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REANALYSIS OF THE NORAH STUDY ON THE ASSOCIATION OF TRANSPORTATION NOISE INDUCED ANNOYANCE WITH RESIDENTIAL GREEN

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ABSTRACT

Residential green receives increasing attention as a measure to reduce negative health effects of transportation noise. In a recent study, the data from the Swiss nation-wide SiRENE survey on road traffic, railway and aircraft noise annoyance was reanalyzed after complementation with a range of green metrics. Exposure to residential green was found to be positively associated with reduced road traffic and railway noise annoyance, but also strongly linked to increased aircraft noise annoyance. The normalized difference vegetation index (NDVI) was particularly strongly associated with noise annoyance. While the findings on road traffic and railway noise were in line with expectations, those on aircraft noise were unexpected in the SiRENE study. We therefore aimed at testing the replicability of our previous results. To that purpose, we completed data from the German NORAH study on road traffic, railway and aircraft noise annoyance with satellite-derived NDVI and reanalyzing the annoyance data set with noise exposure and residential green as predictor variables. In this paper, we will present the results of this analysis and compare them to our previous findings.

Keywords: *noise annoyance, transportation noise, residential green, NDVI*

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1. INTRODUCTION

Urban areas are steadily growing in size and population. This goes along with urban densification, which is often accompanied with the loss of green spaces and increasing noise exposure of the population, in particular due to road, railway and air traffic. Noise exposure entails a range of negative health effects, of which noise annoyance (after sleep disturbance) is second-most prevalent [1].

Given that noise-induced health effects are likely to increase in the future, the question arises whether they may be alleviated by promoting recovery from noise. In this context, residential green (i.e., vegetation and green spaces in residential areas) came into focus in recent years [2]. There is evidence that residential green may mitigate noise effects, ranging from reduced noise annoyance [3] to decreasing mortality [4].

Within a recent study [5], we investigated whether the characteristics and proximity or accessibility of restorative areas (parks, green areas, water, etc.) are suitable for reducing transportation noise annoyance and thus achieving a restorative effect. For this purpose, we supplemented the Swiss SiRENE survey sample (noise annoyance caused by road traffic, railway and aircraft noise [6]) with various "green" metrics and reanalyzed the data set. We found vegetation and green spaces in residential areas to significantly reduce annoyance to road traffic and railway noise, while in the case of aircraft noise, residents living in green areas were significantly more noise annoyed than those in less green areas. While the findings on road traffic and railway noise were in line with expectations according to literature, those on aircraft noise in the SiRENE study were unexpected.

The objective of the current study therefore is to test the replicability of our previous results [5] by complementing the data set from the German NORAH study with the green metric NDVI (normalized difference vegetation index [7]) and reanalyzing the data for road traffic, railway and aircraft noise annoyance in dependence of noise exposure and residential green.

2. THE NORAH STUDY

The German NORAH study (Noise-Related Annoyance, Cognition, and Health; http://www.laermstudie.de/; https://www.norah-studie.de/en/) was an extensive interdisciplinary research project on the impact of transportation noise (road, railway, air) on the quality of life, health, and the development of children [8]. The study comprised the Rhine-Main district around Frankfurt (FRA) airport as well as the areas around the airports of Berlin (BER), Cologne (CGN) and Stuttgart (STR), all in Germany. Amongst a range of health endpoints, noise annoyance was studied around the four airports [9].

2.1 Noise exposure assessment

The noise exposure calculation is described in detail in [10]. In short, road traffic and railway noise exposures were calculated in front of the buildings' "loudest" façade of the residents' addresses, and aircraft noise exposure at the buildings' center.

Noise exposures were calculated according to German legislation, namely, according to the VBUS ("*Vorläufige Berechnungsmethode für den Umgebungslärm an Straßen*"), the VBUSch ("*Vorläufige Berechnungsmethode für den Umgebungslärm an Schienenwegen*"), and the AzB ("*Anleitung zur Berechnung von Lärmschutzbereichen*") for road traffic, railway, and aircraft noise, respectively (cf. [10]). The noise metric used in the current study is the day-evening-night level (L_{den}) of each source.

2.2 Noise annoyance data

Details on the noise annoyance data are given in [9]. The field study was conducted as online and telephone-based surveys, in FRA in the years 2011–2013, in BER in 2012, and in CGN and STR in 2013. The current study uses the full data set except for the data of the follow-up survey waves of the longitudinal study part on the impact of aircraft noise changes at FRA on annoyance (FRA 2012, 2013). After linkage available for the analysis in this study, the final dataset used here contains recordings of 26'607 participants (FRA: 16'253, BER: 5'420, CGN: 2'955, STR: 1'979). Of these, a total of 26'577, 26'574 and 26'601 valid annoyance ratings were available for road traffic, railway and aircraft noise, respectively, besides a wealth of further variables such as personal characteristics (age, sex, noise sensitivity etc.) (cf. [9]).

Following recommendations of ISO/TS 15666 [11], we use the binary variable "highly annoyed (HA_V)", derived from the 5-point verbal scale, as a measure of noise annoyance. HA_V is defined as 1 ("highly annoyed") for the top to verbal response categories 4 (very), and 5 (extremely) of the 5-point scale [11].

2.3 Residential green

As green metric, NDVI [7] was used, which was found in [5] to be particularly strongly linked to annoyance. NDVI is calculated from satellite-derived land surface reflectance, using cloud and snow free satellite images. We used the Landsat 5 data of spring–summer 2009–2011 (period of 01 May–31 July each year). For each respondent, the mean NDVI was calculated (value between −1 and + 1 [7]), in a buffer with a radius of 500 m, which had already been applied in previous studies (e.g., [4, 5]). Increasing values of NDVI indicate increasing greenness (cf. [7]).

