Assessing the relationship between perceived disturbances from traffic, restorative qualities of the living environment, and health

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ABSTRACT

Home is for many a place to recover after a day at work and to find shelter from demands of the outside world. Being at home can thus be regarded as a resource for health and wellbeing. However, it is not always possible for people to ban traffic related disturbances from their home. Consequently, the restorative character of the home may become constrained, and this in turn may result in impaired health and wellbeing.

We addressed this possibility in analyses of data from a door to door survey of residents in a valley near Innsbruck, Austria (N = 572). Participants reported on restorative qualities of their homes, their health, and perceived disturbances from transport-related noise, vibration, and air pollution.

Results from a multiple mediation analysis suggest that transport-related disturbances negatively impact health, and that this apparent effect is indeed partially mediated via constrained restorative qualities of the respondent's home.

Keywords: Traffic, Sound sources, Air pollution, Environment, Restoration, Disturbance, Health
I-INCE Classification of Subjects Number(s): 56.3, 62.5, 63.2, 66.1

1. INTRODUCTION

The research of traffic impacts on human behavior, health and wellbeing is widely scattered between the fields of environmental medicine, environmental and health psychology and various other domains. Therefore, traffic related adverse impacts are rarely studied in an integrated fashion (1)(2)(3)(4)(5)(6)(7)(8)(9). In environmental health impact assessments such an approach is, however, required by law and is needed to plan, promote and achieve sustainable health related solutions at the community level (10)(11).

From the viewpoint of Public Health, another issue which often hampers proper environmental health impact assessment is that the research is (ill)-focused only on rather severe health outcomes in both the noise and air pollution research areas (12)(13)(14)(15)(16). Also cross-national assessments have recently abandoned high annoyance as relevant health outcome (17) – although the WHO has kept it in its own assessment (18). Such an approach rather neglects the more prevalent effects on health related quality of life, coping and restoration capabilities in constrained or suboptimal environments. In addition, the focus is strongly biased towards physical and chemical aspects of environmental exposures and the psychosocial and ecological context is often neglected. This restrictive approach is not able to cover the overall effects. A more contextual approach is required which conceptualizes traffic as environmental stressor at the home residence (10)(19). In this regard research on restorative qualities of environments provides a theoretical and empirical framework that focuses on human-environment transactions.

A central idea in restorative environments research is that people use adaptive resources to meet the requirements of everyday life (e.g., to willful direct attention). These resources become regularly

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and predictably diminished, as when we gradually tire over the course of a workday or workweek. The depletion of resources eventually leads to mental fatigue and limits our responses to other (simultaneous) demands. When being mentally fatigued, attention, performance, and self-regulatory capabilities are compromised (20–25). It is understood that failure to restore the depleted resources will ultimately harm psychological and physical health (26).

Restorative environments research assumes that restoration proceeds more effectively in some environments than in others. Environments can serve restoration through an absence of social and physical sources of stress (like e.g., crowding and noise) and through certain qualities of the environment that positively promote restoration (26).

The environmental qualities that promote restorative person-environment transactions are the subject of prominent theories in restorative environments research, namely psychophysiological stress recovery theory (27,28) and attention restoration theory (29,30). Stress reduction and attention restoration have common features; they are both thought to proceed when a person gains psychological distance from the depleting circumstances and becomes engaged in a positive or pleasant fashion by the given environment. In summary, restorative environments do not only permit people to experience restoration, but also promote restorative outcomes, enabling faster, more complete recovery of depleted resources than environments that merely lack demands or stressors (26).

However, restoration can be constrained by a reduction of restorative quality in an otherwise restorative environment. This constraint of restoration occurs when circumstances hinder the complete or sufficiently rapid renewal of depleted resources (31). For instance, this may be the case when the environment is exposed to noise, vibration, and pollution caused by traffic and means of transportation. In this sense, we frame traffic related exposures as possible constraints for restoration in the residential context.

In the present analysis, we shift the view and consider how exposure to traffic related noise, vibration or other pollution (short: ‘traffic related exposures’) might constrain the psychological restorative qualities of a residential environment.

The current analysis is based on survey data collected in a traffic polluted alpine valley where a broad spectrum of adverse effects of noise as well as air pollution and vibration were already reported in both children and adults (32–39).

We hypothesize that satisfaction with the living environment as well as health related quality of life depend on the perceived restorativeness of the own living environment and on perceived traffic exposures. We also consider the perceived traffic exposures as constraints for the living environment’s restorative qualities. This means that perceived traffic exposures may affect satisfaction with the living environment and health issues both directly and indirectly via impaired restorative qualities of the own home and living environment.

