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Noise sensitivity and future risk of illness and mortality

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HIGHLIGHTS

- Research is scarce on whether noise sensitivity is a risk factor for illness
- Noise sensitivity did not show main effects on CVD morbidity or mortality
- Noise sensitivity did predict angina pectoris in low employment grades
- Noise sensitivity did predict the risk of future psychological distress

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ABSTRACT

Aircraft and road traffic noise exposure increase the risk of cardiovascular disease (CVD). Noise annoyance is the most frequent response to environmental noise. Noise annoyance has been shown to modify the association of transport noise exposure on CVD and noise sensitivity moderates the annoyance response to noise. This study uses prospective data from phases 1, 3, 5, 7 and 9 in 3630 male and female civil servants from the UK Whitehall II Study to examine whether a single question on noise sensitivity measured by annoyance responses to noise in general predicts physical and mental ill-health and mortality. Non-fatal myocardial infarction and stroke morbidity over the follow-up were defined by MONICA criteria based on study ECGs, hospital records, hospital admission statistics or General Practitioner confirmation. Depressive symptoms were measured by the Center for Epidemiologic Studies Depression Scale (CES-D) and psychological distress by the General Health questionnaire (GHQ). There was no association between noise sensitivity and CVD morbidity or mortality except in people from lower employment grades where there was an association with angina. Noise sensitivity was a consistent predictor of depressive symptoms and psychological distress at phases 3, 5 and 7. High noise sensitivity scores at baseline predicted GHQ caseness at phase 3 adjusting for age, sex, employment grade, self-rated health and GHQ caseness at baseline (OR = 1.56 95% CI 1.29–1.88). Noise sensitivity has been identified as a predictor of mental ill-health. More longitudinal research is needed including measures of noise exposure.

1. Introduction

Recently there have been several studies linking prolonged aircraft noise exposure to increased risk of cardiovascular and stroke mortality (Huss et al., 2010; Hansell et al., 2013). These studies are part of accumulating evidence that both aircraft noise exposure and road traffic noise exposure are related to an increased risk of cardiovascular disease and mortality (Sorensen et al., 2011, 2012; Floud et al., 2013). 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 (Babisch, 2008; Jarup et al., 2008; Munzel et al., 2014).

The most frequent response to environmental noise is annoyance, which is a mixture of reported discomfort, anger and feelings of intrusion. Exposure response relationships have been found for road, rail and aircraft noise in which the degree of annoyance rises with increasing noise levels (Miedema and Vos, 1998). Annoyance has also been suggested as a possible moderating factor of the effects of noise on cardiovascular disease — as a subjective indicator of the degree of disturbance from noise that amplifies the stress response to sound (Babisch et al., 2013). However, noise annoyance levels are probably inadequate as a proxy for noise levels in associations with health outcomes. This is because there are non-acoustic factors, that may account for at least 35% of the variance in annoyance such as personality factors, attitudes

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to the noise source and perceptions of malfeasance related to the source of the noise (Job, 1988). Despite this, noise annoyance is associated with health outcomes, especially psychiatric disorder. In cross sectional studies it has been suggested that prior ill-health may lead to increased levels of annoyance and not the other way round (Tarnopolsky et al., 1980; Stansfeld et al., 1993). This has been explained as people who feel unwell being likely to be less tolerant of environmental discomfort.

Noise sensitivity, as a stable response to noise in general, is an independent predictor of the annoyance response to environmental noise (Job, 1999; Paunović et al., 2009; van Kamp et al., 2004). It has been postulated that noise sensitivity might be an indicator of vulnerability to environmental stressors, so that highly sensitive people might be more prone to develop illness when exposed to environmental noise (Stansfeld, 1992).

It is of interest to understand whether noise sensitivity does indicate vulnerability to ill-health, especially that attributable to noise, as this has implications for public health policy on reducing noise and advising noise sensitive individuals of the potential consequences of noise exposure. This is best attempted in longitudinal analyses. A single question on annoyance to noise in general was included in the first phase of the Whitehall II Study of British civil servants. We examined whether this question, which is an indicator of noise sensitivity (Job, 1999), is a predictor of future cardiovascular morbidity and mortality and psychiatric disorder. We hypothesised that with increased levels of noise sensitivity there would be a greater risk of both cardiovascular disease and psychiatric morbidity adjusting for ill-health at baseline.

