Assessment of the joint effects of traffic-related noise, air pollution, and green space on children’s stress

Rebecca Lee | Meredith Franklin | Xiaozhe Yin | Scott Fruin | Robert Urman | Rob McConnell
February 2019
Background

• Growing body of research linking aspects of the physical environment to children’s cognitive and socio-emotional development (e.g. stress).

• Chronic stress in early childhood may lead to:
  • Mental disorders: depression, anxiety, bipolar disorder, etc (Slavich et al, 2014).
  • Behavioral issues: substance abuse and uncontrolled violence (Younan et al, 2016).
Background: Environmental Stressors

Traffic-related air pollution:
- Perceived traffic air pollution among children alters mood and anxiety (Lercher et al, 1995).
- Stress was found to be a mediating factor between air pollution and psychological disorders (Mehta et al, 2015).

Traffic-related noise pollution:
- Sleep disturbance contributes to increased stress (Stansfeld, 2015).
Background: Environmental Stressors

- **Urbanization** poses multiple risks to mental health, including overcrowding and socioeconomic stress.
- Studies have shown that **green space** reduces reported stress among adults and adolescents (Kaplan et al., 2011; Kinnafick et al., 2014).

Traffic-related air pollution, noise pollution and urbanization are spatially associated (Wheeler et al, 2005).
Research Hypotheses

- Traffic-related noise and air pollution is associated with increased levels of stress.

- Stress will be amplified for children residing in communities having limited green space and greater urbanization.
Study Overview

• Stems from Children’s Health Study (CHS), looks at novel exposures: noise and green space.
  • Recruitment began in the early 1990s.
  • Over 12,000 subjects in several cohorts.
• Current study focuses on the last cohort (E), enrolled in 2003 at ages 5 to 7 year old children living in Southern California and were followed until 2012 (McConnell et al, 2006).
• Questionnaires: baseline data
  • Sex, race, income, height, weight, BMI, asthma, cough, smoking exposure, etc.
  • Parents responded to questionnaires 2003-2007.
• Beginning 2008 the children responded biennially.
Cohort E (2003-2012) | Total (N)
---|---
Anaheim | 2120
Glendora | 3036
Long Beach | 1831
Mira Loma | 2680
Riverside | 2447
Santa Barbara | 2807
San Dimas | 2382
Upland | 2602
Data: CHS Questionnaire--Stress

- Stress was added to 2010 and 2012 questionnaire.
- Perceived stress scale (PSS):
  - Validated to measure symptoms of stress.
  - 4 equally weighted questions.
  - PSS-4: scale of 0 to 16.

Data: CHS Questionnaire
PSS-4

• "In the last month, how often have you felt":
  • (1) that you were unable to control the important things in your life?
  • (2) confident about your ability to handle your personal problems?
  • (3) that things were going your way?
  • (4) your difficulties were piling up so high that you could not overcome them?
Data: Air Pollution—Freeway NOx

• CALINE 4 line source dispersion model: estimates annual average ambient concentration of nitrogen oxides (NOx) from traffic near roadways in study area.
  • Utilizes residential locations, roadway geometry, vehicle traffic volume, emission rate by roadway link, and meteorological conditions.
• Estimates pollutant exposures for both highway and non-highway roads and subject-specific exposure was assigned to residential locations.
Data: Traffic Air Pollution

Keck School of Medicine of USC
Data: Traffic Noise

- U.S. Federal Highway Administration (FHWA) developed the Traffic Noise Model (TNM).
- TNM 2.5 version (2004) uses roads, traffic volume, posted road speeds, pavement type, and vehicle type to estimate traffic noise in decibels (dB).

