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Original Article

Longitudinal Analysis of the Influence of Personality on Noise Annoyance and Bidirectional Effects between Noise and Health Outcomes

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Abstract

Background: Long-term noise annoyance can be expected to have worse outcomes than short-term annoyance. This study investigates noise annoyance over time, its association with personality traits and potential reciprocal effects between health outcomes and noise annoyance. **Methods**: Firstly, we conducted a Longitudinal Latent Class Analysis to identify noise annoyance profiles. We further analysed the effect of Big Five personality traits on the likelihood of belonging to these annoyance profiles. Secondly, we used Cross-lagged Panel Models to analyse whether changes in noise annoyance precede changes in health outcomes or vice versa. For both analyses, we used 8 years of data from the Dutch Longitudinal Internet Studies for the Social Sciences (LISS) panel. Between 2708 and 11,068 subjects were included (this varies between models). **Results**: We found three profiles of noise annoyance, namely, chronically, occasionally and never annoyed. Among all participants, 12% were chronically annoyed by neighbour noise and 6% by street noise. Extraversion and emotional stability decreased the chance of belonging to the cluster of chronically annoyed, while openness had the opposite effect. Chronic noise annoyance showed a significant effect on self-reported heart complaints and sleeping problems, while the effects of noise annoyance profiles on high blood pressure and heart attacks were insignificant. Some potential indications for a reverse effect from health outcomes on noise annoyance were found. **Conclusion:** Noise annoyance was relatively stable over time possibly because of its correlation with personality traits. Noise had a small negative effect on health outcomes, and some health outcomes affected noise annoyance. Further research should be conducted to collect dedicated panel data.

Keywords: Health, latent class analysis, neighbourhood noise, personality, transportation noise

Key Messages

(1) Noise annoyance was relatively stable over time for 72–81% of participants, depending on the noise annoyance source.
(2) The Big Five personality dimensions, namely, extraversion, emotional stability, intellect or imagination significantly affected noise annoyance.
(3) Negative health outcomes may increase an individual's noise annoyance because of the subjective nature of annoyance.

Introduction

Noise annoyance is a common reaction to the widespread issue of noise pollution. It is a risk factor for various negative health outcomes, such as high blood pressure,[1] poor mental health,[2] headaches and fatigue.[3] Noise annoyance can also be a mediator for health outcomes of noise exposure,[4] which is known to increase the risk for various cardiovascular diseases, such as hypertension and coronary artery disease,[5] as well as sleep disturbance and cognitive impairment.[6]

Most studies on noise annoyance rely on cross-sectional analysis, while few longitudinal studies measure noise

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annoyance at multiple points on time.[7,8] The panel study of Eze *et al*.[7] suggested that noise annoyance may increase the risk for asthma, so further studies are needed to confirm this effect. Kodji *et al*.[8] analysed the role of noise annoyance on the health effects of aircraft noise exposure and found that noise annoyance mediated the relationship between noise and self-rated health. They recommend the use of causal models for future studies because their modelling approach only reports associations.

Research in noise annoyance has two gaps because of the strong reliance on cross-sectional data. Firstly, how accumulative noise annoyance affects health remains unclear. For instance, if an individual experiences long-term annoyance, then health effects are expected to compound and become more severe over time. Cross-sectional studies are not equipped to address this gap. The accumulative effects of noise annoyance on health are further complicated by the fact that a person's personality may affect the degree of noise annoyance.[9] When exposed to the same noise levels, some people may feel annoyed all the time, while others may not be annoyed at all. At present, the relationships among noise annoyance, personality and health effects are unclear. Secondly, possible reverse effects from health to annoyance have not been explored because of the limitations of cross-sectional studies. Most studies on the effects of noise annoyance on health assume that health outcomes are adverse effects of noise. This finding is in line with the idea that annoyance is an environmental stressor and, therefore, a risk factor for health outcomes. However, reverse effects from health on noise annoyance could also be expected. For instance, a person could become more sensitive to noise after certain health incidents, such as heart attacks or sleeping problems. If one already suffers from bad sleep, then minor disruptions in the night could become even more influential, causing more noise annoyance.

In this paper, we aim to define different noise annoyance profiles based on an individual's changes in annoyance over time and determine the effect of personality on the likelihood of belonging to these profiles. These noise annoyance profiles would be used to study the accumulated effect of noise annoyance on health outcomes. We also aim to identify potential bidirectional effects between noise annoyance and health outcomes to shed light on possible reverse effects. We would analyse 8 years of panel data with two different modelling techniques: Longitudinal Latent Class Analysis (LLCA) for the definition of noise annoyance profiles and Random-Intercept Cross-lagged Panel Models (RI-CLPM) for the estimation of bidirectional effects.