2. Materials and methods

2.1. Participants

The Whitehall II study was established between 1985 and 1988 with a target population of all male and female civil servants, aged between 35 and 55 years, in twenty London based civil service departments. 10,308 civil servants were examined in phase 1 of the study — 6895 men and 3413 women with a response rate of 73%, the true response rate was higher because around 4% of the invited employees had moved before the study and were not eligible for inclusion. The noise sensitivity question was only included in the first version of the questionnaire in a sample of 3630. We analysed data from phase 1 (1985–88, self-report questionnaire and screening), phase 3 (1991–3, self-report questionnaire and screening), phase 5 (1997–9, self-report questionnaire and screening), phase 7 (2003–4, self-report questionnaire and screening) and phase 9 (2008–9, self-report questionnaire and screening) (Marmot and Brunner, 2005). Each of these phases included a clinic visit with measurement of biological variables, such as height, weight, blood pressure, electrocardiograph and a self-completion questionnaire covering demographic details, risk factors and physical and mental health outcomes. Our analyses are based on participants for whom complete data on covariates were available. Although most study respondents were white-collar employees, a wide range of employment grades (and salaries) from office support staff to the most senior government servants were covered.

2.2. Measures

Noise sensitivity was measured by a single question: 'Taking all sorts of noise together how much are you bothered by noise in general? A great deal, somewhat, little, not at all'. Responding as either 'a great deal' or 'somewhat annoyed' was classified as highly sensitive.

Age was divided into four categories between 34 and 55 years. Ethnicity was classified as White, South Asian, Black or Other. Employment grade was classified as high (administrative and professional), medium (executive), or low (clerical and support grades). Self-rated health at baseline at Phase 1 was assessed by a single item on self-rated health 'very good, good, average, poor/very poor'.

2.3. Cardiovascular outcomes

Angina pectoris was measured by the Rose Angina Questionnaire between Phase 1 and Phase 9 (Rose, 1962). Definite angina included ECG changes suggestive of ischaemia. Mortality was identified through linkage to the NHS Central Register and was available up to August 2012. Morbidity measures included non-fatal myocardial infarction and stroke morbidity over the follow-up and were defined following MONICA criteria based on study ECGs, hospital records of ECGs and cardiac enzyme levels and validated using discharge diagnoses from NHS Hospital Episode Statistics data or General Practitioner confirmation, or retrieval of hospital medical records up to the end of Phase 9.

2.4. Psychiatric morbidity

Psychological distress was measured by the 30-item General Health Questionnaire (GHQ), a screening measure for anxiety and depressive disorders, at baseline, Phase 3 and Phase 7 (Goldberg, 1972). It was classified into non-cases and cases at threshold 4/5 based on a prior validation study. Depressive symptoms were measured by the Center for Epidemiologic Studies Depression Scale at Phase 7 (Radloff, 1977). Major depressive episodes at Phase 5 were measured by a self-completion computerised version of the Composite International Diagnostic Interview (Kessler et al., 1998).

2.5. Analysis

Initially, the association of sociodemographic factors and self-rated health with the noise sensitivity question was analysed at baseline. In addition, the cross-sectional association between psychological distress at baseline and noise sensitivity was examined adjusting for age, sex, employment grade and self-rated health. Cox proportional hazard models were used to examine the association between sensitivity and subsequent mortality adjusting for age, sex, employment grade and then, additionally, adjusting for self-rated health and psychological distress. We examined interactions with age, gender and employment grade. Logistic regression analysis was used to examine whether sensitivity at baseline predicted mental health outcomes at Phase 3, 5 and 7 adjusting for age, sex, low employment grade and subsequently additionally adjusting for self-rated health and GHQ caseness at baseline. Prediction of GHQ caseness at Phase 3 and Phase 7 was repeated in a sample from which baseline GHQ cases were excluded. We examined interactions with age, gender and employment grade. We repeated the analyses for key outcomes using a stricter threshold for noise sensitivity to examine whether this changed the associations with health outcomes.

