# Transportation noise and health related quality of life: perception of soundscapes, coping and restoration

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**Summary**
Health impact assessment is often (ill)-focused only on rather severe health outcomes employed by large epidemiological studies. Such an approach rather neglects the more prevalent effects on health related quality of life, coping and restoration capabilities in constrained transportation environments. Instead, soundscape research investigates the perceived quality of the sound environment and its context - but uses mostly small selective samples and rarely relate the observed perceptions to health responses.
We aimed to link the two approaches in a middle sized representative field survey (N = 572) and used scales of health related quality of life, coping and restoration in multiple regression analysis and structural equation modeling. We found evidence for a significant exposure response effect with total and rail sound exposure for perceptual, emotional and coping responses on both indices of neighborhood satisfaction and health status. Supporting earlier results we found active coping efforts to increase affectedness and dissatisfaction but mitigating adverse health effects. We have further observed positive effects of restoration options as measured by the dimensions "being away", "fascination" and "compatibility" on both neighborhood satisfaction and health.
The multiple pathways observed indicate, that the impact of a larger transportation route on health related quality of life and residential satisfaction is significant and constrains restoration. However, effective behavioural (coping) and environmental resources (restorative capacity) can counteract against adverse effects and need consideration in health impact assessment.

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## 1. Introduction

The assessment of effects on quality of life, annoyance, and health of transport noise at the community level is less straightforward than e.g. for the worksite or for other more closed acoustic spaces or products emitting noise. The results at community level are much more varied [1]. This often makes administrators and policymakers to wrongly conclude that the evidence for the effects of the transportation environment on men is weak. Research into these observed variations in effects provides the key to understanding how adverse effects on health could be mitigated or even prevented by considering health promotive and restorative aspects of the acoustic environment ("healthy soundscapes") in environmental planning and land use assignments [2][3][4][5]. We need, however, to admit that the main current approaches addressing the effects of the acoustic environment on health and quality of life have some inherent methodological limits. Only about 10 to 20 % of the variance in the community annoyance reactions is explained by typical acoustic indicators (Lden, Lnight) used in regulations[6]. For health effects the variance explained is even much less (below 5%) and we must ask what is lost and why do we lose large essential information on the variance not explained. It is obvious that any preventive intervention or implementation of measures at the various scales will suffer from such a deficit. These facts underline the importance to develop approaches and analytic tools in research and practice which improve the predictions particularly at the specific scales of inquiry and intervention. The aim of our analyses was to improve the predictions using both a broader conceptual perspective and various statistical analysis tools. We report here due to space limits only the analyses and results from one study.

## 2. Samples and methods

**Sample:** The study was conducted within the framework of an environmental health impact assessment of a large infrastructure traffic project (rail extensions, rail tunnels). The study area covered a stretch of about 40 km in the lower Inn valley (east of Innsbruck, Austria) and consists of densely populated small towns and villages with a mix of industrial, small business, touristic and agricultural activities.

Sampling of the full cross-sectional study was based from a noise map prepared for an environmental health impact assessment by GIS-stratification of noise exposure (35-44, 45-54, 55-64, >64 Leq,dBA). Sampling was conducted in a two-step process and the selected persons were called four times before being replaced. People (aged 20-75 yrs) were sampled randomly from circular areas around 31 noise measurement sites (radius = 500 m). 807 persons from 648 households agreed to participate (50.5 %) in the survey. The results we report here are made on data from a consecutive survey which intended to collect more detailed information on the participants' health and the residential environment. Only N = 572 persons agreed to participate in the second wave, which equals a drop-out rate of 29.1%. However, no socio-demographic or health related selection was observed with the exception of a slightly higher proportion of women compared to census information. Prior written consent was taken from the participants before the interview and the anthropometric measurements were made.

**Exposure assessment:** The measurement points were selected from two experienced acousticians to cover the variety of topography (valley/slope), settlement structure (housing types, rural/suburban/town) and population density of the area of investigation. The final individual assignment of the source specific noise exposure (dBA, day and night, Ldn) was made after calibration of the modelling results against the measurements from the 31 sites in the centre of the circular areas. All procedures were carried out according to Austrian guidelines (ÖAL Nr. 28 + 30, ÖNORM S 5011) with a resolution of 25 m × 25 m.