Materials and Methods

Data collection

In this study, we used data from the Dutch Longitudinal Internet Studies for the Social Sciences (LISS) panel, which consists of approximately 5000 households and is representative of the Dutch population.[10] Subjects of the LISS panel cannot register themselves but are sampled from the Dutch population register. Participants without a computer or Internet were provided access to both to improve the representativeness of the panel.[11] An analysis of the representativeness showed an overall good alignment with the general demographic distribution of the Dutch population, even though people with a foreign background were slightly underrepresented.[12] Additional information about the LISS panel can be found at http://www.lissdata.nl. For the LLCA, eight waves of the survey were collected in 1-year intervals from 2015 to 2022. The RI-CLPM specification restricts how missing data can be handled. Thus, only the last four complete, consecutive waves of each participant are included (more details follow in the data analysis). Table 1 lists descriptive statistics on the panel composition.

Measurement of noise annoyance

Sub-surveys on housing, health and personality are relevant to this study. The housing survey used two dichotomous variables, namely, noise annoyance from neighbours and noise annoyance from street noises. The World Health Organisation defines noise annoyance as 'a feeling of displeasure evoked by noise'. In the LISS panel, noise annoyance was measured as part of the following question: 'Are you ever confronted with the problems listed below in your home environment?' Neighbour noise annoyance is then specifically defined as 'noise annoyance caused by neighbours', while street noise is defined as 'noise annoyance caused by factories, traffic or other street sounds'. A positive response to a noise annoyance question was encoded in the dataset as 1 (no annoyance is therefore encoded as 0). While noise annoyance should ideally be measured on a Likert scale with standardised

Table 1: Gender, age and occurrence of annoyance of the included participants over all eight waves (11,068 participants)

Gender			Age (years)				Occurrences of noise annoyance (all waves)	
Male	Female	Other	15–24	25–44	45–64	≥65	Street noise	Neighbour noise
5029 (45.44%)	6033 (54.51%)	6 (0.05%)	1037 (9.37%)	3408 (30.79%)	3414 (30.85%)	3209 (28.99%)	3596 (11.71%)	6903 (22.47%)

Note: Street and neighbour noise annoyance can occur up to 30,720 times, as each participant may respond between one and eight times, depending on the number of waves they are part of the panel. Each wave has between 3584 and 4183 participants.

questions,[13] the LISS panel is a general-purpose survey and thus measures this concept in a simpler way. However, this practice hinders the analysis of small changes in annoyance because they cannot be captured by the binary nature of annoyance questions.

Measurement of health outcomes

The health survey was conducted 4 months after the housing survey. This paper included the following health outcomes: heart complaints, high blood pressure, heart attacks and sleeping problems, which were all measured as dichotomous variables. For heart complaints, the participants were asked if they regularly suffer from heart complaints, angina or pain in the chest due to exertion (applied to 5.3% of participants in 2022). Regarding high blood pressure and heart attacks, the participants were asked whether these were diagnosed by physicians within the last year (14.9% and 2.7% in 2022). Asking for diagnosed cases may lead to an underestimation of high blood pressure because this requires that a general practitioner examined the blood pressure in the given timespan. For sleeping problems, the participants were simply asked whether or not they regularly suffered from sleeping problems (22.5% in 2022).

Measurement of Big Five personality traits

Big Five personality scores were calculated from the 50-item questionnaire of the International Personality Item Pool.[14] We followed the instructions of the questionnaire for calculating these personality scores, resulting in scores from 10 (lowest possible score for a trait) to 50 (highest). The mean scores ranged from 32.0 to 38.4, with standard deviations from 5.0 to 7.2.

Data analysis

We used two modelling techniques, namely, LLCA and RI-CLPM. The LLCA provided insights into noise annoyance profiles and showed how they correlated with health effects. As such, we could identify patterns in how the subjects reported their noise annoyance over time, such as whether their responses were stable over time or changed from 1 year to the next. The RI-CLPMs provided insights into the bidirectional effects between noise annoyance and health variable pairs. Therefore, the RI-CLPMs indicated if noise annoyance always precedes negative health outcomes or if changes in health outcomes could lead to subsequent changes in noise annoyance as well.

LLCA

The Latent Class Analysis (LCA) allows the clustering of subjects into different profiles, which are not directly observed. Instead, it uses other observed variables, which are influenced by the latent class, to predict the latter. This technique can be particularly useful when subjects should be classified by hidden traits of which they may not be fully aware. Furthermore, an LCA assigns each subject a probability of belonging to a profile, which is then considered when regressing personality on profile membership and profiles on health outcomes.

