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Place effects on noise annoyance: Cumulative exposures, odour annoyance and noise sensitivity as mediators of environmental context

Tor H. Oiamo [a,*], Jamie Baxter [a], Alice Grgicak-Mannion [b], Xiaohong Xu [c], Isaac N. Luginaah [a]

[a] Department of Geography, The University of Western Ontario, London, ON, Canada
[b] Great Lakes Institute for Environmental Research, University of Windsor, Windsor, ON, Canada
[c] Department of Civil and Environmental Engineering, University of Windsor, Windsor, ON, Canada

HIGHLIGHTS

- A survey sample in Windsor, ON, Canada were assessed for exposure to traffic noise and NO_2.
- Cumulative exposures to NO_2 and traffic noise depends on environmental context.
- There is a multiplicative effect of NO_2 and traffic noise on noise annoyance.
- Noise sensitivity and odour annoyance can capture place-effects on noise annoyance.

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ABSTRACT

Previous research suggests there may be combined effects of outdoor air pollution and traffic noise on noise annoyance, but it is not known how environmental context can moderate these effects. Physical attributes of the environment can influence relative levels of exposure, while sociocultural contexts can moderate environmental perceptions. Noise sensitivity is an important factor in appraisal, but previous research has not linked levels of sensitivity to contextual factors. The objectives of this study were to understand how a high-volume traffic corridor and pollution hotspot could influence co-exposures to air pollution and traffic noise and consequent levels of noise annoyance. Data from a community survey ($n = 610$) along with modelled estimates of residential traffic noise and nitrogen dioxide exposure were utilized for the analyses. The effective loudness function for noise annoyance and an ordinal location-scale model showed that varying levels of co-exposure to traffic noise and air pollution along with odour annoyances in the corridor and a control area had strong effects on the noise annoyance dose–response. The results also indicated that there was a significantly higher level of error in predicting noise annoyance in the corridor area. There appeared to be neighbourhood-level differences in the effect of noise sensitivity on noise annoyance. The findings have important implications for our understanding of multiple exposures along with the influence of environmental context on noise annoyance. In particular, this study demonstrates that research on the effects of traffic noise across large urban areas may conceal important phenomena occurring at the neighbourhood level.

1. Introduction

There are different definitions of both noise annoyance and odour annoyance, but the most common view of both is that they are indicators of nuisance, disturbance or disruption to intended or actual activities (Griffiths, 2014; Guski et al., 1999). Previous research has identified dose-dependent and cumulative effects of air pollution and traffic noise on annoyances as well as cardiovascular disease (CVD) outcomes (e.g., Gan et al., 2012; Klaeboe et al., 2000); therefore it is important to gain a clear

* Corresponding author. Department of Geography, Social Science Centre, The University of Western Ontario, 1151 Richmond Street, London, ON N6A 5C2, Canada.
E-mail address: tor.oiamo@gmail.com (T.H. Oiamo).

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understanding of potential interaction effects of multiple exposures. One particular uncertainty that impedes a clear understanding on this topic is the potentially moderating effects of air pollution and associated levels of odour annoyance on the dose–response relationship between traffic noise and noise annoyance. Previous research shows that there are additive effects of exposure to traffic noise and outdoor air pollution on noise and odour annoyances (Klaeboe et al., 2000), but it is not known how additive effects are influenced by environmental context, or *place*, or if there are multiplicative effects of co-exposure. Place and environmental context in this instance refers to the unique combination of physical characteristics that influence exposure along with sociocultural characteristics that may influence environmental perceptions in different communities.

Understanding how the physical environment influences cumulative exposures can aid environmental management to reduce health risks. Noise annoyance is of particular concern because it is associated with a number of health outcomes such as cognitive impairment, sleep disturbance and behavioural change, and may also moderate CVD outcomes (Moudon, 2009; Babisch et al., 2013). If higher levels of odour annoyance increase noise annoyance, such health effects may also be exacerbated when people are exposed to high levels of both traffic noise and air pollution. Furthermore, the moderating effects of noise annoyance on CVD may be confounded when people are also exposed to high levels of malodorous air pollutants.