3. Results

There were 3630 individuals in the sample, 49% were men. Overall, 48% of participants were sensitive, being highly bothered by noise in general. Noise sensitivity or being highly bothered by noise was more common in the 50–55 year age group (OR = 1.20 (95% CI 1.01–1.43)) relative to the 34–39 year age group. Women tend to be more sensitive relative to men (OR = 1.21 (95% CI 1.06–1.39)). Those in the lowest employment grade tend to be less sensitive than those in the highest employment grade (OR = 0.63 (95% CI 0.51–0.78)).

The odds of reporting high sensitivity increased with reporting average and poor self-rated health (Table 1). High sensitivity was cross-sectionally associated with increased odds of psychological distress which was maintained even after adjusting for self-rated health at baseline (OR = 1.67 (95% CI 1.43–1.95) (Table 1)).

There was no association between noise sensitivity and incident coronary heart disease outcomes, either non-fatal myocardial infarction or stroke morbidity, angina pectoris or mortality, adjusting for age, sex, low employment grade, self-rated health and psychological distress

Table 1
Cross-sectional associations between noise sensitivity and risk factors.

Risk factors	N	Bothered by noise[a], n (%)	Adjustment		
			Age, sex	Age, sex, low employment grade	Age, sex, low employment grade, self-rated health
			OR (95% CI)	OR (95% CI)	OR (95% CI)
Age group (N = 3630)					
34–39	1052	485 (46.1)	1.0		
40–44	870	429 (49.3)	1.13 (0.95, 1.36)		
45–49	707	316 (44.7)	0.92 (0.76, 1.12)		
50–55	1001	515 (51.5)	1.20* (1.01, 1.43)		
Age (per 10 years)	3630	1745	1.06 (0.95, 1.18)		
Sex (N = 3630)					
Men	2307	645 (48.8)	1.0		
Women	1323	678 (51.3)	1.21** (1.06, 1.39)		
Ethnic group (N = 3542)					
White	3182	1525 (47.9)	1.0		
South Asian	219	110 (50.2)	1.08 (0.82, 1.42)		
Black	113	50 (44.3)	0.82 (0.56, 1.19)		
Other	28	16 (57.1)	1.40 (0.66, 2.97)		
Employment grade (N = 3630)					
High	1117	528 (47.3)	1.0		
Medium	1666	847 (50.8)	1.10 (0.94, 1.28)		
Low	847	370 (43.7)	0.63*** (0.51, 0.78)		
Age left full-time education (N = 1028)					
≤16 years	454	191 (42.1)	1.0	1.0	
17–18 years	247	103 (41.7)	1.12 (0.80, 1.55)	1.03 (0.74, 1.43)	
≥19 years	327	134 (41.0)	1.13 (0.83, 1.55)	1.02 (0.74, 1.41)	
Self-rated health (N = 3609)					
Very good	1054	419 (39.8)	1.0	1.0	
Good	1518	749 (49.3)	1.47*** (1.25, 1.72)	1.49*** (1.27, 1.75)	
Average	854	455 (53.3)	1.69*** (1.40, 2.03)	1.77*** (1.47, 2.13)	
Poor/very poor	183	114 (62.3)	2.44*** (1.76, 3.37)	2.57*** (1.85, 3.57)	
GHQ caseness (N = 3580)					
Non-cases	2612	1145 (43.8)	1.0	1.0	1.0
Cases	968	572 (59.1)	1.86*** (1.60, 2.16)	1.82*** (1.57, 2.12)	1.67*** (1.43, 1.95)

[a] Numbers given are those responding 'somewhat' or 'a great deal'.
* $p < 0.05$.
** $p < 0.01$.
*** $p < 0.001$.

(Table 2). However, there were significant interactions between noise sensitivity and employment grade with significantly higher risks for definite angina, but not CVD morbidity and mortality in lower employment grades.