The LLCA is an LCA applied to longitudinal data and technically identical to an LCA. We followed the common three-step approach[15] to define different latent noise annoyance profiles from all eight waves. We also estimated the effect of Big Five personality traits on belonging to each profile and the effect of different annoyance profiles on health outcomes at the final wave. Therefore, the profiles can capture noise annoyance over time, but their meaning is not defined a priori. Instead, the LLCA identifies a fixed number of profiles, which are then manually interpreted based on their characteristics; for example, if the subjects with a specific profile score high on annoyance over all waves, then the profile can be interpreted as chronic noise annoyance. The correlation of these profiles with health was limited to health outcomes at the final wave because we were interested in the long-term health effects (e.g., the accumulated effect of chronic noise annoyance on health). The first step in the three-step approach determined the optimal number of latent classes (profiles). We reported the three-class models because they can be explained most intuitively. They can be interpreted as people who are never, occasionally or chronically annoyed. A detailed reasoning for this interpretation is given in the results. The second step assigned each participant probabilities of belonging to the specific latent clusters for both latent variables (neighbour noise annoyance and street noise annoyance). These probabilities were then used in the third step for a logit regression of the noise annoyance profiles on personality and a logit regression of health outcomes on noise annoyance profiles. Both logit regressions were controlled for age, income, education, gender and urbanity (derived from population density). The regression of noise on sleeping disruptions was additionally controlled for Big Five personality scores because they had been linked to sleeping problems.[16] A Wald test was applied to test the logit coefficients for significance. The LLCA was estimated on data from all 11,068 subjects after combining all eight waves (2015–2022).

RI-CLPM

To assess whether noise annoyance influences health or reverse effects exist, we estimated multiple RI-CLPMs. This model is particularly suitable for investigating the bidirectional influences among a set of variables.[17] In this case, we estimated an RI-CLPM for each noise–health variable pair. Considering that all variables were dichotomous, we used a weighted least square mean and variance (WLSMV) adjusted estimator of Mplus software (Muthén & Muthén, Los Angeles, CA, USA). Other estimators cannot handle dichotomous variables (maximum likelihood estimation) or require larger sample sizes (Bayesian estimation). Options for handling missing data were limited because of WLSMV estimation,[18] which

would lead to the exclusion of subjects who did not participate in all waves. Thus, an estimation of the model over eight waves would result in a small sample size. We considered only four waves per participant as a trade-off between sample size and observation time. The exact years of the four waves differ between participants, depending on the years the participant responded to the corresponding questions. Specifically, we used the four most recent consecutive waves for each participant. For example, if a participant responded in all waves, then his responses from 2019 to 2022 were considered. If he or she did not respond in the most recent wave, then the responses from 2018 to 2021 were considered instead. This process was repeated for each variable combination (i.e., each RI-CLPM) because some participants might respond to one survey question (e.g., street noise annoyance) but not to another (e.g., neighbour noise annoyance). This process resulted in a sample size of 2708–2715 participants, depending on the variable combination.

Figure 1 shows the structure of the RI-CLPMs. The Random Intercepts (RIx and RIy) account for differences between persons. The lags show only within-person effects, that is, how a difference from an individual's mean in one wave leads to a difference from the mean in the next wave.[17] The variables x1–x4 represent the street or neighbour noise annoyance at waves one to four, and y1–y4 represent the health variables. The lagged effects (XX, YY, YX and XY) are set to be equal over time because the effect from 1 year to the next can be assumed as the same, independent of the exact year. XY is the effect of noise annoyance in one wave on a given health variable in the next wave, and YX is the opposite effect. The parameter XX estimates if differences from an individual's mean annoyance predict this difference for the next wave (YY is the same estimate for the health).

Results

LLCA

Figure 2 shows the average scores per wave for the neighbour and street noise annoyance profiles. Each participant can only be either annoyed or not annoyed at a given year. Noise annoyance was coded as 1 in the survey; for example, an average annoyance score of 0.82 for participants chronically annoyed by neighbour noise indicates that 82% of the subjects in this cluster were annoyed in the given year. Participants belonging to the first profile (green line in Figure 2) had a low probability of being annoyed throughout all waves. We, therefore, described this category as people who were never annoyed. Participants of the second profile (orange line) were closer to a 50/50 chance of being annoyed at a given wave and were interpreted as occasionally annoyed subjects. Participants attributed to the last profile (red line) were likely to be annoyed at all waves and were interpreted as chronically annoyed subjects. In summary, the three profiles for both noise sources can be interpreted as people who were never annoyed, occasionally annoyed or chronically annoyed.

