, private-school grounds, and community gardens).

Systematic Review and Meta-Analysis

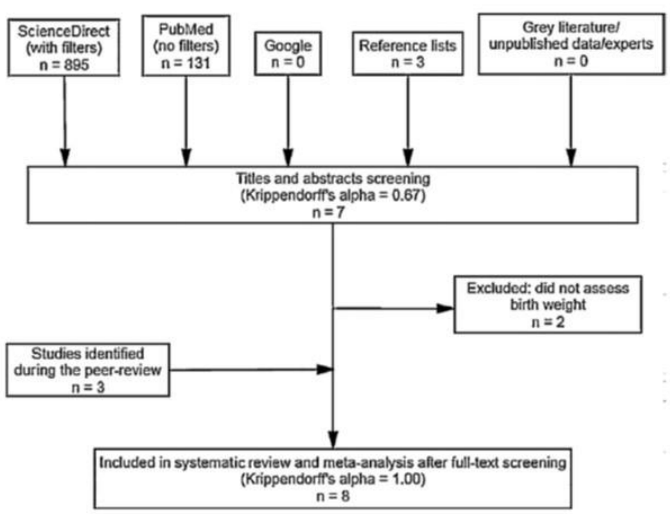


Fig. 1. Flow diagram of study selection and screening process.

Dzhambov A, Dimitrova D, Dimitrakova E. (2014). Association between residential greenness and birth weight: Systematic review and meta-analysis. Urban Forestry & Urban Greening 13 (2014) 621–629

Table 3
Meta-analysis results for 100-m buffer (standardized regression coefficients, quality effects model).

Study	β	LCI	UCI	Weight (%)
Dadvand et al. (2014)	0.004	0.0003	0.007	1.766
Dadvand et al. (2012a)	−0.001	−0.004	0.002	2.372
Dadvand et al. (2012b)	0.007	0.001	0.013	1.494
Markevych et al. (2014)	0.004	−0.001	0.008	1.591
Laurent et al. (2013)	0.0004	0.0001	0.001	58.728
Donovan et al. (2011)	0.005	0.0003	0.010	1.887
Agay-Shay et al. (2014)	0.002	0.001	0.002	16.872
Hystad et al. (2014)	0.003	0.003	0.004	15.790
Pooled β	0.001	−0.001	0.003	100.000
Heterogeneity statistics				
I^2	91.051	84.775	94.740	
Cochran's Q	78.221			
χ^2, P	0.0001			
Q-Index	10.812			

Note. LCI – Lower 95% CI; UCI – Upper 95% CI; β – standardized regression coefficient.

Systematic Review and Meta-Analysis Conclusions

- The pooled correlation coefficient was 0.049 (95% CI: 0.039,0.059) and the pooled standardized regression coefficient was 0.001 (95%CI: −0.001, 0.003).
- "exposure-response" approach towards urban greenness is an oversimplification.
- Need for more theory-driven studies focusing prospectively on a smaller population of pregnant women (rather than extracting data from large populations).

- *Additional studies published since meta-analysis demonstrating association with birth weight.*
- *Mixed evidence for greenspace and gestational age, PTB and VPTB.*

Table 1 Strength of evidence for greenness and health outcomes

Outcome	Study designs	Setting	Findings	Strength of evidence
Physical activity	15 cross-sectional studies [26•, 27, 28, 33-43, 45] 1 prospective study [44]	4 studies in the USA, 6 in the UK, 2 in France, 1 each in Australia, Netherlands, New Zealand, and Spain	Consistent evidence of positive association between greenness and physical activity. Few prospective studies.	I/II
Overweight/ obesity	10 cross-sectional studies [19, 43, 46-49, 51-54] 1 prospective study [50]	3 studies in the USA, 2 in the UK, 2 in Canada, 1 each in Australia, Denmark, Egypt, and Spain	Some evidence of negative association between greenness overweight/obesity, though findings (especially among children) were mixed. Possible effect modification by gender. Few prospective studies.	II
Mental health	11 cross-sectional studies [20, 22•, 23, 56, 58-61, 63-65] 3 prospective studies [57, 66, 67]	4 studies in the UK, 2 in Netherlands, 2 in the USA, 1 each in Australia, Canada, Denmark, New Zealand, Spain, and Sweden	Suggestive protective effect of greenness on self-reported mental health. More prospective studies needed.	II
Birth and developmental outcomes	6 birth cohort studies [31•, 68, 69, 71-73] 2 cross-sectional studies of allergies and asthma and hyperactivity [21, 32, 43].	2 studies in Spain, 2 studies in Germany, 1 each in Canada, France, Israel, and the UK	Consistent evidence of a positive relationship between residential greenness exposure and birth weight. Possible effect modification by SES. Findings for other birth and developmental outcomes require further evidence.	I/II
Cardiovascular outcomes	2 experimental studies [83, 84] 3 ecological studies [16, 78, 79] 3 cross-sectional studies [62, 80, 81] 1 prospective cohort study [82•]	4 studies in the UK, 1 each in the USA, Netherlands, Germany, Australia, and Canada	Consistent evidence of higher greenness and lower cardiovascular disease; however, most studies are ecological and cross-sectional. One prospective study could not account for individual-level smoking.	II/III
Mortality	3 prospective studies [82•, 85, 87] 5 ecological studies [16, 78, 79, 86, 88]	3 studies in the UK, 2 studies in the USA, 1 each in Japan, New Zealand, and Canada	Fairly consistent evidence of higher greenness and lower mortality; however, majority of studies are ecological. Two prospective studies were in specific subpopulations (elderly and stroke survivors). One prospective study could not account for individual-level smoking.	II

Strength of evidence definitions:

I = High: evidence is consistent, plausible, and precisely quantified and there is low probability of bias

II = Intermediate: evidence exists, but not entirely consistent, is not quantified precisely, or may be vulnerable to bias

III = Low: evidence is inconsistent, implausible, and/or may be vulnerable to bias severely limiting the value of the effect being described

James P, Banay R, Hart J, Laden F. (2015). A Review of the Health Benefits of Greenness. Curr Epidemiol Rep (2015) 2:131–142

Driving Questions

- How should cumulative risk assessment frameworks consider greenspace as it relates to reproductive health?
- What greenspace elements and metrics are relevant to reproductive health?
- What are the specific known or presumed mechanisms of reproductive health, and can this be used to inform biologic plausibility of reported associations with greenspace?
- Consideration of potential cumulative effect of greenness on reproductive health -- “active” + “passive” exposure pathways—e.g. outdoor exercise (active) and visible greenspace around residence (passive)
- Considerations of community and individual level outcomes and specific populations

Day 2- Obesity and physical activity

Obesity & Physical Activity

Matilda Annerstedt van den Bosch

Aaron Hipp

May 5, 2015

Estimating Greenspace Exposure & Benefits for Cumulative Risk Assessment Applications

Technical Working Group Meeting

May 4-5, 2015

U.S. Environmental Protection Agency

26 Martin Luther King Drive West, Cincinnati, OH 45220

1

Physical Activity (PA) & health outcomes

General effects

1. Antiinflammatory

Low grade inflammation causes/accelerates long term conditions (increased cytokines)

Exercise:

- muscles release antiinflammatory myokines
- loss of pro-inflammatory visceral fat rather than subcutaneous fat

2. Mitochondrial

Sedentary – mitochondria charges, free radicals – inflammation & aging

Exercise:

- Muscles need energy – reduced charging
- Stimulates autophagy – cleaning of cell cytoplasma

3. Weight loss

Obesity – metabolic syndrome – cardiovascular & chronic kidney diseases

Exercise:

- 250 minutes/week – weight loss
- Lowered BMI – 10% of the health effects of physical activity

Source: BMJ Learning

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Physical Activity (PA) & health outcomes

Organ and disease specific effects

- ✓**Cardiovascular:** reduce fibrinogen and inflammatory response, increase HDL, reduce blood pressure and pulse rate, increase stroke volume
- ✓**Musculoskeletal:** stabilize joints, increase stability and balance, prevents osteoarthiritis, builds up cartilage
- ✓**Brain:** reduce anxiety, depression and dementia, increase memory and learning, induce neuron growth
- ✓**Immune system:** increased number of Natural Killer (NK) cells – tumor suppression
- ✓**Cancer:** Positive hormonal effects (delays menarche, reduced oestrogen & progestersone, increased insulin resistance), decreased cell proliferation, increased cellular antioxidants, increased NK-cells
- ✓**Diabetes:** increased insulin sensitivity, increased number of mitochondria – manufacture antioxidants

Source: BMJ Learning 3

Physical inactivity

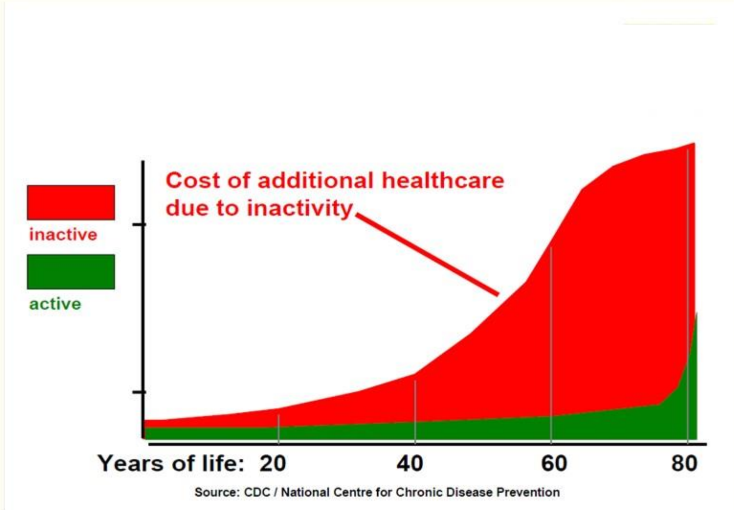
The fourth leading risk factor for premature death globally

Causes more deaths than smoking

World Health Organization, 2010

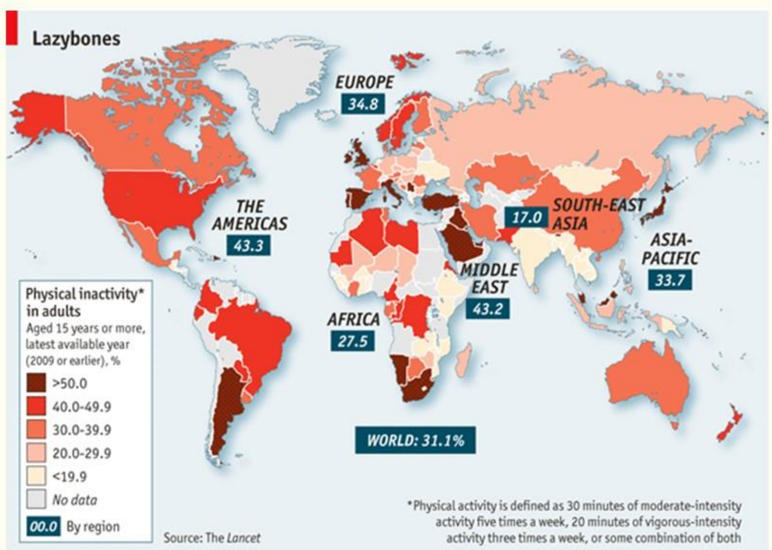
Disease	Risk reduction	Strength of evidence
Death	20-35%	Strong
CHD and Stroke	20-35%	Strong
Type 2 Diabetes	35-40%	Strong
Colon Cancer	30-50%	Strong
Breast Cancer	20%	Strong
Hip Fracture	36-68%	Moderate
Depression	20-30%	Strong
Hypertension	33%	Strong
Alzheimer's Disease	20-30%	Moderate
Functional limitation, elderly	30%	Strong

Day 2- Obesity and physical activity



5

At least UK is worse….



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Choose your place

- PA (with increased breathing rate) in urbanised areas may be hazardous due to environmental stressors (e.g. air pollution, noise)
- Inside a car you're protected from those stressors…
- Biking along a frequent road depletes the positive cognitive effects of PA
- Makes the case for parks, but not street trees

Ref: Vlachokostas et al. 2014; McNabola et al. 2007; de Nazelle et al. 2012

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GS and PA

- Proximity to urban parks is correlated to higher levels of PA
- Some studies have shown a correlation between larger size (> 5 ha) of GS and PA
- But different features attract different user groups (e.g. life course perspective)
- Shape of association may be more important than magnitude
- No thresholds or benchmarking exist

Ref: Gomez et al. 2010; Sugiyama et al. 2010; Giles-Corti et al. 2005, 2013; Koohsari et al. 2013, Schipperijen et al. 2013; Konijendijk et al. 2013

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What is the evidence for health benefits from urban parks?

Konijnendijk, Annerstedt et al. 2013.
Benefits of Urban Parks - A Systematic Review, IFPRA.

Ifpra

Suggested mechanisms

- Distraction
- Sustained effect
- Play and sports
- Shade encourages walking and active transport

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GPS, accelerometer, NDVI

Community design (Smart Growth)

34-39% increased OR of MVPA for NDVI increase of 0.11 (10^{th} to 90^{th} percentile increase in GS exposure)
Stronger association in Smart Growth communities
> 20 min GS exposure – 5 times the rate of MVPA of children with 0 exposure

Health & Place 18 (2012) 46–54

Contents lists available at SciVerse ScienceDirect

Health & Place

journal homepage: www.elsevier.com/locate/healthplace

A study of community design, greenness, and physical activity in children using satellite, GPS and accelerometer data

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ABSTRACT

This study examined relationships between greenness exposure and free-living physical activity behavior of children in smart growth and conventionally designed communities. Normalized Difference Vegetation Index (NDVI) was used to quantify children's ($n=208$) greenness exposure at 30-s epoch accelerometer and GPS data points. A generalized linear mixed model with a kernel density smoothing term for addressing spatial autocorrelation was fit to analyze residential neighborhood activity data. Excluding activity at home and during school-hours, an epoch-level analysis found momentary greenness exposure was positively associated with the likelihood of contemporaneous moderate-to-vigorous physical activity (MVPA). This association was stronger for smart growth residents who experienced a 39% increase in odds of MVPA for a 10th to 90th percentile increase in exposure to greenness (OR = 1.39, 95% CI 1.36–1.44). An individual-level analysis found children who experienced > 20 min of daily exposure to greener spaces (> 90th percentile) engaged in nearly 5 times the daily rate of MVPA of children with nearly zero daily exposure to greener spaces (95% CI 3.09–7.20).

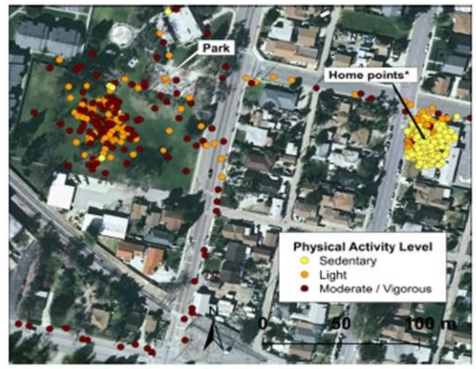

Fig. 1. Geovisualization of a child's personal monitoring points show MVPA occurring within green areas and during active transport (* home points shifted for confidentiality).

Limited Intervention Research

Social Science & Medicine 124 (2015) 246–256

Contents lists available at ScienceDirect

Social Science & Medicine

journal homepage: www.elsevier.com/locate/socscimed

Review

The impact of interventions to promote physical activity in urban green space: A systematic review and recommendations for future research

Ruth F. Hunter[a,*], Hayley Christian[b], Jenny Veitch[c], Thomas Astell-Burt[d,e], J.Aaron Hipp[f], Jasper Schipperijn[g]

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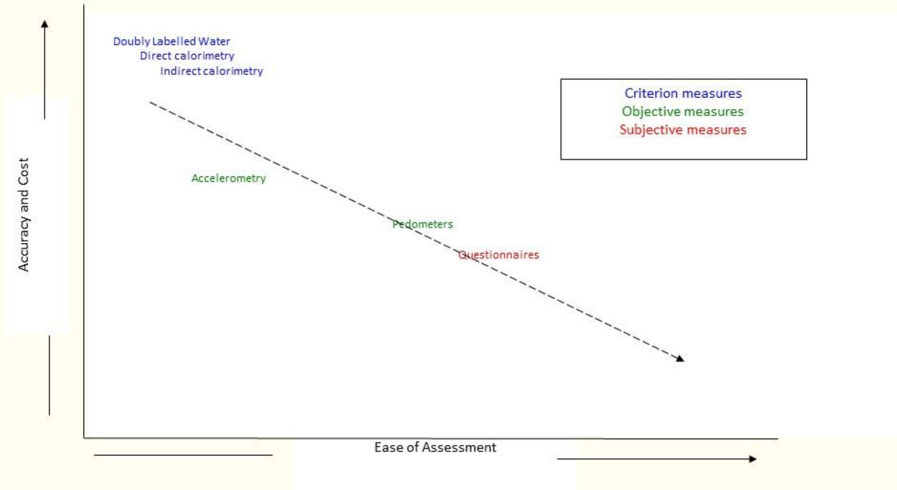
Day 2- Obesity and physical activity

Measuring Physical Activity



Publicly Available Data

frontiers in
PUBLIC HEALTH

ORIGINAL RESEARCH ARTICLE
published: 23 May 2014
doi: 10.3389/fpubh.2014.00041

Use of emerging technologies to assess differences in outdoor physical activity in St. Louis, Missouri

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Brown School, Washington University in St. Louis, St. Louis, MO, USA

Table 1. Use of Parks in St. Louis, MO for Physical Activity in 2012*

	Runs	Walks
N	287	71
Total Distance (in miles)	1722.01	236.84
Distance (in miles) in parks	519.60	101.00
% in or tangential to parks	80.80%	70.40%
% in parks in low-SES neighborhoods	6.97%	15.50%

* running and walking routes downloaded from MapMyRun.com

Figure 1. Running routes, walking routes, and poverty rate in St. Louis, MO, USA.

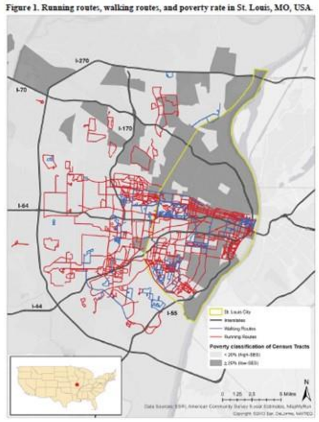
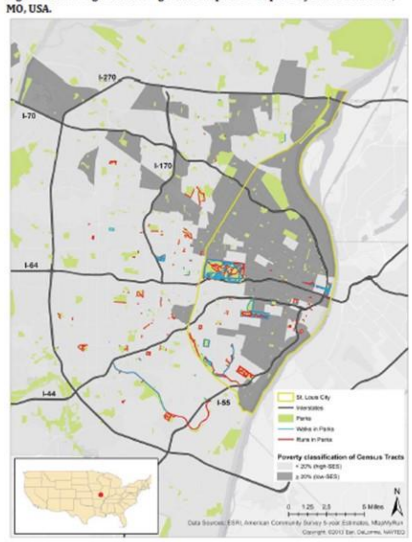
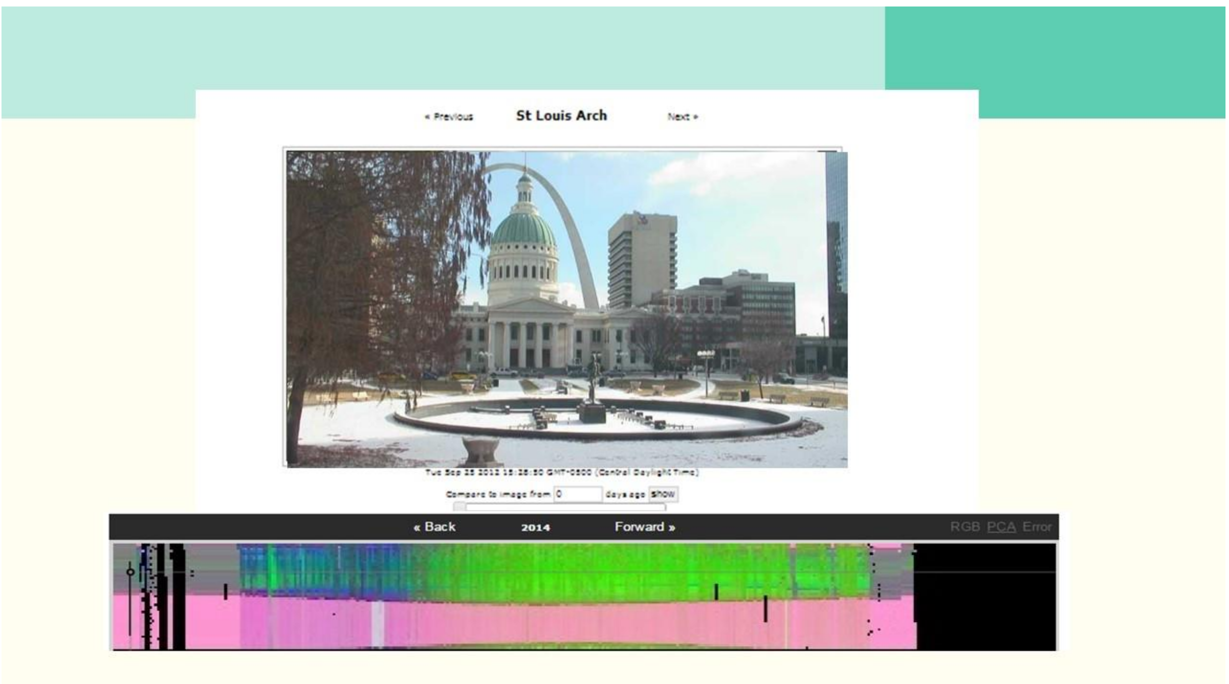


Figure 2. Running and walking routes in parks and poverty rate in St. Louis, MO, USA.