- **Noise Estimates** = Average noise dB level over a day + 10 dB penalty if between 10PM-7AM
Data: Traffic Noise

Exceeds World Health Organization’s noise guideline of 55 dB.
Data: Green Space

- Moderate Imaging Spectroradiometer (MODIS) satellite imagery of:
  - Normalized Difference Vegetation Index (NDVI)
  - Enhanced Vegetation Index (EVI)
- NDVI and EVI represents the ratio between the visible red and near-infrared (NIR) spectral bands.
  - Ranges from -1.0 to +1.0.
- EVI corrects for atmospheric conditions (e.g. aerosols, air particles) that might distort reflected light.
Data: Green Space

Greater vegetation, such as parks, has more reflective NIR, thus higher value of NDVI and EVI.
Data: Artificial Light at Night (ALAN)

- Visible Infrared Imaging Radiometer Suite (VIIRS) satellite operated by NASA and NOAA.
- Multispectral and has a day night band that measures intensity of artificial lights at night.
- Processed monthly and annually at 750m resolution.
- Highly correlated month to month and year to year.
  - Not much temporal variation in the imagery.
Data: Artificial Light at Night

Keck School of Medicine of USC
Statistical Analysis

- Mixed effects model with random effect for the subjects who responded in 2010 and 2012.
- Examined non-linear functions for some of the pollutants, such as noise, ALAN.
- Given clustering of individuals we use a fixed effect for the community.
- Looked at each pollutant separately and combined.
Statistical Analysis

• Adjusted for sex and BMI in the full model.
  • Excluded race and education because they were not significant.

• Confounder adjustments:
  • Income: 6 levels, continuous variable.
  • Sleep: “do you usually have trouble falling asleep at night?”
    • Reported as: never, sometimes, or often
Results: Characteristics of Stress

• Reported stress scores from 2010 was not statistically different from 2012 (p=0.45).

• Stress was significantly lower in males than in females (p<0.01).
  • Male: 2010 = 4.99; 2012 = 4.72 (p=0.06).
  • Females: 2010 = 4.72; 2012 = 6.04 (p=0.01).

• BMI was significantly associated with the reported stress scores (p<0.01).
## Results: Summary Statistics

<table>
<thead>
<tr>
<th>Community</th>
<th>Stress</th>
<th>Noise (dB)</th>
<th>Air (ppb)</th>
<th>EVI</th>
<th>Total Obs.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anaheim</td>
<td>5.48</td>
<td>77.1</td>
<td>34.6</td>
<td>0.15</td>
<td>439</td>
</tr>
<tr>
<td>Glendora</td>
<td>4.96</td>
<td>69.6</td>
<td>4.7</td>
<td>0.22</td>
<td>415</td>
</tr>
<tr>
<td>Long Beach</td>
<td>5.38</td>
<td>75.1</td>
<td>15.8</td>
<td>0.16</td>
<td>371</td>
</tr>
<tr>
<td>Mira Loma</td>
<td>5.68</td>
<td>67.3</td>
<td>11.8</td>
<td>0.20</td>
<td>392</td>
</tr>
<tr>
<td>Riverside</td>
<td>5.43</td>
<td>71.9</td>
<td>8.4</td>
<td>0.21</td>
<td>516</td>
</tr>
<tr>
<td>Santa Barbara</td>
<td>5.47</td>
<td>74.0</td>
<td>7.3</td>
<td>0.23</td>
<td>569</td>
</tr>
<tr>
<td>San Dimas</td>
<td>5.18</td>
<td>72.2</td>
<td>11.9</td>
<td>0.20</td>
<td>397</td>
</tr>
<tr>
<td>Upland</td>
<td>4.91</td>
<td>70.4</td>
<td>9.5</td>
<td>0.22</td>
<td>426</td>
</tr>
</tbody>
</table>

- Stress in Glendora and Upland were significantly lower compared to Anaheim (reference group).
- EVI and NOx showed residential effects.
- Interaction between noise and community.
Results: Pollutants Separately

- Marginal models show EVI is more protective than any of the other environmental factors are detrimental
Results: Environmental Factor Correlations