Table 2 lists the profile composition for latent neighbour noise annoyance and street noise annoyance classes. For both annoyance sources, more than half of the participants were generally not annoyed, about 12% were chronically annoyed by neighbour noises and 6% were chronically annoyed by

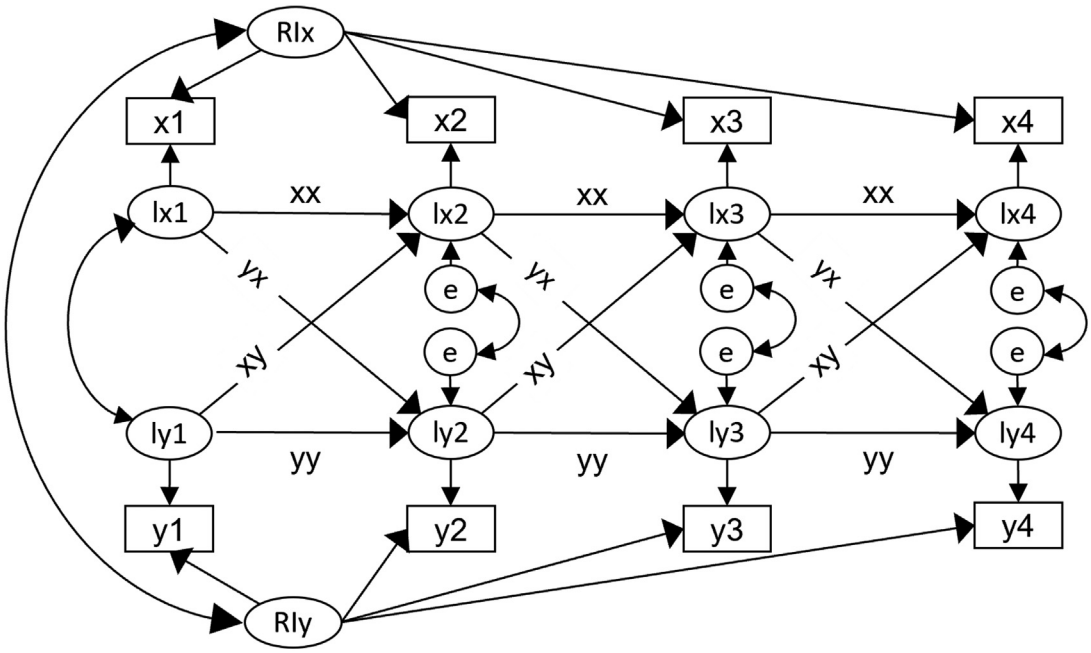

Figure 1: Four-wave Random-Intercept Cross-lagged Panel Model. Notes: x1–x4 represent noise annoyance, and y1–y4 represent health at waves 1–4. The parameter YX estimates the effect of noise annoyance in one wave on health in the next wave, while XY estimates the reverse effect. lx1–4 and ly1–4 are estimated latent variables, and 'e' denotes an error term. RIx and RIy represent the Random Intercepts for noise annoyance (RIx) and health (RIy).

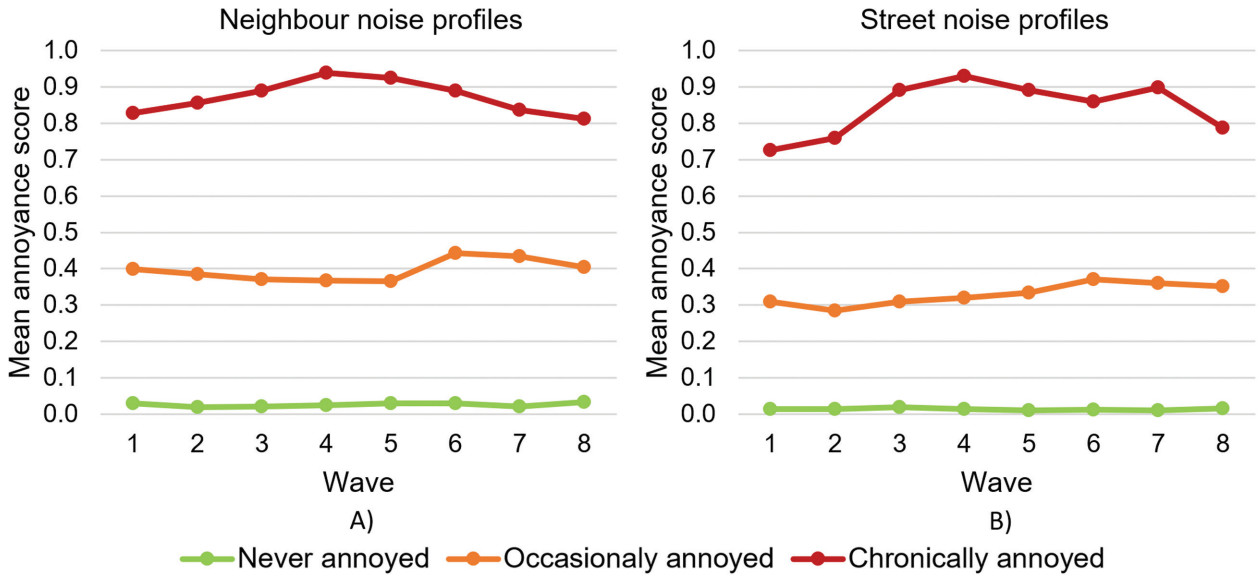

Figure 2: Mean annoyance scores per wave for subjects who are categorised by the LLCA as never annoyed, occasionally annoyed or chronically annoyed by neighbour noise (A) and street noise (B) over 8 years.

