Noise sensitivity, health and mortality – a review and new analyses

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ABSTRACT

This paper presents a review of noise sensitivity and health as well as new longitudinal analyses of road traffic noise, noise sensitivity and cardiovascular and mental health outcomes. Self-reported noise sensitivity is a moderator of the association of environmental noise and annoyance. There is less certainty over whether it also moderates the effects of environmental noise on health outcomes. It has been suggested that noise sensitivity may be an indicator of vulnerability to environmental stressors in general but the biological basis of this remains undetermined. However, there is evidence for heritability of noise sensitivity from twin studies. Analysis of follow up data from men in the Caerphilly Collaborative Heart Disease study demonstrates that high noise sensitivity has a protective effect on mortality risk and moderates the effect of traffic noise exposure on psychological distress. High noise sensitivity is linked to trait anxiety but it is not clear whether they are the same construct. Understanding vulnerability to environmental stressors is important for developing resilience and preventing disease in the future.

INTRODUCTION

There have been several studies linking prolonged aircraft noise exposure to increased risk of cardiovascular and stroke mortality [1,2]. These studies are part of increasing evidence that both aircraft noise exposure and road traffic noise exposure are related to an increased risk of hypertension, cardiovascular disease and mortality [3-7]. The putative mechanism behind these associations is thought to relate to the stress hypothesis where prolonged noise exposure leads to increased stress responses, hypertension and increased risk of cardiovascular disease [8,9].

The question arises: is everyone in the population equally susceptible to the effects of noise on health or are there vulnerable subgroups who are more likely to experience ill-health when they are exposed to noise? Noise sensitivity has been identified as a potential vulnerability factor for ill-health related to exposure to environmental stressors. Noise sensitivity has consistently been demonstrated to moderate the effects of noise on annoyance responses, with those who are highly sensitive reporting more annoyance at lower noise levels than those

who do not report noise sensitivity [10-12]. There is mixed evidence on whether noise sensitivity may moderate the effects of noise on physical ill-health such as cardiovascular outcomes [13] and a suggestion that it might influence the effects of noise on psychological ill-health.

If noise sensitivity is an indicator of increased vulnerability to noise induced ill-health what is the underlying mechanism for this effect? It may be an indicator of a more general sensitivity to environmental stressors, not just confined to environmental noise [14]. It has been linked to disability pension award suggesting an association with a more general vulnerability to ill-health [15]. Also there is evidence of an underlying genetic susceptibility to noise sensitivity based on twin study results [16]. Noise sensitivity, based on self-report questionnaires has also been linked to measures of trait anxiety [17] and psychological ill-health in many studies [18]. Trait anxiety may be marker of general fearfulness of environmental stimuli. There is a need to establish, in longitudinal data whether noise sensitivity moderates the effects of noise on ill-health and also whether it independently predicts physical and psychological ill-health. In recent analyses in the Whitehall II Study we found that noise sensitivity predicted risk of future psychological morbidity but not cardiovascular disease and mortality except in certain subgroups [19].

In earlier longitudinal analyses in the Caerphilly Study an association was found between noise exposure and anxiety symptoms but in general there was little association with more general measures of psychological ill-health [20]. This raises the question could traffic noise exposure be a predictor of psychological ill-health but only in those with high noise sensitivity?

Thus it is of interest to examine in a long established cohort study, such as the Caerphilly Study, whether noise exposure to road traffic noise is related to cardiovascular morbidity and mortality and whether this might be moderated by noise sensitivity. Secondly, to examine in longitudinal data whether road traffic noise is associated with psychological ill-health and whether this association is moderated by noise sensitivity. Thirdly, to examine whether noise sensitivity is an independent predictor of future cardiovascular and psychological ill-health and mortality, adjusting for baseline ill-health.

