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NOISE ANNOYANCE, PERSONALITY, AND HEALTH: A LONGITUDINAL ANALYSIS

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Noise annoyance and its relation to health outcomes have been studied extensively. The vast majority of studies in this field use cross-sectional data. Such data does not allow investigation of temporal effects or the direction of these effects. It is reasonable to expect that the effects of noise on health build up over time. Moreover, noise may not only impact health outcomes, but health outcomes may also impact the sensitivity to noise – hence flipping the direction of the effect. Further adding to the complexity of the relationship between noise and health outcomes is the fact that personality traits may influence reported noise annoyance. This study aims to shed light on the accumulative effects of noise annoyance on health, as well as the bidirectional relationships between noise annoyance and health. To do so, we analyze eight years of data from the Dutch Longitudinal Internet Studies for the Social Sciences (LISS) panel. Specifically, we conduct a Longitudinal Latent Class Analysis to identify annoyance profiles and analyze the effect of Big Five personality traits on the likelihood of belonging to the different annoyance profiles. Furthermore, we use Cross-Lagged Panel Models to analyze whether changes in noise annoyance precede changes in health outcomes or vice versa. We find three different profiles of noise annoyance, namely chronically annoyed people, occasionally annoyed people, and people who are generally not annoyed. Noise annoyance was found to be relatively stable over time. Regarding personality traits, we find that extraversion and emotional stability decrease the chance of belonging to the cluster of chronically annoyed persons, while openness has the opposite effect. Finally, chronic annoyance shows 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 are insignificant.

Keywords: LLCA, RI-CLPM, traffic noise, neighborhood noise

1. Introduction

Potential non-auditory effects from noise are long known [1] and include sleeping disruptions, stress, and cardiovascular diseases. Noise annoyance may act as a mediator between noise exposure and health, as it signals noise-induced stress and has been shown to be correlated with e.g., hypertension [2], and sleeping problems [3].

Few longitudinal studies of noise annoyance have been conducted [4], [5], [6], calling for further studies, including the use of causal inference methods [4]. The underlying mechanism of adverse health effects from noise is expected to accumulate over time, making chronic noise annoyance more important than one-off events. Next to actual noise exposure, annoyance depends on non-acoustic characteristics, such as noise sensitivity. Both noise sensitivity and thus, noise annoyance depend to some extent on personality traits [7]. Furthermore, noise annoyance may be impacted by health due to its subjective

nature: deteriorating health may increase sensitivity to noise and self-reported annoyance, resulting in a reverse effect from health implications on noise annoyance.

In this study, we analyze eight waves from a panel survey, which is representative of the Dutch population, to (1) define noise annoyance profiles and their characteristics in terms of socio-demographics and personality, and (2) assess correlations between noise annoyance and health in general and regarding possible reverse effects from health on noise annoyance.

2. Methods

We apply two modelling techniques, namely Longitudinal Latent Class Analysis (LLCA) and Random-Intercept Cross Lagged Panel Models (RI-CLPM). The LLCA results in noise annoyance profiles and correlates these profiles with health effects, while RI-CLPMs provide insights into bidirectional effects between noise annoyance and health variable pairs.

Both techniques are applied to the Dutch Longitudinal Internet Studies for the Social Sciences (LISS) panel, which consists of approximately 5,000 households and is representative of the Dutch population [8]. We consider the last eight waves of the survey, collected in one-year intervals (2014 - 2022). Relevant to this study are the sub-surveys on housing, health, and personality. From the housing survey, two dichotomous variables are used: noise annoyance from neighbors and noise annoyance from street noises. Street noise refers in the survey to traffic and other street noise, as well as factory noise. While noise annoyance should ideally be measured on a Likert scale with standardized questions [9], the LISS panel is a general-purpose survey and thus measures this concept more simplistic. This does, however, hinder the analysis of small changes in annoyance, as these are not captured by the binary nature of the annoyance questions. The health survey is conducted four months after the housing survey. This analysis considers the following health outcomes: self-reported suffering from heart complaints, high blood pressure, heart attacks, and suffering from sleeping problems. The health outcomes are measured as dichotomous variables as well. Big Five personality scores are calculated from the IPIP 50-item questionnaire [10]. Typical for panel surveys, the LISS panels suffers from attrition. An analysis of participant dropout showed an attrition of 6.2 % from one year to the next [11]. We do not expect attrition to strongly bias this analysis, as attrition likely does not correspond with relevant concepts such as changes in noise annoyance.

