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Noise and somatic symptoms: a role for personality traits?

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ABSTRACT

Objectives

We investigated the role of a stress-sensitive personality on relations between noise, noise annoyance and somatic symptom reporting. Firstly, we investigated the cross-sectional association of road traffic noise exposure and somatic symptoms, and its modification by hostility and vulnerability to stress. Secondly, we investigated the cross-sectional association of noise annoyance from eight sources (e.g. road traffic, aircraft, neighbors) and somatic symptoms, and it's confounding by hostility and vulnerability to stress.

Methods

Data were obtained from LifeLines, a general population cohort from the Netherlands. Road traffic noise was estimated using the Common Noise Assessment Methods in Europe (CNOSSOS-EU) noise model. Noise annoyance, hostility, vulnerability to stress, and somatic symptoms were assessed with validated questionnaires.

Results

Poisson regression models adjusted for demographic and socioeconomic variables indicated no association of noise exposure and somatic symptoms (incidence rate ratio (IRR) 1.001; 95% confidence interval (CI) 1.000-1.001; n=56,937). Interactions of noise exposure and hostility and vulnerability to stress were not statistically significant. Small positive associations were found for noise annoyance from each of the eight sources and somatic symptoms, when adjusted for demographic and socioeconomic variables (e.g. for road traffic noise annoyance IRR 1.014, 95% CI 1.011-1.018; n=6,177). Additional adjustment for hostility and vulnerability to stress resulted in small decreases of the IRRs for noise annoyance from each of the eight sources, but the associations remained statistically significant.

Conclusions

Personality facets hostility and vulnerability to stress did not modify the relation between road traffic noise exposure and somatic symptom reporting, or confound relations between noise annoyance and symptoms.

INTRODUCTION

Around 140 decibels (dB), sound exposure passes the pain threshold [1]. But does sound have to be that loud to hurt? Evidence showing that sound at lower levels can have effects on health already exists. Environmental noise has been associated with a variety of adverse health effects, including hearing loss, cardiovascular disease [1] and impaired neurocognitive function [2]. Not only the actual exposure to noise , but also an individual's annoyance from noise and noise sensitivity contribute to adverse health effects [3]. Some studies suggest it may not be the noise itself that is associated with adverse health for certain outcomes, but instead the individual's annoyance from noise. This is demonstrated by a recent study showing that noise annoyance was strongly associated with somatic symptoms, such as headaches and fatigue, while modelled road traffic noise exposure was not [4]. Similar findings were also reported in studies from Norway and Sweden [5,6]. A strong predictor of noise annoyance is noise sensitivity, which refers to an increased reaction to noise. Individuals that are noise sensitive pay more attention to sound, are more likely to evaluate it negatively, and have stronger emotional reactions to noise [7]. Noise sensitivity has been associated with lower health-related quality of life [8], and depressive symptoms [9]. In addition, noise sensitivity is related to other environmental sensitivities, including environmental chemosensory responsivity [10], to susceptibility to stress in general [11], and to personality traits such as neuroticism [12]. These results lead to the hypothesis that noise sensitivity reflects a more general susceptibility to stressors [13]. If noise sensitivity is part of a more general tendency to be susceptible to stressors, how is such a trait influencing the relation between noise and somatic symptoms? We aim to investigate the role a stress-sensitive personality has on the relations between noise, noise annoyance and somatic symptom reporting. Our research questions are as follows: Firstly, is there a relationship between noise and somatic symptoms in persons who are vulnerable to stressors? We hypothesize that noise exposure may be related to somatic symptoms, but only in a subgroup who are vulnerable to stress. Secondly, is there a relationship between noise annoyance and somatic symptoms because persons vulnerable to stressors report both more noise annoyance and more symptoms? In other words, can this relationship be explained by a confounding effect of a general trait of vulnerability to stress? We hypothesize that sensitive persons will report more noise annoyance [7] and also more symptoms as a result [14].