No research to date has examined how physiological (e.g., effects of air pollution on respiratory and cardiovascular systems) and psychological (e.g., disturbance to activities and nuisance) responses to ambient stressors interact while controlling for both traffic noise and air quality, and previous research on subsets of these variables provides mixed results. For example, Ndrepepa and Twardella (2011) found a significant effect of noise annoyance on arterial hypertension, but not ischemic heart disease, in a meta-analysis of nine studies with various research designs that did not control for noise level. Babisch et al. (2013) observed a significant interaction between aircraft noise level and annoyance in predicting hypertension prevalence, but did not observe an interaction effect from traffic noise and annoyance. The authors conclude that because the effect of objective noise responses (i.e., involuntary arousals of the sympathetic nervous system) is stronger than the subjective noise response, annoyance may function as an effect modifier (Babisch et al., 2013). Conversely, Fyhri and Klaeboe (2009) argue that the association between noise exposure, noise annoyance and hypertension may be a spurious relationship mediated by noise sensitivity.

Noise sensitivity is predominantly operationalized as an invariant personality trait based on empirical research linking self-reported levels of sensitivity to other emotional traits and its apparent stability over time and place (Miedema and Vos, 2003). Reactions to noise are stronger among noise sensitive individuals while levels of sensitivity are not associated with perceived loudness or noise exposure (Miedema and Vos, 2003). However, there is no clear conceptual definition as sensitivity is not a unitary concept (Job, 1999). For example, people can have different sensitivities to loud and quiet noises. Miedema and Vos (2003) suggest that sensitivity is related to a general dissatisfaction with the environment and the perceived existence of a wide range of local environmental problems. Job (1999) proposes a definition of noise sensitivity as an outcome of ‘internal states’ that increase the degree of reactivity to noise in general. Such internal states are then linked to numerous components that include risk perceptions of the noise source, the existence of other ambient stressors, coping resources, hearing acuity, all of which are distinguished as a form of physiological or psychological reactivity.

Alternatively, noise sensitivity may be more usefully conceptualized as a compositional indicator of multiple factors that moderate that relationship between ambient stressors and annoyance, and as such dependent on community and individual contexts. To our knowledge no research to date has demonstrated that environmental context can influence noise sensitivity. However, the definition of noise sensitivity proposed by Job (1999) and demonstrable effects of environmental contexts on noise annoyance, such as proximity to green areas, suggest that this is plausible (Gidlof-Gunnarsson and Ohrstrom, 2007; Li et al., 2012). Klaeboe et al. (2005) showed that neighbourhood soundscapes (i.e., real-time perceptions of sound) affect residential noise annoyance among people exposed to similar sound levels at home. Therefore, the treatment of annoyance and sensitivity in community noise research and the conventional understanding of their relation to noise exposure deserves further examination (Schomer et al., 2013). While noise sensitivity remains a somewhat clouded concept, the current knowledge on noise annoyance is based on decades of meticulous research.

The noise annoyance dose–response curves estimated by Schultz (1978) and more recently by Miedema and Oudshoorn (2001) were based on comparing annoyance survey data and monitored noise levels from numerous cities. However, as their data suggest, noise annoyance varies considerably in different communities with similar noise levels (Fidell, 2003). As an alternative, Fidell et al. (2011) proposed a first-principles model from *a priori* determinants of noise annoyance for estimating its prevalence by fitting noise survey data to an exponential function. The ‘effective loudness function’ estimates the community tolerance level (CTL) to noise based on a hypothesized relationship between noise exposures, its perceived loudness, and the percentage of people highly annoyed (%HA) at different levels of noise.

The CTL represents the noise level at which 50 percent of the sample is highly annoyed. Schomer et al. (2012) found that the average CTL of 78 dB(A) can differ notably between communities. They attribute this difference to non-acoustic factors, or what we refer to as place effects. Therefore, the CTL can be interpreted as a measure of place effects on noise sensitivity and consequently annoyance. Other variables demonstrated as influential on annoyance that may also be influenced by place include fear of danger from the noise source and importance attributed to the noise source (Fields, 1993; Fyhri and Klaeboe, 2009; Miedema and Vos, 1999). Schomer et al. (2013) articulate the influence of environmental context on human reactions to environmental noise as central to the soundscape perspective. They further argue that the soundscape perspective can help advance the field of noise research from a traditional framework concerned with unwanted sound and minimally acceptable health risks to a research agenda framed around the promotion of health and quality of life (Schomer et al., 2013).

The soundscape perspective considers noise exposure as one of many influences on noise perception. With respect to environmental health it is important to understand how soundscapes are affected by exposures to other ambient stressors such as air pollution. To this end, previous research has also demonstrated dose–response relationships between common air pollutants and odour annoyance at exposure levels well below most regulatory guidelines (Atari et al., 2012; Forsberg et al., 1997; Klaeboe et al., 2008). Taken together with the soundscape perspective and previously demonstrated noise annoyance dose-responses, this suggests that there may be an interaction effect between noise and odours on noise annoyance and that absolute levels of noise annoyance depend on environmental context.