2.1 Longitudinal Latent Class Analysis

A 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. A Longitudinal Latent Class Analysis (LLCA) is an LCA applied to longitudinal data. We follow the common 3-step approach [12] to define different latent noise annoyance profiles, estimate the effect of Big Five personality traits on belonging to each profile, and estimate the effect of different profiles on health outcomes in the final wave.

The first step in the 3-step approach determines the optimal number of latent clusters (profiles). For this, statistical criteria such as the Bayesian Information Criterion (BIC), theoretical assumptions, and interpretability is considered. We conduct this step for both latent variables, neighbor noise annoyance and street noise annoyance, resulting in three profiles for both classes. This leads to the most intuitive profiles. The second step assigns each participant probabilities of belonging to the specific latent clusters. This is done for both latent variables (neighbor noise annoyance and street noise annoyance). These probabilities are then used in the third step for a regression of the noise annoyance profiles on personality, and a regression of health outcomes on noise annoyance profiles. Both regressions are controlled for age,

income, education, gender, and urbanity (derived from population density), The regression of noise on sleeping disruptions is additionally controlled for Big Five personality scores.

2.2 Random-Intercept Cross-Lagged Panel Models

To assess whether noise annoyance influences health or whether there also exists an effect the other way around, we estimate multiple Random-Intercept Cross Lagged Panel Models (RI-CLPMs). This model is suited to investigate the bidirectional influences among a set of variables [13]. In this case, one RI-CLPM is estimated for each noise-health variable pair. The RI-CLPM cannot account for missing values when dichotomous variables are used. Therefore, we use the four most recent, complete waves for each participant. Figure 1 shows the structure of the RI-CLPMs. The Random-Intercepts (RIx and RIy) account for differences between persons (between-person effects). The lags therefore show only within-person effects, i.e., how a difference from an individual's mean in one wave leads to a difference from the mean in the next wave [13]. The variables x1-x4 represent the street or neighbor noise annoyance at wave 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, where 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 health).