The general trait of vulnerability to stress is captured in the personality trait neuroticism. Neuroticism can be described as the tendency to experience negative and distressing emotions, and is positively correlated with noise annoyance

[15,16], and noise sensitivity [17]. Neuroticism is considered to be a broad personality trait composed of six facets: anxiety, hostility, depression, self-consciousness, impulsiveness, and vulnerability to stress. Some argue that research is needed on the level of neuroticism's facets instead of the trait in general [18]. When investigating noise, noise annoyance and somatic symptoms, the neuroticism facets hostility and vulnerability to stress seem relevant to these relations, while the remaining facets might be less appropriate to study. Studying facets of neuroticism that are theoretically more related to the relationship tested here, may provide a better insight in the relation of noise, noise annoyance, somatic symptoms and personality. We tested these associations in LifeLines, a large population based cohort from the Netherlands [19].

METHODS

Study design and participants

LifeLines is a multi-disciplinary prospective population-based cohort study examining in a unique three-generation design the health and health-related behaviors of 167,729 persons living in the North East region of The Netherlands. It employs a broad range of investigative procedures in assessing the biomedical, socio-demographic, behavioural, physical and psychological factors which contribute to the health and disease of the general population, with a special focus on multimorbidity and complex genetics [20]. Inclusion of study participants began in 2006 via general practitioners and also self-enrollment. All participants provided written informed consent. The study protocol was carried out in accordance to the Declaration of Helsinki, and was approved by the medical ethical review committee of the University Medical Center Groningen. A detailed description of the LifeLines Cohort Study has been published elsewhere [19].

Baseline measurements were performed between 2006 and 2013 and approximately three years thereafter a follow up questionnaire was sent out. The present study included baseline data with road traffic noise estimates available for 75,304 participants, aged between 18 and 92 years. At the time of our study follow up measurements were still ongoing, and follow up data were released for 61,967 participants. Data obtained during baseline and follow up measurements were used in this study, resulting in different sample sizes for the main constructs. Modelled road traffic noise was estimated for home addresses at the time of baseline measurements. Noise annoyance was assessed during the follow up measurements. Baseline data (n=56,937) were used to investigate the association between road traffic noise exposure and somatic symptoms, and the

modification of this association by hostility and vulnerability to stress. Follow up data (n=46,558) were used for evaluation of the association between noise annoyance and somatic symptoms and its confounding by hostility and vulnerability to stress. Participants with incomplete data regarding somatic symptoms (baseline n=2,365; follow up n=1,372), hostility (baseline n= 5,402; follow up n=5,544), vulnerability to stress (baseline n=5,114; follow up n=5,318), and household equivalent income (baseline n= 9,904; follow up n=9,343) were excluded. The sample size at follow up differed for the various analyses depending on the number of missing data for the noise annoyance questions.

Road traffic noise

Road traffic noise was estimated using a new implementation of the CNOSSOS-EU noise modelling framework [21]. Briefly, the noise level is estimated on road segments within 500 meters of a receptor. Noise propagation to the receptor is assessed with a consideration of possible attenuation due to refractions on buildings, absorption by the atmosphere and interactions with reflective or absorbent land cover surfaces. The CNOSSOS-EU framework contains empirically derived equations to determine both the initial noise level based on traffic flow and also the sound attenuation based on known environmental factors and physical processes. To estimate source noise on road segments in the Netherlands, information is used of hourly flow of passenger cars, heavy goods vehicles and their average speeds. The sound propagation model is based on the CORINE landcover dataset that has a European wide coverage. Traffic data originated from year 2009 and landcover data from 2006. The final sound level is expressed as the day-evening-night time (Lden) annual average in A weighted decibels (dB(A))[22]. Lden is the average A-weighted noise level, estimated over a 24 hour period, with a 10 dB(A) penalty added to the night (23.00–07.00 hours), and a 5 dB(A) penalty added to the evening period (19.00–23.00 hours) noise level. The penalties are added to indicate people's extra sensitivity to noise during the night and evening.

Noise annoyance

Noise annoyance from eight different sources was assessed using a standardized questionnaire [23]. Participants were asked whether the noises were audible in their homes, and if so, to what extent they were bothered, disturbed or annoyed by the noise. The sources of annoyance include noise from road traffic, railroad, aircraft, industrial sources, wind turbines, construction and demolition activities, shops and restaurants, and neighbors. Annoyance could be indicated on a scale ranging from "0: not bothered" to "10: extremely bothered" [23]. When participants indicated that the noise from a specific source was not audible in their

home, the value for annoyance was set to zero. Noise annoyance was assessed during follow up measurements. The item regarding road traffic noise annoyance was implemented in the questionnaire at a later stage than the other noise annoyance questions, and was therefore available for a smaller sample (n=6,162).

