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Response to Invited Commentary

Zhong et al. Respond to "There's No Place Like Home"

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We appreciate the comments by Hauptman et al. (1) highlighting the challenges in understanding how environmental exposures and their inequities contribute to sleep disruptions. The recent interest in how sleep, and the lack thereof, affects human health has led several large cohort studies, such as the California Teachers Study, to include such questions in follow-up questionnaires. We agree with Hauptman et al. that racial equity issues indeed require further interrogation than present in our study (2); even in in our cohort, non-Hispanic White participants experienced lower levels of artificial light at night (ALAN), noise, and air pollution and higher levels of green space compared with the rest of the cohort (Table 1). Diverse populations are required to further understand how the role that social and racial disparities affect levels of light, green space, noise, and air pollution and subsequent health effects.

The limitations of satellite imagery in assessing artificial light at night (ALAN) are well known (3, 4), although new technologies and efforts such as those being undertaken by the Cities at Night project led by Dr. Alejandro Sánchez (https://citiesatnight.org/) are helping to improve our ability to estimate exposure more accurately at the residential level. Importantly, as noted by Hauptman et al., these new measures include the ability to assess short-wavelength blue light, believed to be most disruptive to circadian rhythm (4, 5). While we were unable to assess indoor exposure to ALAN, we recognize that it is of increasing concern, as an estimated 85% of Americans now own a smartphone (6). Many smartphones now include some form of built-in, time-dependent blue light filtering to address these concerns, and such filtering does appear to be an effective means of at least partially reducing disruptions to circadian rhythm (7, 8). The increased prevalence of smartphone ownership across all racial, ethnic, and socioeconomic backgrounds, and more recently smartwatches that include sleep tracking features, provides opportunities to cost effectively include measures of indoor ALAN and sleep patterns in future studies. Measurement of the correlation between outdoor light and indoor exposure, as well as the relative contribution of outdoor light to indoor exposure, remains an important focus for future efforts. Such validation of satellite-based exposure metrics, especially in cities where urban morphology differs substantially from rural and suburban contexts, is likely to yield further insights. In addition, smartphone apps may be

Table 1. Distribution of Environmental Exposures According to Race/Ethnicity, California Teachers Study Cohort, United States, 2014

Environmental Exposure	Mean (SD)	
	Non-Hispanic White Participants	Other Participants
Light at night, mcd/m^2	2.68 (2.0)	3.77 (2.5)
Noise, dB	40.4 (5.9)	41.7 (6.2)
Green space, EVI	0.21 (0.06)	0.19 (0.06)
Air pollution, $PM_{2.5}$ μg/m^3	10.3 (4.0)	11.4 (4.2)

Abbreviations: dB, decibel; EVI, enhanced vegetation index; mcd, millicandela; $PM_{2.5}$, particulate matter with an aerodynamic diameter $\leq$2.5 μm; SD, standard deviation.

an avenue for intervention through reinforcement of good sleep habits. Several of these apps have been evaluated with mixed results (9–11), and it has yet to be seen if such interventions are sustainable outside of the research setting.

We appreciate the complex nature of the built environment and the further work necessary on how different exposures work synergistically or antagonistically to affect our health. One potential solution could be improvements to green space. Living in areas with greater green space appears to be an effective means of improving mental health and sleep (12, 13). Green space appears to attenuate the detrimental health outcomes observed with harmful environmental exposures, and this reduction in risk may be more pronounced in lower-income communities, possibly due to less reliance on personal modes of transportation and greater utilization of local green space (14). An example of how such findings have been implemented can be seen in a unique community-based intervention conducted in Philadelphia that showed reductions in depression by converting vacant lots into green space (15). Similar interventions, zoning, and policy level changes may be a means of reducing these inequities and achieving environmental justice.

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