Health effects and major co-determinants associated with rail and road noise exposure along transalpine traffic corridors

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INTRODUCTION

Traffic noise exposure in the community is generally considered as a weak risk factor for more severe health effects. Reported relative risks associated with noise exposure vary typically in the range of 1.0 to 1.5 (Babisch 2006, 2008) for cardio-vascular effects. As it is known from annoyance research that up to three quarters of the variance can be explained by non-acoustic factors (Job 1988) - it is a major public health interest to gain equally insight into co-determinants/moderators for other health effects of noise which render people with certain personal or environmental characteristics at higher risk than others. Hitherto, only few studies reported the modifying effect on the noise-health relationship of personal and environmental factors.

Among the personal factors e.g. studies have observed an inconsistent sex-noise relationship with hypertension and myocardial infarction (von Eiff & Neus 1980; Herbold et al. 1989; Babisch et al. 2005; Belojevic & Saric-Tanaskovic 2002; Jarup et al. 2007). Recently, the HYENA study did show a noise-hypertension relationship for men with road traffic but no sex difference with air traffic. In another large study a significant noise-hypertension relation was evident only in middle-aged people (45-55 yrs) but not in older ones and no sex difference were observed (de Kluizenaar et al. 2007). Further, persons without pre-existing disease did show stronger associations of noise with myocardial infarction (Babisch et al. 2005).

Among the environmental factors studied – e.g. duration of residence, single versus apartment homes, double versus triple-glass windows, bedroom orientation did show modifications of the noise-hypertension relationship (Bluhm et al. 2007). Recently, the HYENA-study did show associations with hypertension of night-time aircraft noise but daytime road traffic noise (Jarup et al. 2007). It has been hypothesized that stronger associations observed with the reported factors may only indicate less exposure misclassification rather than real factors. Bluhm et al. (2007) demonstrated a much stronger relationship with noise when three of these factors (triple glazed, old house, bedroom facing road) were combined (RR 2.47).

Another general concern is about possible confounding from air pollution. Especially for myocardial infarction there is good reason to be concerned, while for blood pressure there is less good evidence (Ibald-Mulli et al. 2001; de Kluizenaar et al. 2007). However, it could also be a reasonable assumption to expect combined effects of air and noise pollution on cardiovascular health outcomes.

Hitherto, only one study has investigated by design this possibility of a combined effect and found a relationship with doctor’s visits for bronchitis (Ising et al. 2005).

In the framework of an environmental health impact assessment (BBT) and in a research study (ALPNAP) we had the opportunity to study the relationship between noise exposure from road and rail traffic with a broad range of health outcomes.

METHODS

Area characteristics

Both areas of investigation, the Unterinntal and the Wipptal are part of the most important access route for heavy goods traffic over the Brenner Pass which provides the most direct link for central and northern Europe's traffic to southern Europe. The goods traffic over the Brenner has tripled within the last 25 years and the fraction of goods moved on the road has substantially increased (up to 2/3). The area consists of small towns and villages with a mix of industrial, small business and agricultural activities. The primary noise sources are motorway and rail traffic. Also important are main roads, which link the villages and provide access to the motorway. The areas differed in topography (U versus V valley), meteorology (much wind versus lot of temperature inversions), geographic orientation (north-south versus east-west) and reason for study (EHIA versus research study).

Study characteristic, sample selection and recruitment

All 3 studies were cross-sectional. In the Wipptal (BBT surveys) a phone (N=2,002) and a interview study (N=2,070) were carried out. A pooled sample was created (N=3,630) from both studies (omitting those who participated in both studies: N=442) to get more statistical power and better representation. In the Unterinntal (ALPNAP study) a nearly identical phone survey (N=1,643) was conducted. The participation at the individual level varied between studies (62, 80, 35 % respectively). The research phone study had the lowest participation. Participation at the household level was significantly higher (61 to over 80 %).The age range included was slightly broader in the Wipptal (17-85 yrs) than in the Unterinntal (25-75 yrs).

People were contacted by phone based on a stratified, random sampling strategy. The address base was stratified by the use of a Geographic information system (GIS) into areas defined by distance categories to the major traffic sources (rail, motorway, main road), leaving a common „background area" lying outside major traffic activities and an area with exposure to more than one traffic source "mixed traffic area". Households were randomly selected from these areas and replaced in case of non-participation. Apart from age selection criteria were sufficient hearing and language proficiency. Excluded were persons living less than one year at this address. Some addresses were not valid, did not have telephone or could not be reached by 3 attempts at different times of the day. While the BBT-interview survey resulted in a balanced sex ratio (983 men and 1,082 women), both phone surveys showed a clear excess of participating women (65 % and 61 %). This reflects the much higher flexibility of the interviewers in terms of appointments compared with the limited random dialing approach on the phone (3 attempts), which favored women's participation who on average spend more time at home and easier to reach.