Somatic symptoms

The Symptom Checklist-90 somatization scale (SCL-90 SOM) questionnaire was used for the assessment of 12 common somatic symptoms [24]. The SCL-90 SOM is a widely used and validated self-report symptom checklist [25] that assesses headaches, faintness or dizziness, pains in heart or chest, pains in lower back, nausea or upset stomach, soreness of your muscles, numbness or tingling in your body, hot or cold spells, feeling weak in parts of your body, heavy feelings in arms or legs, a lump in your throat, and trouble getting your breath [24]. The questionnaire assesses to what extent participants have been limited by these symptoms in the past seven days. Items were scored on a 5-point scale ranging from *(1)* "Not at all" to *(5)* "Extremely". A sum score of all twelve items, ranging from 12 to 60, was calculated. The Cronbach's alpha was 0.80 at baseline and follow up, indicating acceptable internal consistency of the SCL-90 SOM. We used the sum score as a measure of symptom reporting in general, instead of individual symptoms. The reason for this is that we hypothesized that noise, noise annoyance, and certain personality aspects may be related to symptom reporting in general, and not to any symptoms in particular. The SCL-90 SOM questionnaire was assessed at both baseline and follow up.

Hostility and vulnerability to stress

Hostility and vulnerability to stress are two facets of the personality trait neuroticism. These facets were measured using the neuroticism subscale of the Revised NEO Personality Inventory (NEO-PI-R) [26]. The authorized Dutch translation of this scale has good reliability and validity [27]. Hostility and vulnerability to stress were both assessed with 8 items, which were answered on a 5-point Likert-type scale that ranged from strongly disagree to strongly agree. Sum scores for both hostility and vulnerability to stress were calculated by adding all items belonging to that particular facet, ranging from 8 to 40. In our study, Cronbach's alpha was 0.74 for hostility and 0.81 for vulnerability to stress, indicating acceptable internal consistency of the scales. Hostility and vulnerability to stress were assessed during baseline measurements.

Demographic variables

Details on sex, age, highest obtained educational degree, household income and number of persons in the household were obtained with a questionnaire at baseline. Household equivalent income was calculated as net household income per month divided by the square root of the number of persons in the household [28].

Statistical analyses

Descriptive statistics were used to describe the characteristics of the study population. Because of the non-normal distributions of road traffic noise and the SCL-90 SOM sum score, medians and interquartile ranges (IQRs) were calculated. For other variables, means with standard deviations (SD) and percentages were calculated. Correlations between modelled road traffic noise, noise annoyance, hostility, vulnerability to stress, and somatic symptoms were calculated with Spearman's rho. Incidence rate ratios (IRR) of somatic symptoms were estimated with Poisson regression. Poisson regression is used to model count variables. Although somatic symptom score is not a classical example of a count variable, it can be interpreted as a count of symptom severity and its distribution resembles the Poisson distribution. The "robust option" was used for obtaining robust standard errors for the parameter estimates to control for overdispersion of the data [29]. For the association between road traffic noise and somatic symptoms, a model adjusted for age, sex, education and household equivalent income was analyzed using the baseline sample. In the second model, hostility and vulnerability to stress and an interaction term of road traffic noise exposure and hostility and vulnerability to stress were added, for the investigation of modification by hostility and vulnerability to stress. For the association between noise annoyance and somatic symptoms, models adjusted for age, sex, education, and household equivalent income were fitted using the follow up sample. Subsequently, models additionally adjusted for hostility and vulnerability to stress were fitted, to investigate confounding of the association between noise annoyance and somatic symptoms. Model fit was deemed acceptable when the p-value of the goodness-of-fit chi-squared test was >.05, and when the p-value of the Omnibus test was <.05. Associations were considered statistically significant if the 95% confidence intervals (CI) for the IRRs did not include one. All analyses were performed with IBM SPSS Statistics.

RESULTS

Population characteristics

Of the 56,937 participants in our baseline sample, 43.5% were male, mean age was 42.4 years, and median road traffic noise exposure was 55.9 Lden dB(A). Median sum score on the SCL-90 SOM was 15 (Table 1a). Muscle soreness (47%), lower back pain (45%) and headaches (43%) were the most often reported symptoms in the study population. Population characteristics of the follow up sample (n=46,558) were comparable to the baseline sample (Table 1b).