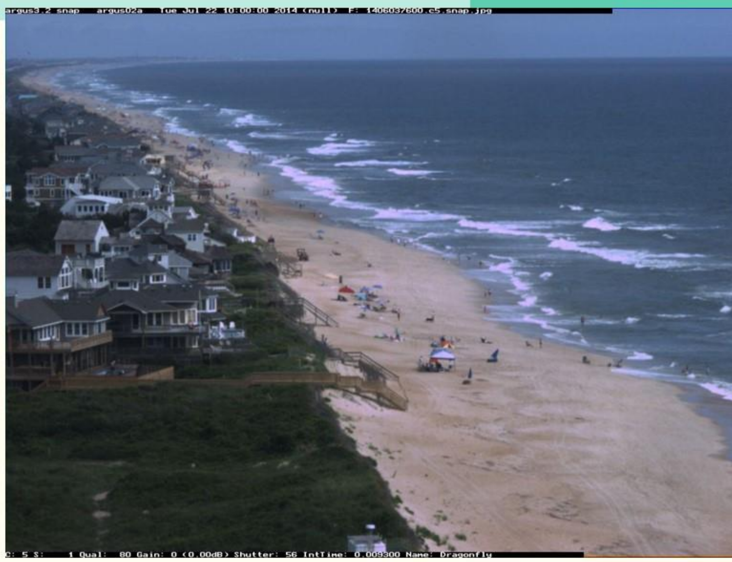
Day 2- Obesity and physical activity

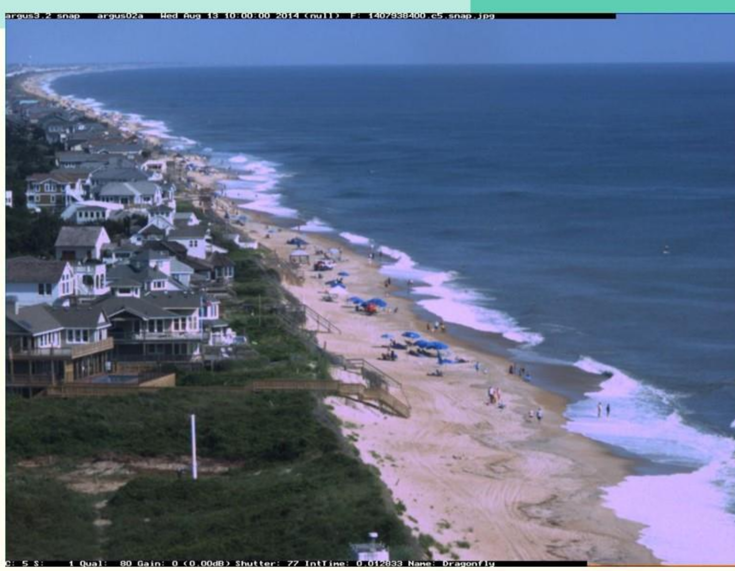


Day 2- Obesity and physical activity

USACE Field Research Facility

Kitty Hawk, NC





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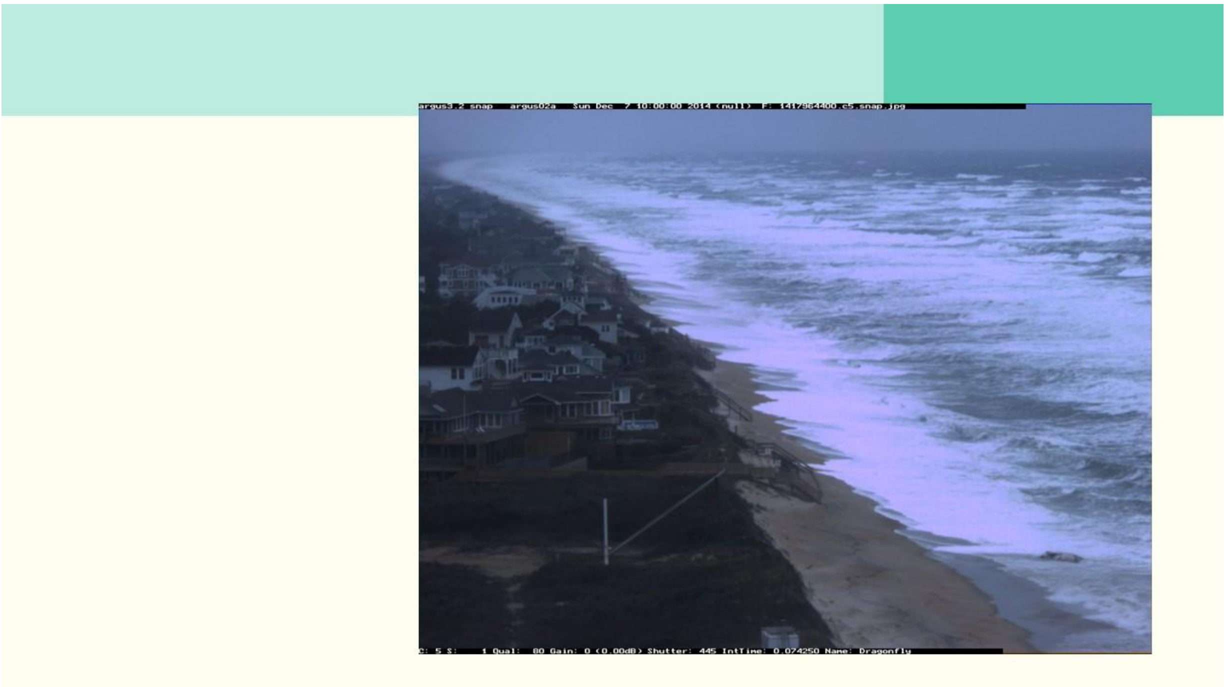
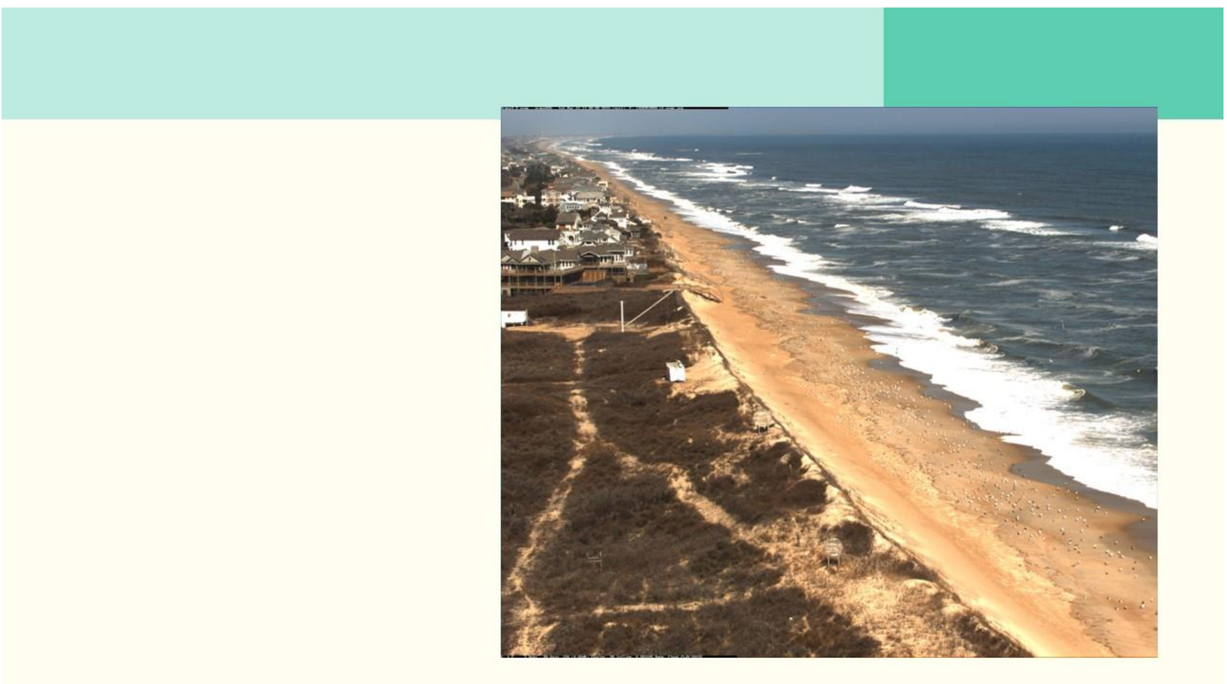


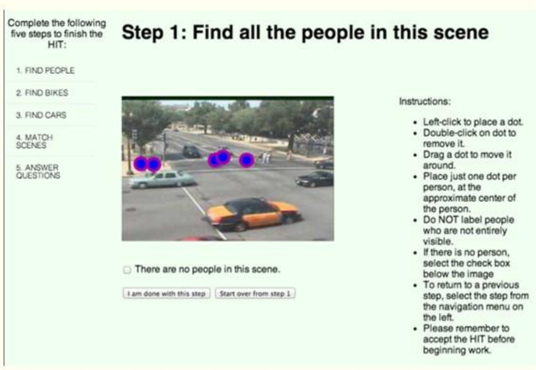


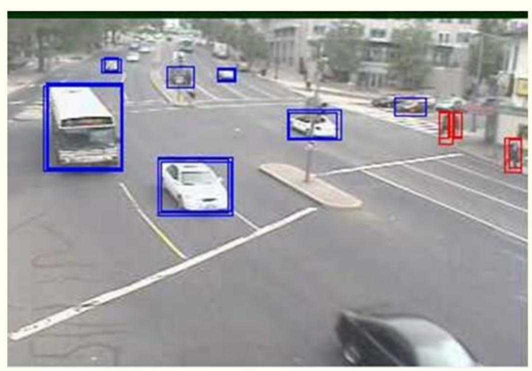
Day 2- Obesity and physical activity

2007 2008

Hipp, J.A. et al. Emerging Technologies: Webcams and Crowd-sourcing to Identify Active Transportation. American Journal of Preventive Medicine. 44(1) 96-97.

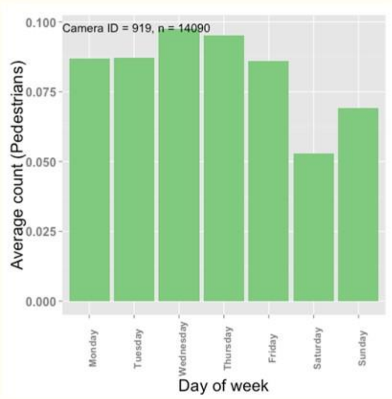
Human Intelligence Task



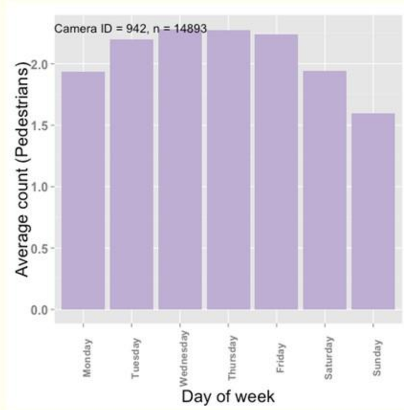


Hipp, J.A. et al.. 2013. Do you see what I see: Crowdsource annotation of captured scenes. In Proceedings SenseCam 2013. ACM 978-1-4503-2247-8/13/11.

Weekly Pedestrian Trends

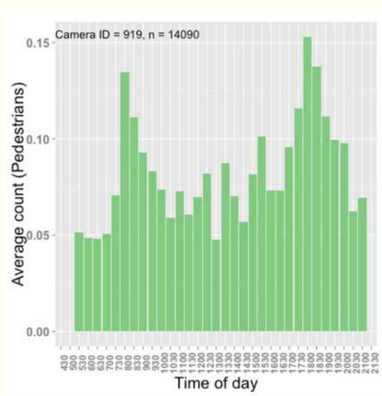


Residential Intersection

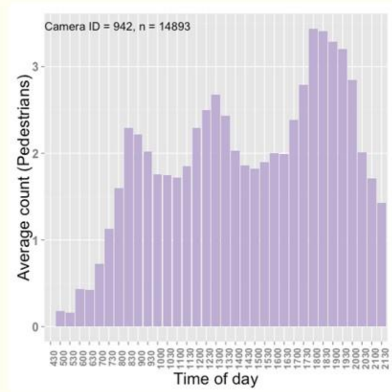


Commercial Intersection

Hourly Pedestrian Trends

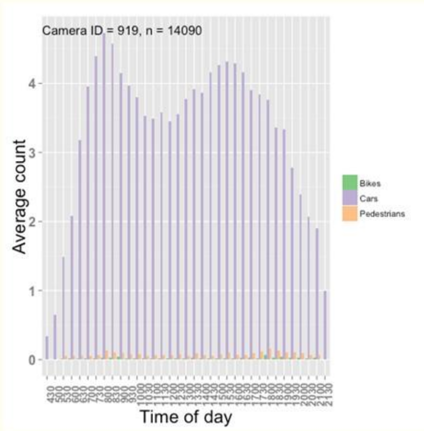


Residential Intersection

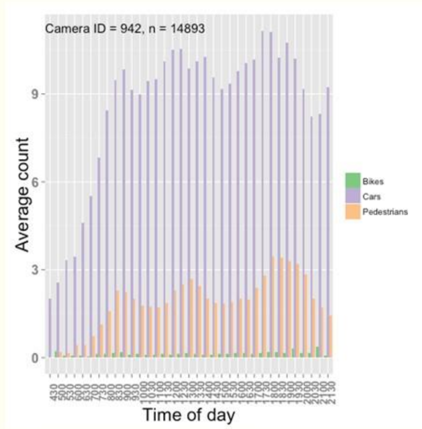


Commercial Intersection

Hourly Transportation Trends

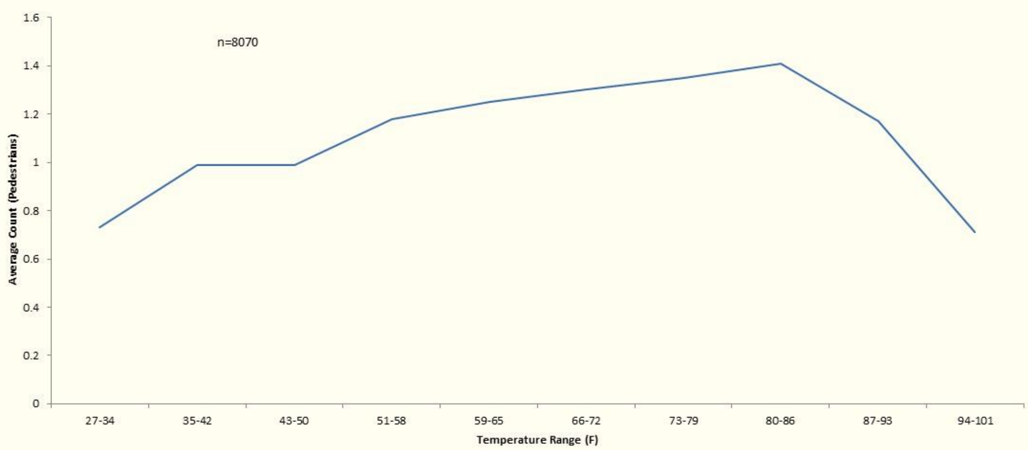


Residential Intersection



Commercial Intersection

Weather and Active Transportation



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Mobile devices for collecting data

- Hardware sensors: accelerometers, GPS, barometer, luminance, microphone, temperature, heart rate, etc.
- Behaviour inference sensors: calendar availability, communication patterns, social interactions
- Qualitative sensors: on-screen questionnaires, diaries, experience sampling
- Necessary to have power-efficient sensing architecture
- Real-time analysis
- Existing platforms: e.g. AWARE

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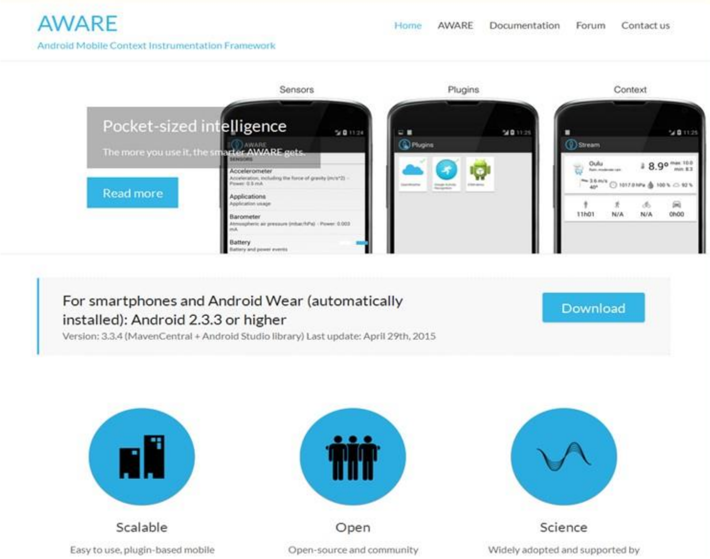
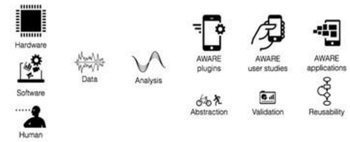
www.awareframework.com





University of Oulu, Finland.
V Kostakos, D Ferreira

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Standards in policies

- Area-percentage (percentage reserved for GS)
- Catchment areas (size and distance)
- Often based on "common-sense approaches", rarely empirical evidence
- Internationally little or no evidence-based approach for developing planning standards for GS
- Quality of GS often ignored
- Consider needs-based approaches
- Lack of cost-efficiency analyses

Ref.: Veal, 2012; Kellett and Rofe, 2009)

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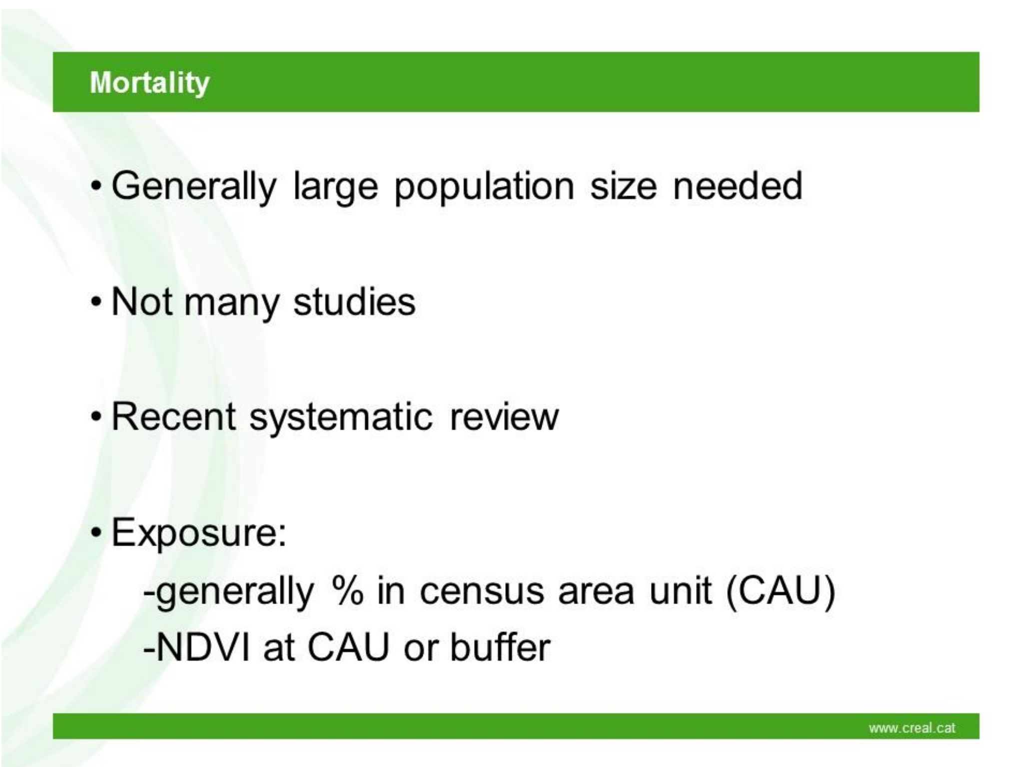
GREEN SPACE AND HEALTH:
Mortality and Cardiovascular
Mark J Nieuwenhuijsen PhD
Perry Hystad
5-6 May 2015 / EPA Cincinnati
CREAL
Generalitat de Catalunya
Parc de Salut MAR
UNIVERSITAT POMPEU FABRA


Mortality
• Generally large population size needed
• Not many studies
• Recent systematic review
• Exposure:
-generally % in census area unit (CAU)
-NDVI at CAU or buffer
www.creal.cat

Day 2−Cardiovascular disease and mortality

Table 1. Main estimations of the association between surrounding greenness or access to green spaces and mortality.

Author (year)	N	Exposure type	Exposure description	Mortality outcome	Outcome description	Estimate type	Estimate provided by the study
Harlan et al. 2013, The USA	2081 CAUs	Surrounding greenness at CAU (Factor calculated from NDVI)	IQR=1.16[a]	Extreme heat	11.4% of CAUs with at least one death	OR (95%CI)	1.19 (1.02, 1.39)[a,b]
Hu et al. 2008, The USA	Not reported	"Amount" of GS at CAU (LCM)	Min, Max= -52.4 to 7.1	Stroke SMR	Min, mean, max (average of all CAU)=4.22, 8.06, 34.42	β (SD)	-0.161 (0.067)[c]
Lachowycz et al. 2014, The UK	Not reported	% GS at CAU and 5 and 10km buffer (LCM)	Quintiles (highest vs lowest)	Circulatory causes SMR	Not reported	Rate Ratio (95%CI)	0.95 (0.92, 0.98)[a]
Mitchell et al. 2008, The UK	40813236 individuals	% GS at CAU (LCM)	Five equal interval groups (every 20% - highest vs lowest)	All-cause	366348 cases	IRR (95%CI)	0.94 (0.93, 0.96)
				Circulatory diseases	90433 cases		0.96 (0.93, 0.99)
				Lung cancer	25742 cases		0.96 (0.91, 1.02)
				Intentional self-harm	12308 cases		1.00 (0.92, 1.09)
Mitchell et al. 2011, The UK	1625495 individuals	% GS at CAU (LCM)	Five equal interval groups (every 20% - highest vs lowest)	All-cause	Not reported	IRR (95%CI)	0.63 (0.54, 0.73)
Richardson et al. 2010, The UK	28.6 million individuals	% GS at CAU (LCM)	Four equal interval groups (every 25%- highest vs lowest)			IRR (95%CI) by gender	
				Cardiovascular disease	103711 cases	Men	0.95 (0.91, 0.98)
						Women	1.00 (0.95, 1.06)

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Gascon et al (under review)

Author (year)	N	Exposure type	Exposure description	Mortality outcome	Outcome description	Estimate type	Estimate provided by the study
				Respiratory disease	26591 cases	Men	0.89 (0.83, 0.96)
						Women	0.96 (0.88, 1.05)
				Lung cancer	30110 cases	Men	0.96 (0.90, 1.02)
						Women	1.02 (0.94, 1.11)
Richardson et al. 2010, New Zealand	1546405 individuals	% GS at CAU (LCM)	Quartiles (highest vs lowest) - mean (range) for all CAU= 42% (0-100%)	Cardiovascular disease	9484 cases	IRR (95%CI)	1.01 (0.91, 1.11)
				Lung cancer	2603 cases		1.12 (0.94, 1.32)
Richardson et al. 2012, The USA	43 million individuals	% GS at CAU (LCM)	Three categories (highest (59%-72%) vs lowest (20%-45%))		Average (all cities)=27000 cases	β (95%CI) by gender	
				All-cause		Men	132.9 (18.3, 247.5)
						Women	94.2 (21.8., 166.7)
				Heart disease		Men	6.5 (-62.5, 75.5)
						Women	1.9 (-42.0, 45.8)
				Diabetis		Men	4.3 (-3.06, 11.73)
						Women	4.2 (-0.8, 9.2)
				Lung cancer		Men	7.9 (-8.8, 24.6)
						Women	2.5 (8.8, 13.7)
				Motor vehicle fatalities		Men	0.6 (-8.1, 9.2)
						Women	-3.4 (-8.5, 1.7)
Tamosiunas et al. 2014, Lithuania	5112 individuals	Distance to the nearest green space (LCM)	Tertiles (≤347.8m, 347.81-629.6m, ≥629.61)	Cardiovascular disease	83 cases	HR (95%CI)	1.15 (0.64, 2.07)[a,d]

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Gascon et al (under review)

Author (year)	N	Exposure type	Exposure description	Mortality outcome	Outcome description	Estimate type	Estimate provided by the study
Uejio et al. 2011, The USA	1741 CAUs	Surrounding greenness at CAU (NDVI)	IQR=0.047[a]	Extreme heat	3.6% of CAUs with at least one death[a]	OR (95%CI)	0.64 (0.01, 40.4)[a,b]
Villeneuve et al. 2012, Canada	574840 individuals	Surrounding greenness in 50 and 300m buffers (NDVI)	IQR=0.24	All-non accidental cause	181110	Rate Ratio (95%CI)	0.95 (0.94, 0.97)
				Cardiovascular disease	66530		0.95 (0.93, 0.97)
				Respiratory disease	13730		0.92 (0.88, 0.96)
Wilker et al. 2014, The USA	1645 individuals	Surrounding greenness in 250m buffer (NDVI)	Quartiles (highest vs lowest)	Post-stroke all-cause	929	HR (95%CI)	0.80 (0.65, 0.99)

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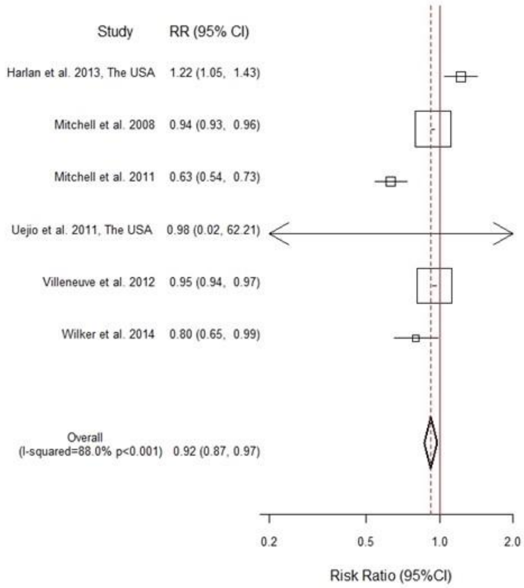
Gascon et al (under review)