**Perception, susceptibility and health assessment:** Perceived traffic exposures were assessed by asking respondents to judge the severity of disturbances they perceive in their living environment or in their home. Among the different sources of disturbances were noise from motorways, noise from local traffic, noise from railways, vibration from railways, air pollution from traffic, and pollution through particles. Ratings were made on a 11-point visual-analogue scale (0 = not at all susceptible; 10 = particularly susceptible).

Personal Susceptibility to traffic exposures was assessed with three items. The items asked the respondents how susceptible in general they perceive themselves towards air pollution, noise, and vibration. A visual-analogue scale rangingfrom 0 (no disturbance at all) to 10 (extraordinary strong disturbance) was used.

Health issues were assessed by employing 14 items (the subscales somatic health and anxiety) from the 28-item version of the General Health Questionnaire (GHQ,[7]), an additional item reflecting the overall health status and a sleep quality scale. The 14 GHQ-based items could be answered on a 4-point scale (1 = not at all, 2 = not more than usual, 3 = slightly more than usual, 4 = much more than usual).

**Environmental satisfaction and restorativeness:** Satisfaction with the living environment was measured by a total of 4 items. One item represented also the satisfaction with the respondent's individual quality of life during the last month. The perceived restorativeness of the respondent's home was assessed with the perceived restorativeness scale (PRS) developed by Hartig et al. [8].

**Coping and emotional response:** active coping is based on 3 yes-no items (closing window during day or during night and using ear plugs when sleeping). Social coping consists of 2 items (talking with neighbours or with community administrators about noise problem). Emotional response was queried by two items (feeling angry or helpless towards exposure). The responses were simply summed up.

**Statistical approaches: S**tatistical analysis was conducted with R-Software. Exposure-effect relationships were modelled with multiple logistic regression techniques using Harrell's RMS-library [9]. To account for non-linearity in selected predictors splines were applied. Approximate 95% confidence intervals were estimated using

smoothing spline routines with three knots and the exposure-effect plots were generated with the RMS-library. Predicted probabilities are derived from the estimated odds with a specific function in the RMS-library (plogis). The predicted are adjusted to the median (continuous variables) or the reference category (non-continuous variables) of the other variables in the model.
The structural equation model (SEM) was run with the R package lavaan [10]. Missing data were treated with FIML [11]. Robust standard errors were computed to account for non-normality of data.

## 3. Results

**Multiple regression results**: The final model (adjusted for age, GHQ-score, sensitivity score, neighbourhood satisfaction, FA-, BA- and COM-scales of the PRS, active and social coping, smoking, sleep score, and IAs sound*FA, sound*BA, sound*emotion) has an overall high explanatory power (pseudo $R^2$=0.49). The most important variables were GHQ-score and age.

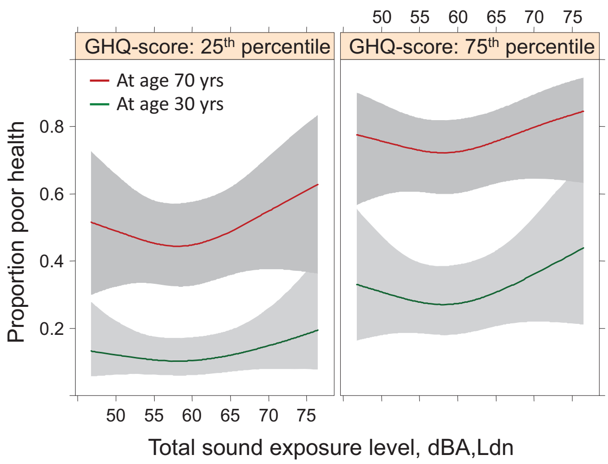


Figure 1. Predicted probability of poor health status with total sound level by GHQ-scores

In Figure 1 you see the relation with noise is stronger in the higher age group with lower GHQ-scores compared with the high GHQ-score-group.

This must be considered when the overall relation with noise is interpreted. Overall, both, total and railway noise exposure are weakly associated with poorer health (grade 3-5) beyond 60 dBA,Ldn (see Figure 2). Highway noise does not show any significant association with health status.