Table 1a. Population characteristics of baseline sample (n=56,937)

Males, %	43.5
Age (years), mean (SD)	42.4 (10.3)
Highest obtained educational degree, %	
No education or primary education	1.6
Lower or preparatory vocational education	11.1
Lower general secondary education	12.4
Intermediate vocational education or apprenticeship	31.9
Higher general secondary education or pre-university secondary education	9.4
Higher vocational education or university	33.6
Household equivalent income per month (%)	
<€1000	17.8
€1000 - €1300	22.1
€1300 - €1600	16.7
€1600 - €1900	22.2
>€1900	21.1
Road traffic noise (L_{den}), median (IQR)	54.6 (4.2)
SCL-90 SOM sum score, median (IQR)	15 (5)
Hostility, mean (SD)	22.7 (2.6)
Vulnerability to stress, mean (SD)	25.7 (2.1)

Abbreviations: SD: standard deviation; IQR: interquartile range; L_{den}: annual average day-evening-night time road traffic noise; SCL-90 SOM: Symptom Checklist-90 somatization scale

Noise from road traffic and neighbors was most often audible in participant's homes (72.1% and 61.1% respectively; Table 2). If audible in their homes, participants were mostly annoyed by noise from neighbors (15.0%) and construction and demolition activities (11.8%) (Table 2). Correlations between the dependent and independent variables are presented in the Supplementary Table. For example, the correlation between modelled road traffic noise and road traffic noise annoyance was low (Spearman's rho .223, p<.001), and correlations between annoyance from other noise sources and modelled road traffic noise were even lower.

Table 1b. Population characteristics of follow up sample (n=46,558)

Males, %	41.2
Age (years), mean (SD)	46.6 (10.6)
Highest obtained educational degree, %	
No education or primary education	1.4
Lower or preparatory vocational education	10.9
Lower general secondary education	12.6
Intermediate vocational education or apprenticeship	31.2
Higher general secondary education or pre-university secondary education	9.5
Higher vocational education or university	34.5
Household equivalent income per month (%)	
<€1000	16.1
€1000 - €1300	22.2
€1300 - €1600	17.1
€1600 - €1900	21.4
>€1900	23.1
SCL-90 SOM sum score median (IQR)	15 (6)
Hostility, mean (SD)	18.5 (4.3)
Vulnerability to stress, mean (SD)	18.1 (4.1)

Abbreviations: SD: standard deviation; IQR: interquartile range; SCL-90 SOM: Symptom Checklist-90 somatization scale

Table 2. Noise annoyance from eight sources in the follow up sample.
Participants indicated whether noise from eight specific sources was audible in their homes. If so, they rated the noise annoyance on a scale from 0 (not bothered) to 10 (extremely bothered).

	N	Audible in home, %	Noise annoyance score >4, %
Road traffic	6,162	72.1	8.0
Railroad	46,440	16.3	1.6
Aircraft	46,323	26.8	5.6
Industrial sources	46,413	8.1	6.4
Wind turbines	46,558	1.6	2.3
Construction and demolition activities	46,310	14.2	11.8
Shops and restaurants	46,449	6.7	8.1
Neighbors	45,886	61.1	15.0

Associations of road traffic noise and somatic symptoms, and modification by hostility and vulnerability to stress

Poisson regression was used for the investigation of the association of road traffic noise and somatic symptoms, and the modification by hostility and vulnerability to stress (Table 3). First, a model adjusted for age, sex, education, and household equivalent income showed no association between road traffic noise and somatic symptoms (IRR 1.001; 95% CI 1.000-1.001). In the second model, interaction effects of noise and hostility and vulnerability to stress were analyzed to investigate

Table 3. Associations between road traffic noise (L_{den}) and somatic symptoms (baseline sample n=56,937) estimated from Poisson regression analyses.