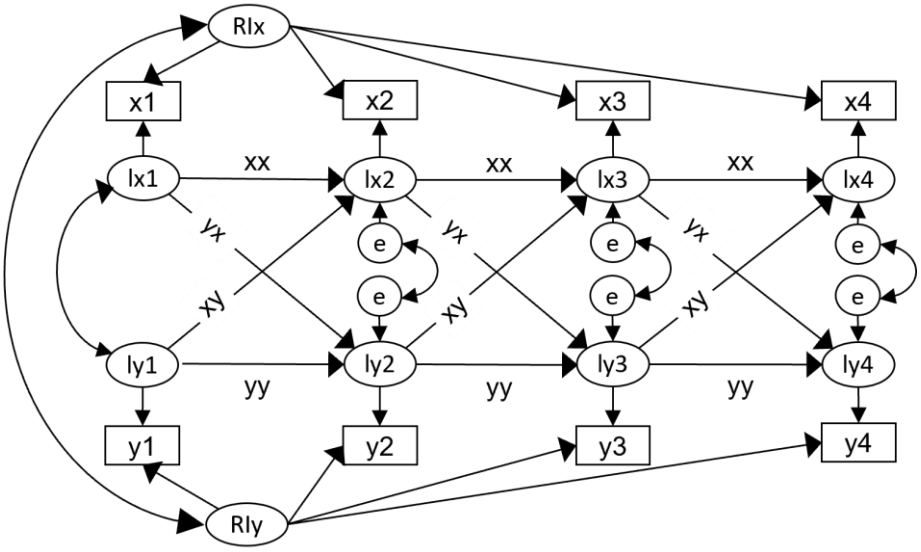

Figure 1: Four-wave RI-CLPM. x1-x4 represent noise annoyance and y1-y4 represent health. The parameter YX estimates the effect of noise annoyance in one wave on health in the next wave, while XY estimates the reverse effect.

3. Results

We first present the results of the Longitudinal Latent Class Analysis and second the results from the Random-Intercept Cross-Lagged Panel Models.

3.1 Longitudinal Latent Class Analysis

Figure 2 shows the average scores per wave for the neighbor and street noise annoyance profiles. The three profiles for both classes can be interpreted as people who are never annoyed, occasionally annoyed,

or chronically annoyed. Table 2 lists the size and composition of each profile for the latent noise annoyance classes. We observe that for both annoyance sources, more than half of the participants are generally not annoyed, 12% are chronically annoyed by neighbor noises, and 6% are chronically annoyed by street noise. Generally, the data shows that most subjects are either never annoyed or chronically annoyed, and therefore rather stable in their noise annoyance scores. Only 28% are occasionally annoyed by neighbors and thus, shift between being annoyed or not. For street noise, only 19% are occasionally annoyed.

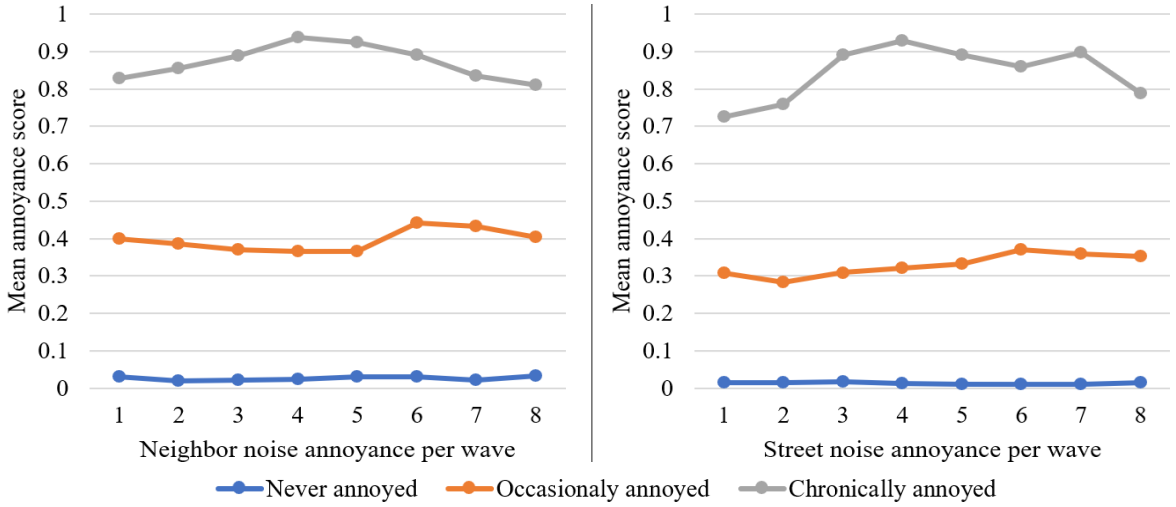

Figure 2: Latent class scores for subjects who are never annoyed, occasionally annoyed, and chronically annoyed by neighbor noise (left) and street noise (right) over eight years

The profile composition in table 2 shows that chronically annoyed subjects are generally younger and live more urban than their never annoyed counterparts. Annoyed subjects also followed university education more often than non-annoyed subjects.