We hypothesised that noise sensitivity (Weinstein's Scale) will not moderate the association between traffic noise exposure and the cardiovascular outcomes but will moderate the association of traffic noise exposure on mental ill-health. We hypothesised there will be no direct association of noise sensitivity with cardiovascular morbidity or mortality. We hypothesised that noise sensitivity will predict future psychological ill-health.

METHODS

Sample

The Caerphilly Collaborative Heart Disease Study [21] is a prospective study of risk factors for ischaemic heart disease (IHD) and their determinants in men. All men between 50 and 64 years living in Caerphilly, South Wales, UK, and its environs were invited to attend a screening clinic where physiological measurements were obtained and questionnaires completed.

At the first follow-up the cohort was reconstructed with men new to the area, and effectively a new baseline established for the population-based cohort. A total of 2398 men comprise this re-established cohort in 1984/88.

Traffic noise exposure

Traffic noise maps of the study area were derived from street measurement of A-weighted sound pressure level in 1984 [22]. Continuous noise measurements were carried out on three consecutive days on all busy roads and many side streets. In addition, short-term measurements of $L_{eq\ 30\ minutes}$ were carried out during representative periods of the day (10-18hr) at all other relevant streets. The majority of exposed houses were within 12m from the street. In accordance with the noise measurements, the subjects were grouped into 5 dB categories of traffic noise emission level, in terms of' Leq' referring to the period from 6 a.m. to 10 p.m. and a distance of 10 metres from the street. Daytime outdoor noise level was used as a general descriptor of traffic noise load in the street.

Noise sensitivity

Noise sensitivity was measured by Weinstein's 10-item self-report noise sensitivity scale [14]. Scores were classified as tertiles of high, medium and low noise sensitivity for analysis.

Ischaemic heart disease and mortality

Clinical details of all possible ischaemic heart disease events, including ECG and cardiac enzyme levels, were evaluated against standard diagnostic criteria. Notifications of deaths of cohort members were obtained from the Office of National Statistics.

Psychological ill-health

Psychological ill-health was measured by Goldberg's 30-item General Health Questionnaire (GHQ) [23]. This is a screening questionnaire of largely depression and anxiety, the predominant psychological morbidity expected in a community sample. The conventional threshold of 4/5 on the GHQ was confirmed in a subsample of 97 men distinguishing between 'probable non-cases' and 'probable cases' using ROC analysis [24]. Trait anxiety was measured by the Trait Scale of the State-Trait Anxiety Inventory [25]. Psychological ill-health was measured at baseline 1984/88, at phase 3 follow up 1989/93 and phase 4 follow up in 1993/6.

Statistical Analysis

All data analysis was performed in Stata Version 14 (StataCorp, 2015). The association of traffic noise, noise sensitivity and anxiety with CHD mortality and morbidity were analysed using Cox Proportional Hazard Models. The Cox Proportional Hazard Models were first run univariately and then adjusted in a hierarchical fashion. The models were first adjusted by age, marital status, social class and employment status. The final stage of adjustment added smoking status, BMI, alcohol consumption, physical activity at leisure, cholesterol, noise at work, pre-CHD history and bedroom orientation.

The association of psychological ill-health with noise, noise sensitivity and anxiety was analysed using logistic regression. These models were adjusted for age, marital status, social class, employment, smoking status, BMI, alcohol consumption, physical activity at leisure, cholesterol, bedroom orientation and noise at work (the adjustment of noise sensitivity models with Spielberger anxiety were also explored). Interactions between sensitivity and anxiety with noise were analysed, however due to low power, stratification was not feasible.

Missing data

The total sample includes 2398 individuals at phase 2 of the study. Missing item responses ranges from 0% to 13.6% (cholesterol) at phase 2. Two GHQ score items were used from follow up phases. The percentage of missing data for these items were 27.9% for GHQ at phase 3 and 37.7% for GHQ at phase 4. The analysis represented within this paper is based on complete records.