However, the interpretation is much more complicated: in the presence of three interactions the main effect cannot be interpreted correctly.

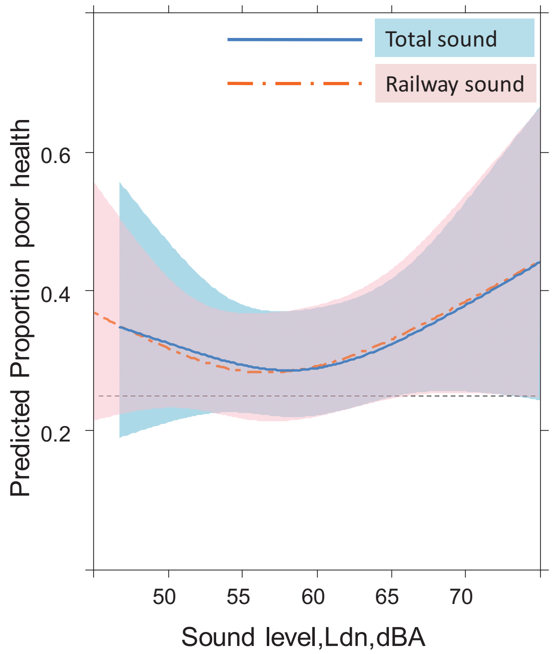


Figure 2. Predicted probability of poor health status with total and railway sound level exposure

The interactions included two of the restoration dimensions (being away and fascination) and emotional affectedness. The interactions were significant in the total and railway sound models and showed strong non-linear components. A higher score on the "being away" restoration dimension is associated with a lower proportion of poor health at all sound levels while a low score shows an increase at both lower and higher levels of both total and railway sound. Similar results were obtained for the emotional response: A stronger emotional response is associated with a higher proportion of poor health at higher sound levels while little emotional affection has no association with sound exposure levels.
Furthermore (see Figure 3), in the model higher active coping efforts are associated with lower predicted proportions of poor health (= positive effect). Similar results were obtained for social coping efforts. Both associations were, however, only significant when tested at the extreme values (low versus high) and not from low to medium or medium to high scores. An easy explanation for the higher levels of poor health at lower sound levels is not available – although this could be people exposed at the slopes of the valley.

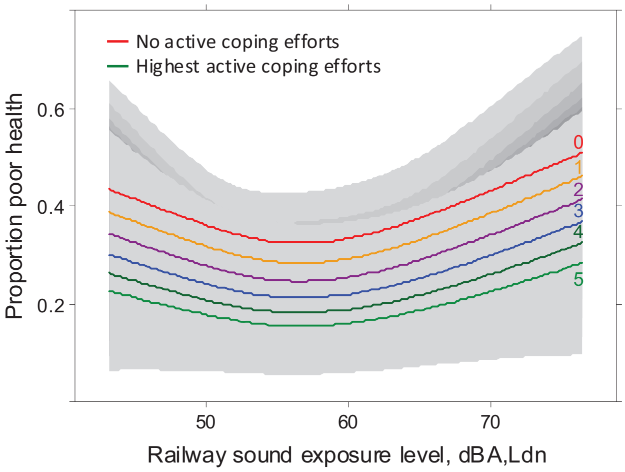


Figure 3. Predicted probability of poor health status with railway sound level by active coping

**The structural equation model results**: As we had sufficient a priori knowledge we developed a latent construct including actual exposures (noise, air), susceptibility to traffic (noise, air, vibration), perceived exposures (judgments of exposure severity) and the perceived restorativeness (PRS) of the respondent's home in relation to satisfaction with the living environment (4 items) and health (14 items of GHQ, health status, 5 sleep quality items). The correlations between all latent constructs showed medium to strong associations and all correlations pointed in the expected direction. We therefore included regression paths between the latent variables in the next step to test our assumptions, that health issues as well as the satisfaction with the living environment are impacted directly and indirectly by perceived traffic related exposures and directly by the perceived restorativeness of the living environment (see **Figure 4**). We also controlled for possible impacts from demographic variables on the latent constructs and regressed each latent construct on the type of housing (single, row, or multiple housing), gender (male or female), age, education, and density (average people per room). The model fit was acceptably well.