Meta-analysis All cause mortality



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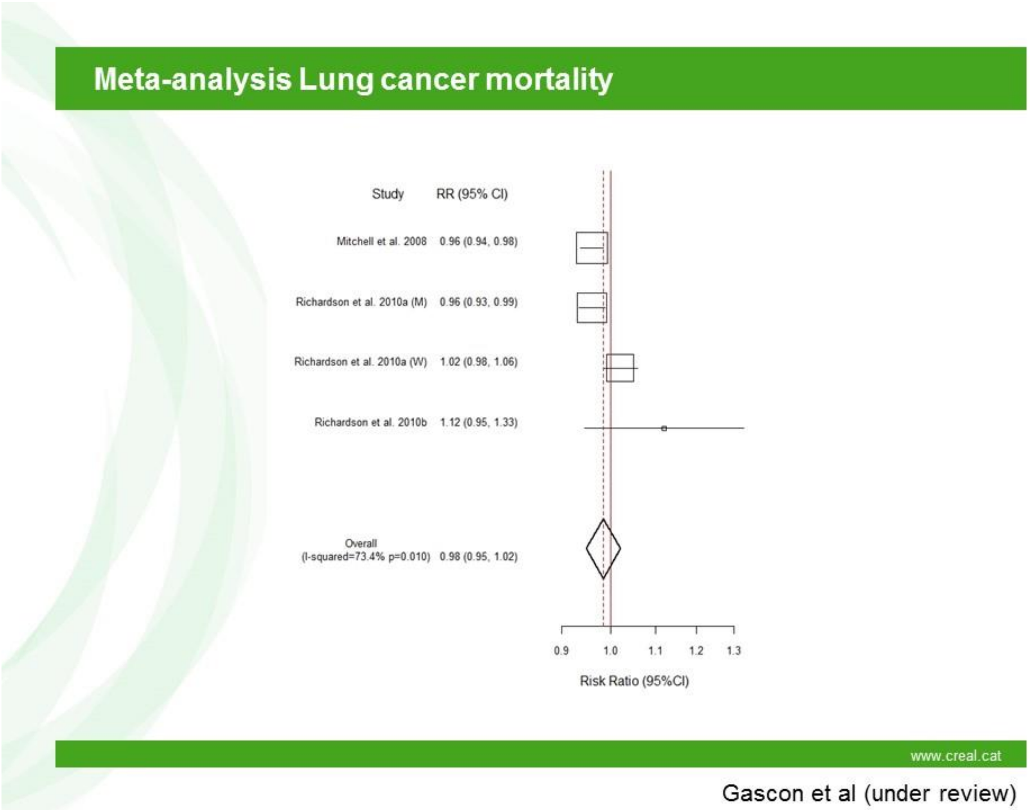
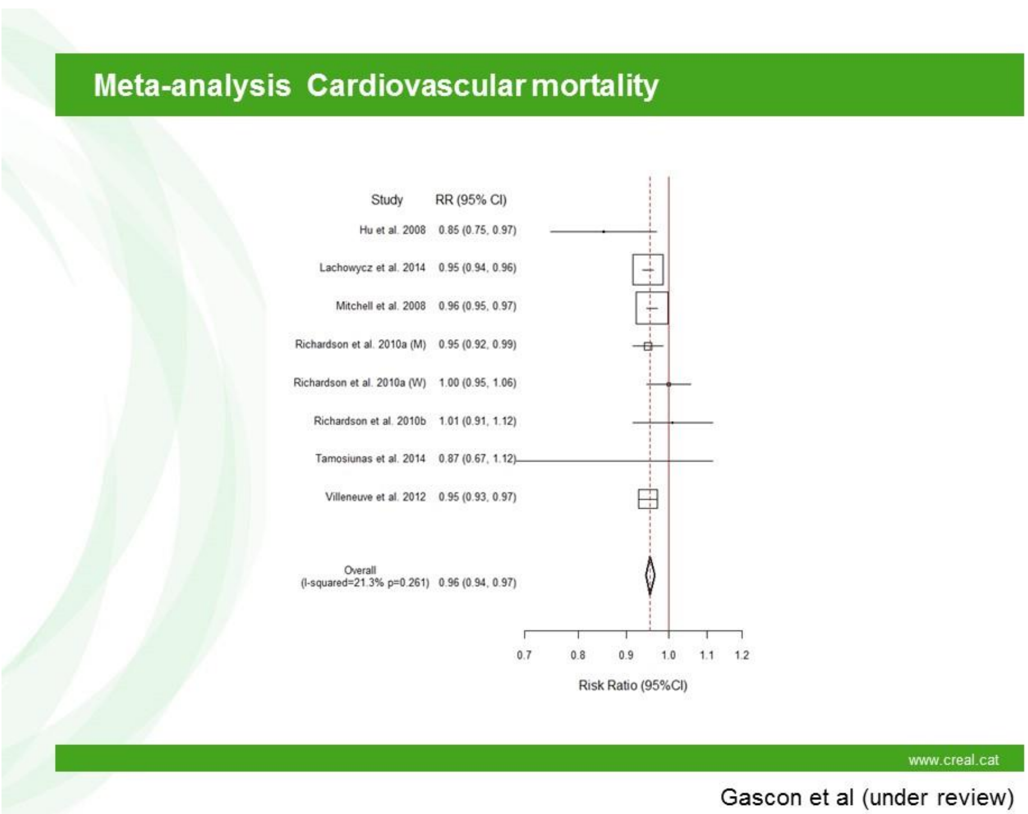
Day 2−Cardiovascular disease and mortality





TREES AND MORTALITY IN THE USA

The Relationship Between Trees and Human Health

Evidence from the Spread of the Emerald Ash Borer

Geoffrey H. Donovan, PhD, David T. Butry, PhD, Yvonne L. Michael, ScD,
Jeffrey P. Prestemon, PhD, Andrew M. Liebhold, PhD,
Demetrios Gatziolis, PhD, Megan Y. Mao

Purpose: A natural experiment, which provides stronger evidence of causality, was used to test whether a major change to the natural environment—the loss of 100 million trees to the emerald ash borer, an invasive forest pest—has influenced mortality related to cardiovascular and lower-respiratory diseases.

Am J Prev Med 2013;44(2):139–145

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Gascon et al (under review)

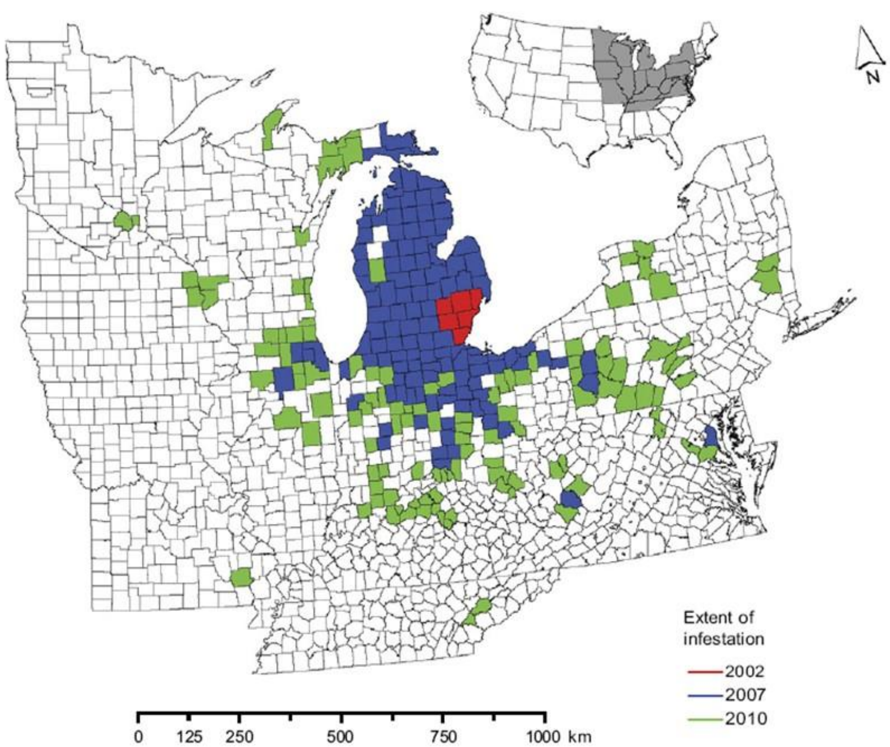

Figure 1. Counties where the emerald ash borer had been detected in 2002, 2007, and 2010

TREES AND MORTALITY IN THE USA

Results: There was an increase in mortality related to cardiovascular and lower-respiratory-tract illness in counties infested with the emerald ash borer. The magnitude of this effect was greater as infestation progressed and in counties with above-average median household income. Across the 15 states in the study area, the borer was associated with an additional 6113 deaths related to illness of the lower respiratory system, and 15,080 cardiovascular-related deaths.

Table 1. Longitudinal regression model of adult lower-respiratory-tract disease–related mortality, adjusting for covariates, U.S., 1990–2007

Variable	Beta coefficient* (95% CI)	p-value
Time trend	−2.98 (−3.23, −2.72)	<0.001
1-year mortality-rate lag	0.31 (0.303, 0.310)	<0.001
Percentage non-Hispanic white	9.40 (6.40, 12.40)	<0.001
Percentage Native Hawaiian and other Pacific Islander	2.14 (0.32, 3.97)	0.022
High median income	13.95 (6.50, 21.39)	<0.001
Aged >25 years with no high school diploma, %	1.22 (0.92, 1.52)	<0.001
Aged >25 years with college degree, %	−0.33 (−0.70, 0.03)	0.077
Population below 100% of poverty line, %	2.24 (1.89, 2.58)	<0.001
Percentage of county covered by ash canopy	−5.22 (−7.79, −2.64)	<0.001
Emerald ash borer	−4.24 (−8.10, −0.39)	0.031
Emerald ash borer X high median income	6.23 (2.23, 10.22)	0.002
Years of infestation	1.44 (0.95, 1.92)	<0.001
Ash canopy X high median income	−0.85 (−1.30, −0.41)	<0.001
R^2		
Within counties	0.609	
Between counties	0.187	
Overall	0.352	

*Mortality rate per 100,000 adults

The presence of the borer in a county is associated with 6.8 additional deaths per year per 100,000 adults (95% CI4.8, 8.7).

Table 3. Longitudinal regression model of adult cardiovascular-related mortality adjusting for covariates in the U.S., 1990−2007

Variable	Beta coefficient* (95% CI)	p-value
Time trend	−6.49 (−7.45, −5.54)	<0.001
1-year mortality-rate lag	0.45 (0.43, 0.47)	<0.001
High median income	11.03 (5.71, 16.34)	<0.001
Native Hawaiian and other Pacific Islander, %	30.07 (2.44, 57.71)	0.033
Aged >25 years with no high school diploma, %	5.80 (4.67, 6.92)	<0.001
Aged >25 years with college degree, %	−1.92 (−3.26, −0.57)	0.005
Population below poverty line, %	−8.99 (−10.33, −7.64)	<0.001
Percentage of county covered by ash canopy	−1.80 (−9.51, 5.91)	0.648
Emerald ash borer	−13.51 (−25.38, −1.64)	0.026
Ash canopy X high median income	18.24 (5.45, 31.02)	0.0005
Years of infestation	2.77 (1.05, 4.48)	0.002
Emerald ash borer X high median income	−3.42 (−4.71, −2.13)	<0.001
R^2		
Within counties	0.753	
Between counties	0.298	
Overall	0.488	

*Mortality rate per 100,000 adults

The presence of the borer on cardiovascular related mortality is 16.7 additional deaths per year per 100,000 adults (95% CI5.7, 27.7)

Gascon et al (under review)

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Emerald Ash Borer and Mortality in the Women's Health Study

- Preliminary Results Examining Emerald Ash Borer and Mortality in the Women's Health Initiative Study (from Geoff Donovan, under review)
- Women living in a county infested with emerald ash borer had an increased risk of cardiovascular disease (HR=1.41, 95% CI: 1.37-1.45).

Variable	HR	95% CI
Live in county infested with EAB	1.406	1.37-1.45
Age	0.667	0.636-0.700
(Age)^2	1.003	1.002-1.003
Race		
White	RER	
Asian	0.729	0.649-0.819
Black	0.653	0.616-0.692
Hispanic	0.855	0.773-0.946
Native	0.973	0.767-1.24
Other	0.962	0.835-1.11
Income		
<$35,000	REF	
$35,000-$49,999	0.911	0.875-0.948
$50,000-$74,999	0.854	0.817-0.893
$75,000-$100,000	0.759	0.709-0.814
$100,000-$150,000	0.743	0.682-0.811
>$150,000	0.720	0.637-0.814
Smoking Status		
Never Smoked	REF	
Smoker	1.755	1.66-1.86
Former Smoker	1.131	1.1-1.17
Intervention Received		
HRT	1.097	1.04-1.16
Dietary Modification	0.969	0.922-1.02
Calcium and Vitamin D	0.962	0.917-1.01
Observational Study	1.513	1.45-1.57
BMI	1.018	1.002-1.036
(BMI)^2	0.9997	0.999-1.000
Alcohol Servings Per Week	0.9877	0.984-0.992
(Alcohol Servings Per Week)^2	1.0001	1.0001-1.0002
Recreational Energy Expenditure MET-Hours Per Week	0.9972	0.996-0.998
Mean(Emotional Wellness)	0.9951	0.994-0.996
Diabetes	1.9470	1.86-2.04
Hypertension	2.4696	2.39-2.55

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Life expectancy

- Jonkers *et al.* (2014)
  - An increase of 1 SD in the percentage of urban green space was associated with a 0.1-year higher LE, and, in the case of quality of green, with an approximately 0.3-year higher LE and HLE

- Takano *et al.* (2002)
  - The probability of five year survival of the senior citizens studied increased in accordance with the space for taking a stroll near the residence ($p<0.01$), parks and tree lined streets near the residence ($p<0.05$), and their preference to continue to live in their current community ($p<0.01$).

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Gascon et al (under review)

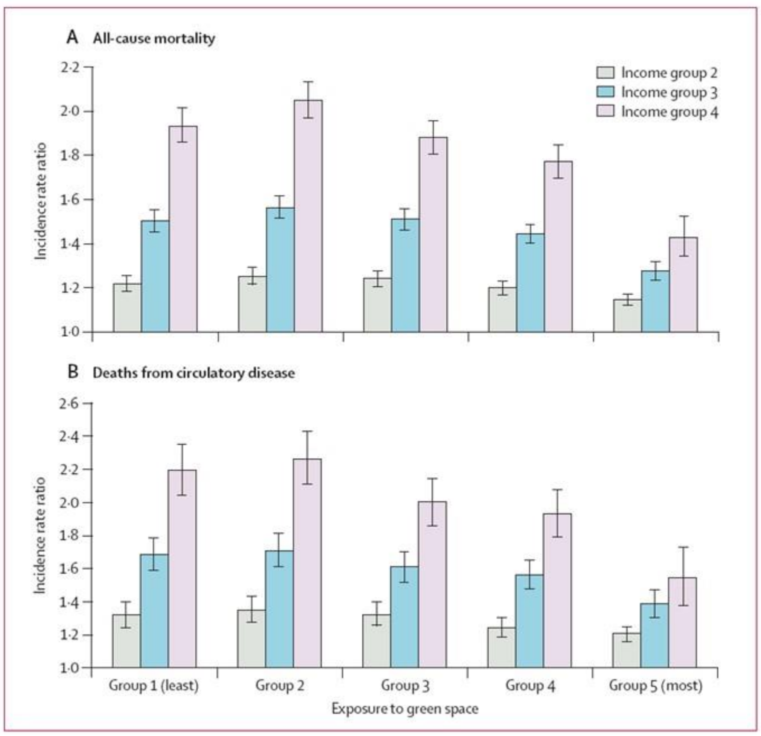

Figure 2: Incidence rate ratios for all-cause mortality (A) and deaths from circulatory disease (B) in income-deprivation quartiles 2–4, relative to income deprivation quartile 1 (least deprived), stratified by exposure to green space

Mitchell and Popham 2008

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CVD Incidence

- Generally large population size needed
- Very few studies available looking at long-term greenspace and CVD incidence
  - •Most examine mortality of short-term influences on risk factors (e.g. Blood pressure, HRV, etc.)
- Exposure:
  - -Generally NDVI

Table 1 Strength of evidence for greenness and health outcomes

Outcome	Study designs	Setting	Findings	Strength of evidence
Physical activity	15 cross-sectional studies [26•, 27, 28, 33-43, 45] 1 prospective study [44]	4 studies in the USA, 6 in the UK, 2 in France, 1 each in Australia, Netherlands, New Zealand, and Spain	Consistent evidence of positive association between greenness and physical activity. Few prospective studies.	I/II
Overweight/ obesity	10 cross-sectional studies [19, 43, 46-49, 51-54] 1 prospective study [50]	3 studies in the USA, 2 in the UK, 2 in Canada, 1 each in Australia, Denmark, Egypt, and Spain	Some evidence of negative association between greenness overweight/obesity, though findings (especially among children) were mixed. Possible effect modification by gender. Few prospective studies.	II
Mental health	11 cross-sectional studies [20, 22•, 23, 56, 58-61, 63-65] 3 prospective studies [57, 66, 67]	4 studies in the UK, 2 in Netherlands, 2 in the USA, 1 each in Australia, Canada, Denmark, New Zealand, Spain, and Sweden	Suggestive protective effect of greenness on self-reported mental health. More prospective studies needed.	II
Birth and developmental outcomes	6 birth cohort studies [31•, 68, 69, 71-73] 2 cross-sectional studies of allergies and asthma and hyperactivity [21, 32, 43].	2 studies in Spain, 2 studies in Germany, 1 each in Canada, France, Israel, and the UK	Consistent evidence of a positive relationship between residential greenness exposure and birth weight. Possible effect modification by SES. Findings for other birth and developmental outcomes require further evidence.	I/II
Cardiovascular outcomes	2 experimental studies [83, 84] 3 ecological studies [16, 78, 79] 3 cross-sectional studies [62, 80, 81] 1 prospective cohort study [82•]	4 studies in the UK, 1 each in the USA, Netherlands, Germany, Australia, and Canada	Consistent evidence of higher greenness and lower cardiovascular disease; however, most studies are ecological and cross-sectional. One prospective study could not account for individual-level smoking.	II/III
Mortality	3 prospective studies [82•, 85, 87] 5 ecological studies [16, 78, 79, 86, 88]	3 studies in the UK, 2 studies in the USA, 1 each in Japan, New Zealand, and Canada	Fairly consistent evidence of higher greenness and lower mortality; however, majority of studies are ecological. Two prospective studies were in specific subpopulations (elderly and stroke survivors). One prospective study could not account for individual-level smoking.	II

Strength of evidence definitions:

I = High: evidence is consistent, plausible, and precisely quantified and there is low probability of bias

II = Intermediate: evidence exists, but not entirely consistent, is not quantified precisely, or may be vulnerable to bias

III = Low: evidence is inconsistent, implausible, and/or may be vulnerable to bias severely limiting the value of the effect being described

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James P, Banay R, Hart J, Laden F. (2015). A Review of the Health Benefits of Greenness. Curr Epidemiol Rep (2015) 2:131–142

Neighborhood greenness and cardiovascular disease

- ***Pereira et al. (2012). The association between neighborhood greenness and cardiovascular disease: an observational study***

- Cross-sectional study of 11,404 adults obtained from a population representative sample for the period 2003–2009 in Perth, Western Australia.
- Neighborhood greenness was ascertained for a 1600 m service area surrounding the residential address using NDVI.
  - Measured average greenness and
  - variation of greenness levels in service area
- Assessed associations with medically diagnosed and hospitalization for coronary heart disease or stroke

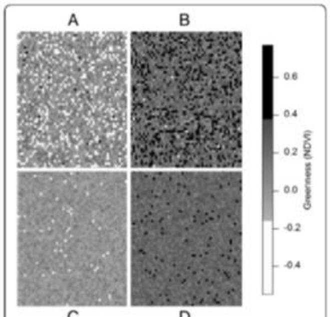


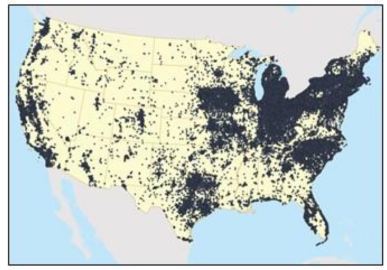
Figure 1 Four simulated service areas. Area A has low mean but high variability (standard deviation) in greenness. Area B has both high mean and variability in greenness. Area C has both low mean and variability in greenness. Area D has high mean but low variability in greenness. In general, the prevalence of high NDVI pixels illustrates mean greenness, and the prevalence of contrasting high and low NDVI pixels illustrates variability in greenness.

Table 2 Odds ratios (OR) and 95% confidence intervals (CI) of coronary heart disease or stroke for differences in neighborhood greenness for the 11,404 adults in the study population. Adjustment was made by cumulative inclusion of risk factors

	Model A	Model B	Model C	Model D	Model E	Model F
Adjustment	**No adjustment**	**Sociodemographics**	**Sociodemographics** **Biological factors**	**Sociodemographics** **Biological factors** **Behavioral factors**	**Sociodemographics** **Biological factors** **Behavioral factors** **Air quality**	**Sociodemographics** **Biological factors** **Behavioral factors** **Air quality** **All greenness**
Self-reported medical diagnosis with coronary heart disease or stroke						
Sample size (N)	11,374	9,216	7,216	5,903	5,903	5,903
Mean greenness (NDVI) in 1600 m service area						
Low	1	1	1	1	1	1
Moderate	0.91 (0.79, 1.05)	**0.81 (0.69, 0.96)**	**0.83 (0.69, 1.00)**	0.83 (0.68, 1.02)	0.83 (0.68, 1.02)	0.84 (0.69, 1.02)
High	1.09 (0.95, 1.24)	0.98 (0.84, 1.15)	1.01 (0.85, 1.22)	0.92 (0.75, 1.13)	0.92 (0.75, 1.13)	0.94 (0.76, 1.15)
Linear increase	0.98 (0.93, 1.04)	0.97 (0.90, 1.03)	0.98 (0.91, 1.05)	0.98 (0.93, 1.04)	0.93 (0.85, 1.01)	0.93 (0.85, 1.01)
Standard deviation (SD) of greenness (NDVI) in 1600 m service area						
Low	1	1	1	1	1	1
Moderate	0.84 (0.74, 0.97)	**0.71 (0.60, 0.83)**	**0.70 (0.58, 0.84)**	**0.76 (0.62, 0.93)**	**0.76 (0.62, 0.93)**	**0.76 (0.62, 0.94)**
High	0.91 (0.80, 1.04)	**0.83 (0.70, 0.97)**	**0.83 (0.69, 0.99)**	0.84 (0.68, 1.02)	0.84 (0.68, 1.03)	0.84 (0.68, 1.03)
Linear increase	0.94 (0.88, 1.01)	0.89 (0.82, 0.97)	0.90 (0.82, 0.99)	0.91 (0.82, 1.01)	0.91 (0.82, 1.01)	0.91 (0.82, 1.02)
Hospital admission with coronary heart disease or stroke						
Sample size (N)	11,198	8,901	6,941	5,637	5,637	5,637
Mean greenness (NDVI) in 1600 m service area						
Low	1	1	1	1	1	1
Moderate	1.16 (0.90, 1.50)	0.88 (0.65, 1.17)	0.87 (0.64, 1.19)	0.92 (0.65, 1.30)	0.92 (0.65, 1.30)	0.90 (0.63, 1.27)
High	1.11 (0.86, 1.44)	0.95 (0.71, 1.28)	0.82 (0.59, 1.13)	0.85 (0.58, 1.24)	0.85 (0.58, 1.24)	0.87 (0.60, 1.27)
Linear increase	0.98 (0.88, 1.08)	0.94 (0.83, 1.06)	0.89 (0.77, 1.02)	0.90 (0.77, 1.05)	0.90 (0.77, 1.05)	0.90 (0.77, 1.05)
Standard deviation (SD) of greenness (NDVI) in 1600 m service area						
Low	1	1	1	1	1	1
Moderate	1.01 (0.79, 1.30)	0.92 (0.69, 1.23)	0.92 (0.68, 1.24)	0.87 (0.61, 1.22)	0.85 (0.60, 1.20)	0.85 (0.60, 1.21)
High	0.90 (0.69, 1.16)	0.81 (0.60, 1.09)	**0.71 (0.51, 0.99)**	**0.66 (0.45, 0.96)**	**0.63 (0.43, 0.92)**	**0.63 (0.43, 0.92)**
Linear increase	0.94 (0.82, 1.07)	0.92 (0.79, 1.07)	0.89 (0.74, 1.05)	0.84 (0.70, 1.02)	**0.82 (0.68, 1.00)**	**0.82 (0.68, 1.00)**

Preliminary Results from Nurses Health Study (Peter James)

- Urban greenness exposures and CVD incidence in the Nurses' Health Study prospective cohort.
- 92,053 women followed from 2000-2010.
- Time-varying MODIS satellite NDVI (absolute and relative to urban area) linked to addresses.
- 1,715,019 person-years and 3,503 CVD events identified.
- Adjusted for wide-range of individual and contextual variables.