RESULTS

Ischaemic heart disease

Road traffic noise did not predict ischaemic heart disease (IHD) morbidity or mortality in this sample (Table 1). There was an indication of reduced risk of IHD morbidity in men exposed to 61- 65 dB but this was no longer statistically significant in the fully adjusted model. There was no significant interaction between noise exposure and noise sensitivity and either IHD mortality or morbidity.

Table 1 Road traffic noise and Ischaemic Heart Disease Mortality and Morbidity

Noise IHD mortality	Hazard Ratio (95% CI) Model 1	Hazard Ratio (95% CI) Model 2	Hazard Ratio (95% CI) Model 3
	N=2364	N=2353	N=1915
1			
2	0.86 (0.59, 1.26)	0.82 (0.56, 1.20)	0.83 (0.55, 1.24)
3	0.89 (0.66, 1.20)	0.89 (0.66, 1.19)	0.98 (0.70, 1.38)
4	1.20 (0.82, 1.75)	1.14 (0.77, 1.67)	1.00 (0.65, 1.54)
IHD morbidity			
1			
2	1.03 (0.78, 1.36)	0.95 (0.72, 1.25)	0.98 (0.73, 1.32)
3	0.80* (0.64, 1.00)	0.78* (0.62, 0.98)	0.90 (0.69, 1.17)
4	1.26 (0.95, 1.67)	1.25 (0.94, 1.67)	0.96 (0.69, 1.34)

Model 1: Univariate; Model 2: Adjusted for age, marital status, social class and employment; Model 3: Adjusted for age, marital status, social class, employment, smoking status, BMI, alcohol consumption, physical activity at leisure, cholesterol, noise at work, pre-CHD history and bedroom orientation. *** p<=0.001, ** p<=0.01, *p<=0.05

Further analyses were carried out on the direct associations between noise sensitivity and IHD mortality. High noise sensitivity was associated with a reduced risk of IHD mortality (HR=0.71, 95%CI 0.54-0.94) (Figure 1, TW3= high noise sensitivity). When trait anxiety was substituted

for noise sensitivity in the prediction of mortality analyses there was a similar reduced risk of mortality (HR=0.68, 95%CI 0.49,0.94).