In the present study we further assume that the amount of perceived traffic exposures depends on both measured exposures to traffic related air pollution and noise, and on a person’s susceptibility to those exposures.

2. Methods

2.1 Study area, study design, and sampling procedure

The study area covers 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.

The cross-sectional study was conducted in fall 1998. Sampling was based on an 'a priori' GIS-stratification of noise exposure (35-44, 45-54, 55-64, >64 Leq,dBA) and conducted in a two step process with replacement. People (aged 20-75 years) 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 sampling from these circular areas should increase the validity of the noise assignments by minimizing the known errors of sound propagation procedures for larger distances. Only persons with a permanent residence of more than one year were included in the study. A consecutive survey was conducted 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.

2.2 Sample

The final sample comprises of N = 572 individuals. As socio demographics measures we assessed the respondents age (in years), their gender (1 = female, 2 = male), the highest level of formal education (1 = basic, 2 = skilled labor, 3 = vocational, 4 = higher education), the type of housing (1 = single, 2 = row, 3 = multiple), and the density in terms of average amount of persons per room. Mean age was 46.4 years (*SD* = 14.7 years), 58% were male and 42% female. The educational background was quite mixed, with 28% indicating only basic education, 25% skilled labor, 22% vocational training, and 16% a higher level of formal education (A-level or university). The majority of the sample lived in a single home (68%), whereas 19% lived in multiple flats building and 13% in a row house. On average, there were 0.86 persons living per available room (minimum = 0.14, maximum = 4).

2.3 Statistical treatment of the data

All analyses were conducted with the statistical software R version 3.1.1 for MAC. Missing data were treated with FIML (40). For data analyses, mainly the R package lavaan (41) was used to test measurement model by running multiple CFAs simultaneously and the assumed relationship with a structural equation model (SEM). Robust standard errors were computed to account for non-normality of data. We additionally conducted 5000 bootstrap resamples to test the robustness of our results and mediation effects (42–44).

All data used were elicited in a cross-sectional study design. This means we cannot make strong claims for causality of the relationships tested in the model. However, the formulation of specific items refers to different time points, so that causality may only be suggested.

2.4 Measurements

All items were originally formulated in German. The socio-demographic measures (see above) served as control variables for the statistical analyses. In the following, we will present the measures and scales used in the analyses.

Traffic related exposures were measured twofold, as *exposure to traffic noise* and *exposure to air pollution*. The primary noise sources were roads (highway, main road) and rail traffic. In the present analysis, we used the calibrated sound level of the highway (bsldn) and the railway (bbldnos) exposure. The final individual assignment of the source specific noise exposure (dBA,day and night, Ldn) was made after calibration of the modeling results against the measurements from the 31 sites in the center 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.

Additionally, we used calibrated measures for particles and nitrogen dioxide as indicators of the air pollution exposures. These exposures to air pollution were assessed by a Swiss expert group (OEKOSCIENCE AG), who had long-term experience in monitoring and calibrating air pollution exposure in the alpine areas with special consideration of meteorological and topographical conditions (45,46) An adapted Gaussian propagation model procedure was used under the prevailing meteorological conditions (3 seasons) for the respective area. The results were assigned via GIS to the addresses of the study participants. The calculations were done for a resolution of 100 m x 100 m.

This specification given, e*xposures to traffic noise* and *exposures to air pollution* contain information about the objectively measured noise and air pollution the respondents are exposed to. Higher values on these measures represent stronger exposure to traffic related noise and air pollution.

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. The -susceptibility ratings was made on a 11-point visual-analogue scale (0 = not at all susceptible; 10 = particularly susceptible). Cronbach's alpha was .83 and can be considered as a satisfactorily high internal consistency. The higher the scores respondents receive on this scale, the more susceptible they feel towards traffic related exposures.

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. The visual-analogue scale ranged from 0 (no disturbance at all) to 10 (extraordinary strong disturbance). Internal consistency can be considered as satisfactorily high with a Cronbach's alpha value of .81. A higher score on this scale means that the respondent perceived more severe traffic related disturbances in his/her living environment or home.

To assess the *perceived restorativeness of the respondent's home*, we employed the perceived restorativeness scale (PRS) developed by Hartig et al. (47). We focused on the PRS subdimensions fascination and being away. *Fascination* was assessed with a total of five items. The internal consistency of these five items was Cronbach's alpha = .77 and can be considered as acceptable high. The five items for *being away* also received an acceptable high Cronbach's alpha value of .71. Higher scores are associated with a more frequent sense of being psychologically away, and experiencing fascination, respectively, in the living environment.