The coping construct could not appropriately be accommodated by the model and was excluded. The full results are given in Figure 4. The model explains high amounts of variance for the latent constructs perceived traffic exposures ($r^2$ = .78), and satisfaction with the living environment ($r^2$ = .52). Perceived traffic exposures were mainly explained by measured traffic-related exposures to air pollution and noise, and the respondents' susceptibility towards traffic exposures. The more susceptible one felt and the stronger one was exposed to traffic related noise and air pollution, the stronger the disturbances a person reports.

Perceived traffic exposures were strongly associated with the satisfaction with the living environment. This means: the more traffic related disturbances one perceives the lower is the satisfaction with the living environment. On the other hand, the more people experience fascination in their living environment, the more they are satisfied with the living environment. Interestingly, the ratings for being away had no significant influence on the satisfaction with the living environment.

For health issues, the emerging picture is quite similar: The more a person perceived traffic exposures, the more health issues were present. Mixed results were obtained from the restorativeness of the respondents' home. For fascination, the impact on health issues was insignificant, but a stronger sense of being away in the own living environment significantly reduces health issues. It is particularly striking that having a sense of being away was associated with health, while perceiving the own home and living environment as fascinating was associated with satisfaction. Concerning the control variable included in the analyses, only marginal effects could be found.

For satisfaction with the living environment neither the path via being away nor the path via fascination became significant. Also the total indirect effect remained insignificant. However, when considering the possible indirect effects, the Considering health issues, however, we found a significant indirect effect via having a sense of being away, but not via fascination. The total indirect effect was also significant, contributing to a stronger total effect from perceived traffic exposures on health issues. Although having a sense of being away helps reducing health issues, indirect effects from perceived traffic exposures may thus undermine this positive impact.