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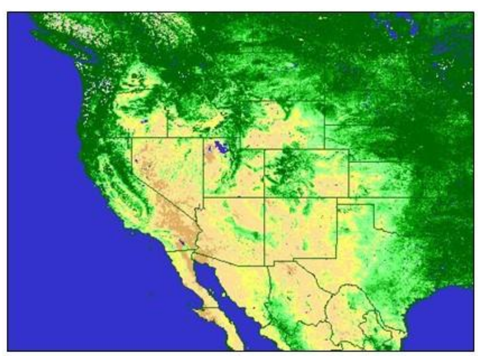
Preliminary Results

- No association between NDVI and CVD.
- One unit increase in long-term average Z-score of relative NDVI was associated with a 6% reduction in CVD incidence (95%CI: 0.90, 0.99).
- No associations between short-term relative greenness and CVD.



Greenness and Cardiovascular Disease Incidence in the Nurses' Health Study
Authors: Peter James, Jaime E. Hart, Perry Hystad, Rachel F. Banay, Francine Laden

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Greenspace and CVD Incidence: Conclusions

- Very little research has examined greenspace and CVD incidence
- Little evidence of an association in observational studies
- Some evidence of short-term impacts on CVD risk factors (e.g. blood pressure, hypertension, HRV, etc)

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Greenspace and Neurological / Neurodevelopmental Effects

Background: Mental Health

- Mental and behavioral disorders
  - Clinically significant conditions characterized by alterations in thinking, mood (emotions), and behavior associated with personal distress and/or impaired functioning – WHO 2001 report
- Prevalence of mental and behavioral disorders rising globally
  - Affect > 25%
    - Point prevalence – 10% adults

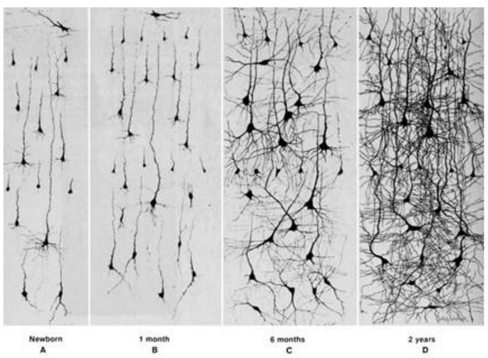
Leading causes of disability-adjusted life years (DALYs), in all ages

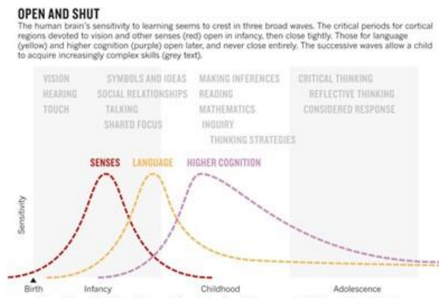
	Both sexes, all ages	% total
1	Lower respiratory infections	6.4
2	Perinatal conditions	6.2
3	HIV/AIDS	6.1
4	Unipolar depressive disorders	4.4
5	Diarrhoeal diseases	4.2
6	Ischaemic heart disease	3.8
7	Cerebrovascular disease	3.1
8	Road traffic accidents	2.8
9	Malaria	2.7
10	Tuberculosis	2.4
11	Chronic obstructive pulmonary disease	2.3
12	Congenital abnormalities	2.2
13	Measles	1.9
14	Iron-deficiency anaemia	1.8
15	Hearing loss, adult onset	1.7
16	Falls	1.3
17	Self-inflicted injuries	1.3
18	Alcohol use disorders	1.3
19	Protein–energy malnutrition	1.1
20	Osteoarthritis	1.1

WHO: The World Health Report: 2001: Mental Health: New Understanding, New Hope.

Background: Neurodevelopment

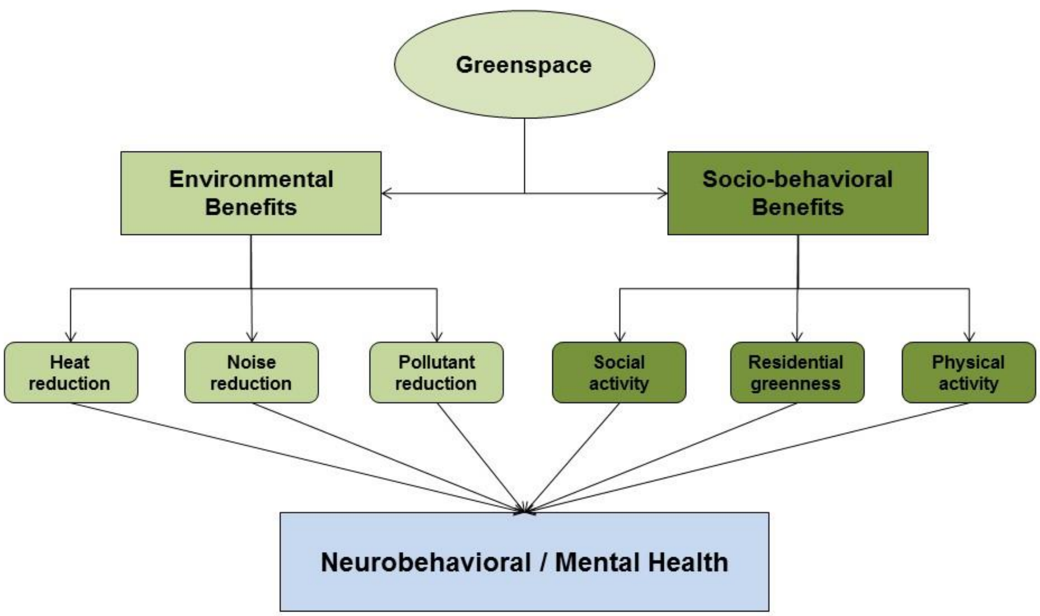
- Learning disabilities and activity disorders ↑ ~3% annually
  - ~12 million children in the U.S. have at least one neurobehavioral disability impacting cognitive function, language, emotion, motor function, or behavior
- Prenatal and early childhood are particularly important as this is the time of rapid growth and cellular differentiation, unprotected barriers
  - Brain growth continues throughout childhood and prolonged period of myelination →brain is not mature until young adulthood
- Multiple factors including genetics, social, nutritional, and environment
  - Environmental neurotoxicants are associated with ~25% of neurobehavioral disabilities
  - Lead, pesticides, tobacco smoke, traffic



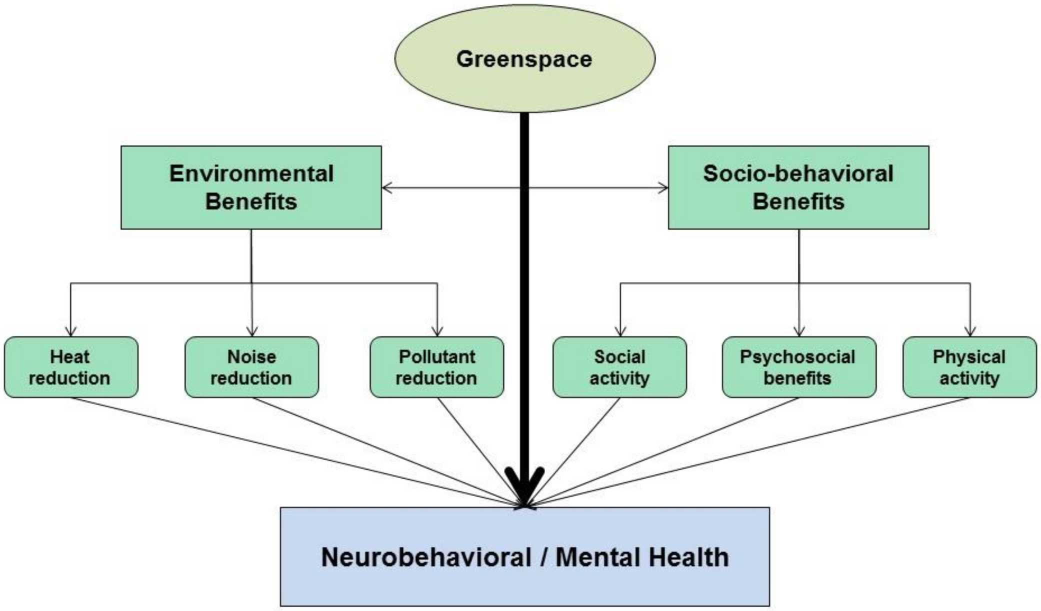


Bardin J. Unlocking The Brain. Nature. 2012. 487:24-26.

Greenspace: Potential Beneficial Pathways for Neurodevelopment / Mental Health



Greenspace and Neurobehavior / Mental Health



Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review

Mireia Gascon [1,2,3,4,*], Margarita Triguero-Mas [2,3], David Martinez [2,3], Payam Dadvand [2,3], Joan Forns [2,3,4], Antoni Plasència [1] and Mark J. Nieuwenhuijsen [2,3] *Int. J. Environ. Res. Public Health* **2015**, *12*, 4354-4379; doi:10.3390/ijerph120404354

- Four studies of children identified
  - All evaluated emotional and behavioral problems using SDQ and/or ADHD symptoms
  - No studies of cognitive or psychomotor development

Table 1. Main characteristics and results of the studies on surrounding greenness and mental health.

Author (Year, Country)	Study Design	Age of the Study Population (Stratifications/Interactions)	N	Tools to Measure Mental Health	Mental Health Item	Greenness Data Source	Surrounding Greenness Indicator	Risk of Mental Health Problems
Exclusively children								
Amoly 2014 *et al.*, Spain [30]	Cross-sectional	Children 7–10 y	2111	SDQ ADHD/DSM-IV	Emotional & behavioural problems [a]	NDVI	100 m, 250 m, 500 m buffers	Increasing greenness 100 m buffer: ↓ total SDQ difficulties, SDQ hyperactivity/inattention & ADHD (inattention) 250 m buffer: ↓ total SDQ difficulties, SDQ hyperactivity/inattention 500 m buffer: ↓ total SDQ difficulties, SDQ hyperactivity/inattention, SDQ emotional symptoms
Balseviciene *et al.* 2014, Lithuania [28]	Cross-sectional	4–6 y (maternal education)	1468	SDQ	Emotional & behavioural problems [a]	NDVI	300 m buffer	Higher maternal education group: increasing greenness ↑ conditional problems & ↓ prosocial behaviour
Flouri *et al.* 2014, The UK [19]	Longitudinal	3, 5 & 7 y (socioeconomic status)	6384	SDQ	Emotional & behavioural problems [a]	Land-cover map	% GS at CAU	Poor children of age 3y to 5y: increasing greenness ↓ emotional problems
Markevych *et al.* 2014, Germany [29]	Cross-sectional	10 y (gender, urbanity degree)	1932	SDQ	Emotional & behavioural problems [a]	NDVI	500 m buffer	-

Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review

Mireia Gascon [1,2,3,4,*], Margarita Triguero-Mas [2,3], David Martínez [2,3], Payam Dadvand [2,3], Joan Forns [2,3,4], Antoni Plasència [1] and Mark J. Nieuwenhuijsen [2,3] *Int. J. Environ. Res. Public Health* **2015**, *12*, 4354-4379; doi:10.3390/ijerph120404354

- Twenty-four studies of adults
  - 6 longitudinal, 1 ecological, 17 cross-sectional
  - Most conducted in Europe, none in Asia or Africa

Table 1. *Cont.*

Author (Year, Country)	Study Design	Age of the Study Population (Stratifications/Interactions)	N	Tools to Measure Mental Health	Mental Health Item	Greenness Data Source	Surrounding Greenness Indicator	Risk of Mental Health Problems
Adults (or population irrespective of age)								
Alcock *et al.* 2014, The UK [22]	Longitudinal	Adults	1064	GHQ-12	Mental health	Land-cover map	% GS at CAU (residence change in time)	↑ mental health in people moving to greener areas
Araya *et al.* 2007, Chile [31]	Cross-sectional	Adults 16–64 y	3870	CIS-R ICD-10	Psychiatric, anxiety and depressive disorders	BEAT (audit)	Presence of public green areas and its quality [b] at CAU	Increasing presence of public green areas ↓ risk of depression (ICD-10)
Astell-Burt *et al.* 2013, Australia [32]	Cross-sectional	>45 y (physical activity)	260061	K10	Psychological distress	Land-cover map	% GS in 1 km buffer	Increasing greenness ↓ risk in all population (after stratification only in physically active adults)
Astell-Burt *et al.* 2014, The UK [18]	Longitudinal	>15 y (age, gender)	65407	GHQ-12	Minor psychiatric morbidity	Land-cover map	% GS at CAU	Increasing greenness ↓ risk in males >30 years and in females >41 years & living in moderate greenness
Beyer *et al.* 2014, The USA [33]	Cross-sectional	21–74 y	2479	DASS	Depression Anxiety Stress	NDVI Land-cover map	At CAU % tree canopy coverage at CAU	Increasing greenness ↓ risk of depression & anxiety Increasing greenness ↓ risk of depression & stress
De Vries *et al.* 2003, The Netherlands [34]	Cross-sectional	All ages (education, urbanity degree)	10197	GHQ	Minor psychiatric morbidity	Land-cover map	% GS in 1 km & 3 km buffers	Increasing greenness between 1 and 3 km ↓ risk in all population (after stratification only in low educated)
Fan *et al.* 2011, The USA [27]	Cross-sectional	Adults 18–75 y	1544	PSS	Stress	NDVI Land-cover map	800 m buffer Total park acreage in a 800 m buffer	- -

Mental Health Benefits of Long-Term Exposure to Residential Green and Blue Spaces: A Systematic Review

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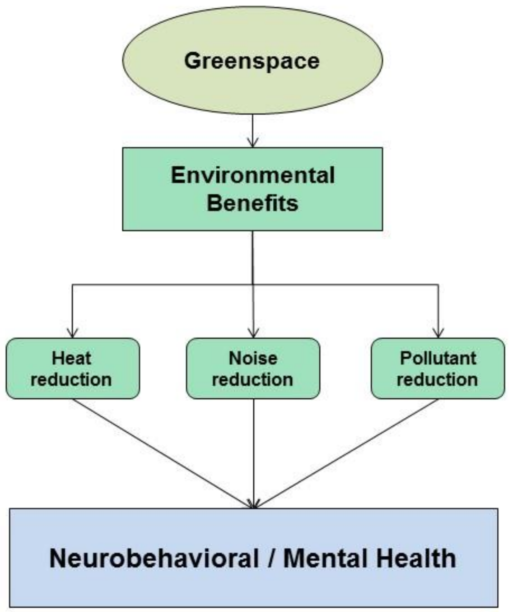
- Summary and Conclusions
  - Limited evidence for causal relationship between surrounding greenness and mental health in adults
    - Inadequate evidence for children
  - Limitations
    - Few studies
    - Heterogeneity in exposure assessment
  - Recommendations
    - Effect modification by social class, education, age, and gender
    - Sensitivity analyses regarding appropriate distance (300 m?)
    - Euclidian or network distances?
    - Greenspace surrounding work / schools
    - Additional outcome assessments

Potential Pathways: Environmental Benefits of Greenspace



Greenspace, heat, air quality, and health

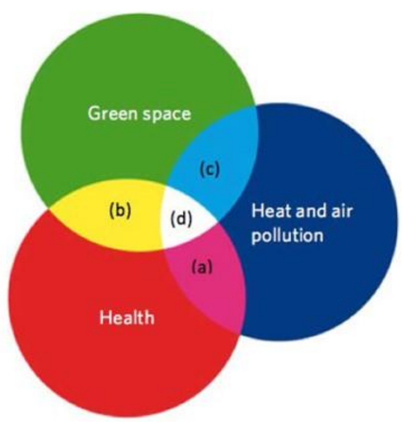
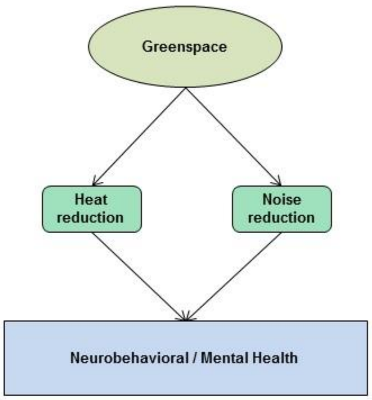


Figure 1. The data gap: understanding the evidence base on green space, heat, air quality and health
(a) Strong evidence base on the relationship between heat and health and air pollution and health; (b) Large and growing evidence base on the relationship between green space and health in general; (c) Growing evidence base on the relationship between green space heat and air quality but gaps regarding the specific settings and greening characteristics to maximize benefits; (d) Data gap: documented health impacts as a result of greening strategies that reduce urban heat and air pollution.

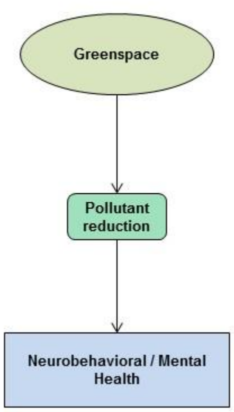
Zupancic T, Westmacott C, Bulthuis M. The Impact of Green Space on Heat and Air Pollution in Urban Communities: A Meta-Narrative Systematic Review. March 2015. David Suzuki Foundation.

Greenspace: Heat and noise reduction



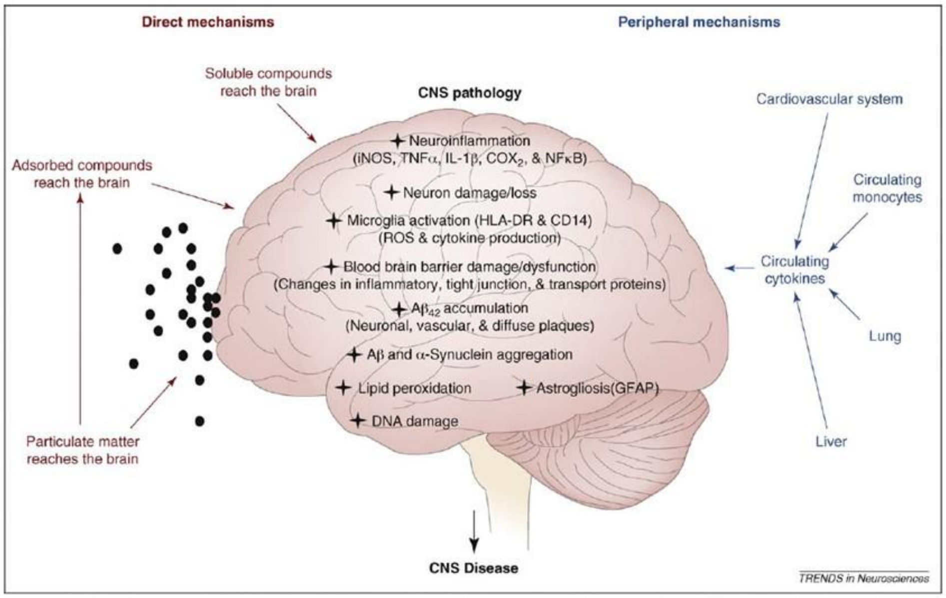
- Heat
  - Greenspace reduces urban heat islands, particularly in hottest months / times of day
    - Bowler et al. 2010: air temp of parks ~1°C (or more) less than non-green urban areas
      - Max cooling distance ~200 – 500 m depending on park size, temperature, vegetation density (Feyisa et al 2014; Cao et al. 2010)
  - Effect of heat reduction on neurobehavior / mental health?
- Noise
  - Greenspace (trees and shrubs) may reduce noise by 5-10 db / 30m
  - Exposure to noise associated with cognition and neurobehavior in children

Greenspace: Pollutant reduction



- ↓ ozone?
  - Dependent on vegetation type
- Gaseous pollutants
  - Uptake via leaf stomata
- PM
  - Trees may serve as a barrier to PM
    - Maher et al (2013): ~50%↓ in measured PM inside houses
  - Dependent on PM size
  - Large urban forests ↓ PM2.5

Air Pollution and the Central Nervous System

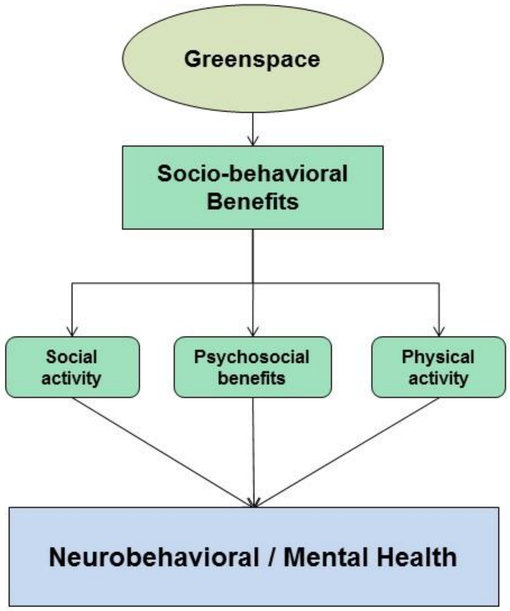


Block and Calderon-Garciduenas. *Trends in Neurosciences*. 2009;32:506-516.