2.4 Statistical analysis

We established exposure-response curves for the probability of high annoyance (pHA_V) as a function of exposure to transportation noise (L_{den}) and to residential green (NDVI), separately for the noise sources (road, rail, air) and airports (BER, CGN, FRA, STR). The exposure-response curves were established by means of logistic regression analysis. We used generalized estimating equations, which yield a population-averaged response [12].

3. RESULTS

Fig. 1 shows the modelled exposure-response curves for pHA_V (centered over the four airports) as a function of the L_{den} and NDVI. The curves are drawn for the 5th, 50th and 95th percentile of residential green in the study sample (NDVI of 0.24, 0.40 and 0.55, respectively), representing residential areas with little, average and a lot of green.

Increasing NDVI is associated with distinctly lower road traffic noise annoyance. The corresponding shift in the exposure-response curves on the abscissa may be interpreted as an equivalent sound pressure level change [5]. This level change (between 5th and 95th percentile) amounts to ~3 dB for road traffic noise (i.e., corresponding to a halving of the sound energy). For railway noise, in contrast, the exposure-response curves overall (pooled over the four airports) remain unaltered by NDVI. Finally, for

aircraft noise, the opposite trend as for road traffic noise is observable (increasing noise annoyance with NDVI), with an equivalent sound pressure level change of ~1 dB.
Analogous observations as for the pooled data can be made for the individual airports in the case of road traffic and mostly also aircraft noise, although the strength of the equivalent sound pressure level change with NDVI varies between airports. The association of the exposure-response curves with NDVI for railway noise, in contrast, distinctly differs between airports – exposing positive, negative, or no association at all of NDVI with annoyance. We do not have a well-founded explanation for this currently.

4. CONCLUSIONS AND OUTLOOK

In this study, we explore the association of noise annoyance with exposure to transportation noise (road traffic, railway and aircraft) and residential green (quantified with the metric NDVI). As the individual contributions of noise and residential green to annoyance are separated in the analysis, the effect of residential green on annoyance goes beyond reducing the noise levels in green spaces. Rather, the effect is attributable also to other pathways, namely, to building capacities (i.e., promoting physical activity and social cohesion) as well as to restoration [13].
The association of residential green on (reduced) road traffic noise annoyance was expected and in line with literature [3], while less pronounced than in [5]. The findings thus add to the body of literature underlining the importance of residential green to promote health [2].
The (contrasting) increase of aircraft noise annoyance with increasing residential green confirms our previous findings [5], although the effect observed here is less strong than in the Swiss SiRENE survey sample. Possible mechanisms explaining this (annoyance increasing) effect are discussed in [5].
For railway noise annoyance, overall (i.e., pooled over the four airports) we did not observe any link with residential green, and found very disparate and contrasting associations per airport. This result is in contrast with [5], where a protective effect (although less pronounced than in the case of road traffic) was disclosed. Possible reasons for this (contrasting) observation are currently explored.

5. ACKNOWLEDGMENTS

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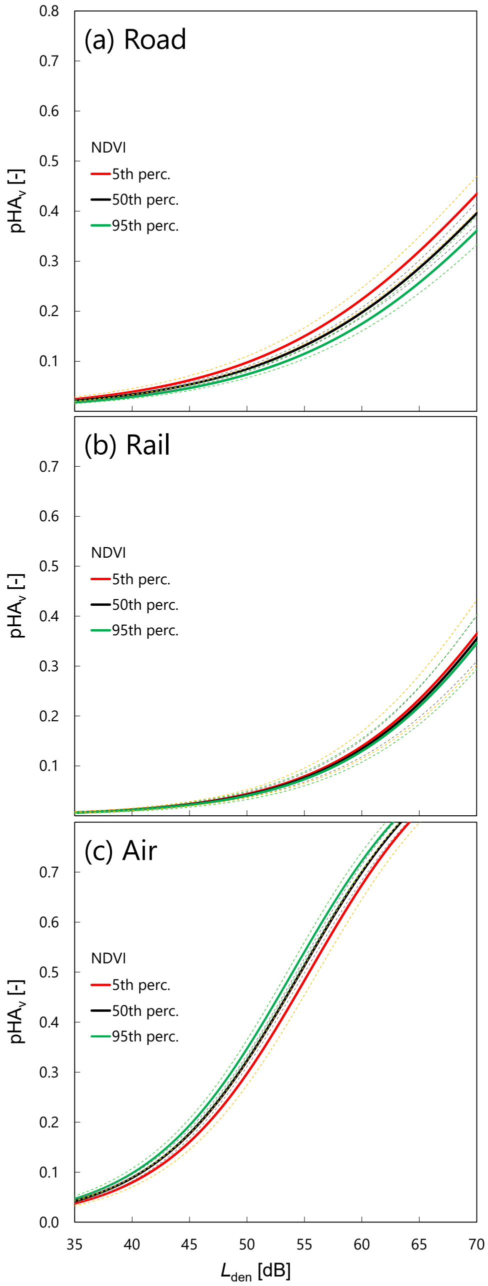

Figure 1. Exposure-response curves for the probability of high annoyance (pHA$_V$) as a function of the L_{den} and NDVI for (a) road traffic, (b) railway and (c) aircraft noise, including 95% CI. The three curves per panel represent the 5th, 50th and 95th percentiles (perc.) of NDVI of the study sample. The curves are centered on all covariates.

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