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Road traffic noise, sensitivity, annoyance and self-reported health—A structural equation model exercise

Aslak Fyhri *, Ronny Klæboe

Institute of Transport Economics Gaustadalleen 21, 0349 Oslo, Norway

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ABSTRACT

The proposed effect of road traffic noise on hypertension and ischemic heart disease finds mixed empirical support. One problem with many studies is that the directions of the causal relationships are not identified. This is often the case when cross-sectional data and multivariate regression models are utilised. The aim of the study was to explore the relationship between road traffic noise and health. More specifically the relationships between noise complaints, noise sensitivity and subjectively reported hypertension and heart problems were investigated. 1842 respondents in Oslo, Norway were interviewed about their experience of the local environment and their subjective health complaints. The interviews were conducted as part of two surveys. Individual measures of air pollution (NO_2) and noise (Lden) were calculated. The data were analysed using Structural Equation Models. Only sensitivity to noise is related to hypertension and chest pain. No relationships between noise exposure and health complaints were identified. Rather than noise being the causal agent leading to health problems, the results suggest that the noise–health relationships in these studies may be spurious. It is conceivable that individual vulnerability is reflected both in ill health and in being sensitive to noise. The benefit of including more contextual variables in a model of noise–health relationships is supported.

1. Introduction

It has been estimated that more than 30% of EU citizens are exposed to road traffic noise levels above those regarded as acceptable by the World Health Organisation (WHO), and that about 10% report severe sleep disturbance because of transportation noise at night (EEA, 2003). One noise annoyance assessment study suggests that around 24 million people (out of 380 million) in the European Union are highly annoyed by road traffic noise (EEA, 2000). Even with a low impact of noise on health, the large number of EU citizens exposed to road traffic noise implies that the potential population health impacts of road traffic noise can be substantial (de Hollander et al., 1999; de Hollander, 2004). A clear understanding of the causal relationships between noise, noise experience and its potential adverse health effects is therefore crucial for academics, planners and the authorities.

Annoyance and sleep disturbance have been proposed as mediators of the impact of noise on health (Babisch, 2006). The potential role of stress in this relationship is supported by studies suggesting links between noise level and increased noradrenaline concentrations in urine (Babisch et al., 2001), myocardial infarction (Babisch et al., 2005) and hypertension (Aydin and Kaltenbach, 2007; Bluhm et al., 2007; de Kluizenaar et al., 2007; Jarup et al., 2008). However, a meta-analysis of 43 epidemiologic studies found only an effect of *occupational noise* and *air traffic noise (military)* on hypertension, and no effect from *road traffic noise* (van Kempen et al., 2002). The authors concluded that although there was a tendency for increased risk of ischemic heart disease (IHD) and myocardial infarction as a result of *road traffic noise*, the quality of these relationships was in question, mainly due to publication bias and poor noise descriptions in the reviewed studies. Their suggestion that there might be differential effects of road and air traffic noise on IHD was not confirmed. A study looking at noise effects on children found that neither aircraft noise nor road traffic noise had an adverse effect on children's self-reported health status (Stansfeld et al., 2005).

In an attempt to overcome some of the theoretical shortcomings of research on environmental noise and health Lercher (1996) outlines a conceptual framework based on the concept of "embeddedness". This reasoning is based on the work of Cohen (Cohen et al., 1986) who describes an approach where the phenomenon of study (e.g. community noise) is best viewed as systematically surrounded or embedded by a set of events. The embeddedness framework has been applied successfully in previous studies looking at noise exposure and annoyance (Öhrström, 1997; Clench-Aas et al., 2000; Engelien et al.,

* Corresponding author. Tel.: +47 22573822; fax: +47 22609200.
E-mail address: af@toi.no (A. Fyhri).

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2004; Klæboe et al., 2005; Berglund and Nilsson, 2006), with particular focus on the concept of neighbourhood soundscapes. One important variable to be considered with particular care in such an embedded framework is *noise sensitivity*.

1.1. The role of noise sensitivity on health complaints

Noise sensitivity can be defined as a personality trait that makes certain individuals report more annoyance than their neighbours when exposed to a given noise level (Griffiths and Langdon, 1968). It is a strong predictor of noise annoyance, and moderates the effect of noise exposure on annoyance (Stansfeld, 1992). Noise sensitivity has been associated with subjective health complaints including also cardiac complaints (Nivison and Endresen, 1993). Noise sensitivity has also been linked with a number of medical conditions: hypertension, emphysema, the use of psychotropic drugs, and with behavioural risk factors for disease such as stress, smoking and hostility (Heinonen-Guzejev et al., 2004). A recent study found that cardiovascular mortality is significantly increased among noise-sensitive women. Among men, there were no statistically significant effects (Heinonen-Guzejev et al., 2007). However this study only used a subjective retrospective measure of lifetime noise exposure, and also used a measure of sensitivity where the questionnaire item is more likely to be a measure of general annoyance rather than sensitivity as such ("are you disturbed by noise?").