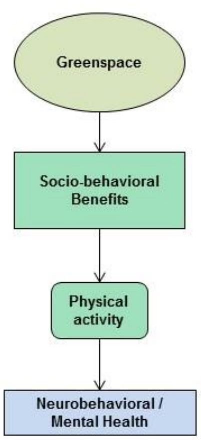
Air Pollution and the Central Nervous System

- Experimental Studies
  - ↑ microglia
  - ↑ neuroinflammation (TNFα, IL1β, IL-6)
- Epidemiologic Studies
  - Estimated life-time exposure to BC associated with ↓ vocabulary, IQ, memory and learning at age 10 (Suglia et al. *Am J Epidemiol.* 2008)
  - Prenatal exposure to polycyclic aromatic hydrocarbons associated with ↓ cognition (age 3), ↓ IQ (age 5), and ↑ anxiety and attention (age 6-7) (Perera et al. *Environ Health Perspect.* 2006, 2012. *Pediatrics* 2009)
  - Traffic-related air pollution associated with autism (Volk et al. *JAMA Psychiatry.* 2013; Becerra et al. *Environ Health Perspect.* 2013)

Potential Pathways: Socio-behavioral Benefits of Greenspace

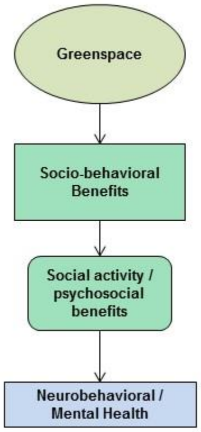


Greenspace: Physical Activity



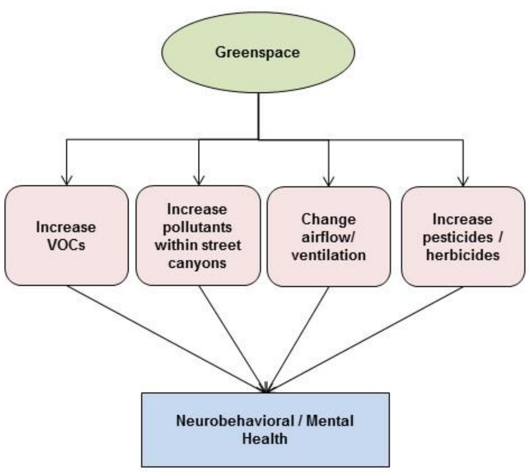
- Inconsistent / weak evidence for greenspace → physical activity → mental health link
  - Maas et al. 2008: No association between greenspace and meeting physical activity recommendations
  - Ord, Mitchell, et al. 2013: Availability of greenspace in the neighborhood not associated with physical activity
  - Lee and Maheswaran 2010: Physical activity → health, but weak evidence for greenspace → physical activity

Greenspace: Social activity and psychosocial benefits



- Provide a meeting place for users to develop and maintain neighborhood social ties
  - Increased social support (Maas et al. 2009)
  - Increased sense of community
- Mechanism not well studied

Potential Deleterious Effects of Greenspace on Pollutant Concentrations



- Increase ground-level ozone precursors
  - Vegetation that emits biogenic VOCs
- ↑ NO2 concentrations in street canyons?
  - Increased exposure for pedestrians in canyon
- Change in airflow may ↓ ventilation resulting in reduction in TRAP dilution
  - ↑ CO

– Exposure to pesticides / herbicides associated with behavior and cognition

Greenspace and Behavioral Outcomes in the CCAAPS Cohort

- Cincinnati Childhood Allergy and Air Pollution Study (CCAAPS)
  - Objective: Determine if children exposed to traffic-related air pollution, specifically diesel exhaust particles, are at increased risk for developing allergic diseases, asthma, and impaired neurobehavioral development
  - Longitudinal birth cohort study of infants born 2001-2003 in greater Cincinnati region
    - Eligibility: Birth record address < 400 m major road or > 1500 m from major road
    - Enrolled – 762; Age 7 – 617; Currently ongoing Age 12 - ~500

CCAAPS Methods

- Clinical evaluations
  - 1-4: Questionnaire, SPT, physical exam, hair, saliva, blood, eNO, spirometry
  - 7: All above + behavior
  - 12: All above + intelligence, reading ability, attention/inhibition, memory, executive function, neuromotor function, behavior, anxiety/depression, MRI (structure, organization, and function)
- Indoor exposure (1,7)
  - Walk-through, dust (allergens, mold, endotoxin)
- Outdoor exposure
  - PM2.5, EC
  - Land-use regression model

Neurobehavioral Assessment Battery

Child Direct Assessments	Outcome / Assessment
Wechsler Intelligence Scale for Children (WISC-IV)	Verbal comprehension, perceptual reasoning, working memory, processing speed, and full scale IQ
Conner's Continuous Performance Test (Conner's CPT)	Inattentiveness, impulsivity, sustained attention, and vigilance
Children's Depression Inventory (CDI-II)	Cognitive, affective, and behavioral signs of depression in children
Spence Children's Anxiety Scale (SCAS)	Generalized anxiety, panic/agoraphobia, social phobia, separation anxiety, obsessive compulsive disorder, and physical injury fears
Grooved Pegboard Test	Eye-hand coordination and motor speed
Wide Range Achievement Test (WRAT-4)	Word reading and sentence comprehension
Children's Sleep Habits Questionnaire (CSHQ)	Behaviorally and medically-based sleep problems in school-aged children
Caregiver Survey about Child	**Outcome / Assessment**
Behavior Assessment System for Children (BASC-2)	Child's behavioral and emotional function including internalizing, externalizing, and adaptive behaviors
Behavior Rating Inventory of Executive Function (BRIEF)	Assessment of executive function in children
Children's Sleep Habits Questionnaire (CSHQ)	Behaviorally and medically-based sleep problems in school-aged children
Parenting Relationship Questionnaire (PRQ)	Parent perspective on the parent-child relationship and rearing environment
Social Responsiveness Scale (SRS)	Social impairment and behaviors associated with autism spectrum disorders
Caregiver Direct Assessment	**Outcome / Assessment**
Wechsler Abbreviated Scale of Intelligence (WASI-2)	Brief measure of cognitive ability that provides a full scale IQ
Beck Depression Inventory – 2nd Ed. (BDI-II)	Measure of depression in adults

Neuroimaging

- Nested substudy of children exposed to high (n = 100) and low (n = 100) TRAP during early childhood
  - 3T MRI Scanner

Sequences Acquired	Imaging Outcome
Three dimensional T1 weighted imaging	Whole brain and substructure volumes
Standard T2 weighted	Inflammatory changes noted with hyperintense signals
T2 map for quantitative T2 measurements	T2 rates for brain tissues
Diffusion Tensor Imaging of White Matter	White matter integrity metrics
Magnetic Resonance Spectroscopy	Metabolite concentrations
Functional Magnetic Resonance Imaging Verb generation task	Neural activation levels

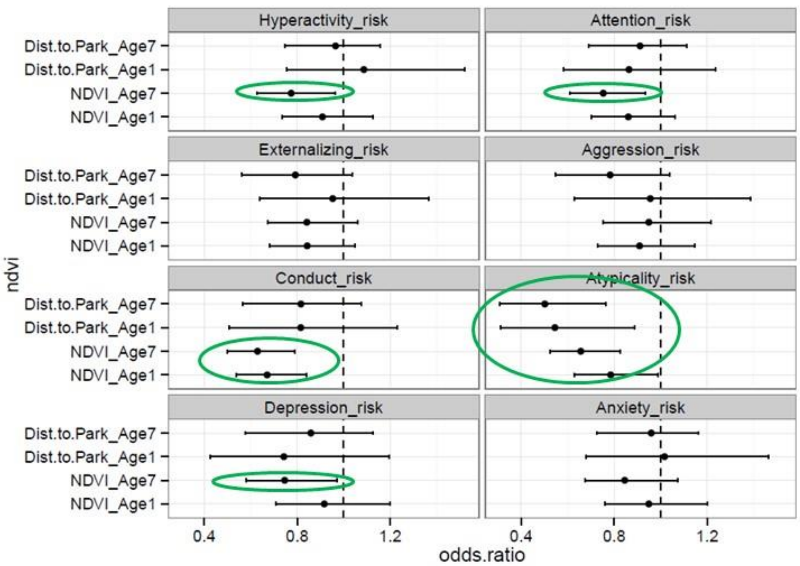
TRAP Exposure Prior to Age 1 and Behavioral Scores at Age 7

BASC-2 Subscale	% "at risk" (>59)	TRAP (High/Low)-Unadjusted OR		TRAP (High/Low)-Adjusted** OR	
		OR	95% CI	OR	95% CI
Hyperactivity	18%	**1.9**	**(1.2 - 2.9)**	**1.7**	**(1.0 - 2.7)**
Attention problems	19%	1.4	(0.9 - 2.2)	1.1	(0.6 - 1.7)
Aggression	16%	1.5	(0.9 - 2.4)	1.2	(0.7 - 2.0)
Conduct problems	14%	**2.1**	**(1.3 - 3.3)**	1.5	(0.9 - 2.6)
Atypicality	14%	**2.0**	**(1.3 - 3.2)**	1.5	(0.9 - 2.6)

* Adjusted for gender, tobacco smoke exposure prior to age one, maternal education

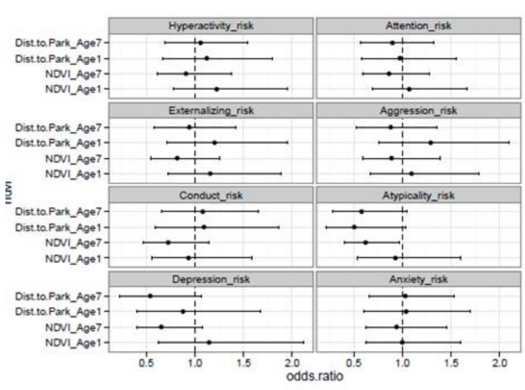
Newman et al. *Environmental Health Perspectives*. 2013.

CCAAPS Preliminary Data: Greenspace and Behavior

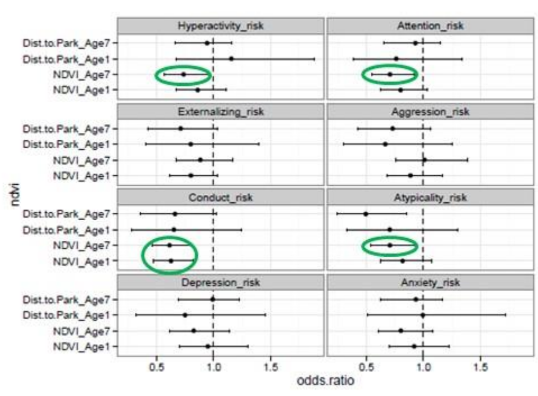


CCAAPS Preliminary Data: Greenspace, Traffic, and Behavior

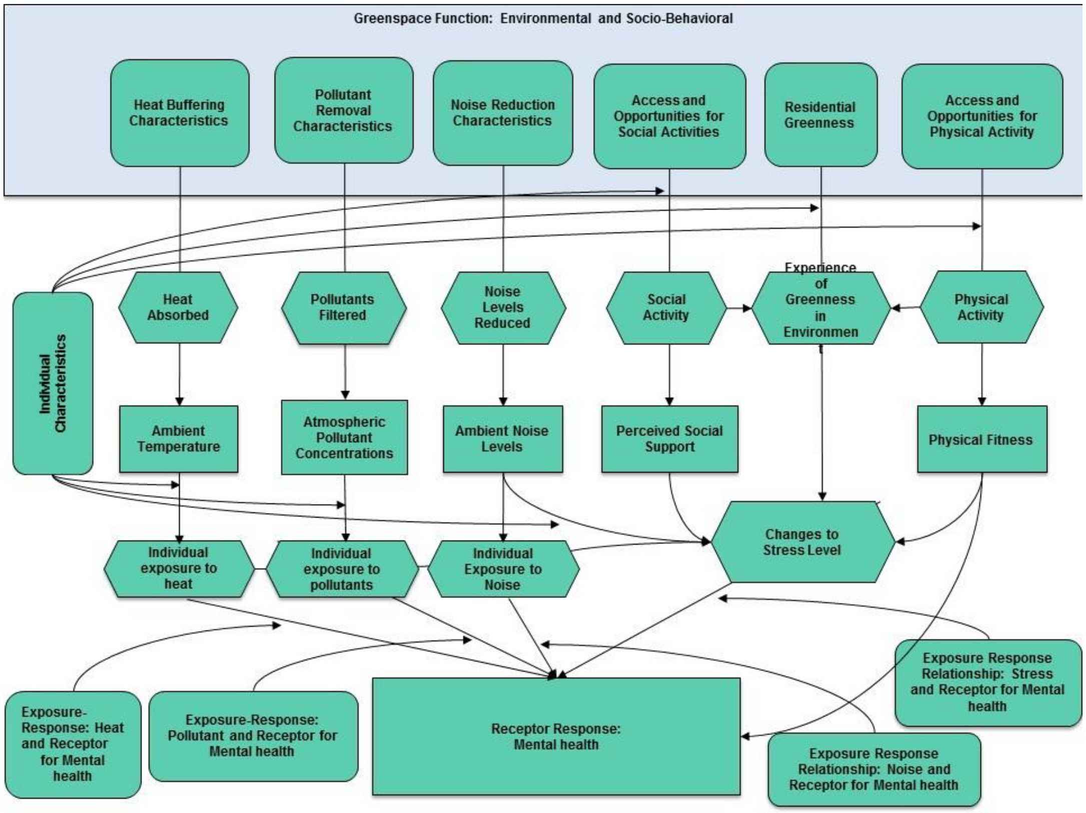
Low TRAP



High TRAP



Day 2−Neurological/neurodevelopmental effects



Driving Questions

- How should cumulative risk assessment framework consider greenspace as it relates to neurodevelopment?
- What greenspace elements and metrics are relevant to neurodevelopment?
- What are the specific known or presumed mechanisms of neurodevelopment, and can this be used to inform biologic plausibility of reported associations with greenspace?
- Consideration of potential cumulative effect of greenness on neurodevelopment – “active” + “passive” exposure pathways – e.g. outdoor exercise (activie) and visible greenspace around residence (passive)
- Considerations of community and individual level outcomes and specific populations

Contribution of Greenspace to Neurobehavior / Mental Health

- Greenspace widely viewed as beneficial to mental health
  - Recovery from fatigue
  - Reduction in stress
  - Reduction in crime
  - Improved self-reported general health
- Greenspace linked to reduction in biomarkers of stress
  - ↓cortisol
- Potential mechanisms
  - ↑ physical activity → improved mental health
  - Exposure to nature
  - ↑ social interaction
  - Decreased exposure to pollutants, noise, and heat

"…in every walk with Nature one receives far more than he seeks"
John Muir 1992, p. 918

Psychosocial effects

Michelle Kondo
Julia Africa
Matilda Annerstedt van den Bosch
May 5, 2015

Estimating Greenspace Exposure & Benefits for Cumulative Risk Assessment Applications
Technical Working Group Meeting
May 4-5, 2015

U.S. Environmental Protection Agency
26 Martin Luther King Drive West, Cincinnati, OH 45220

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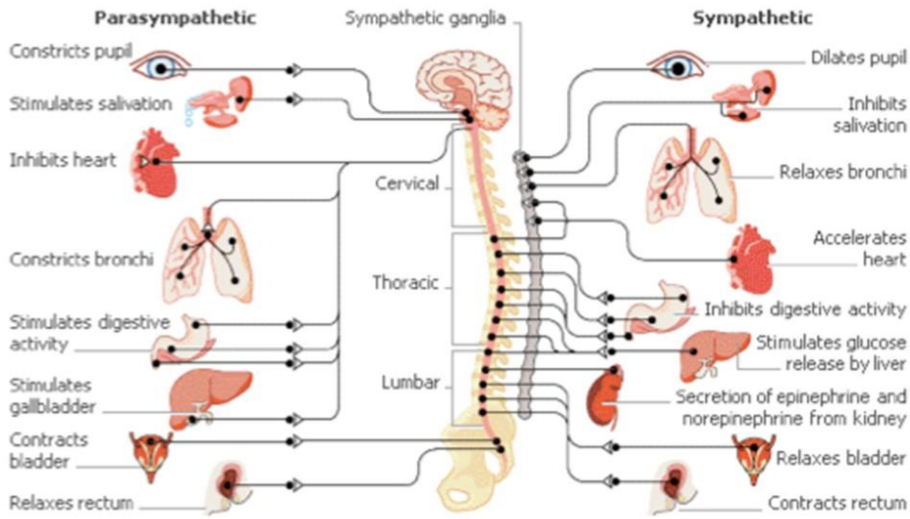
Psychosocial health

Determinants:

- Stress
- Social capital
- Genetics
- Environment

Stress biology: Autonomic nervous system (ANS)



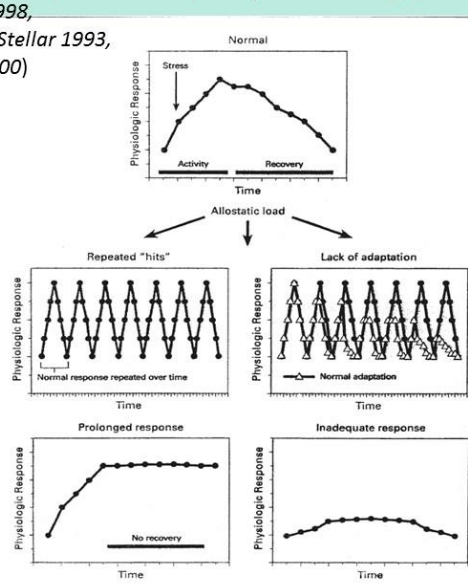
Biomarkers:
- Pulse rate
- Blood pressure
- HRV, TWA (ECG)
- Hormones (e.g. cortisol)
- Brain electricity signals (EEG)
- Skin conductance

Adaptation & pathophysiology

Allostasis (homeostasis)

(McEwen 1998, McEwen & Stellar 1993, McEwen 2000)

Stress mediators:
Glucocorticoids (e.g. cortisol)
Cathecolamines



Maintaining stability through change (acute stress responses and recovery)

Repeated stressful events – chronic stress (e.g. multiple periods of poverty, child abuse)
Effects: early aging, depression, decline of physical and mental Functioning

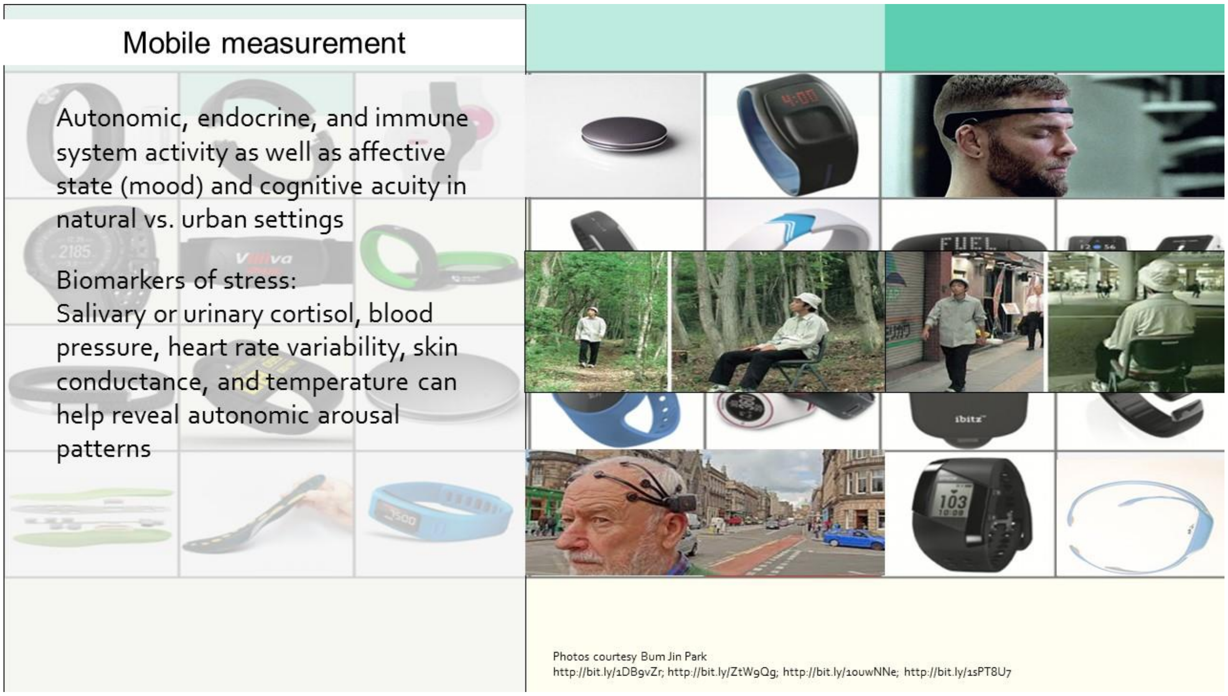
Failure to adapt (e.g. if lack of self-confidence & self-esteem)

Failure to turn off

Inadequate stress response (genotype)
Low cortisol and high inflammatory Cytokines
e.g. fibromyalgia, chronic fatigue syndrome

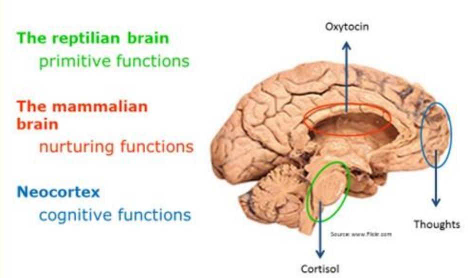
4

Day 2−Psychosocial effects



Stress and the brain

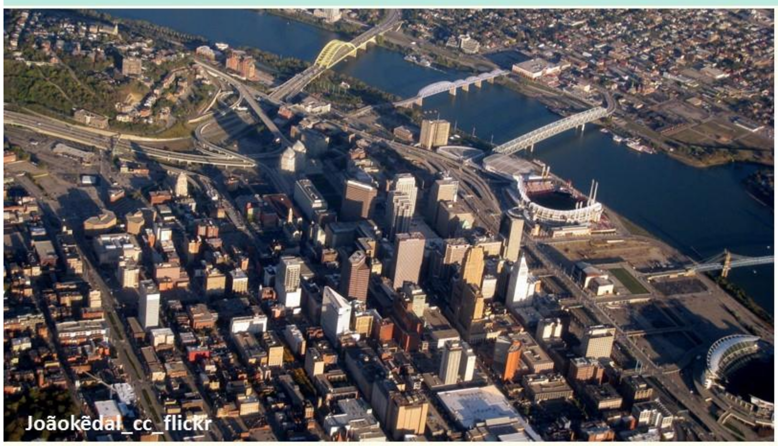
- Deactivates neo-cortex
- Activates amygdala in limbic system (including interactions with hippocampus and prefrontal cortex)
- Paleocortex
- Unreasonable, agitated,
  thoughtless behaviour
- Chronic stress – chronic changes in brain
  (incl. epigenetic changes)
- Impaired coping/adaptation (allostasis)

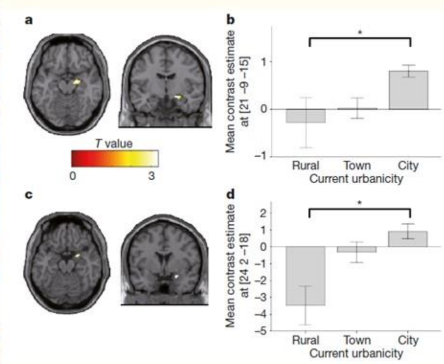


Ref: Gray et al. 2013, McEwen 2012, Davidson & McEwen 2012, McEwen & Gianaros, 2011)

The brain: stress & environment

Urbanisation





Lederbogen et al. 2011.
City living and urban upbringing affect neural social stress processing in humans. Nature.