		SCL-90 SOM sum score	
		IRR	**95% CI**
Model 1	Road traffic noise	1.001	1.000;1.001
Model 2	Road traffic noise	0.999	0.997;1.002
	Hostility	1.007	1.000;1.014
	Vulnerability	1.009	1.002;1.017
	Road traffic noise*hostility	1.000	1.000;1.000
	Road traffic noise*vulnerability	1.000	1.000;1.000

Abbreviations: SCL-90 SOM: Symptom Checklist-90 somatization scale; IRR: incidence rate ratio; 95% CI: 95% confidence interval; vulnerability: vulnerability to stress
Models were adjusted for sex, age, educational level and household equivalent income

modification by hostility and vulnerability to stress. Both interaction terms were not statistically significant, suggesting no modification by hostility and vulnerability to stress.

We used multiple imputation methods to account for the missing values for somatic symptoms, hostility and vulnerability to stress, education and household equivalent income at baseline. Analyses with imputed values did not result in different conclusions as with the original data. This indicates that the missing values probably had no effect on our data, and results based on the original dataset were reported.

Associations of noise annoyance and somatic symptoms, and confounding by hostility and vulnerability to stress

Positive associations of noise annoyance and somatic symptoms were found in the Poisson regression models conducted in the follow up sample (Table 4). The models adjusted for age, sex, education level, and household equivalent income resulted in IRRs ranging from 1.014 (95% CI 1.011-1.018; road traffic noise annoyance) to 1.022 (95% CI 1.018-1.026; railroad noise annoyance). This means that, for example, each additional unit on the railroad noise annoyance scale is associated with an estimated 2.2% increase on the somatic symptoms scale. The models were subsequently adjusted for hostility and vulnerability to stress to investigate confounding of the noise annoyance-somatic symptoms relationship. Here, all associations of noise annoyance and somatic symptom score remained positive and statistically significant. Generally, adjustment for hostility and vulnerability to stress did result in small decreases of the IRRs for noise annoyance with respect to the models without hostility and vulnerability to stress. The largest associations with somatic symptom score were found for noise annoyance from

industrial sources (IRR 1.018, 95% CI 1.014-1.021) and railroad noise annoyance (IRR 1.017 95% CI 1.013-1.022), while the smallest association was found for annoyance from road traffic noise (IRR 1.011, 95% CI 1.007-1.014). In each of these

Table 4. Associations between noise annoyance and somatic symptoms (follow up sample) estimated from Poisson regression analyses.

		SCL-90 SOM sum score	
		IRR	**95% CI**
Model 1a	Road traffic (n=6,177)	1.014	1.011;1.018
Model 1b	Railroad (n=46,485)	1.022	1.018;1.026
Model 1c	Aircraft (n=46,376)	1.016	1.014;1.019
Model 1d	Industrial sources (n=46,451)	1.021	1.017;1.024
Model 1e	Wind turbines (n=46,558)	1.012	1.005;1.020
Model 1f	Construction and demolition activities (n=46,346)	1.020	1.018;1.022
Model 1g	Shops and restaurants (n=46,494)	1.018	1.015;1.021
Model 1h	Neighbors (n=45,967)	1.016	1.015;1.017
Model 2a	Road traffic (n=6,177)	1.011	1.007;1.014
	Hostility	1.010	1.009;1.012
	Vulnerability	1.008	1.006;1.009
Model 2b	Rail road (n=46,485)	1.017	1.013;1.022
	Hostility	1.011	1.010;1.012
	Vulnerability	1.008	1.007;1.008
Model 2c	Aircraft (n=46,376)	1.013	1.011;1.016
	Hostility	1.011	1.010;1.012
	Vulnerability	1.008	1.007;1.008
Model 2d	Industrial sources (n=46,451)	1.018	1.014;1.021
	Hostility	1.011	1.010;1.012
	Vulnerability	1.008	1.007;1.008
Model 2e	Wind turbines (n=46,558)	1.010	1.003;1.017
	Hostility	1.011	1.010;1.012
	Vulnerability	1.008	1.007;1.008
Model 2f	Construction and demolition activities (n=46,346)	1.016	1.014;1.018
	Hostility	1.011	1.010;1.011
	Vulnerability	1.008	1.007;1.008
Model 2g	Shops and restaurants (n=46,494)	1.016	1.013;1.019
	Hostility	1.011	1.010;1.012
	Vulnerability	1.008	1.007;1.008
Model 2h	Neighbors (n=45,967)	1.012	1.011;1.013
	Hostility	1.010	1.010;1.011
	Vulnerability	1.008	1.007;1.008

Abbreviations: SCL-90 SOM: Symptom Checklist-90 somatization scale; IRR: incidence rate ratio; 95% CI: 95% confidence interval; vulnerability: vulnerability to stress

Models 1a-1h were adjusted for sex, age, educational level and household equivalent income

Models 2a-2h were adjusted for sex, age, educational level and household equivalent income, hostility and vulnerability to stress

models, hostility and vulnerability to stress were also positively associated with somatic symptom reporting. We also used multiple imputation methods to account for the missing values for somatic symptoms, hostility and vulnerability to stress, education and household equivalent income at follow up. Again, analyses with imputed values did not result in different conclusions as with the original data. Therefore results based on the original dataset were reported.