street noise. About 28% of the participants were occasionally annoyed by neighbours and shifted between being annoyed and not annoyed. For street noise, 19% of the participants were occasionally annoyed. Gender had no significant effect on noise annoyance, but females were more often affected by chronic neighbour noise annoyance than men. Subjects living in urban areas had a significantly higher probability of being chronically annoyed by both noise sources. Subjects aged 25–44 years were significantly more likely to experience chronic neighbour noise experience. This age group made up 40% of chronically annoyed subjects and only 23% of never annoyed subjects. The largest age group for never annoyed subjects was 65 years and older. Education level had a significant effect on street noise annoyance. Subjects who completed prevocational secondary education made up a larger share of never annoyed than chronically annoyed subjects. University education was more common for subjects experiencing chronic street noise annoyance.

We reported the effect of Big Five personality scores on noise annoyance [Table 3]. The effects were controlled for gender, age, income, education level and urbanity. Participants scoring higher on extraversion were less likely to be annoyed by neighbour noise and street noise. The same effect was observed for emotional stability. High scores on intellect and imagination increased the chance of belonging to a class of occasionally or chronically annoyed people. Estimates for agreeableness and conscientiousness were not significant.

Figure 3 shows how the probability of belonging to the highly annoyed cluster varied based on Big Five personality scores, assuming that all other factors remained unchanged. The effects of extraversion, emotional stability and intellect/imagination were significant [Table 3]. The slopes matched the direction of effects indicated by the estimated effects.

Table 4 shows the effects of the noise annoyance profiles on health outcomes, namely self-reported suffering from heart complaints, diagnosed high blood pressure, heart attacks, and suffering from sleeping problems. Both annoyance classes had a significant influence on sleeping problems, where chronic annoyance increases the chance of sleeping problems the most. Self-reported heart complaints are significant for neighbour noise annoyance but not for annoyance caused by street noises. No significant effects of noise annoyance on high blood pressure or heart attacks are found.

RI-CLPM

Table 5 shows the results of the RI-CLPMs. Each model estimated the effects of noise annoyance (either from neighbour or street noises) on a specific health variable. In contrast to the LLCA, this model estimated the direction of causality from changes between waves. We report the correlation of the between-person effect (RIy with RIx), the autoregressive lags (XX, YY), and the cross-lagged effects (YX, XY) as modelled in Figure 1. Annoyance and health variables both show significant stability over time (XX, YY). A new occurrence of heart complaints in 1 year leads to a significant increase in neighbour noise annoyance in the next year, while the opposite effect is found to be insignificant. The same holds true for the variable pair neighbour noise annoyance and heart attacks. Furthermore, increased neighbour noise annoyance shows a significant effect on sleeping problems in the following year. The reverse effect from sleeping problems on self-reported neighbour noise is also significant, but lower by one

Table 2: Profile composition for latent neighbour noise annoyance and street noise annoyance classes