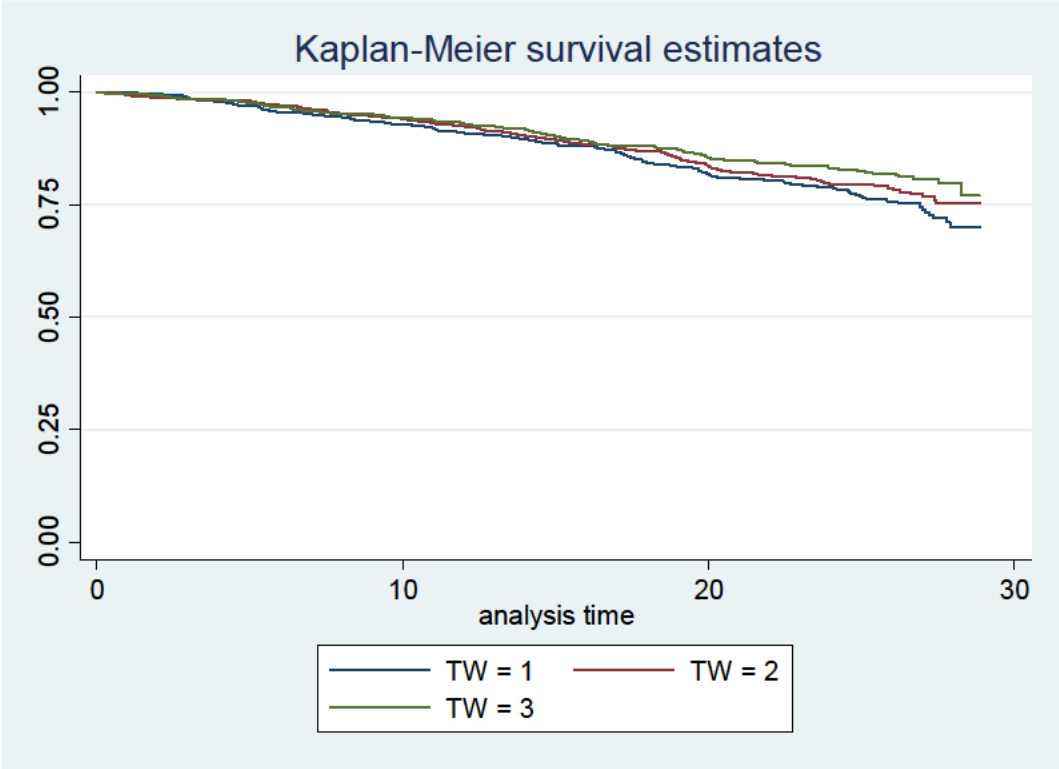

Figure 1: Survival analysis of high (TW3), medium (TW2) and low (TW1) noise sensitivity and mortality

Psychological ill-health

In a sample from which GHQ cases were removed at baseline there was a small significant association between road traffic noise at baseline and psychological ill-health at Phase 4 but only among those exposed to 56-60dBA (Table 2). This was not statistically significant at phase 3.

In men at baseline there was an interaction between road traffic noise and noise sensitivity and psychological ill-health at phase 3 such that men who were highly noise sensitive in the highest noise exposure category had a greatly increased risk of psychological distress (Table 3). This interaction was still present after adjustment for the Spielberger trait anxiety scale (results not shown). This interaction was not statistically significant using phase 4 data.

High and moderate noise sensitivity was a predictor of future psychological ill-health at both phase 3 and phase 4, regardless of exclusion of baseline caseness or not. This association remained after further adjustment for trait anxiety (results not shown).

Table 2: Road traffic noise and Psychological ill-health at phase 3 and phase 4

Noise	Odd Ratio (95% CI) Model 1*	Odd Ratio (95% CI) Model 2	Odd Ratio (95% CI) Model 3
Phase 3	N=1254	N=1250	N=1214
1			
2	1.61 (0.99, 2.62)	1.48 (0.90, 2.45)	1.52 (0.90, 2.56)
3	1.09 (0.69, 1.73)	1.10 (0.69, 1.74)	1.18 (0.73, 1.91)
4	1.21 (0.65, 2.26)	1.35 (0.71, 2.54)	1.41 (0.74, 2.68)
Phase 4			
	N=1085	N=1082	N=1056
1			
2	1.98** (1.21, 3.24)	1.88* (1.14, 3.13)	1.81* (1.07, 3.05)
3	0.82 (0.51, 1.34)	0.82 (0.50, 1.36)	0.84 (0.51, 1.39)
4	1.18 (0.63, 2.23)	1.27 (0.67, 2.42)	1.31 (0.68, 2.52)

*Sample who were not GHQ cases at baseline

Model 1: Univariate; Model2: Adjusted for age, marital status, social class and employment; Model 3: Adjusted for age, marital status, social class, employment, smoking status, alcohol consumption, noise at work, bedroom orientation and physical activity at leisure.

*** p<=0.001, ** p<=0.01, *p<=0.05

Table 3: Road traffic noise, noise sensitivity and psychological ill-health

GHQ: Phase 3- Weinstein Sensitivity

		Odds Ratio (95% CI)	Odds Ratio (95% CI) (With Interaction)
		N=1524	N=1524
Noise	1		
	2	1.71* (1.11, 2.63)	1.13 (0.51, 2.51)
	3	1.22 (0.83, 1.79)	0.83 (0.40, 1.74)
	4	1.28 (0.75, 2.19)	0.40 (0.09, 1.78)
Weinstein Sensitivity (WS)	1		
(Tertiles)	2	1.58** (1.13, 2.21)	1.36 (0.91, 2.03)
	3	1.82*** (1.30, 2.56)	1.37 (0.91, 2.04)

(continued)			
Noise, WS Interaction	2,2		1.58 (0.55, 4.58)
	2,3		2.08 (0.68, 6.37)
	3,2		1.42 (0.53, 3.81)
	3,3		1.98 (0.75, 5.20)
	4,2		2.47 (0.43, 14.00)
	4,3		7.57* (1.35, 42.49)

Adjusted for age, marital status, social class, employment, smoking status, alcohol consumption, noise at work, bedroom orientation and physical activity at leisure.