Stress and mental illness

- Persons with major depression or schizophrenia have a **40 – 60% higher risk of dying** prematurely as compared to a general population.
- Mental illness represents three of the **ten leading causes of disease burden** in low- and middle-income countries, and four of the leading ten in high-income countries.
- More than 800 000 persons die from **suicide** each year.
- Globally, only **2.8% of the health budget** is allocated to mental health.
- Depression affects one of five people over the age of 65
- **Prevention** programmes are often the most efficient
- **Unequal** distribution
- High level of **co-morbidity** (somatic diseases, e.g. cancer, cardiovascular)
- Costs: **US$ 16.3 million** 2011 – 2030

(Source: WHO; Bloom et al. 2012)

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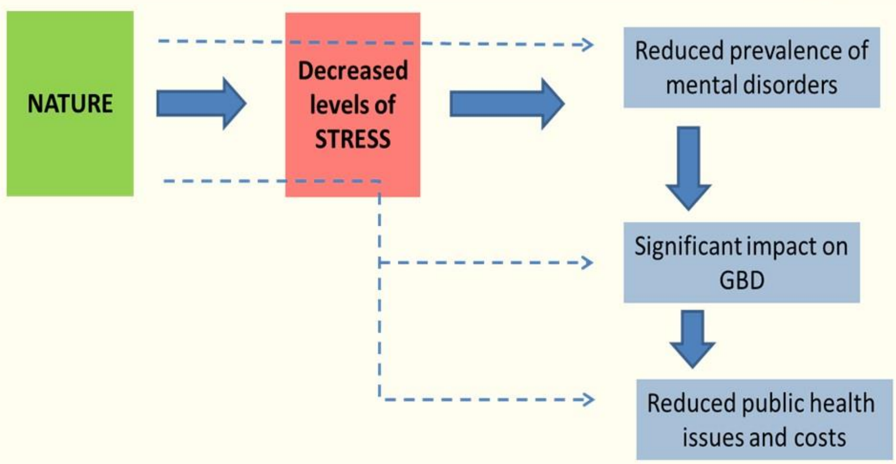
GS – stress – mental disorders

Prevention



Ref: Annerstedt et al. 2012, 2013, 2015; Ward Thompson et al. 2012; Roe et al. 2013; Ulrich et al. 1991; van den Berg et al. 2010; Grahn & Stigsdotter, 2003

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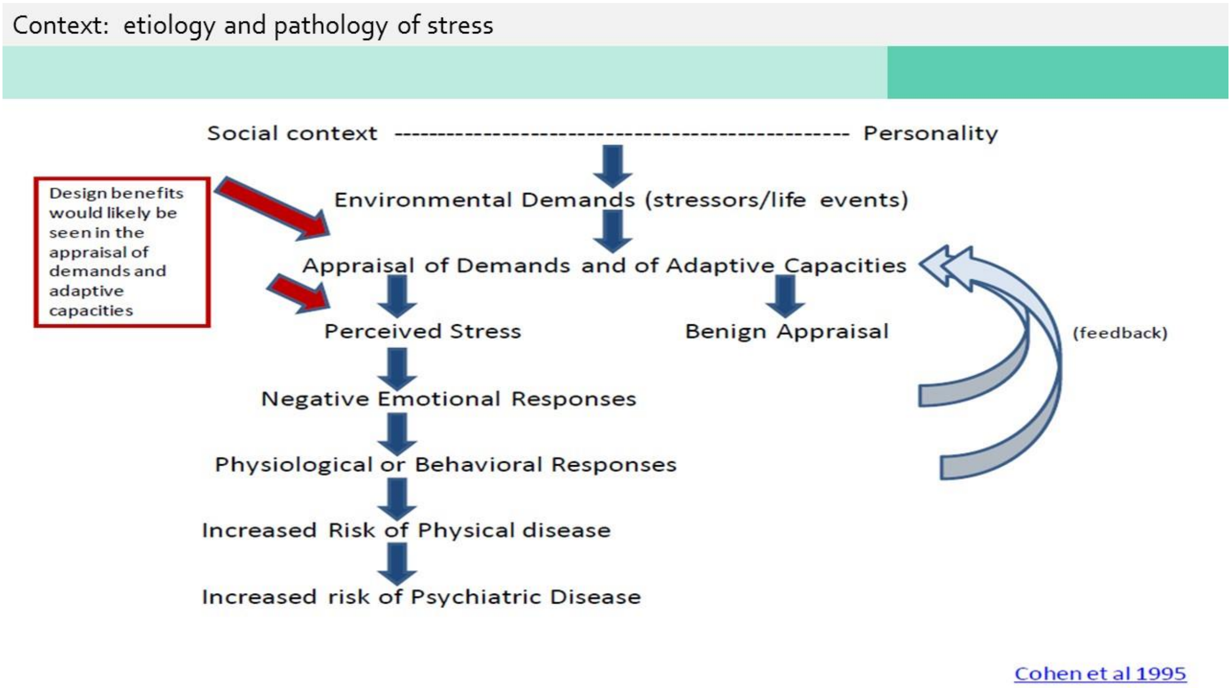
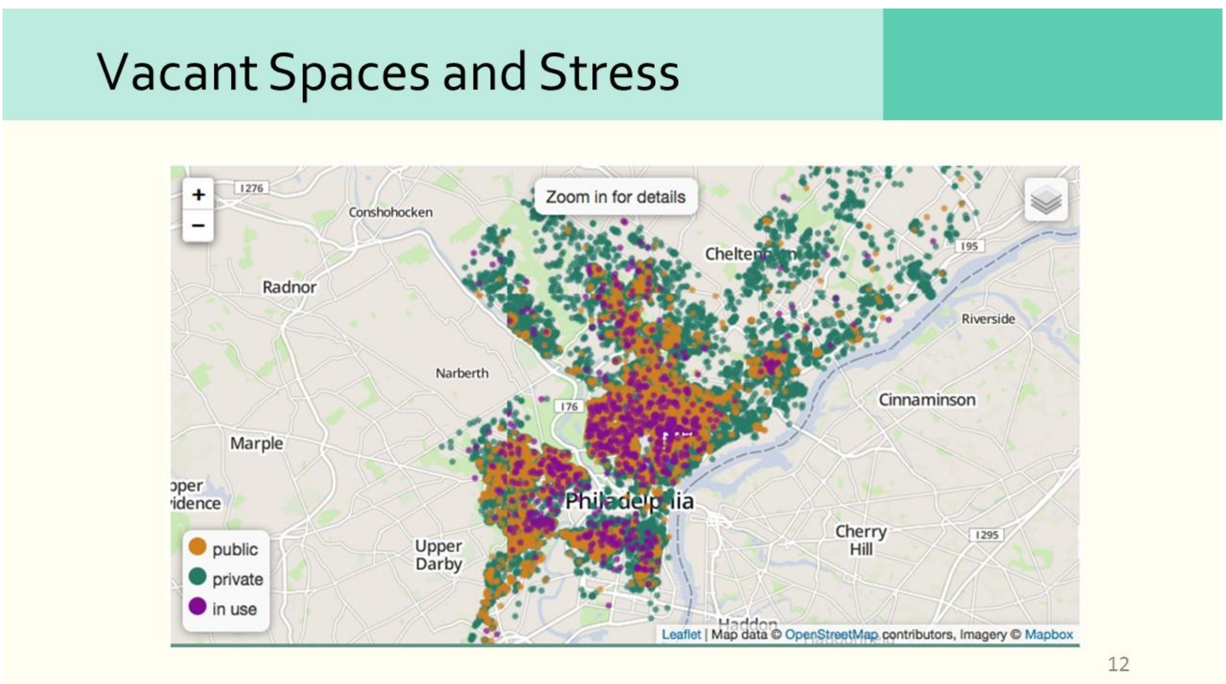
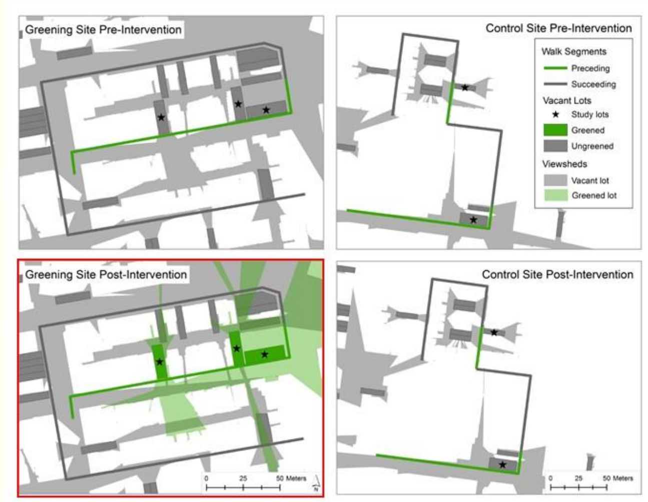
Day 2−Psychosocial effects





Vacant Lot Greening & Stress

A mobile biosensing project with residents living near vacant lots



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Vacant Lot Greening & Stress

Results: heart rate decreases when in view of vacant lots

- 12 participants (7 Trx: 5 Ctrl)
- DDD estimates for Trx & Ctrl sites based on:
  - pre-post greening
  - within- vs. out-of-view
  - preceeding vs. succeeding greened lots
- -15.6 bpm (Trx site) vs. -1.7 bpm (Ctrl site)

USDA

Urban Health Lab
Science. Making. Cities. Better
www.urbanhealthlab.org

Penn University of Pennsylvania

South, Kondo, Cheney, Branas (2015) Neighborhood blight, stress, and health: A walking trial of urban greening and ambulatory heart rate. *American Journal of Public Health* 105(5): 909-913.

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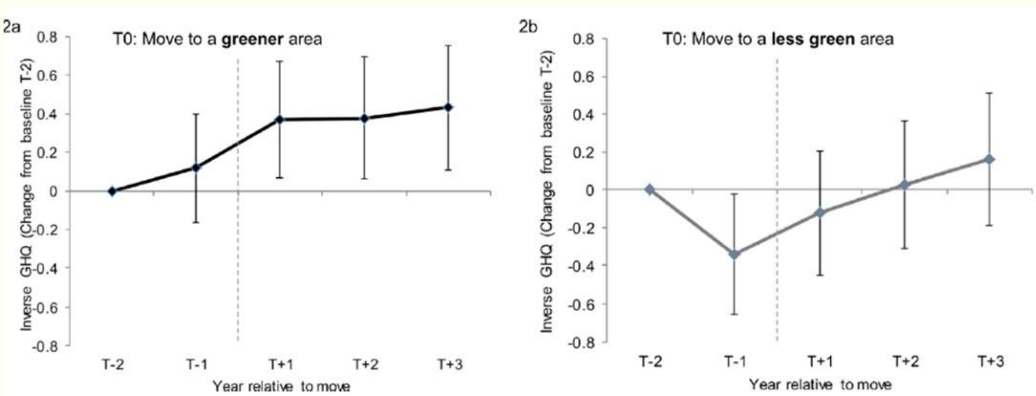
Direct relation between nature and mental health



Alcock et al. 2014. *Longitudinal effects on mental health of moving to greener and less green urban areas.* Environmental Science and Technology

Social cohesion

- Interaction with neighbors
- Sense of community

Barriers:
- Illness
- Lack of supportive community/environment
- Lack of social opportunities
- Fear
- Lack of self confidence

Ref: Goll et al. 2015, Bergh et al. 2009, Åslund et al. 2010

Social cohesion and disease

- Social cohesion, both personally and in the environment prevents chronic illness
- Loneliness among main risk factors for disease, at same level as smoking
- Loneliness significantly correlated to impaired cognitive function
- Social cohesion mitigates other risk factors (e.g. smoking, physical inactivity, drug abuse)
- Elderly often affected
- Immigrants
- Biological causality between loneliness and disease is unclear

Ref. Boss et al. 2015, Waverijn et al. 2014, Samuel et al. 2015

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Social cohesion and GS

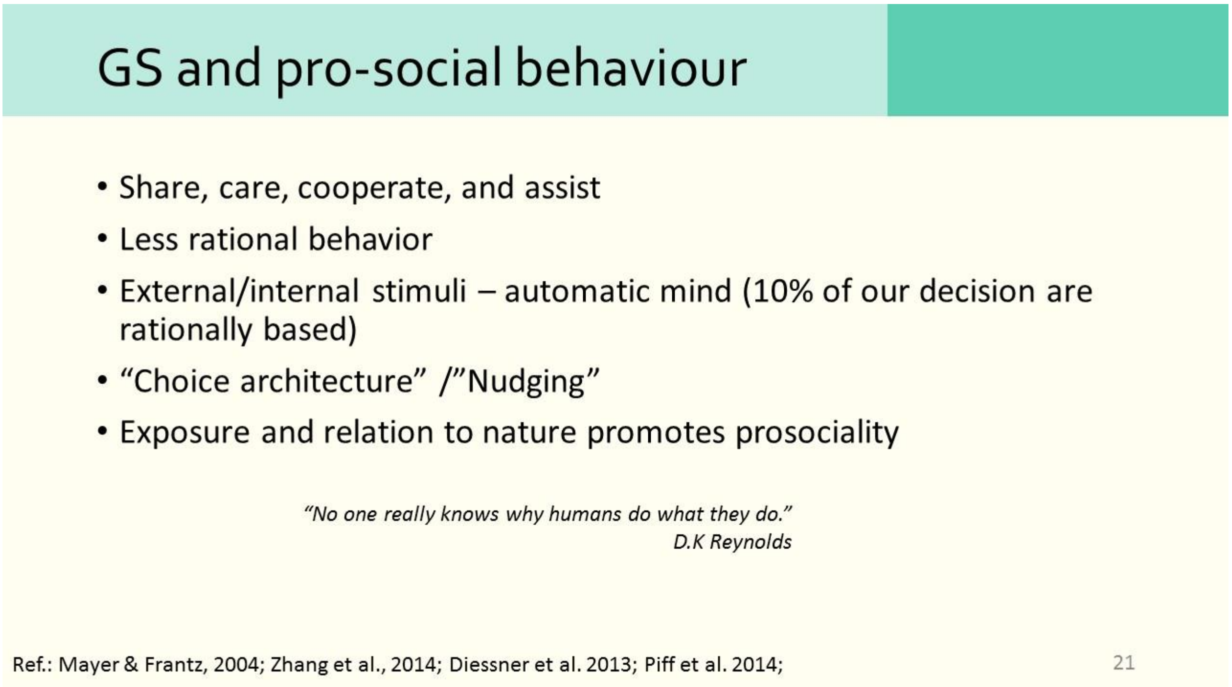
- Green spaces and crime reduction
- Green Spaces increase social contact and the sense of belonging within a community
- Encourage getting familiar with persons of different social and ethnic backgrounds

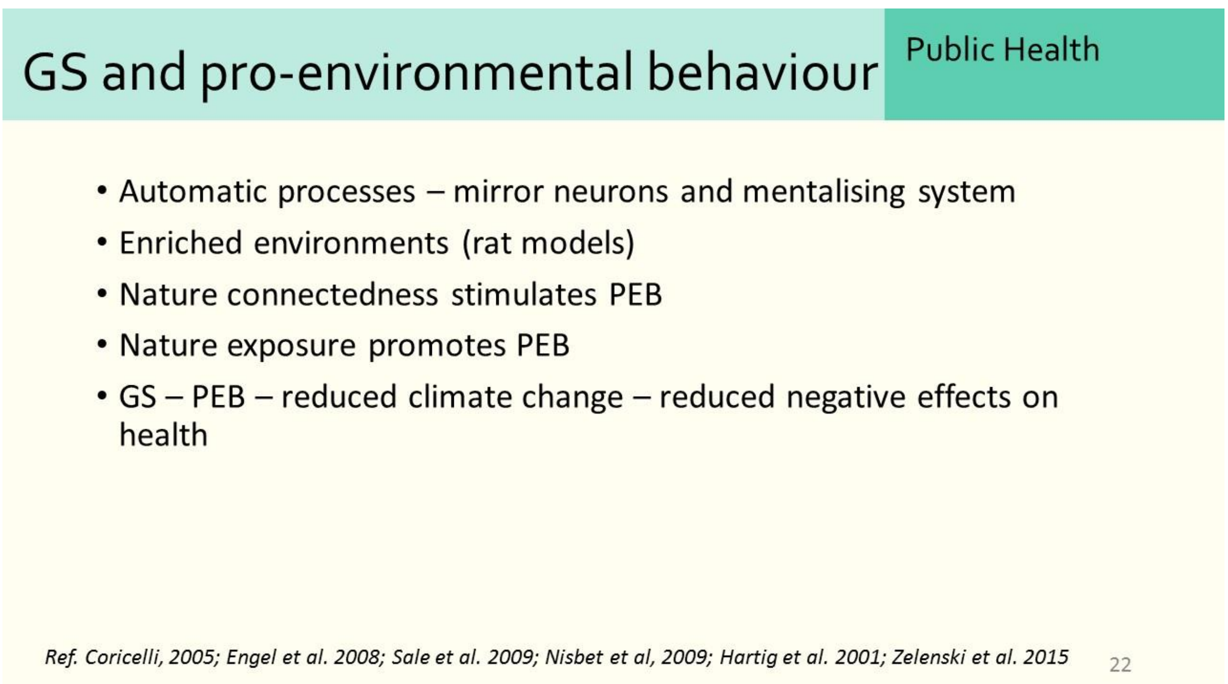
Ref: Donovan & Prestemon, 2012; Maas et al. 2009; Lofland 1998; Peters et al. 2010; Kuo et al. 1998; Cohen et al. 2008; de Vries et al. 2013

Quality aspects of GS & social cohesion

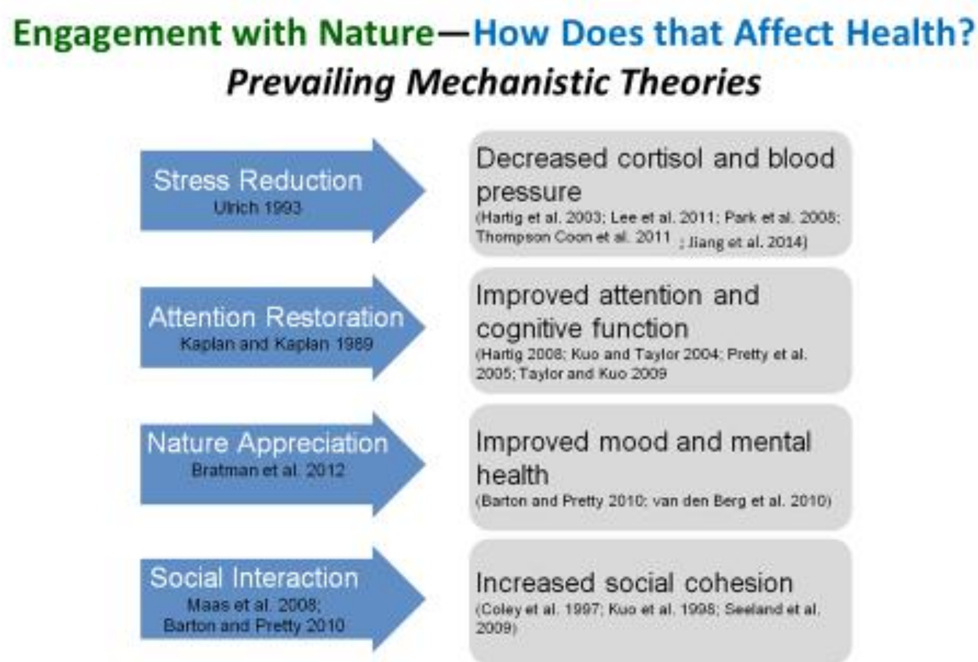
- Safety perceptions
- High quality GS
- Well maintained
- Good, attractive recreational facilities
- Community gardens

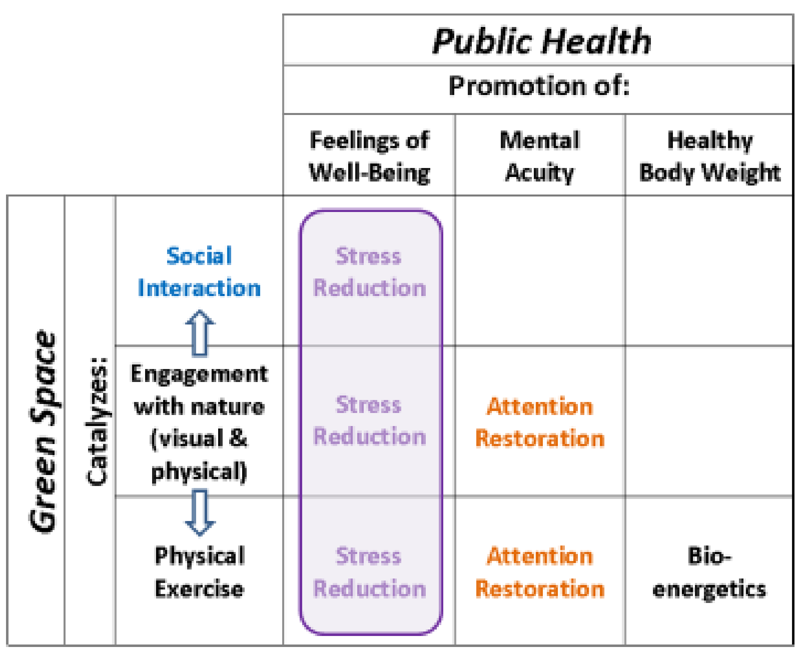
Ref.: Francis et al. 2012; Hartig et al. 2014; Kazmierczak, 2013


GS and pro-social behaviour
• Share, care, cooperate, and assist
• Less rational behavior
• External/internal stimuli – automatic mind (10% of our decision are rationally based)
• “Choice architecture” /”Nudging”
• Exposure and relation to nature promotes prosociality
“No one really knows why humans do what they do.”
D.K Reynolds
Ref.: Mayer & Frantz, 2004; Zhang et al., 2014; Diessner et al. 2013; Piff et al. 2014;
21

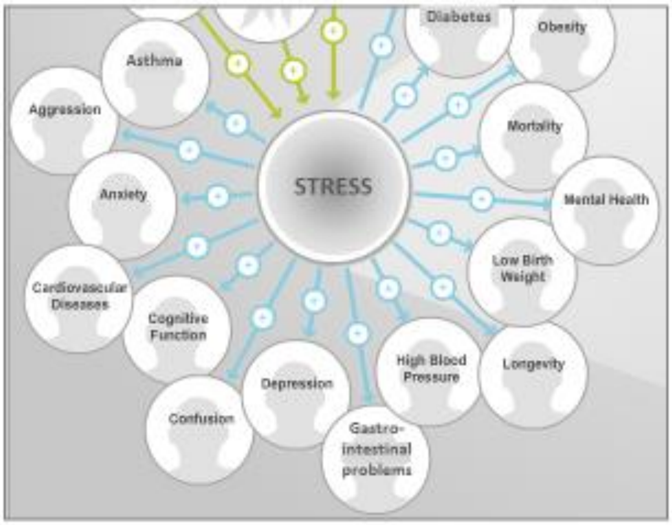

GS and pro-environmental behaviour
Public Health
• Automatic processes – mirror neurons and mentalising system
• Enriched environments (rat models)
• Nature connectedness stimulates PEB
• Nature exposure promotes PEB
• GS – PEB – reduced climate change – reduced negative effects on health
Ref. Coricelli, 2005; Engel et al. 2008; Sale et al. 2009; Nisbet et al, 2009; Hartig et al. 2001; Zelenski et al. 2015
22

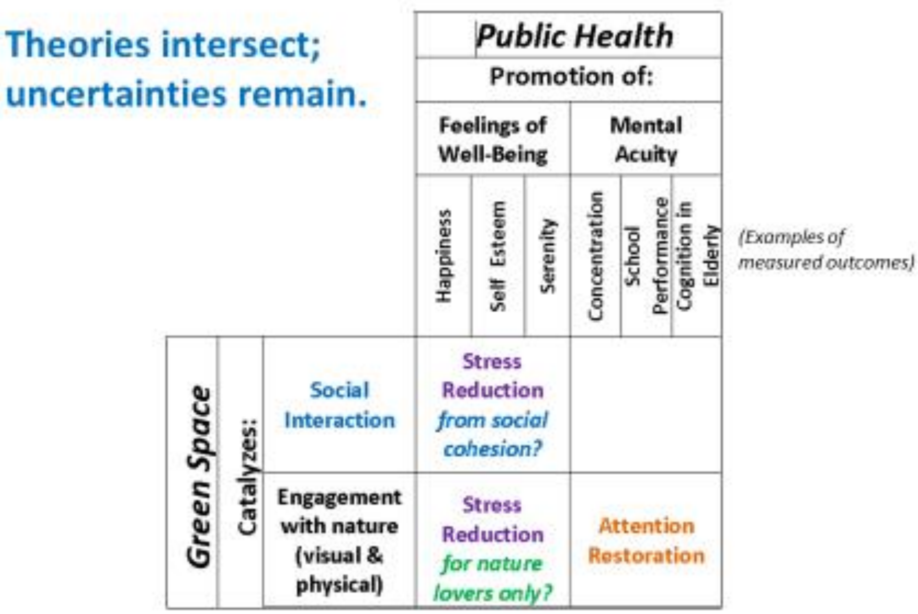
Day 2−Attention Restoration/cognition effects





Day 2−Attention Restoration/cognition effects





Day 2−Attention Restoration/cognition effects

			Public Health					
			Promotion of:			Protection against:		
			Feelings of Well-Being	Mental Acuity	Healthy Body Weight	Toxicity	Extreme Events	Deprivation
Green Space	Catalyzes:	Social Interaction	Stress Reduction			*Increased Resilience*	*Increased Resilience*	*Increased Resilience*
		Engagement with nature (visual & physical)	Stress Reduction	Attention Restoration				
		Physical Exercise	Stress Reduction	Attention Restoration	Bio-energetics			
	Provides:	Hazard Buffers				Filtration	Modulation	
		Food Water Raw Materials					*Increased Resilience*	*Increased Resilience*

Community Benefits

Michelle Kondo (USFS)
Geoffrey Donovan (USFS)

Estimating Greenspace Exposure & Benefits for Cumulative Risk Assessment Applications
Technical Working Group Meeting
May 4-5, 2015

U.S. Environmental Protection Agency
26 Martin Luther King Drive West, Cincinnati, OH 45220

1

Green Space and Safety Perception

1-3

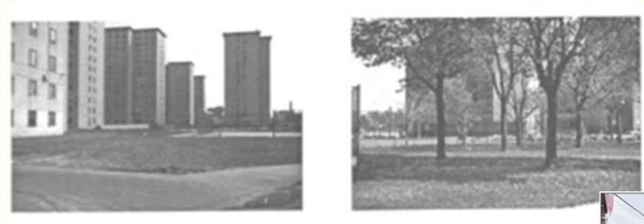
4

Low (M = 1.78)   High (M = 6.08)

1. Nasar JL, Fisher B, Grannis M. Proximate physical cues to fear of crime. *Landsc Urban Plan.* 1993;26(1).
2. Nasar JL, Jones KM. Landscapes of fear and stress. *Environ Behav.* 1997;29(3).
3. Fisher BS, Nasar JL. Fear of crime in relation to three exterior site features prospect, refuge, and escape. *Environ Behav.* 1992;24(1).
4. Chiang, Yen-Cheng, Jack L. Nasar, and Chia-Chun Ko. "Influence of visibility and situational threats on forest trail evaluations." *Landscape and Urban Planning* 2014;125.