In contrast, high noise sensitivity was a consistent predictor of depressive symptoms and psychological distress at Phases 3, 5 and 7 (Table 3). Strikingly the predictive power of high noise sensitivity remained strong even after 15–19 years of follow up at Phase 7. However, noise sensitivity did not predict major depressive episodes on the Composite Diagnostic Interview at Phase 5. There was a modest diminution in the odds ratios after adjusting for psychological distress at baseline (Table 3). There was little difference in the magnitude of the odds ratios comparing analyses from samples where GHQ cases at baseline had been excluded with samples where GHQ cases at baseline were still included. There were no interactions with age, gender or employment grade for the psychological outcomes.

Table 2
Association between noise sensitivity and incident CVD outcomes and mortality.[a]

Outcome	Employment grade	N	Bothered by noise[b], n (%)	Total events	Adjustment	
					Age, sex, low employment grade[c]	Age, sex, low employment grade[c], self-rated health, GHQ caseness
					HR (95% CI)	HR (95% CI)
All cause mortality	All	3559	1708 (48.0)	493	0.96 (0.80, 1.15)	0.95 (0.79, 1.14)
CHD mortality/non-fatal MI	All	3542	1703 (48.1)	184	1.13 (0.84, 1.51)	1.03 (0.77, 1.39)
CHD/stroke mortality or morbidity[d]	High/medium	2709	1337 (49.4)	178	0.87 (0.65, 1.17)	0.79 (0.58, 1.07)
	Low	832	365 (43.9)	48	1.75 (0.98, 3.12)	1.69 (0.94, 3.03)
Total angina	All	3420	1636 (47.8)	553	1.16 (0.98, 1.37)	1.06 (0.89, 1.25)
Definite angina[e]	High/medium	2709	1338 (49.4)	249	1.05 (0.82, 1.35)	0.93 (0.72, 1.20)
	Low	828	362 (43.7)	76	1.99 (1.26, 3.14)	1.88 (1.18, 3.00)

[a] Mortality is up to August 2012 and morbidity is up to Phase 9. Combined mortality/morbidity outcomes are up to Phase 9.
[b] Numbers given are those responding 'somewhat' or 'a great deal'.
[c] Adjustment for low employment grade applies to outcomes where all grades are included.
[d] P-value for interaction between noise sensitivity and employment grade is 0.04, so separate estimates are presented for high and low employment grades.
[e] P-value for interaction between noise sensitivity and employment grade is 0.03, so separate estimates are presented for high and low employment grades.

Table 3
Association between noise sensitivity and subsequent psychological distress and depression.

Outcome	Sample, N	Number of cases with depressive symptoms, %	Bothered by noise[a], n (%)	Adjustment		
				Age, sex, low employment grade	Age, sex, low employment grade, self-rated health	Age, sex, low employment grade, self-rated health, GHQ caseness[b] at baseline
				OR (95% CI) P-value	OR (95% CI) P-value	OR (95% CI) P-value
CIDI depression at Phase 5	1169	44 (3.7%)	549 (47.0)	1.22 (0.66, 2.25) 0.52	1.16 (0.63, 2.16) 0.63	1.10 (0.59, 2.06) 0.76
CES-D depression/medication at Phase 7	2053	329 (16.0%)	1022 (49.8)	1.70 (1.33, 2.17) <0.001	1.53 (1.19, 1.97) <0.001	1.39 (1.08, 1.80) 0.011
CES-D depression at Phase 7	2038	280 (13.7%)	1011 (49.6)	1.66 (1.28, 2.15) <0.001	1.51 (1.16, 1.97) 0.002	1.35 (1.03, 1.77) 0.03
GHQ caseness at Phase 3	2835	642 (22.6%)	1375 (48.5)	1.87 (1.56, 2.25) <0.001	1.76 (1.46, 2.11) <0.001	1.56 (1.29, 1.88) <0.001
GHQ caseness at Phase 3 among GHQ non-cases at baseline	2050	324 (15.8%)	900 (43.7)	1.70 (1.34, 2.17) <0.001	1.65 (1.29, 2.10) <0.001	1.58 (1.23, 2.02) <0.001
GHQ caseness at Phase 7	2353	451 (19.2%)	1166 (49.6)	1.75 (1.41, 2.16) <0.001	1.60 (1.29, 1.99) <0.001	1.44 (1.15, 1.80) 0.001
GHQ caseness at Phase 7 among GHQ non-cases at baseline	1667	222 (13.3%)	744 (44.6)	1.69 (1.27, 2.26) <0.001	1.64 (1.22, 2.20) 0.001	1.58 (1.17, 2.12) 0.003