Table 2: Profile sizes and composition for latent neighbor noise annoyance and street noise annoyance

	Neighbor 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 (%)						
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 (%)						
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 (%)						
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	09.88	8.95	16.05	10.11	07.57
CBS Level of education (%)						
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
Net monthly income (%)						
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
Big Five Personality (mean)						
Extraversion	32.38	32.30	30.99	32.39	31.49	31.80
Agreeableness	38.50	38.08	38.68	38.43	38.22	38.58
Conscientiousness	37.12	36.66	36.80	37.02	36.54	37.38
Emotional stability	35.46	33.49	31.65	34.95	32.97	32.52
Intellect/imagination	34.68	35.53	36.08	34.93	35.29	36.47

Next, we report the effect of Big Five personality scores on noise annoyance, listed in table 3. The effects are controlled for age, income, education level, and urbanity. We observe that participants scoring higher on extraversion are less likely to be annoyed by neighbor noise and street noise. The same effect is observed for emotional stability. Higher scores on intellect and imagination increase the chance to belong to the class of occasionally or chronically annoyed people. Estimates for agreeableness and conscientiousness were not significant.

Table 3: Effects of Big Five personality scores and urbanity on noise annoyance classes, controlled for the socio-demographic background

	Neighbor noise annoyance class				**Street noise annoyance class**			
Big Five personality	never	occasional	chronic	p-value	never	occasional	chronic	p-value
Extraversion	0	0	-0.05	0***	0	-0.02	-0.02	0***
Agreeableness	0	-0.03	0	0.12	0	0.01	0.01	0.82
Conscientiousness	0	0	0	0.87	0	0	0.02	0.41
Emotional stability	0	-0.04	-0.08	0***	0	-0.04	-0.07	0***
Intellect/imagination	0	0.05	0.09	0***	0	0.01	0.07	0***

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 neighbor noise annoyance, but not for annoyance caused by street noises. No significant effect of noise annoyance on high blood pressure or heart attacks is found.

Table 4: Effects of noise annoyance classes on health outcomes at the final wave, controlled for socio-demographic and in case of suffering from sleeping problems also controlled for Big Five personality scores

	Neighbor noise annoyance class				**Street noise annoyance class**			
Health outcome	never	occasional	chronic	p-value	never	occasional	chronic	p-value
Heart complaints	0	0.44	0.71	0.04*	0	0.52	0.53	0.26
High blood pressure	0	0.14	0.06	0.82	0	0.16	0.22	0.49
Heart attack	0	0.02	0.30	0.68	0	0	0.44	0.53
Sleeping problems	0	0.26	0.80	0***	0	0.37	0.52	0***

3.2 Random-Intercept Cross-Lagged Panel Models

Table 5 shows the results of the RI-CLPMs. Each model estimates the effects of noise annoyance (either from neighbor- or street noises) on a specific health variable. In contrast to the estimates from the LLCA above, these results provide an indication of the direction of causality. 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 one year leads to a significant increase in neighbor noise annoyance in the next year, while the opposite effect is found to be insignificant. The same holds true for the variable pair neighbor noise annoyance and heart attacks. Furthermore, increased neighbor noise annoyance shows a significant effect on sleeping problems in the following year. The reverse effect from sleeping problems on self-reported neighbor noise is also significant, but lower by one magnitude. For street noise annoyance, no significant interaction with the health variables is found.

Table 5: 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	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

4. Discussion

We find three different profiles of noise annoyance for both neighbor and street noise. The profiles for these annoyance classes can be interpreted as people who are never, occasionally, or chronically annoyed by neighbor noise and street noise respectively. 12% of participants belong to the chronically annoyed cluster from neighbor noise, and 6% of participants were chronically annoyed by street noises. Interestingly, this indicates that more people are annoyed by neighbor noise than street noise. This is in contrast to another study on noise annoyance in the Netherlands, which found road traffic to be the largest source of noise annoyance, followed by neighbor noise [14]. Importantly, most people were rather stable in their noise annoyance, as they are either never or chronically annoyed. Less than a third of participants are occasionally annoyed by neighbor noise and less than a fifth by street noise.