2

Green Space and Safety Perception



1

2

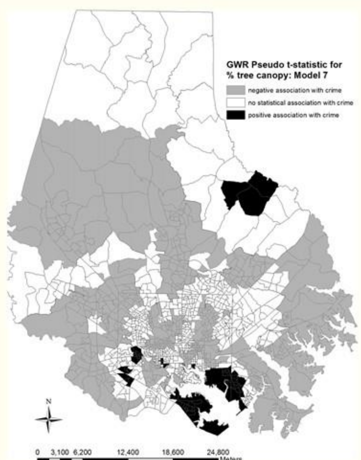
Before greening After greening

1. Kuo FE, Sullivan WC, Coley RL, Brunson L. Fertile ground for community: Inner-city neighborhood common spaces. *Am J Commun Psychol.* 1998;26(6):823-851.
2. Garvin EC, Cannuscio CC, Branas CC. Greening vacant lots to reduce violent crime: a randomised controlled trial. *Inj Prev.* 2012;19(3):198-203.

3

Green Space and Crime

1



2

1. Kuo FE, Sullivan WC. Environment and crime in the inner city: Does vegetation reduce crime? *Environ Behav.* 2001;33(3).
2. Troy A, Morgan Grove J, O'Neil-Dunne J. The relationship between tree canopy and crime rates across an urban–rural gradient in the greater Baltimore region. *Landsc Urban Plann.* 2012;106(3)
3. Donovan GH, Prestemon JP. The effect of trees on crime in Portland, Oregon. *Environ Behav.* 2012;44(1)

4

Vegetation Type or Scale

1

2

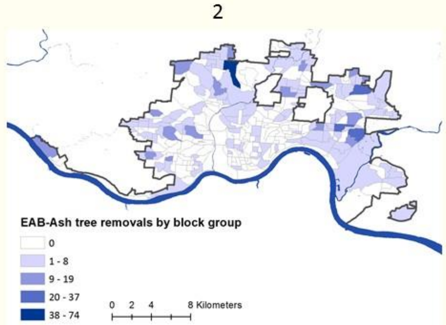
1. Valley Green Space
2. Green Cities: Good Health. Kathleen Wolf, University of WA / USFS
3. Kuo FE, Bacaicoa M, Sullivan WC. Transforming inner-city landscapes trees, sense of safety, and preference. *Environ Behav.* 1998;30(1)
4. Donovan GH, Prestemon JP. The effect of trees on crime in Portland, Oregon. *Environ Behav.* 2012;44(1)

5

Location

1

2



1. Kondo M, Low S, Henning J, Branas C. The impact of green stormwater infrastructure installation on surrounding health and safety. *Am J Public Health.* 2015(105):3
2. Kondo, MC, Han, S, Donovan, G, MacDonald, JM. The Effect of Trees on Urban Crime: Evidence from the Spread of the Emerald Ash Borer in Cincinnati. Under review.
3. Donovan GH, Prestemon JP. The effect of trees on crime in Portland, Oregon. *Environ Behav.* 2012;44(1)

6

Maintenance

1

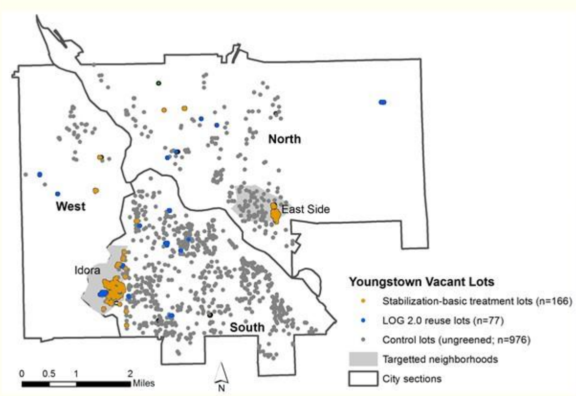
3

2

1. youngphillypolitics.com
2. nakedphilly.com
3. Garvin EC, Cannuscio CC, Branas CC. Greening vacant lots to reduce violent crime: a randomised controlled trial. *Inj Prev.* 2012;19(3).

7

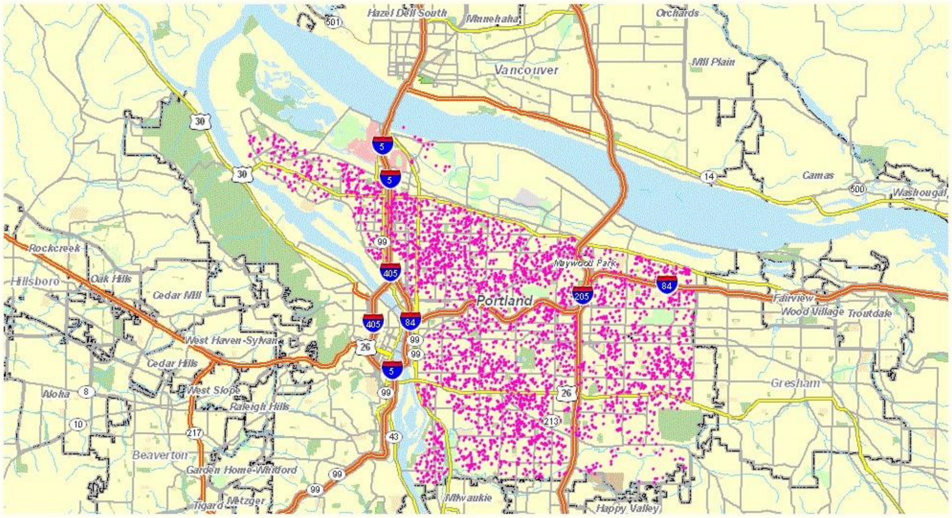
Community Involvement



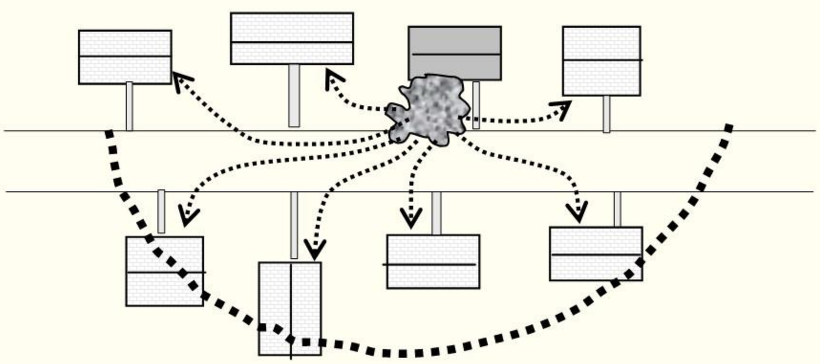
Kondo, MK, Hohl, BC, Han, S, Branas, C (under review) Effects of Greening and Community Reuse of Vacant Lots on Crime.

8

Day 2−Economic and community benefits

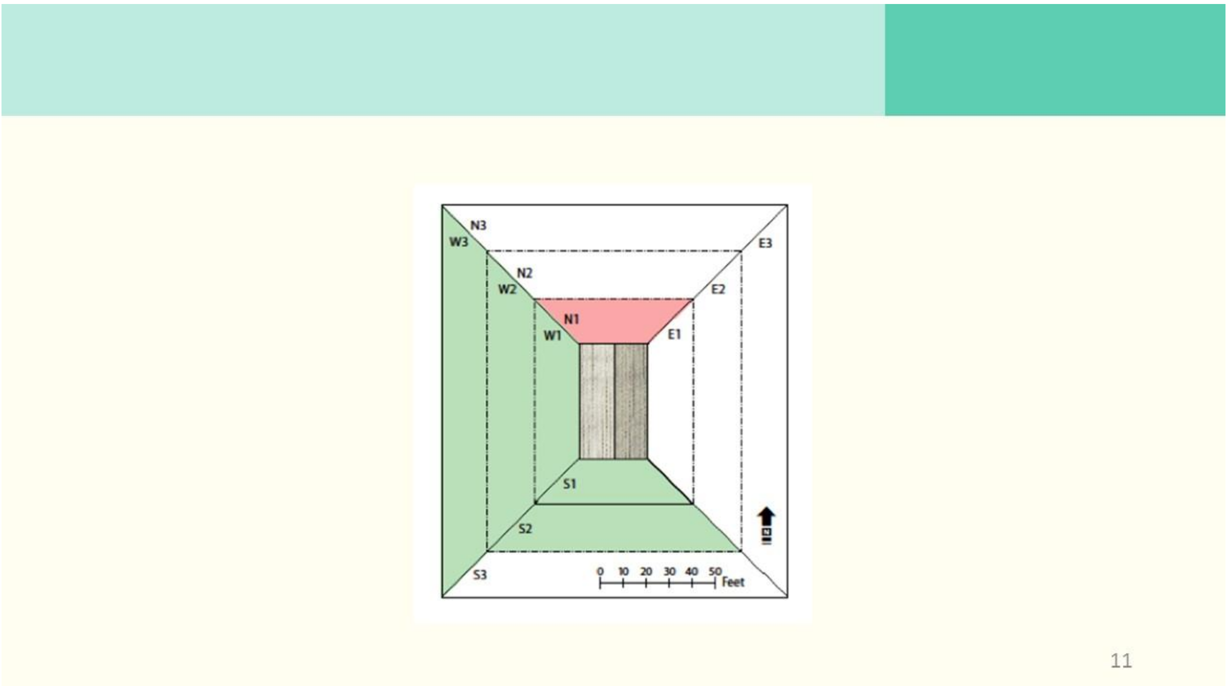


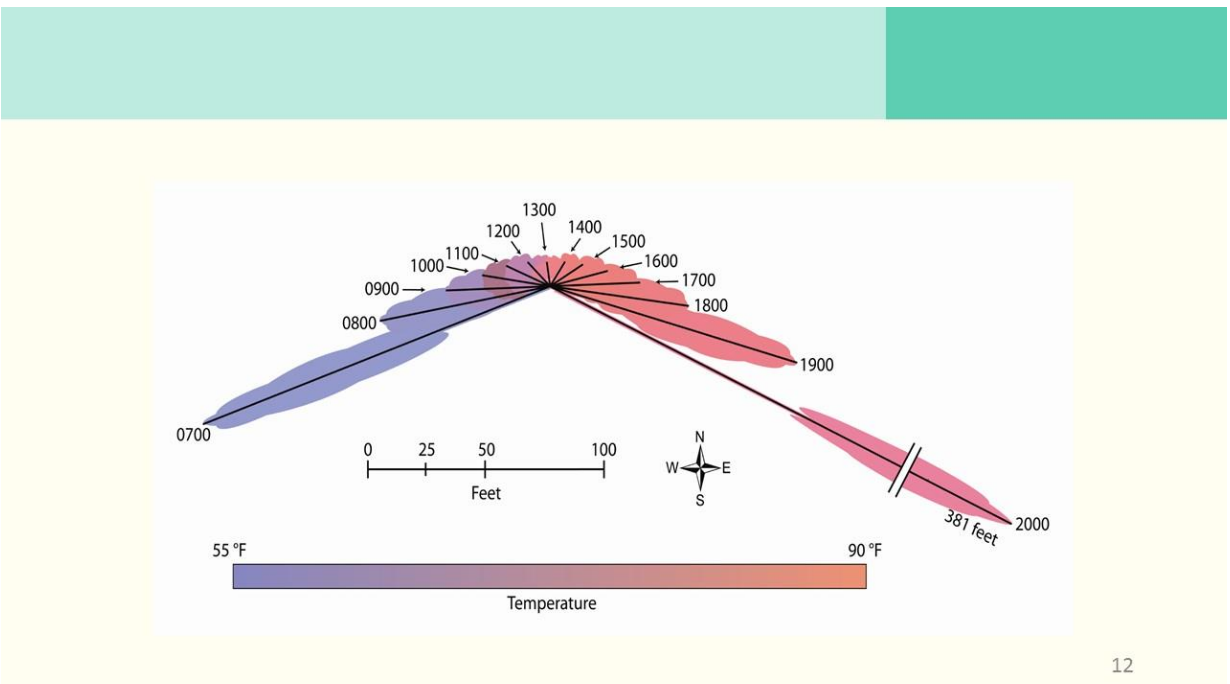
9



10

Day 2−Economic and community benefits





Specific populations (health)

Rich Mitchell

Pat Ryan

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1

Introduction

1. Summary of health topic and underlying biology of health condition
2. Summary of research to date
3. Applied GS metrics and data sources
4. Discussion of established and hypothesized mechanisms associated with exposure to GS using conceptual model templates

- Why should we care that green space might have different health effects for different groups?
  - Inequalities
  - Equigenesis
- What groups should we look at?
  - Borrowing the groups from yesterday's talk – gender, sep/race and age
- What should we expect?
  - Important to note that the experimental studies, particularly on physiological benefits and psychological restoration, have generally not been stratified by population sub-group
  - We have no reason to think that the mechanisms will *work* in a different way for different sub-groups, but they might be triggered differently, be more or less important..

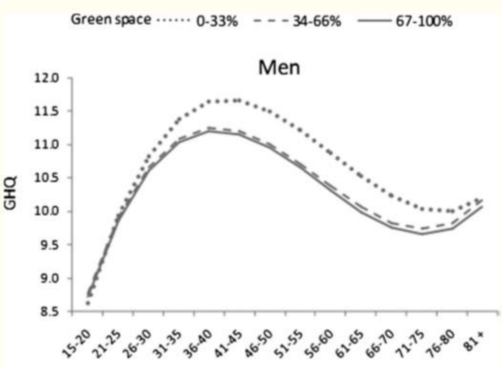
2

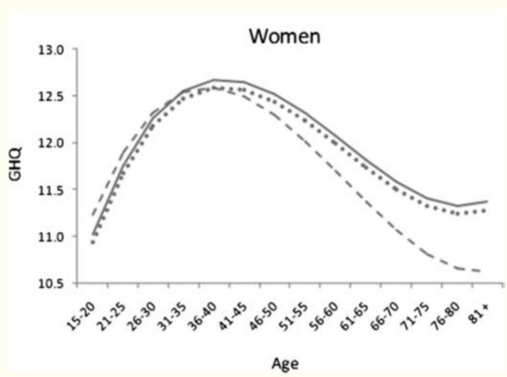
Gender

- Mixed evidence for differential ‘effects’ (observational studies!) by gender
- Richardson and Mitchell found significant negative associations between amount of green space in the neighbourhood and risk of mortality from CVD and respiratory diseases for men, but not for women.
- Ward Thompson et al found beneficial effects of residence in greener neighbourhoods on diurnal cortisol patterns for both men and women, but they were of different kinds…
- Astell-Burt et al found some interesting differences between men and women in association with GHQ score
- Of course, the pregnancy / green space literature applies only to women ☺

3

Gender differences in ‘effects’ on mental health, across the life course

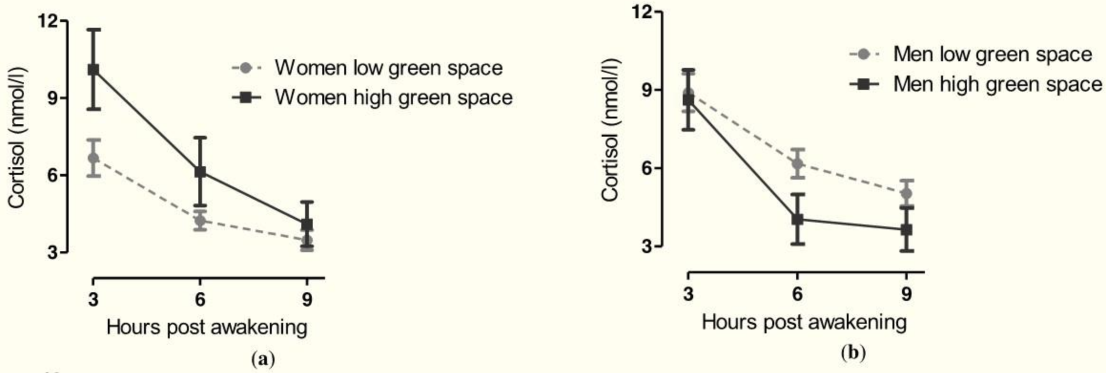




Astell-Burt T, et al. J Epidemiol Community Health 2014;0:1–6. doi:10.1136/jech-2013-203767

4

Example of gender difference in green space 'effects'



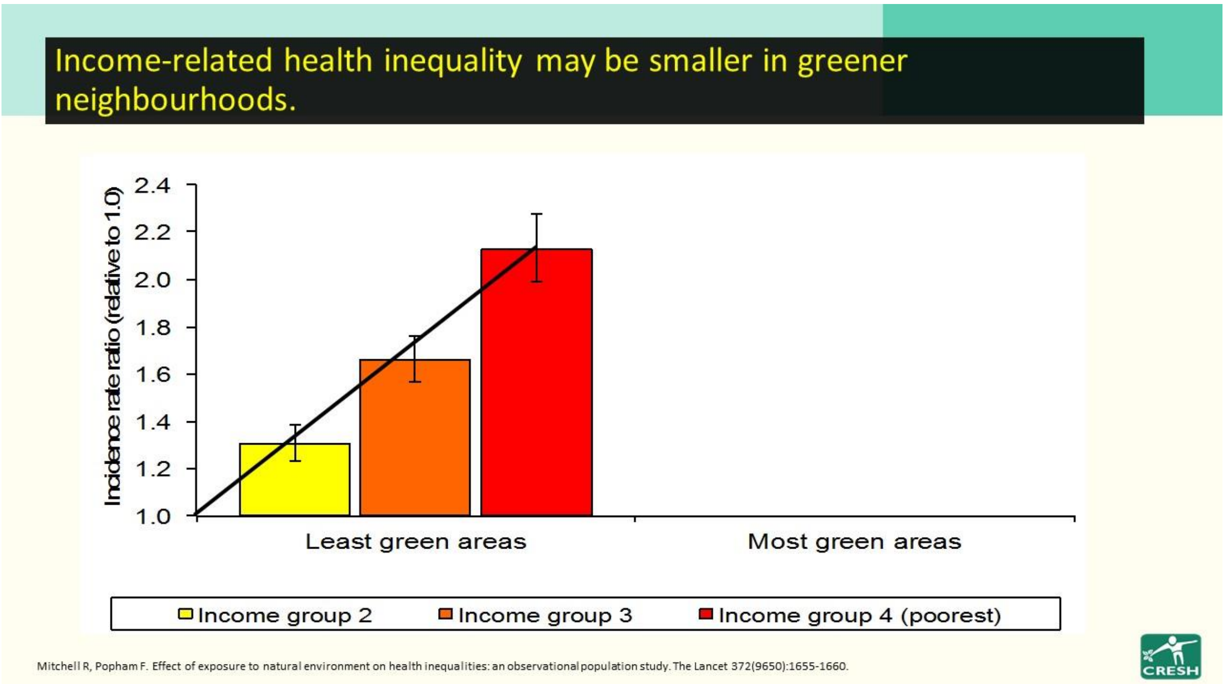
Roe et al Int. J. Environ. Res. Public Health 2013, 10, 4086-4103; doi:10.3390/ijerph10094086

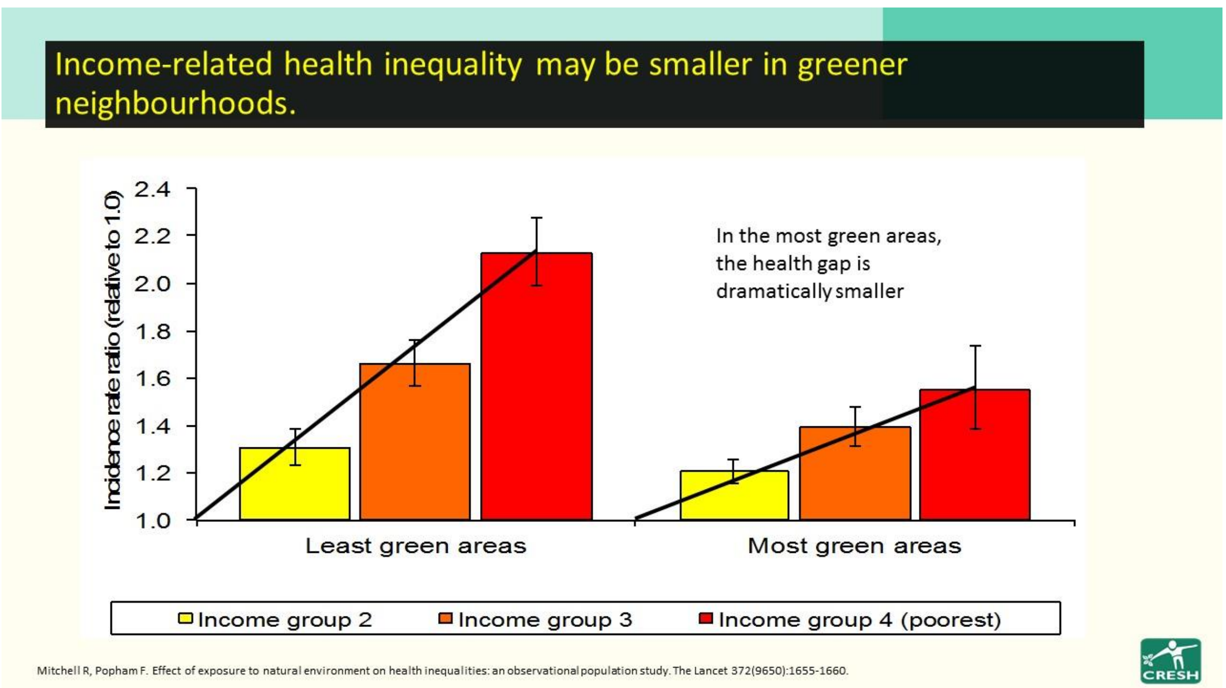
5

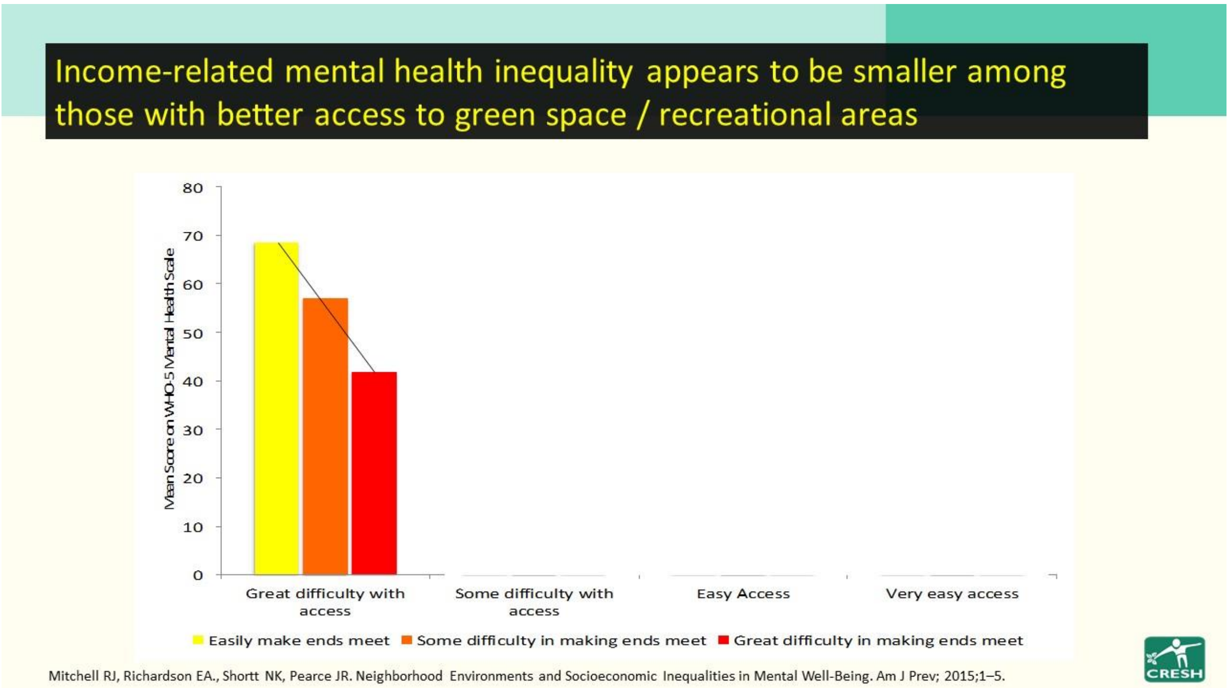
Socio-economic position

- Differences in association with health by SEP is a key area of interest in my team.
- Chronic medical conditions of the kinds that green space might plausibly help - along with their associated signs/symptoms and mortality risks – are far more common among vulnerable populations.