Satisfaction with the living environment was measured by a total of 4 items. Three items were formulated to explicitly measure the satisfaction with the appearance of the living environment, the general quality of the living environment, and the possibilities for recreation in the living environment. A fourth item represented the satisfaction with the respondent's individual quality of life during the last month. All four items could be rated on a 5-point scale (1 = very unsatisfied, 2 = mostly unsatisfied, 3 = neither satisfied nor unsatisfied, 4 = mostly satisfied, 5 = very satisfied). The value for Cronbach's Alpha was acceptable high (.80). Higher values on the satisfaction with living environment scale represent higher amounts of satisfaction.

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, (48)), 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). These 14 items received a high value for Cronbach's alpha of .88. The higher the GHQ-based score, the more health issues a respondent reports. Additionally, a five grade standard self reported measure of respondents' general health status was used with 3 grades (1 = very good, 2 = good, 3 = less than good) in this analysis. Eventually, self-reported quality of sleep was measured with a summary scale (Cronbach's alpha = 0.86) derived from five sleep frequency items. Thus, health issues were represented by a total of 16 items. The items were coded in a way that a higher score reflects more issues in general.

3. Results

In this section we will first provide results obtained from the measurement model. Results from the structural equation model including the analysis of direct and indirect regression paths on health issues and satisfaction with the living environment will be presented in the second part of this section.

3.1 Measurement model

The measurements described above were used as manifest indicators for the corresponding latent constructs depicted in Figure 1. First, we run a correlation analysis for all manifest variables included in the measurement model. The analysis resulted in some strong and significant correlations between specific manifest indicators within the latent constructs, but correlations for manifest indicators between latent constructs were mainly weak and statistically insignificant (except for the latent dimensions being away and fascination). We analyzed in a second step correlative relations between all latent variables that we included in our model (Table 1).

Table 1 – Correlations between all latent variables that were defined in the analysis (N = 572).

Fascination (1)	(1)				
Being away (2)	0.49	(2)			
Health issues (3)	-0.08	-0.27	(3)		
Perceived traffic exposures (4)	-0.03	-0.2	0.4	(4)	
Satisfaction with living environment (5)	0.45	0.28	-0.29	-0.56	(5)

Susceptibility to traffic exposures (6)	-0.07	-0.13	0.27	0.69	-0.41	(6)		
Measured exposures to traffic air pollution (7)	-0.04	-0.09	0.19	0.46	-0.28	0	(7)	
Measured exposures to traffic noise (8)	0.09	-0.06	0.1	0.27	-0.08	0.03	0.01	(8)

The correlations between all latent constructs in the analysis suggest medium to strong associations between the constructs under scrutiny. However, all correlations obtained from the measurement model were 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 also directly by the perceived restorativeness of the living environment (see also Figure 1).

3.2 Structural equation model

We additionally controlled for possible impacts from demographic variables on the latent constructs. We therefore also regressed each latent construct on the type of housing (single, row, or multiple housing), gender (male or female), age, education, and density (in terms of average people per room). With these specifications, we obtained still acceptable fit indices for the structural equation model: N = 572; dF = 989; Free parameters = 215; CFI = .90; TLI = .89; x^2/dF = 2.09; RMSEA = .04, 90%-CI [.041, .046]; SRMR = .063. This means that the model fits the empirical data satisfactorily well, although slightly higher values for the CFI and TLI would be preferable (e.g., 49, 50). The results, including standardized path-coefficients and r^2 values for endogenous latent constructs are given in Figure 1.