[a] Numbers given are those responding 'somewhat' or 'a great deal'.
[b] For the analysis among GHQ non-cases at baseline, adjustment for baseline GHQ is using GHQ score among the non-cases.

We carried out a 'sensitivity analysis' analysing the associations of noise sensitivity with the key cardiovascular and psychological outcomes using a more stringent threshold for noise sensitivity. We found a very similar pattern of associations with cardiovascular and psychological outcomes (Table 4).

4. Discussion

Being highly sensitive to noise in general was more common in 50–55 year olds, women, and those of high employment grade, similar to findings in a national UK survey (Clark et al., 2014). As has been found previously in the literature, there were cross-sectional associations between high noise sensitivity and self-rated health and psychological distress (Tarnopolsky et al., 1980; Stansfeld et al., 1993). Being highly sensitive did not predict angina pectoris, non-fatal myocardial infarction/morbidity or stroke, CHD or all-cause mortality in the main effects analysis. These results were all negative except for an interaction between sensitivity and employment grade such that those in lower employment grades had a greater risk of definite angina. By contrast, high sensitivity was associated with psychological distress in the short-term (Phase 3) and depressive symptoms and psychological distress in the longer-term (Phase 7). Moreover, although the odds-ratios for psychological distress reduced after adjustment for baseline psychological distress the associations still remained significant. Similarly, after removing GHQ cases at baseline, the association changed very little.

In contrast to associations of transport noise exposure and cardiovascular disease where a pattern of persistent associations is being built up, these analyses show little evidence that sensitivity by itself is a predictor of coronary heart disease. This was still the case after using a stricter threshold criterion for 'high noise sensitivity'. The association

Table 4
Association between noise sensitivity and incident CVD outcomes and psychological distress.

Outcome	Employment grade	Bothered by noise	Sample, N	No. events	Adjustment		
					Age, sex, low employment grade	Age, sex, low employment grade, self-rated health	Age, sex, low employment grade, self-rated health, GHQ caseness[a] at baseline
					HR/OR[a] (95% CI)	HR/OR[b] (95% CI)	HR/OR (95% CI)
CHD/stroke mortality or morbidity	High/medium	Little/not at all	1372	97	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
		Somewhat	1017	57	0.79 (0.57, 1.09)	0.73 (0.52, 1.01)	0.72 (0.52, 1.01)
		A great deal	320	24	1.17 (0.74, 1.84)	1.02 (0.65, 1.61)	1.02 (0.64, 1.61)
CHD/stroke mortality or morbidity	Low	Little/not at all	467	20	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
		Somewhat	263	21	1.82 (0.99, 3.37)	1.75 (0.94, 3.24)	1.76 (0.94, 3.27)
		A great deal	102	7	1.57 (0.66, 3.71)	1.47 (0.62, 3.52)	1.50 (0.62, 3.62)
Definite angina	High/medium	Little/not at all	1371	123	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
		Somewhat	1016	94	1.01 (0.77, 1.33)	0.92 (0.70, 1.21)	0.92 (0.70, 1.20)
		A great deal	322	32	1.18 (0.80, 1.75)	0.98 (0.66, 1.46)	0.96 (0.65, 1.44)
Definite angina	Low	Little/not at all	466	31	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
		Somewhat	261	32	1.94 (1.18, 3.17)	1.83 (1.11, 3.01)	1.85 (1.12, 3.04)
		A great deal	101	13	2.12 (1.11, 4.07)	1.93 (1.00, 3.72)	1.98 (1.02, 3.85)
GHQ caseness at Phase 3	All	Little/not at all	1460	251	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
		Somewhat	1038	282	1.76 (1.45, 2.13)	1.68 (1.38, 2.04)	1.52 (1.24, 1.86)
		A great deal	337	109	2.27 (1.73, 2.97)	2.03 (1.54, 2.67)	1.69 (1.27, 2.25)
GHQ caseness at Phase 3 among GHQ non-cases at baseline	All	Little/not at all	1155	145	1.0 (Ref)	1.0 (Ref)	1.0 (Ref)
		Somewhat	702	136	1.65 (1.27, 2.14)	1.60 (1.24, 2.08)	1.55 (1.19, 2.01)
		A great deal	194	43	1.92 (1.30, 2.83)	1.81 (1.22, 2.68)	1.69 (1.14, 2.51)