*** p<=0.001, ** p<=0.01, *p<=0.05

DISCUSSION

In longitudinal analyses there was little evidence of effects of road traffic noise exposure on IHD mortality and morbidity. Also road traffic noise was not consistently associated with psychological ill-health. There were no significant interactions of road traffic noise and noise sensitivity with IHD morbidity and mortality. However, there were significant interactions of road traffic noise and noise sensitivity with psychological ill-health. In terms of direct health effects of noise sensitivity, high noise sensitivity was a predictor of a reduced mortality rate compared to moderate and low sensitivity. High noise sensitivity was a consistent predictor of future psychological ill-health.

The lack of direct effects of road traffic noise on health outcomes is perhaps not surprising given the relatively low exposure levels and the long interval between initial exposure measurement and follow up, and the possibility of exposure misclassification. The finding that noise sensitivity is not a moderator of IHD outcomes in relation to road traffic noise exposure is in keeping with other studies [13].

This study shows that noise sensitivity may be a vulnerability factor for psychological ill-health following exposure to road traffic noise although the results were not entirely consistent for both psychological ill-health at phase 3 and phase 4 and the confidence intervals were wide suggesting these analyses may be underpowered. Noise sensitivity is a very consistent predictor of psychological ill-health, irrespective of an interaction with noise exposure. Many previous studies have demonstrated the association between noise sensitivity and psychological ill-health [17, 18, 24] and between noise sensitivity and neuroticism [17,18,24] as a personality trait linked to negative affectivity and trait anxiety. However, studies have also contested that noise sensitivity is merely an index of negative affectivity manifest as a general sensitivity to environmental stressors [26]. Our results suggest there is an association between noise sensitivity and trait anxiety but this is by no means the whole story. The associations of noise sensitivity with psychological ill-health and the interaction between noise exposure and noise sensitivity and psychological ill-health remained after adjustment for trait anxiety. Although neuroticism or trait anxiety may still partly explain the association of noise sensitivity and future risk of psychological ill-health [27].

The potential protective effect of noise sensitivity on mortality was an unexpected finding although a trend in this direction was noted in an earlier study [13]. Could this be related to

earlier findings in which high levels of anxiety have been found to protect against mortality perhaps because anxious people tend to avoid risk-taking and exposure to environmental stressors which may increase mortality risk? [28]. This is supported by the finding of a similar protective effect when trait anxiety was substituted for noise sensitivity in our models. This might have implications in terms of noise research that noise sensitive people may tend to try and avoid noise exposure more than we realise and hence the associations linking noise and ill-health in highly noise sensitive people may be confounded by avoidance of exposure. However, it seems unlikely that noise sensitivity is a major determinant of moving home because of economic constraints. In which case avoidance of noise may be limited to shifting the location of bedrooms and living rooms so they are not facing on to a noisy road.

The limitations of this study include that it was confined to middle aged and older men, and that although it is based on a population sample there may not be generalisability to the wider population. Nevertheless, the response rate was high and there was excellent follow up of the cohort and their health outcomes. There was missing data, especially for psychological ill-health, less so for IHD outcomes.

In conclusion, there is some evidence for noise sensitivity being a vulnerability factor for psychological ill-health following exposure to road traffic noise and also that noise sensitivity is a risk factor for psychological ill-health independent of noise exposure. Also these effects are not entirely explained by trait anxiety, although there may be some residual confounding in these analyses. These findings strengthen the case for more research to understand the biological underpinning of noise sensitivity [29] in the search for what confers resilience to environmental stressors.

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