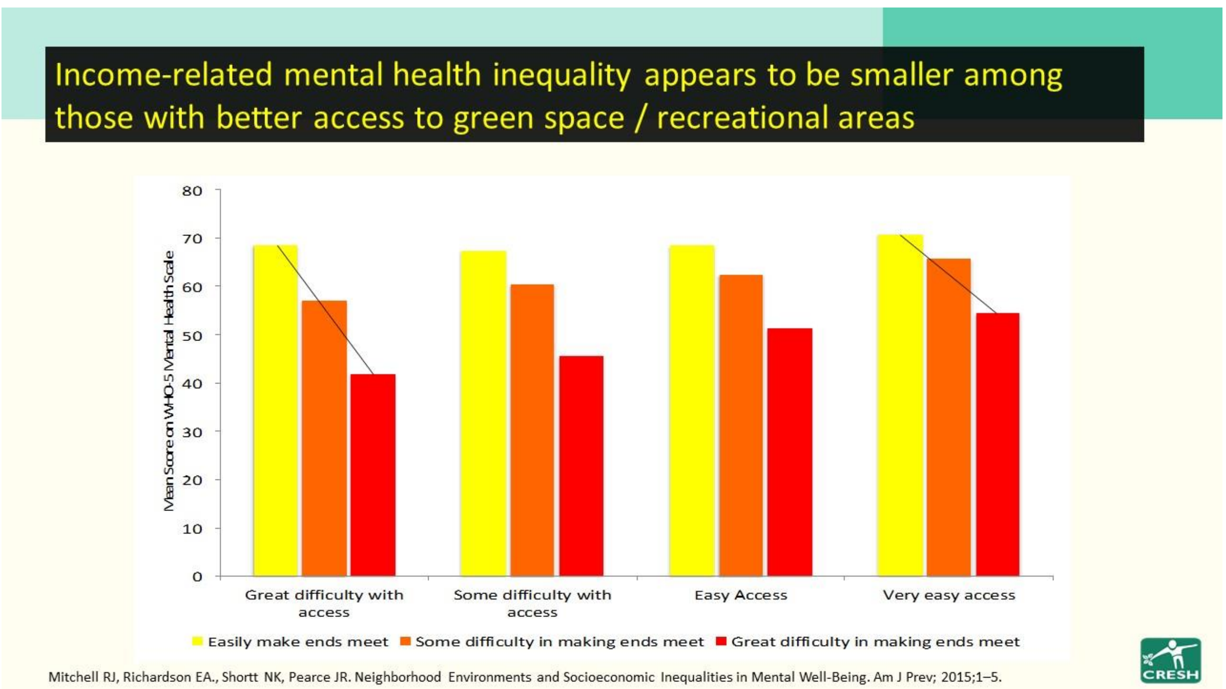
6


Income-related health inequality may be smaller in greener neighbourhoods.
Incidence rate ratio (relative to 1.0)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
Least green areas
Most green areas
Income group 2
Income group 3
Income group 4 (poorest)
Mitchell R, Popham F. Effect of exposure to natural environment on health inequalities: an observational population study. The Lancet 372(9650):1655-1660.
CRESH


Income-related health inequality may be smaller in greener neighbourhoods.
Incidence rate ratio (relative to 1.0)
2.4
2.2
2.0
1.8
1.6
1.4
1.2
1.0
In the most green areas, the health gap is dramatically smaller
Least green areas
Most green areas
Income group 2
Income group 3
Income group 4 (poorest)
Mitchell R, Popham F. Effect of exposure to natural environment on health inequalities: an observational population study. The Lancet 372(9650):1655-1660.
CRESH



Income-related mental health inequality appears to be smaller among those with better access to green space / recreational areas
Mean Score on WHO-5 Mental Health Scale
80
70
60
50
40
30
20
10
0
Great difficulty with access
Some difficulty with access
Easy Access
Very easy access
Easily make ends meet
Some difficulty in making ends meet
Great difficulty in making ends meet
Mitchell RJ, Richardson EA., Shortt NK, Pearce JR. Neighborhood Environments and Socioeconomic Inequalities in Mental Well-Being. Am J Prev; 2015;1–5.
CRESH



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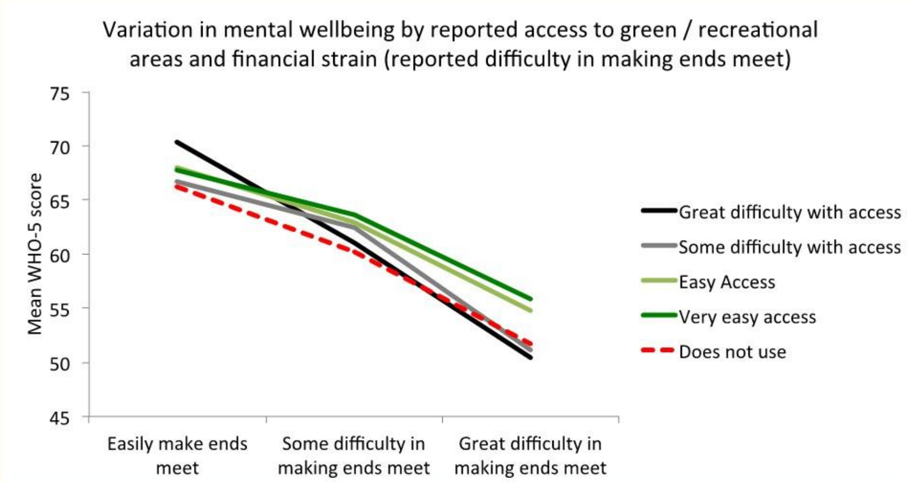
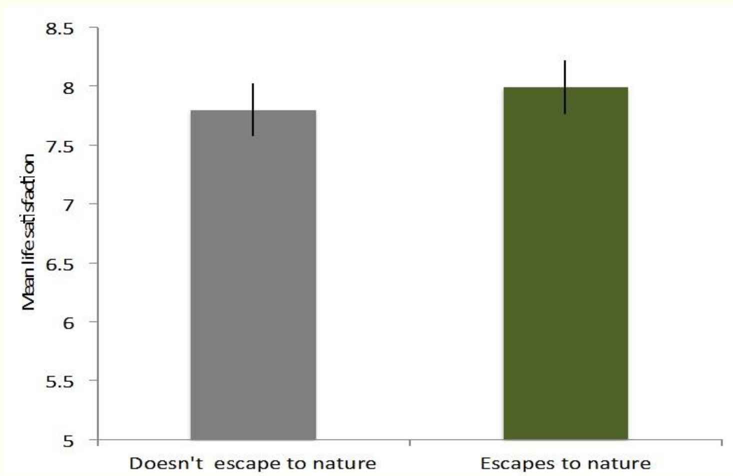
Some difficulty in making ends meet
Great difficulty in making ends meet
Mitchell RJ, Richardson EA., Shortt NK, Pearce JR. Neighborhood Environments and Socioeconomic Inequalities in Mental Well-Being. Am J Prev; 2015;1–5.
CRESH



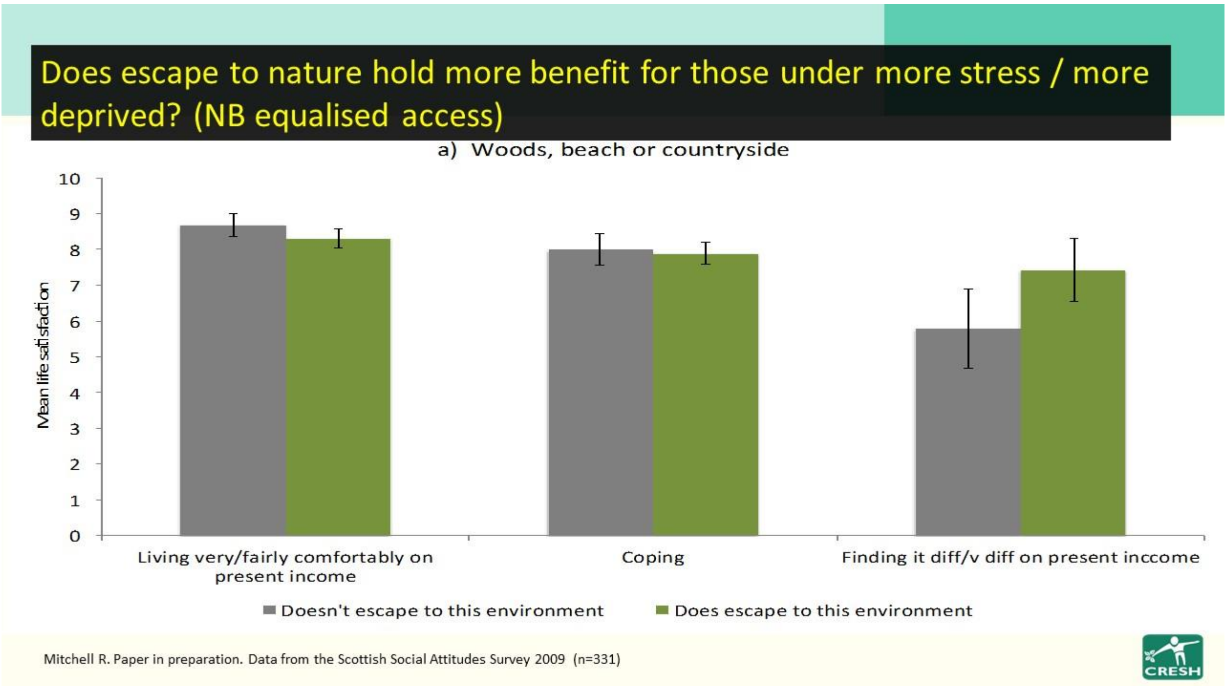
11

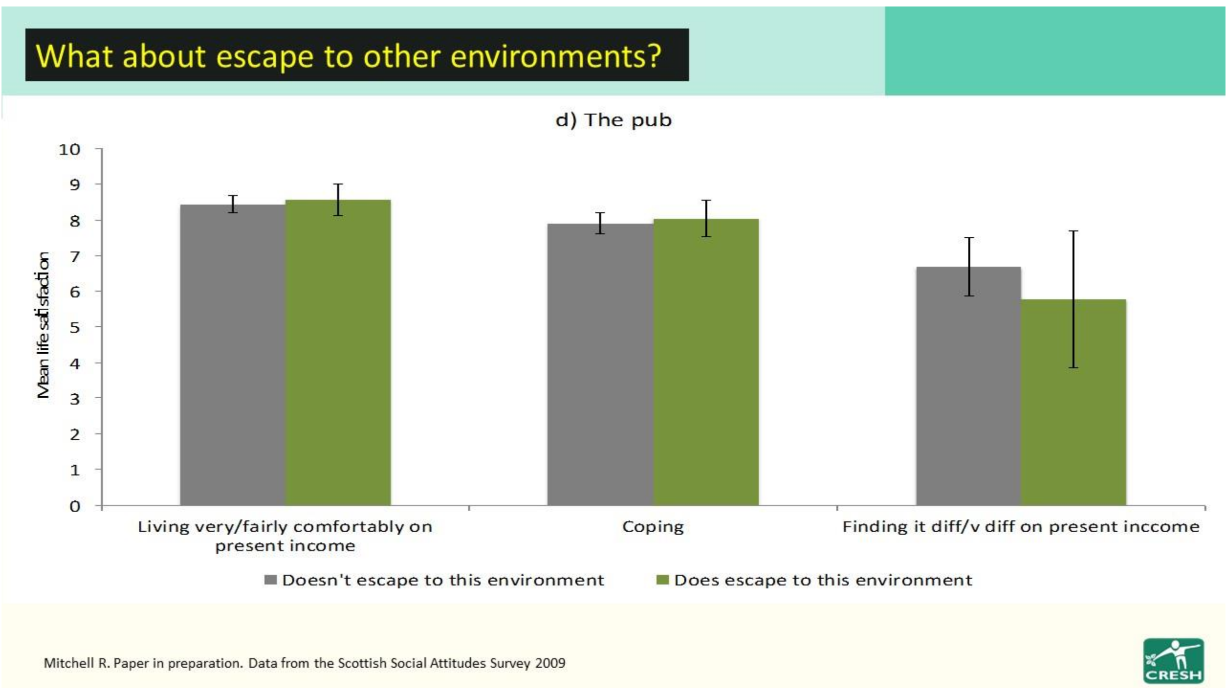
http://cresh.org.uk/2015/04/21/more-reasons-to-think-green-space-may-be-equigenic-a-new-study-of-34-european-nations/

Is escaping to nature related to life satisfaction? (all those who need to escape)



Mitchell R. Paper in preparation. Data from the Scottish Social Attitudes Survey 2009 (n=949)


Does escape to nature hold more benefit for those under more stress / more deprived? (NB equalised access)
a) Woods, beach or countryside
Mean life satisfaction
10
9
8
7
6
5
4
3
2
1
0
Living very/fairly comfortably on present income
Coping
Finding it diff/v diff on present inccome
Doesn't escape to this environment
Does escape to this environment
Mitchell R. Paper in preparation. Data from the Scottish Social Attitudes Survey 2009 (n=331)
CRESH

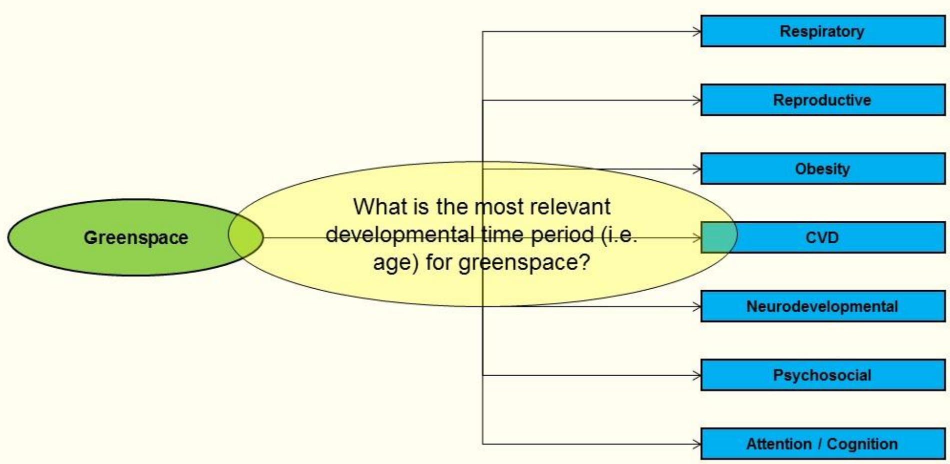

What about escape to other environments?
d) The pub
Mean life satisfaction
10
9
8
7
6
5
4
3
2
1
0
Living very/fairly comfortably on present income
Coping
Finding it diff/v diff on present inccome
Doesn't escape to this environment
Does escape to this environment
Mitchell R. Paper in preparation. Data from the Scottish Social Attitudes Survey 2009
CRESH

Challenges to this work

- It's (so far) cross-sectional
- We don't know how the equigenic effect happens (if it's real)
  - Differences in use of the spaces seem an unlikely explanation
  - Perhaps the effects are more readily felt by those with a poorer health status to begin with
  - Perhaps our models (which assess variance after all), aren't well equipped to see a similarly supportive effect of nature for a population that already has good health
  - Residual confounding is a big problem

15

Review: Greenspace and Health



Identifying Critical Windows of Exposure for Children's Health

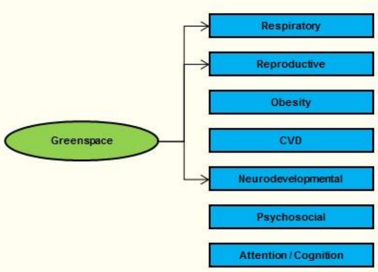
Sherry G. Selevan,[1] Carole A. Kimmel,[1] and Pauline Mendola[2]

[1]National Center for Environmental Assessment, Office of Research and Development, U.S. Environmental Protection Agency, Washington, DC, USA; [2]National Health and Environmental Effects Research Laboratory, Office of Research and Development, U.S. Environmental Protection Agency, Research Triangle Park, North Carolina, USA

Environmental Health Perspectives • Vol 108, Supplement 3 • June 2000

- Window of susceptibility / exposure
  - Specific developmental period during which an individual is especially vulnerable to increased health risks associated with environmental exposures
    - In utero
    - Neonatal
    - Pubertal
    - Adolescence
    - Elderly
- Many health effects are unique to the stage of exposure
  - E.g. prenatal → miscarriage, low birth weight
  - E.g. prenatal /early childhood → neurodevelopment
- Relevant time periods (age) is dependent on health outcome and the mechanism

Exposure to Greenspace: Prenatal



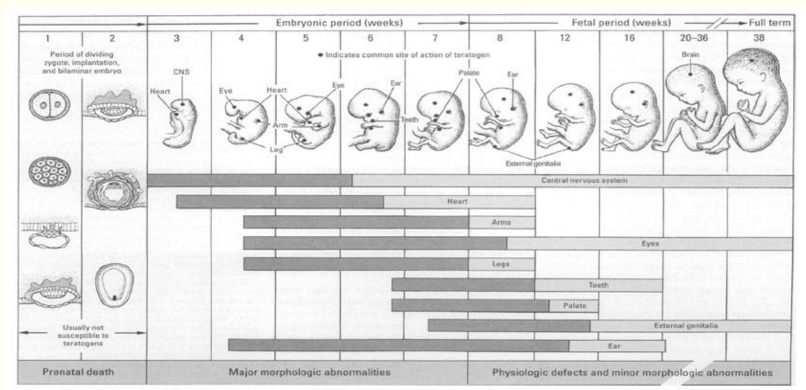
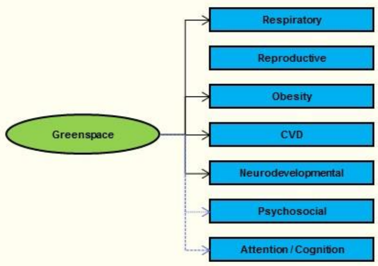
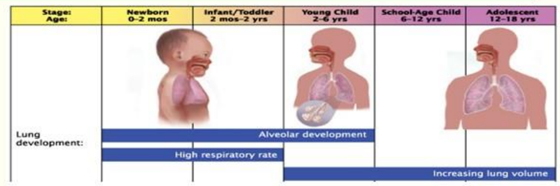


Figure 3. Schematic illustration of the sensitive or critical periods in human development. Dark gray denotes highly sensitive periods; light gray indicates stages that are less sensitive to teratogens. Reprinted with permission of W.B. Saunders Co. [(3); first published in 1973].

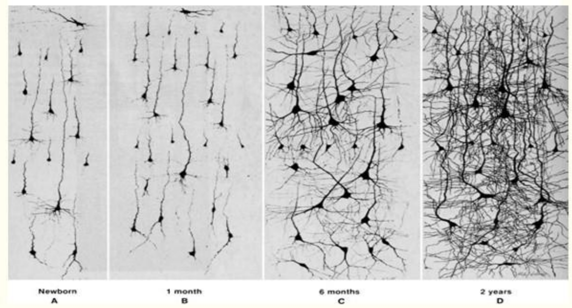
Exposure to Greenspace: Early Childhood

- ‘Children are not little adults’
  - Developing organ systems
    - CNS
    - Respiratory
    - Immune
  - Behavior
    - ↑ time outdoors
    - ↑ respiratory rate

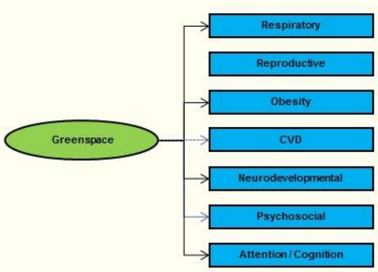




Ritz B. and Wilhelm M. UCLA Institute of the Environment and Sustainability. www.environment.ucla.edu/reportcard/article1700.html.

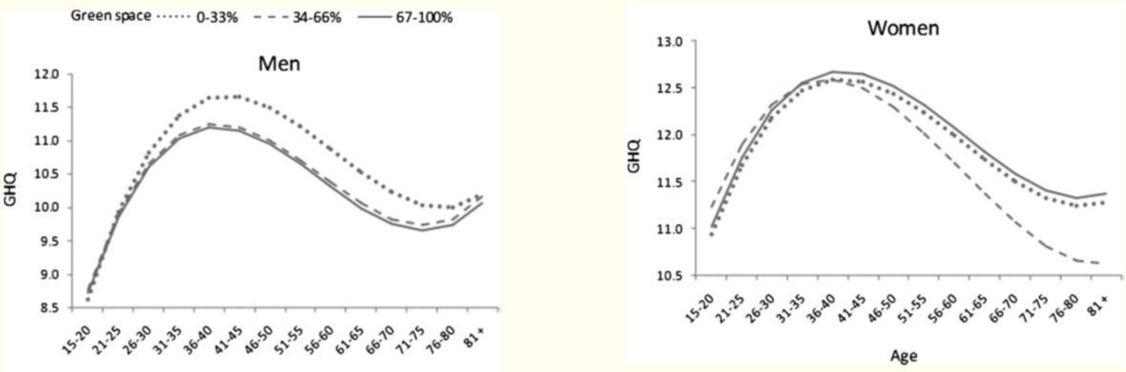


Adolescence, Adulthood, Elderly



- Adolescence
  - Relevant time period for greenspace in relationship to obesity, attention, respiratory, psychosocial
  - CVD?
- Adulthood
  - Mental health, obesity, CVD, psychosocial, reproductive
- Elderly
  - CVD, respiratory, mental health,

Gender differences in 'effects' on mental health, across the life course



Astell-Burt T, et al. J Epidemiol Community Health 2014;0:1–6. doi:10.1136/jech-2013-203767

21

Summary

- Potential role for greenspace on health throughout lifespan
  - Similar to environmental exposures, the impact of greenspace is likely to vary by age and health outcome
  - Understanding the mechanism by which greenspace is associated with each health outcome is critical to define window of susceptibility
    - E.g. Potential mechanism: Greenspace → ↓ air pollution
      - Health outcomes: Respiratory, CVD, reproductive, neurodevelopmental
      - Relevant time windows: Prenatal, early childhood, adolescence, elderly