Class size or demographic variable	Neighbour noise annoyance class			Street noise annoyance class		
	Never	Occasional	Chronic	Never	Occasional	Chronic
Class size (%)	59.47	28.30	12.24	75.29	18.95	5.76
Gender (%) ($P = 0.74$ for neighbour noise annoyance, $P = 0.08$ for street noise annoyance)						
Male	47.16	43.39	41.81	44.97	47.16	45.86
Female	52.83	56.54	57.99	55.01	52.72	53.89
Other	0.02	0.07	0.20	0.02	0.12	0.25
Age group (%) ($P = 0.00$ for neighbour noise annoyance, $P = 0.06$ for street noise annoyance)						
15–24 years	7.94	13.02	7.89	9.16	10.66	7.82
25–44 years	23.00	43.18	40.00	28.61	39.74	29.97
45–64 years	30.73	28.44	36.98	31.45	26.84	36.09
65 years and older	38.33	15.36	15.14	30.78	22.76	26.12
Urbanity (%) ($P = 0.00$ for neighbour noise annoyance and street noise annoyance)						
Extremely urban	15.17	25.51	40.21	16.72	32.96	40.32
Very urban	25.83	28.59	27.07	26.42	28.59	25.23
Moderately urban	20.18	17.48	17.58	20.28	16.79	11.31
Slightly urban	20.43	17.78	5.68	19.84	10.90	15.04
Not urban	17.74	9.88	8.95	16.05	10.11	7.57
Unknown	0.65	0.76	0.51	0.69	0.65	0.53
Level of education (%) ($P = 0.73$ for neighbour noise annoyance, $P = 0.00$ for street noise annoyance)						
Primary school	7.33	6.38	6.70	7.57	4.76	6.63
Prevocational secondary	20.13	13.82	13.44	18.36	16.85	8.83
Senior general secondary	10.27	11.39	10.82	10.58	10.23	13.01
Secondary vocational	23.55	25.60	22.77	25.41	19.06	22.40
Higher vocational	26.84	24.07	28.93	26.14	26.22	28.80
University	11.56	18.38	16.93	11.61	22.48	19.96
Unknown	0.32	0.36	0.41	0.33	0.40	0.37
Net monthly income (%) ($P = 0.00$ for neighbour noise annoyance, $P = 0.68$ for street noise annoyance)						
0–1500 EUR	36.98	41.87	38.00	39.03	35.51	40.94
1501–3500 EUR	50.02	47.76	53.34	48.78	54.29	48.19
3501 EUR and more	6.21	4.47	3.40	5.57	4.28	6.37
Unknown	6.79	5.90	5.26	6.62	5.92	4.50
Big Five Personality (mean ± standard deviation, see Table 3 for significance and logit coefficients)						
Extraversion	32.38 ± 6.59	32.30 ± 6.76	30.99 ± 6.90	32.39 ± 6.63	31.49 ± 6.77	31.80 ± 6.92
Agreeableness	38.50 ± 5.14	38.08 ± 5.48	38.68 ± 5.46	38.43 ± 5.27	38.22 ± 5.28	38.58 ± 5.37
Conscientiousness	37.12 ± 5.24	36.66 ± 5.43	36.80 ± 5.38	37.02 ± 5.28	36.54 ± 5.39	37.38 ± 5.49
Emotional stability	35.46 ± 7.11	33.49 ± 7.35	31.65 ± 7.34	34.95 ± 7.17	32.97 ± 7.35	32.52 ± 7.71
Intellect/imagination	34.68 ± 4.98	35.53 ± 5.10	36.08 ± 5.18	34.93 ± 5.01	35.29 ± 5.09	36.47 ± 5.28

Note: The results were obtained with Latent Gold 5.0 (Statistical Innovations, Arlington). Standard deviations were calculated by Python. *P* values were obtained by Wald tests.

magnitude. For street noise annoyance, no significant effect with the health variables is found.

Discussion

We found three different profiles of noise annoyance for neighbour noise and street noise. The profiles for these annoyance classes can be interpreted as people who are never, occasionally or chronically annoyed by neighbour noise or street noise. The results indicate that more people are annoyed by neighbour noise than street noise. This finding contrasts with another study on noise annoyance in the Netherlands, where road traffic is the largest source of noise annoyance, followed by neighbour noise.[19] Importantly, most people are rather stable in their annoyance response because they are either never or chronically annoyed. Less than one-third of participants are occasionally annoyed by the neighbour noise, and less than one-fifth of participants are annoyed by the street noise. One important implication of this finding is that cross-sectional measurements of annoyance form relatively good proxies for long-term annoyance.

Three of the Big Five personality dimensions influenced the noise annoyance profile when controlled for socio-demographic and neighbourhood density. Extraversion and emotional stability decreased the probability of being chronically annoyed, which is in line with previous research.[20,21] We found a positive correlation between intellect, imagination and noise annoyance, which has been