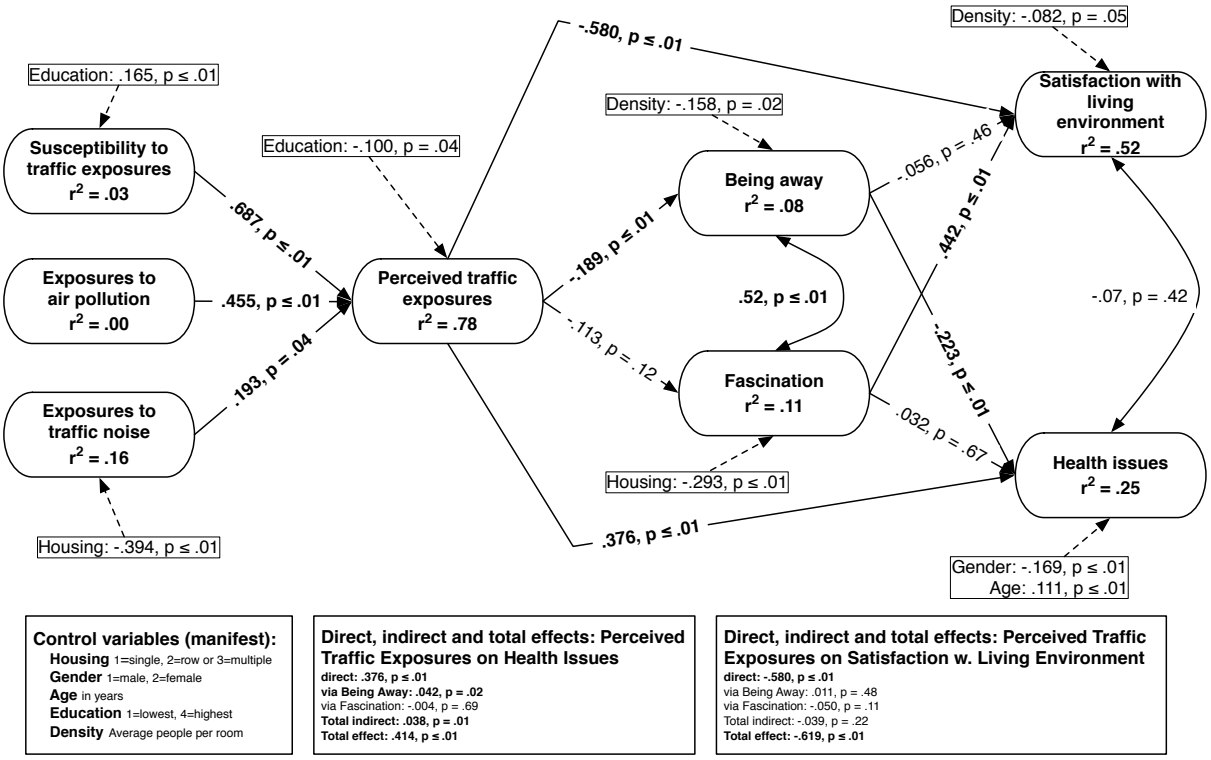

Figure 1 – Structural equation model with standardized regression path-coefficients, explained proportion of variance (r^2), impact of control variables, and calculations for the direct, indirect and total effect from perceived traffic exposures on both health issues and satisfaction with the living environment. Significant regression paths are bold, only control variables with statistically significant impact are displayed. Manifest

indicators for latent constructs and error terms are omitted in the figure due to readability reasons.

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 that 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.

Whether or not perceived traffic exposures may constrain having a sense of being away or experiencing fascination in the living environment is particularly a question of mediation effects. We therefore calculated the indirect effect from perceived traffic exposures via being away and fascination on satisfaction with the living environment and health issues as well.

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 total, combined effect from perceived traffic exposures on satisfaction with the living environment gained in strengths.

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. 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, and fascination.

4. CONCLUSIONS

In this study, we aimed at generating a more comprehensive understanding of the associations between increasing traffic related exposures (noise and air pollution), restorative qualities of the living environment, satisfaction with the living environment and health in the residential context. The results obtained from a survey among residents in the Unterinntal (Austria) were in support for our assumption that the amount of perceived traffic exposures directly impairs the satisfaction with the living environment and even directly contributes to health issues. Additionally, perceived traffic exposures had a similar indirect effect via being away on health issues. We thus found evidence that perceived traffic exposures indeed constrain restoration in the living environment by lowering the sense of being away for the residents. Although a stronger sense of being away was found to be negatively associated with health issues, perceived traffic exposures have the potential to counteract and impair this effect, so that the restorative quality of the home becomes constrained. Interestingly,

this effect of constrained restoration was only found for the association between having a sense of being away and health issues, but neither for fascination nor being away and satisfaction with the living environment. Satisfaction with the living environment seem to be solely dependent from perceived traffic related exposures. Of course, it is likely that other factors that have been omitted in this study also contributed to the satisfaction with the living environment. We are aware that our results should not be interpreted in a strict causal way, because we relied on data from a cross-sectional study design. However, all items were formulated in a way that points in a specified temporal direction, so that causality may only be assumed.

Limitations notwithstanding, our results support the assumption that traffic can indeed be seen as an environmental stressor that impacts the ecological as well as the psychosocial context. Eventually, this analysis proves that a extended framework, as provided by the concepts of restorative environments research is capable to generate a more sophisticated and integrated understanding of traffic, restorative qualities of the living environment, and health in the residential context.

ACKNOWLEDGEMENTS

The first author would like to thank the Swiss National Science Foundation (SNF) for funding the research project APARIS (Grant number PBZHP1_147313), which allowed the author to contribute to the present study. The underlying data were collected in the framework of an environmental health impact assessment. We thank the Austrian Ministry of Science and Transportation for financial support and the Tyrolean government for providing GIS-data.

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