DISCUSSION

We found no indications for a relationship of road traffic noise exposure on somatic symptom reporting, both in the entire group and in the subgroup characterized by hostility or vulnerability to stress. In contrast, noise annoyance from road traffic and seven other noise sources were positively associated with somatic symptom reporting. This association could not entirely be explained by hostility or vulnerability to stress. These findings are comparable to previous studies. Two other studies, that also used modelled noise estimates and comparable symptom questionnaires also did not find a relation between road traffic noise and somatic symptoms [4,5]. Comparable conclusions were also drawn by a study that used measured traffic noise [6]. We did find positive associations between self-reported noise annoyance from several sources and somatic symptoms. A recent study undertaken in Switzerland also found that increased noise annoyance from road traffic, aircraft, railroad, industry and neighbors was related to higher symptom reporting [4]. Discrepancies between actual and perceived exposures in relation to somatic symptoms were also reported in a recent study examining electromagnetic fields and symptom reporting [30]. Related to this, the correlation of road traffic noise annoyance and modelled road traffic noise in our study was rather low, and was similar to a previous study [13].

Hostility and vulnerability to stress did not modify the relation between noise and symptoms and they explained only a small part of the effect of noise annoyance on symptom reporting. From this, it seems that in the current study, hostility and vulnerability to stress did not play a large role in the relationship between somatic symptoms and exposure to noise or noise annoyance. A previous study [31] showed that neuroticism, of which hostility and vulnerability to stress are components of, accounted for the relationship found for noise sensitivity and mental health complaints, but similar to our study, not for somatic complaints. The authors argued that neuroticism, noise sensitivity and mental health complaints are highly related to each other, while for somatic complaints, these relations are smaller [31]. Fyhri and Klæboe (2009) found that the relation between noise

sensitivity and somatic symptom reporting was far stronger than the relation between noise annoyance and symptoms. This indicates that noise sensitivity plays an important role in the noise and symptom relationship. They argued that noise sensitivity is an important factor in the noise-symptom relationship, but they also proposed that a third variable, which they described as "susceptibility", is involved in both increased noise sensitivity and increased symptom reporting [5].

Schreckenberg and colleagues hypothesized that noise sensitivity partly reflects a general environmental sensitivity and is associated with a decreased evaluation of subjective health. In their study, noise sensitivity was related to subjective physical health, and noise sensitivity was related to noise annoyance from aircraft, but not to noise annoyance from road traffic. In addition, noise sensitivity was generally not associated with residential satisfaction. As a conclusion, they state that noise sensitivity is more specifically related to noise responses rather than a predictor of perception of environmental quality [13]. Although not investigated here, noise sensitivity may be a more important factor than the personality facets hostility and vulnerability to stress in relations between noise exposure, noise annoyance and somatic symptoms.

Several strengths and limitations of this study need to be taken into consideration when interpreting the results. One limitation of our study is the amount of missing data in the dataset, especially for household equivalent income. Despite this missing data, a large number of subjects (n=56,937 and n=46,558) were still available for this study. Analyses with imputed values did not result in different conclusions as with the original dataset. This suggests that the missing values had little or no effect on our results. The sample size for the analyses of noise annoyance from road traffic noise was smaller compared to the sample size for analyses on the other noise annoyance sources. The road traffic noise annoyance question was implemented in the LifeLines questionnaire at a later stage, and therefore not filled out by all participants. Nevertheless, results from road traffic noise annoyance were comparable to noise annoyance results from other sources with a larger sample size. Furthermore, only the association with road traffic noise and the interaction with hostility and vulnerability to stress was investigated. Noise from other sources (aircraft, railroad or neighbors) could have effects on somatic symptom reporting, as some sources of noise might provoke different reactions or effects than others [32]. However, in the LifeLines study area, the flight frequency is quite low and only a small airport is situated there. Also, the rail network is not very extensive. Our data on noise annoyance from aircraft and railroads showed that this was audible by 27% and 16% of the participants, versus 72% for road traffic noise. Also, noise annoyance from aircraft and railroads was relatively low. Noise from neighbors was often heard in participants' houses