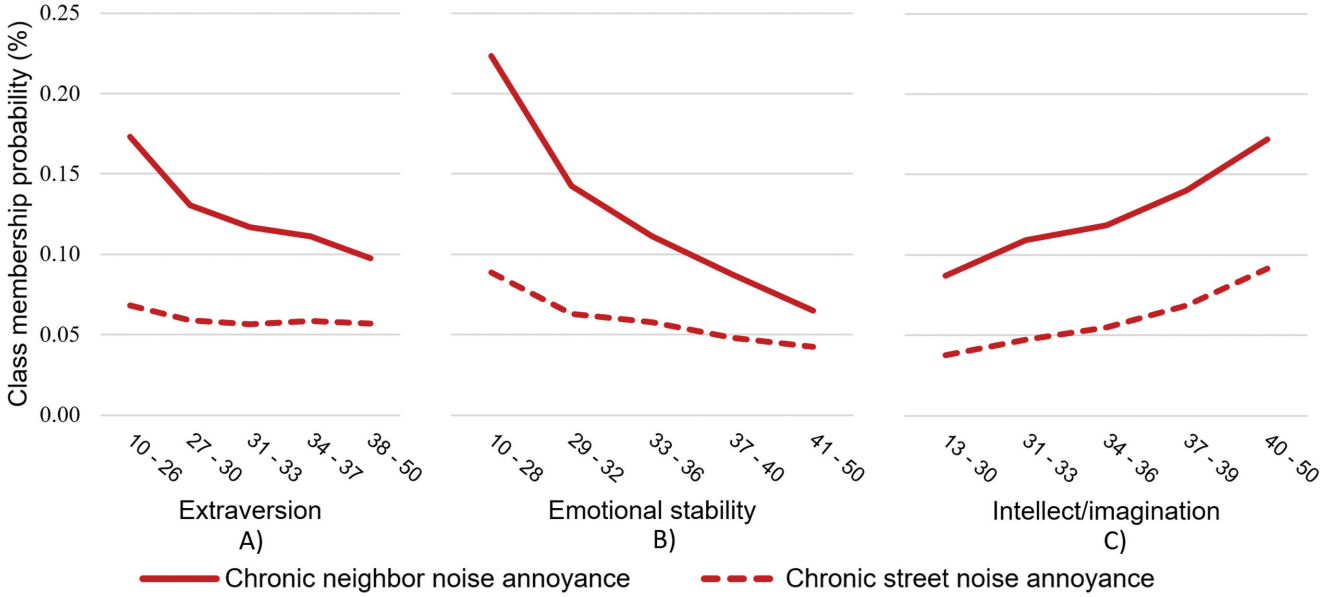

Figure 3: Class membership probabilities for chronic neighbour and street noise annoyance with varying Big Five scores for extraversion (A), emotional stability (B) and intellect/imagination (C). The results were obtained with Latent Gold 5.0 (Statistical Innovations, Arlington, TX, USA).

Table 3: Logit coefficients for the effect of Big Five personality scores on noise annoyance classes controlled for the socio-demographic background and level of urbanity

Big Five personality	Neighbour noise annoyance class				Street noise annoyance class			
	Never	Occasional	Chronic	*P*-value	Never	Occasional	Chronic	*P*-value
Extraversion	0.00	0.00	–0.05	0.00***	0.00	–0.02	–0.02	0.00***
Agreeableness	0.00	–0.03	0.00	0.12	0.00	0.01	0.01	0.82
Conscientiousness	0.00	0.00	0.00	0.87	0.00	0.00	0.02	0.41
Emotional stability	0.00	–0.04	–0.08	0.00***	0.00	–0.04	–0.07	0.00***
Intellect/imagination	0.00	0.05	0.09	0.00***	0.00	0.01	0.07	0.00***

Notes: Obtained via 3-step approach Latent Class Analysis. The significance level is indicated through asterisks at the *P*-value (***$P < 0.001$). The *P*-values are obtained from a Wald test. The results have been obtained with LatentGold 5.0 (Statistical Innovations, Arlington).

previously reported as the least important dimension in explaining noise annoyance.[20] Agreeableness and conscientiousness are insignificant in predicting noise annoyance. The (significant) effects of personality on reported annoyance might also contribute to the stability of noise annoyance over time because personality is inherently rather stable over time as well.

Considering the health effects of noise annoyance, we could not find strong evidence for a link between noise annoyance and high blood pressure or heart attacks based on the LLCA. This finding is counterintuitive under the common assumption that noise pollution is a risk factor for cardiovascular effects.[22] The model further indicates a significant correlation between neighbour noise and self-reported heart complaints. For street noise, this effect was insignificant possibly because of a small number of people who experienced chronic annoyance from street noises only. Moreover, noise annoyance from neighbour and street noises had a significant effect on sleeping problems.

Table 4: Logit coefficients of noise annoyance classes on health outcomes at the final wave

Health outcome	Neighbour noise annoyance class				Street noise annoyance class			
	Never	Occasional	Chronic	*P*-value	Never	Occasional	Chronic	*P*-value
Heart complaints	0.00	0.44	0.71	0.04*	0.00	0.52	0.53	0.26
High blood pressure	0.00	0.14	0.06	0.82	0.00	0.16	0.22	0.49
Heart attack	0.00	0.02	0.30	0.68	0.00	0.00	0.44	0.53
Sleeping problems	0.00	0.26	0.80	0.00***	0.00	0.37	0.52	0.00***

Note: The results were obtained with Latent Gold 5.0 (Statistical Innovations, Arlington, TX, USA). Logit coefficients were controlled for socio-demographic variables, and in case of suffering from sleeping problems, also controlled for Big Five personality scores. The significance level is indicated through asterisks at the *P*-value (*$P < 0.05$, ***$P < 0.001$).