<table>
<thead>
<tr>
<th>Correlation Matrix</th>
<th>Noise</th>
<th>Freeway NOx</th>
<th>Non-Freeway NOx</th>
<th>ALAN</th>
<th>EVI</th>
<th>PopDen</th>
<th>Elevation</th>
<th>Stress</th>
</tr>
</thead>
<tbody>
<tr>
<td>Noise</td>
<td>1</td>
<td>0.53</td>
<td>0.38</td>
<td>0.42</td>
<td>-0.38</td>
<td>0.36</td>
<td>-0.30</td>
<td>0.06</td>
</tr>
<tr>
<td>Freeway NOx</td>
<td>1</td>
<td>0.25</td>
<td>0.40</td>
<td>-0.44</td>
<td>0.29</td>
<td>-0.27</td>
<td>0.10</td>
<td></td>
</tr>
<tr>
<td>Non-Freeway NOx</td>
<td>1</td>
<td>0.56</td>
<td>-0.44</td>
<td>0.57</td>
<td>-0.50</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>ALAN</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>-0.68</td>
<td>-0.51</td>
<td>-0.38</td>
<td>0.07</td>
</tr>
<tr>
<td>EVI</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>-0.51</td>
<td>0.31</td>
<td>-0.10</td>
<td></td>
</tr>
<tr>
<td>PopDen</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>-0.61</td>
<td>0.05</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Elevation</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td>-0.09</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stress</td>
<td></td>
<td></td>
<td></td>
<td>1</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- ALAN showed high collinearity with EVI.
- Could not be included in joint linear mixed effects model.
Results: Joint Environmental Effects

• Linear Mixed Effects Model:
  • Stress = EVI + FreewayNOx + noise + adjustments

• After adjustments:
  • EVI: Per IQR increase in EVI (IQR=0.06), the reported stress score significantly decreased by 0.22 points.
  • NOx: Per IQR increase in Freeway NOx (IQR=10.7 ppb), the reported stress score significantly increased by 0.15 points.
Results: Joint Environmental Effects

- **Noise** after adjustments:
  
  The association between noise and stress differed by community.

  - Per IQR (10.1dB) increase in noise:
    - Glendora is associated with a 0.73 point increase in stress ($p=0.021$).
    - Mira Loma is associated with a 0.87 point decrease in stress ($p=0.002$).
    - The effect estimates differ in other communities but none were statistically significant.
Results: Joint Environmental Effects

- Treated ALAN as a non-linear function with community interaction in the model, as shown previously.
- Statistically significant community-level effect in Long Beach compared to other communities.
  - Higher stress at ALAN exposures > 65 (radiance in nW/cm^2/sr) possibly due to ports.
  - ALAN function was relatively flat in other communities.
Summary

• Living in a greener residential environment has a greater impact of reducing stress.
  • EVI was more individually protective than Freeway NOx is detrimental.
• Other social factors at the community level may influence the effect of noise pollution on stress.
• Evidence for policy makers to reduce traffic-related exposures and integrate more green space in city planning to protect children’s health.
Strengths and Limitations

• **Strengths:**
  - Longitudinal data from a prospective study with repeated measures of perceived stress.
  - Large number of children assessed with residential locations.
  - Novel exposure assessment (satellite, modeled data).
  - Ability to determine both within (NOx, EVI) and between community effects (noise, ALAN).

• **Limitations:**
  - Correlated exposures in a multi-pollutant assessment.
  - Jointly interpreting within and between community effects of multiple pollutant.
Acknowledgements

Thanks to the study team at USC:
Meredith Franklin (PI)
Scott Fruin
Rob McConnell
Robert Urman
Xiaozhe Yin
This research is funded by the Health Effects Institute (HEI) Research Agreement #4961-RFA17-1/18-3

“Intersections as hot spots: Assessing the contribution of localized non-tailpipe emissions and noise on the association between traffic and children’s health”
Thank You!

Questions?