(61%) and was found to be relatively annoying. Strengths of this study include the use of standardized assessments for road traffic noise [22], noise annoyance [23], somatic symptoms [24], and neuroticism facets hostility and vulnerability to stress [26] enabling comparisons with other studies. Previous studies used, for example, other measures for the assessment of noise exposure, for example road traffic volume [31], which is a rather crude measure of road traffic noise. Some specific symptoms, such as sleeping problems, fatigue and headaches, are more likely to be related to noise and noise annoyance than other symptoms [33]. We used a composite index of symptom severity, based on the 12 symptoms of the SCL-90 SOM. Although not each of these symptoms may related to noise and noise annoyance, we hypothesized that noise, noise annoyance, and certain personality aspects are related to symptom reporting in general, and not to any symptoms in particular. High internal consistency of the SCL-90 SOM (Cronbach's alpha of 0.80) also underlines that it measures a general construct. A similar composite symptom score has also been used in previous studies [4,31]. Another strength is that we investigated two facets of neuroticism: hostility and vulnerability to stress. Studying these two facets of neuroticism may be more relevant to the noise and somatic symptom relationship, instead of neuroticism in general that also entails less appropriate facets such as self-consciousness and impulsiveness.

Conclusions

In the LifeLines Cohort Study, a large population cohort from the Netherlands, no evidence was found for a relationship between road traffic noise and somatic symptoms in a subgroup that is hostile and vulnerable to stress. Increases in noise annoyance from several noise sources were associated with increases in the reporting of somatic symptoms, and this was independent of hostility and vulnerability to stress. The role of the personality facets hostility and vulnerability to stress in the relations of noise, annoyance and symptoms appears small.

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Supplemental table. Spearman's correlations between road traffic noise, noise annoyance, somatic symptoms, hostility and vulnerability to stress.

	Road traffic noise (Lden)	NA road traffic	NA railroad	NA aircraft	NA industrial	NA wind turbines	NA construction	NA shops	NA neighbors	SCL-90 SOM BL	SCL-90 SOM FU	Hostility	Vulnerability
Road traffic noise (Lden)	-	-	-	-	-	-	-	-	-	-	-	-	-
NA road traffic	.223*	-	-	-	-	-	-	-	-	-	-	-	-
NA railroad	.064*	.205*	-	-	-	-	-	-	-	-	-	-	-
NA aircraft	.035*	.223*	.139*	-	-	-	-	-	-	-	-	-	-
NA industrial	.006	.183*	.080*	.111*	-	-	-	-	-	-	-	-	-
NA wind turbines	-.040*	.044*	.042*	.058*	0.71*	-	-	-	-	-	-	-	-
NA construction	.101*	.220*	.099*	.153*	.107*	.013*	-	-	-	-	-	-	-
NA shops	.090*	.198*	.051*	.066*	.124*	.005	.131*	-	-	-	-	-	-
NA neighbors	.101*	.297*	.137*	.167*	.066*	-.004	.203*	.093*	-	-	-	-	-
SCL-90 SOM baseline	.006	.094*	.029*	.045*	.045*	.011*	.069*	.037*	.101*	-	-	-	-
SCL-90 SOM follow up	.011*	.097*	.039*	.049*	.049*	.013*	.079*	.041*	.113*	0.557*	-	-	-
Hostility	.003	.080*	.020*	.025*	.025*	.005	.045*	.017*	.094*	0.263*	0.238*	-	-
Vulnerability	.013	.091*	.018*	.034*	0.13*	.005	.058*	.020*	.092*	0.267*	0.231*	0.467*	-

*p<0.05

Abbreviations: Lden: annual average day-evening-night time road traffic noise; NA: noise annoyance; SCL-90 SOM BL: Symptom Checklist-90 somatization scale baseline measurement; SCL-90 SOM FU: Symptom Checklist-90 somatization scale follow up measurement; vulnerability: vulnerability to stress