Table 5: Unstandardised parameter estimates for RI-CLPMs with different variable combinations

Variables		Parameter estimates				
Annoyance X	Health Y	RIy with RIx	XX	YY	YX	XY
Neighbour noise	Heart complaints	−0.32	0.42***	0.73***	0.00	0.37*
Neighbour noise	High blood pressure †	−1.13	0.76***	0.35*	−0.15	−1.27
Neighbour noise	Heart attack	−0.93	0.57***	1.41***	−0.38	0.45**
Neighbour noise	Sleeping problems	0.29***	0.22**	3.41***	0.70**	0.02*
Street noise	Heart complaints	−0.05	0.81***	1.21***	−0.12	0.38
Street noise	High blood pressure	−0.47	0.43***	1.21***	−0.02	0.10
Street noise	Heart attack	−0.43	0.45***	1.62***	−0.68	0.03
Street noise	Sleeping problems †	−6.93	1.01***	1.00***	−0.06	−0.02

Notes: YX reads Y (health) regressed on X (annoyance) and indicates the effect of an annoyance variable on a health variable in the subsequent wave. XY indicates the reverse effect. RIy with RIx is the correlation of the random intercepts (RIs), that is, the between-person effect. The significance level based on the *P*-value is indicated through asterisks (*$P < 0.05$, **$P < 0.01$, ***$P < 0.001$). The second and last variable combination (†) caused potential estimation issues because of high correlations between waves. The estimates should, therefore, be interpreted with caution. The results were obtained with Mplus 8.10 (Muthén & Muthén, Los Angeles, TX, USA).

In our second analysis, we estimated bidirectional effects between noise annoyance and health outcomes by using RI-CLPMs. Although most effects were insignificant, we found a significant effect of self-reported suffering from heart complaints on neighbour noise annoyance. However, we could not confirm the opposite effect. The same pattern of results was observed for heart attacks and noise annoyance, suggesting that deteriorating health increased the annoyance caused by noise. However, we would still expect a stronger effect from noise on heart complaints and heart attacks. The absence of such a correlation in the RI-CLPM may be due to the relatively short difference in time between waves (1 year) because health effects from noise likely manifest over a long time. This explanation is also supported by the insignificant effect of noise annoyance on high blood pressure, which may suffer from the same issue.

Neighbour noise annoyance had a significant effect on sleeping problems. In addition, sleeping problems showed an effect on noise annoyance in the subsequent wave as well. This reverse effect, however, is much smaller and may indicate that people who suffer from sleeping problems become more sensitive to neighbour noise. Health and annoyance questions are part of different surveys within the LISS panel and were conducted at different times. Health-related questions were asked a few months before the noise annoyance questions. Thus, the time difference might result in the estimation of non-existent reverse effects in the RI-CLPM. Furthermore, perceived annoyance may not always correspond with actual noise exposure. Participants may also not always be aware of changes in health, and small changes may not be reflected by the binary nature of the questionnaire.

Besides the limitations linked to the underlying data mentioned above, only health outcomes previously correlated with noise annoyance have been considered for reverse effects. General physical and mental well-being has not been considered but could arguably also show reverse effects.

Although the RI-CLPM controls for time-invariant variables, such as gender or age, it does not control for time-dependent variables that could potentially influence annoyance (e.g., residential relocation). However, we do not expect such events to occur in a systematic manner and therefore do not significantly affect the estimates of the model.

Conclusion

This study identified three longitudinal annoyance profiles, namely, chronically, occasionally and never annoyed people, for street and neighbour noise. Noise annoyance is stable over time and partly depends on a subject's personality, specifically extraversion, emotional stability and intellect/imagination. The results indicate possible reverse effects from deteriorating health conditions to increased self-reported noise annoyance. This work supports the thesis that degrading health increases noise annoyance due to an overall increased sensitivity or awareness.

Further studies should be conducted on the bidirectional effects of noise annoyance because of the limitations of the underlying panel data. Specifically, we recommend the use of standardised noise annoyance questionnaires for a fine-grained measurement of annoyance.

Availability of data and materials

The data used for this study is openly available at "https://www.dataarchive.lissdata.nl/"

Author contributions

Lion Cassens: concepts, data analysis, statistical analysis, manuscript preparation, manuscript editing, guarantor. **Sander van Cranenburgh:** concepts, manuscript preparation, manuscript editing. **Simeon Calvert:**

manuscript preparation, manuscript review. **Maarten Kroesen:** concepts, statistical analysis, manuscript preparation, manuscript editing.

Ethics Approval and Consent to Participate

Data in this study was collected by Centerdata, who also ensured informed consent and ethical approval.

The informed consent declaration can be found at https://www.lissdata.nl/app/uploads/sites/4/2023/10/Informed-consent-LISS-panel-2023.pdf

Further information on consent, GDPR and ethical approval can be found at https://www.lissdata.nl/ethics

Presentation or awards

Presented at the 30th International Conference of Sound and Vibration.[23]

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Conflicts of interest

There are no conflicts of interest.

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