[a] Estimates are hazard ratios for the cardiovascular outcomes and odds ratios for the psychological distress outcomes.
[b] Adjustment for low employment grade applies to outcomes where all grades are included.

between noise sensitivity and definite angina in the lower employment grades is not shown in the higher grades and is not significant with CHD/stroke morbidity or mortality. Mixed results have been found in previous studies with increased risk of cardiovascular mortality associated with noise sensitivity in women but not men in the Finnish Twin cohort (Heinonen-Guzejev et al., 2007). Subjective reports of hypertension, which may be subject to reporting bias, were associated with noise sensitivity in a Norwegian study (Fyhri and Klaeboe, 2009).

Noise sensitivity, however, does seem to be an indicator of risk of future psychiatric disorder. Noise sensitivity has been identified as having a strong association with psychological distress and as a potential vulnerability factor for psychological disorders related to exposure to environmental stressors (Stansfeld et al., 1993). Noise sensitivity is strongly associated with negative affectivity (Smith, 2003) and trait anxiety and its power as a risk indicator for future psychiatric disorder may be related to its association with these traits as has been found in cross sectional analyses (Hill et al., 2014). It has also been found, potentially, to be an indicator of a genetically linked proneness to disease (Heinonen-Guzejev et al., 2005) and has been linked to increased risk of disability pension award (Heinonen-Guzejev et al., 2013) both of which might be in keeping with a link to trait anxiety. Annoyance to a range of environmental sources, similar to the measure of sensitivity examined here is associated with trait anxiety (Persson et al., 2007) and it may be that environmental annoyance responses are more frequent in people who are anxious and fearful about aspects of their environment (Osterberg et al., 2007). Noise sensitivity has often been identified as an indicator of a wider range of environmental sensitivities (Nordin et al., 2014; Palmquist et al., 2014; Baliatsas et al., 2014) although this has not been found in all studies (Heinonen-Guzejev et al., 2012).

There are many limitations to this study: the lack of objective noise measurement, the simplicity of the noise sensitivity measure and the lack of generalisability to the general population from a white-collar occupational sample. The strengths of the study are the longitudinal measures of CVD morbidity and mortality and psychiatric disorder within a well-defined occupational cohort study.

5. Conclusions

Future research should be pursued in several directions. First, there is a need for a replication of these findings in a cohort study with noise exposure measures as well as noise sensitivity. In particular the associations between noise sensitivity and cardiovascular outcomes should be explored further in people of less advantaged social position. Less advantaged social position may be a marker for exposure to environmental stressors including noise exposure. If there is an association with CVD morbidity it would be worthwhile to also examine associations with risk factors for CVD such as hypertension, inflammatory markers and health behaviours which could be mediating or confounding factors.

A second research direction should involve examining the link with psychiatric disorder. It may be that noise sensitivity is associated with identifiable attitudes to the environment, such as phobic avoidance (Stansfeld, 1992) that underlie general sensitivity to the environment. A greater understanding of how sensitivity and psychiatric disorder are linked is needed. Is sensitivity linked to a greater discriminative capacity for the environment or is it a proxy measure for chronic anxiety or both? Further psychobiological research on noise sensitivity would be valuable to take the field further forward.

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