Three of the Big Five personality dimensions are found to influence the noise annoyance profile when controlled for socio-demographic and neighborhood density. Extraversion and emotional stability are found to decrease the chance of noise annoyance, both in line with previous research [7], [15]. We further find a positive correlation between intellect and imagination and noise annoyance, which has been previously reported as the least important dimension for noise annoyance [7], and as insignificant for noise sensitivity [16]. Agreeableness and conscientiousness are found to be insignificant for noise annoyance.

Considering the health effects from noise annoyance, we could not find strong evidence for a link between noise annoyance and high blood pressure or heart attacks. This is counterintuitive under the common assumption of noise pollution as a risk factor for cardiovascular effects [17]. The model indicates a correlation between neighbor noise and self-reported heart complaints. For street noise this effect is insignificant. This may be due to the high correlation between both noise sources and the small number

of people who experience chronic annoyance from street noises only. Looking at sleeping problems we find a significant effect with noise annoyance from neighbors and street noises.

In our second analysis we estimate the direction of causality for the effects between noise annoyance and health outcomes, using RI-CLPMs. While most effects are insignificant, we find a significant effect from self-reported suffering from heart complaints to neighbor noise annoyance. Surprisingly, we could not confirm the opposite effect from noise annoyance to heart complaints. The same pattern of results is observed for heart attacks and noise annoyance, suggesting that deteriorating health indeed increases 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 (one year), as the health effects from noise likely manifest over a longer time. This explanation is also supported by the insignificance of the effect from noise annoyance on high blood pressure, which may suffer from the same issue.

For neighbor noise annoyance a significant effect on sleeping problems is found. In addition, sleeping problems showed an effect on noise annoyance in the subsequent wave as well. This effect, however, is much smaller and may indicate that people who suffer from sleeping problems become more sensitive to neighbor noise. It is important to note that the health and annoyance questions are part of different surveys within the LISS panel and are 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 the actual noise exposure. Participants may also not always be aware of changes in health, and smaller changes may not reflected by the binary nature of the questionnaire.

5. Conclusion

This study analyzed data from the Dutch Longitudinal Internet Studies for the Social Sciences (LISS) panel to fulfil two objectives: identification of different noise annoyance profiles over time, and estimation of the relationship between chronic noise annoyance and various health outcomes. Using Longitudinal Latent Class Analysis, three noise annoyance profiles are identified: chronically, occasionally, and never annoyed people, for both street and neighbor noise. Noise annoyance was found to be relatively stable over time. Extraversion and emotional stability were found to decrease the chance of being occasionally and chronically annoyed, while intellect and imagination increased the chance of being annoyed by neighbor and street noises. Chronic annoyance is correlated with self-reported heart complaints and sleeping problems but not with high blood pressure or heart attacks. It is important to note, that smaller changes cannot be reflected in the model as the questionnaire only asked for diagnosed high blood pressure. Undiagnosed or slightly elevated levels are therefore not detectable. Smaller changes in annoyance are also not measured. Using Cross-Lagged Panel Models, we investigate the causal direction between noise annoyance and health outcomes. Perceived neighbor noise in one year predicted sleeping problems in the following year. For street noise, this was not significant. Unlike the LLCA, the RI-CLPMs only consider changes from one year to another, which might explain the absence of significant effects from noise on the other health variables. For heart complaints and sleeping problems, a reverse effect was found, potentially suggesting that deteriorating health may increase reported noise annoyance. Due to the time difference between the health-related and noise-related survey, it is not fully clear whether this reverse effect is real or caused by the time delay. To better understand the relationship between noise annoyance and health, we propose further longitudinal studies with more elaborate, non-binary annoyance and health questions administered at the same time.

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