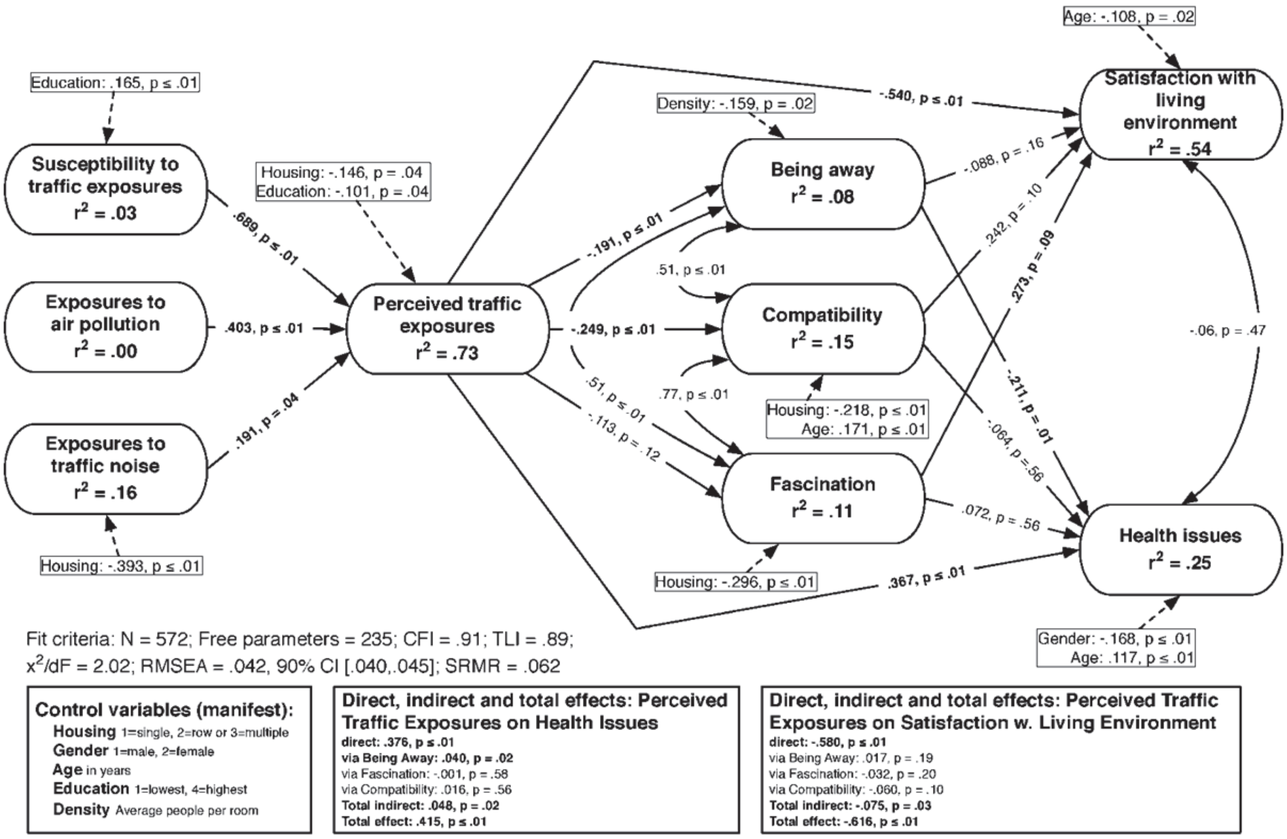


Figure 4. Structural equation model with standardized regression path-coefficients, explained proportion of variance (r2), impact of control variables, and calculations for the direct, indirect and total effect

This means that the sense of being away may be impaired by traffic exposures, which we consider as a case of constrained restoration.

All included variables and pathways considered, the model resulted in quite high amounts of explained variance in the exogenous latent constructs. By considering exposures to air pollution, noise, and susceptibility to these exposures, 78% of variance for perceived traffic exposures could be explained. These perceived traffic exposures accounted for 8% of explained variance for having a sense of being away, and for 11% of explained variance for fascination, respectively. For satisfaction with the living environment 52% of variance and 25% of variance of health issues, respectively, could be explained by perceived traffic related exposures, being away, compatibility and fascination.

## 4. Discussion

In these analyses, we aimed at generating a more comprehensive understanding of the associations between increasing traffic related exposures (noise and also air pollution), satisfaction with the living environment, restorative qualities of the living environment, coping and health in a community context. We used two complementary statistical approaches (multiple non-linear regression and SEM).

The results support our assumption that the amount of perceived traffic exposures directly impairs the satisfaction with the living environment and even directly contributes to health issues. Perceived traffic exposures had also a similar indirect effect via being away on health issues. In the regression analysis, active and social coping efforts were additionally associated with a lower proportion of people in self-rated poor health status. The SEM-model was not able to deal with coping in addition. The observed non-linear relation with total and railway sound exposure in the regression model is only interpretable when the significant interactions with two of the restoration dimensions (being away and fascination) and emotional affectedness are considered. The data suggest that the interaction is strong at higher but not observed at lower sound levels. While this may be expected with emotional affectedness it is surprising to observe restoration dimensions counteracting adverse effects also at higher levels of exposure.

An important result is the differential positive effect of the "being away" dimension of the PRS on the health outcome while the "fascination" dimension is (marginally) associated with the residential satisfaction experience. Surprisingly, the compatibility dimension neither contributed significantly to health outcomes nor to residential satisfaction in the SEM-model. However, compatibility was strongly related to neighborhood satisfaction in the multiple regression models. Noteworthy in this context is that all PRS measures were strongly correlated with each other. We therefore suggest that the distinct contribution of "being away", "compatibility" and "fascination" should be interpreted with care, and that testing a model with only one latent PRS construct instead might be more appropriate. However, results from the SEM clearly indicate that including measures for restorative qualities of the residential environment enhances understanding of the relationship between traffic-related exposures, health and residential satisfaction.

In both statistical approaches the explained variances were rather high (regression model: 49%). In the SEM-model (78%) the specific inclusion of air pollution and vibration may have contributed additional explanatory power. Obviously, the cross-sectional nature of the study prohibits a causal interpretation. The multiple pathways observed indicate, that the impact of a larger transportation route on health and residential satisfaction is significant and restricts restoration. However, effective behavioural (coping) and environmental resources (restorative capacity) can counteract against adverse effects.

## 5. Conclusions

A broader methodological framework - covering environmental and life quality, residential satisfaction, restoration, coping, health related quality of life is needed to understand the wider adverse and cumulative effects from transportation sources beyond severe clinical health outcomes (hypertension, stroke etc.) at the community level.

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