In an attempt to confirm the role of biological stress mechanisms, laboratory studies have investigated links between levels of the stress hormone cortisol and noise sensitivity. One study looked at noise sensitivity and stress during working conditions when exposed to low-frequency annoying sounds (Waye et al., 2002). The authors concluded that the normal circadian decline in cortisol concentration was significantly affected among subjects who regarded themselves as having a high sensitivity to noise in general. However, the general levels of cortisol were not affected by noise sensitivity or noise exposure during the tasks, implying an interaction between noise, noise sensitivity and time of day on stress response. A recent study aimed at replicating these findings found that cortisol levels, experienced stress or performance during the exposure did not differ between high- and non-sensitive subjects. However, correlations between noise exposure, stress (subjective and objective), and performance were stronger in the highly sensitive group than among the non-sensitive subjects (Ljungberg and Neely, 2007).

1.2. Causal relationships between noise and bad health

The most commonly suggested physiological mechanism for the relationship between noise exposure and detrimental health effects is that noise induces a number of negative outcomes (sleep disturbance, disturbance of daily activities and rest, concentration problems) that results in the chronic activation of the sympathetic nervous and endocrine systems, and elevated levels of physiological risk factors (hypertension, blood lipid levels) that over time give rise to serious health disorders such as cardiovascular disease (Babisch, 2005). In such a model (Fig. 1), annoyance is only described as a psychological side effect. It is however clear from a number of studies that annoyance, rather than actual noise levels, is the factor that has the closest association with cardiovascular diseases (Babisch, 2006). Further, it should be noted that according to psychological theories of stress (Cohen et al., 1986; Levine and Ursin, 1991), it is the persons conscious and cognitive assessment of the stressor (e.g. noise) and its outcomes that is crucial for the stress response. In other words, the potential health effects of noise via stress would have to be mediated by annoyance or some other measure of appraisal.

Stansfeld (1992) discusses the causal relationship between noise sensitivity and psychiatric disorders. He argues that increased sensitivity to noise might be an indicator of increased vulnerability to minor psychiatric disorders. According to this view sensitivity acts as a causal agent for increased degrees of annoyance. The causal relationship with negative (psychiatric) health outcomes is not resolved, but merely described as "associations".

van Kamp et al. (2004) tested the nature of the relationship between sensitivity and annoyance. This study found no evidence of a moderating effect of noise sensitivity on the relationship between exposure and annoyance, but concluded that sensitivity acted as an independent contributor to annoyance. In other words, highly sensitive participants reported higher levels of annoyance regardless of noise level.

Stansfeld's suggestions about vulnerability could be expanded to a model where a third "vulnerability" variable influences sensitivity and also influences health problems. According to such an explanation the proposed relationship between annoyance and health impacts is spurious, and exists because of the impact of noise sensitivity on annoyance.

Stansfeld's model relates vulnerability to mild psychiatric disorders. In the current study we will expand on this and include a range of subjective health complaints as dependent variables in the model (Fig. 2).

2. Objective

The aim of this study is to investigate the hypothesized influence of noise exposure and noise annoyance on subjective health complaints in general, and on reported hypertension and heart problems in particular by the use of an embedded model of the proposed relationships. By exploring the causal pathways between noise, noise sensitivity and reported health outcome the study aims at shedding light on the viability of different causal models for the relationship between noise and health.

3. Method

The studies that were used to analyse the noise–health relationship are two studies conducted in 1987 and 1996 in the city of Oslo (Klæboe et al., 2000). The sub-areas in the study were selected to represent those experiencing increased, decreased and unaltered traffic situations and were not intended to obtain a representative sample of the inhabitants of the area. Within each sub-area we used probability sampling. After quality assurance there were 1842 respondents available for analyses of relationships between noise exposure, sensitivity and health complaints. The respondents were older than 15 years. The mean age of respondents was 42 years, with the oldest respondent being 89 (median 34 years), and 54% were female.

In 1987 face-to-face interviews were carried out in 8 sub-areas. In 1996 we conducted telephone interviews in 14 areas, which along with the original 8 also included 6 sub-areas geographically adjacent. In the analysis, the data from both studies were pooled and treated as one sample of respondents. The response rate was approximately 50% across both surveys.

3.1. Annoyance questions

In both surveys the same wording was used to assess degree of annoyance. Participants were first asked if they heard noise from a certain source, when staying indoors (at home). Thereafter they were asked "Is this noise highly, somewhat or not annoying?" The annoyance scale categories "does not hear" and "hears/not annoyed" were merged before the analyses.

3.2. Sensitivity to noise

Noise sensitivity was measured by a single question using a 3-point scale: "Would you say you are highly, somewhat or not sensitive to noise?"