Environmental Factors Affecting Stress in Children: Interrelationships Between Traffic-Related Noise, Air Pollution, and the Built Environment

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Background: A growing body of research suggests that stressors such as traffic-related noise, air pollution and artificial light at night may be directly and indirectly associated with decrements in children's mental health. On the other hand, living near greenspace can reduce stress and provide other health benefits for children.

Methods: At ages 13-14 and 15-16 years, participants in the Southern California Children's Health Study responded to four questions pertaining to stress. An individual's combined responses to these questions resulted in scores ranging from 0 to 16 on the Perceived Stress Scale (PSS-4). Residential exposures of noise were derived from the U.S. Traffic Noise Model, NOx from the CALINE line dispersion model, artificial light at night from satellite observations in the day-night band, and greenspace from satellite observations of enhanced vegetation index (EVI). We assessed the marginal and joint associations of these exposures on stress using mixed effects models with adjustments for subject-specific characteristics.

Results: Overall, PSS-4 is significantly higher ($p<0.001$) for girls [mean (s.d.) = 5.8 (3.4)] than boys [4.9 (3.2)], and over two years it increased for girls [5.6 (3.3) to 6.0 (3.4)]. In single pollutant models many environmental factors were significantly associated with stress after adjustment. In multipollutant models we found a -0.26 (95% CI: -0.46, -0.05) decrease in PSS-4 per IQR increase in EVI, together with a 0.14 (95% CI: 0.03, 0.26) increase in PSS-4 per IQR increase in freeway NOx. A non-linear increase in PSS-4 was observed with an increase in LAN.

Conclusions: The physical environment consists of a complex mixture of factors that can both positively and negatively affect health. We find evidence that residential greenspace may mitigate the impact of traffic–related pollution on perceived stress in a cohort of children in Southern California.

Environmental Factors

- Ambient concentrations of NOx from local traffic were estimated from the CALINE4 dispersion model. Inputs include residential locations, roadway geometry, vehicle traffic volume and emission rate by roadway link, and meteorological conditions (Figure 1a).
- Estimates of greenness were derived from MODIS enhanced vegetation index (EVI), which was developed to address some limitations of NDVI by reducing the influence of atmospheric conditions and to be more sensitive to canopy structural variations. It is a unitless measure from -1 to 1 EVI=G*((NIR-RED))/((NIR+C1*RED-C2*BLUE+L)) (Figure 1b).
- The U.S. Federal Highway Administration (FHWA) Traffic Noise Model (TNM) uses roads, traffic volume, posted road speeds, pavement type, and vehicle type to estimate traffic noise in decibels as the average day-night sound level, L_{dn} (Figure 1c).
- Artificial light at night (LAN) from the the world atlas of artificial night sky brightness combines satellite observations from VIIRS with brightness measurements from the precision charged-couple decide and sky quality meters to generate "skyglow" (Figure 1d).

Stress in the Children's Health Study

- The primary tool to quantify perceived stress is the Perceived Stress Scale (PSS), a self-report metric by questionnaire
- Our outcome of interest is the 4-item version, PSS-4.
- PSS-4 was assessed when children were aged 13-14 and 15-16.

Epidemiological Assessment

- Mixed effects models were fit with a random effect for subject id. We examined both single and multi pollutant models.

Table 1. Effect estimates for single pollutant models

Environmental Factor	Environmental Factor IQR	Effect Estimate* (95% CI)
Freeway NOx	11.15	0.14 (0.05, 0.24) [a]
Non-Freeway NOx	3.34	0.06 (-0.14, 0.26)
Noise	10.23	0.11 (-0.05, 0.28) [b]
LAN, VIIRS	22.71	0.25 (0.03, 0.46) [a]
LAN, World Atlas	2.46	0.48 (0.07, 0.89) [a]
NDVI	0.11	-0.30 (-0.51, -0.09) [a]
EVI	0.06	-0.30 (-0.49, -0.11) [a]

* All models adjusted for height, weight, age, race, exposure to smoke, community and are scaled by the IQR.

[a] $p<0.05$, [b] $p<0.1$

Table 2. Effect estimates for multipollutant model

Environmental Factor	Effect Estimate* (95% CI)
Freeway NOx	0.14 (0.03, 0.26) [a]
Noise	-0.13 (-0.33, 0.07)
EVI	-0.26 (-0.46, -0.05) [a]
LAN, World Atlas	3 edf [b]

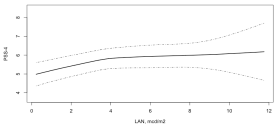

Figure 3. LAN in multipollutant model

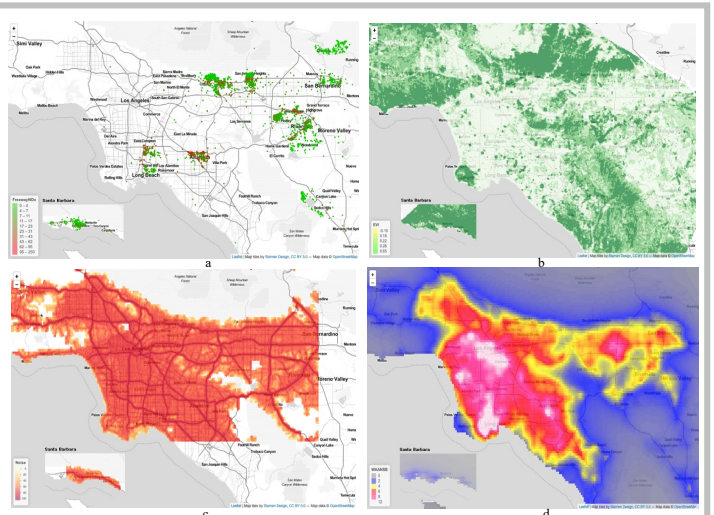

Figure 1. Maps of exposures over study area: a) Freeway NOx assigned to each study participant's residential address; b) MODIS-derived EVI; c) TNM noise; d) World Atlas LAN

Noise Measurements

- We are supplementing the TNM with measurements in the 8 communities using two Brüel & Kjær 2250 sound meters.
- We are taking a walking transect approach to capture gradients in sound from busy arterials and residential streets.
- With these data we will have better estimates of noise on smaller roads and at intersections.

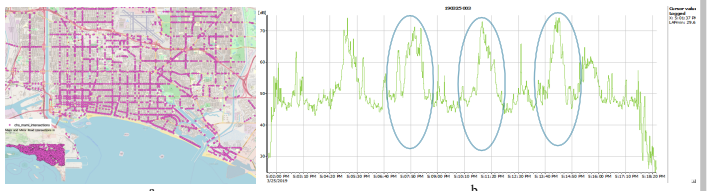

Figure 2. a) Intersections of major arterials and residential streets; b) Noise measurements by walking transects from arterial roads to residential streets.

Intersections, Traffic Lights, Stop Signs, Ramps

- We have characterized all classes of roads and their intersections, along with traffic lights and stop signs using OpenStreetMap. These features are being used in the development of the noise models and for modeling non-tailpipe PM metals.

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