Noise exposure assessment

Three traffic noise sources were considered in the noise exposure assessment: Motorway traffic, traffic on main roads and railway traffic. For motorway traffic the yearly average load (light and heavy vehicles) is combined with an average diurnal traffic pattern. Available traffic frequency data on main roads were supplemented with additional traffic counting. Noise emission by road traffic was calculated on an early version (BBT-study) and the later version (ALPNAP-study) of the Harmonoise source model (Jonasson 2007). In addition, micro-simulations of the traffic flow were conducted with Paramics (Quadstone®, www.paramics-online.com) to obtain optimal individual vehicle characteristics (speed and acceleration). Railway noise emission is extracted from a typical day out of several long-term noise immission measurements (up to two weeks at different seasons) at close distance to the source. Noise modeling was carried out with Bass3, which is an extended version of ISO 9613. The model includes up to four reflections and two sideway diffractions (de Greve et al. 2005, 2007). Extensive noise monitoring campaigns during summer and winter were conducted in both areas to check the validity of these simulations against the measurement results. In addition, the predicted sound pressure levels resulting from PE-modeling have been evaluated against the long-term measurements in the Inntal (van Renterghem et al. 2007).

Indicators of day, evening, night exposure and Lden were calculated for each source. Eventually, total exposure from all or from specific source combinations at several points of the building facade of the participant's home was calculated. In the present analyses Lden of the individual sources at the most exposed façade was utilized.

Air pollution exposure assessment

Annual means for NOx, NO2 and PM10 were calculated for an area 27 km (W-E) × 23 km (N-S) east of Innsbruck and seven overlapping model domains along the Wipptal (>300 km²). For these air quality assessment about 300 flow fields were calculated with the meteorological model GRAMM (Graz Mesoscale Model, Almbauer et al. 2000; Öttl et al. 2005) for each domain and sub-domain (up to 100 x 100 m2 resolution). Traffic emissions were modeled using the network emission model NEMO (Rexeis & Hausberger 2005). For each flow field a dispersion simulation with the Lagrangian particle model GRAL (Öttl et al. 2003a, b, 2007) was calculated on horizontal resolutions of 10 x 10m^2 and in the vertical on 2 m resolution. The model system uses special algorithms to account for low wind or calm conditions (Öttl et al. 2001, 2005). Each run was weighted due to its meteorological classification and frequency. Thereafter, annual, summer and winter means were calculated by post processing and weighting the numerous dispersion calculations. The NOx to NO2 conversion is calculated according to the scheme of Romberg et al. (1996). The entire model chain was developed at the Institute for Internal Combustion Engines and Thermodynamics, Technical University Graz, Austria. The model type resolves the dispersion processes close to strong sources such as busy roads. Model results can be compared with measurements from air quality monitoring stations located very close to strong sources (so called hot spots). Hence, in contrast to many other air quality models the model results are meaningful in areas with high exposure levels and where people live.

Because the model calculates the exposure resulting from specified emissions such as traffic, domestic heating etc. a residuum results when comparing simulations versus observations. This residuum or so-called background value which is the abscissa of the regression analysis is attributable to not accounted emissions or secondary aerosol formation or regional transport not accounted in these micro-scale dispersion calculations. Within ALPNAP the simulation results were compared with 7 air quality stations located in the Inn Valley. The background values within this study were height corrected according to Seinfeld & Pandis (1997). Calculated NO2 and PM10 values for each of the participant's home were assigned by GIS.

Questionnaire information

The questionnaire covered socio-demographic data, housing, satisfaction with the environment, general noise annoyance, attitudes toward transportation, interference of activities, coping with noise, occupational exposures, lifestyles, dispositions such as noise and weather sensitivity, health status, selected illnesses and medications. The phone interview took about 15-20 minutes. The longer questionnaire of the face to face interview required about 45-60 minutes.

Health information was based on doctor reported diagnoses and prescriptions. Reporting time was related to the last 12 months. Health status was assessed by a five grade Likert type question. In the analyses only three categories were used: very good, good and less than good (3+4+5 of the 5-point scale). Education was measured in 5 grades (basic, skilled labor, vocational school, A-level, University degree). The top two grades (University and A-level) were combined in the analyses.

Statistical analysis

Exposure-effect curves were calculated with extended logistic regression methods using restricted cubic spine functions to accommodate for non-linear components in the fit if appropriate (Harrell 2001). The non-parametric regression estimate and its 95 % confidence intervals are based on smoothing the binary responses and taking the logit transformation of the smoothed estimates. Adjustments for confounding differ with respect to the health outcome. However, basic adjustments were always made for age, sex, education and the most important co-factors known in literature. The analysis was carried out with R version 2.4.1 and 2.5.1 (R Development Core Team 2006) using the contributed packages “Design” and “Hmisc” from Harrell (2001).

RESULTS

Wipptal (BBT-studies)

Figures 1 and 2 show the noise-health status relationships for motorway and overall sound level. There is a clear gradient for education but also a significant trend with sound level visible. The ranking in the educational gradient differs slightly from the Inntal results: the group with higher education is not better than all other groups with some additional schooling. Figure 2 reveals an interaction with chronic illness: there is no increase in poor health status with increasing noise in people without chronic illness – but with chronic disease status in spite of less power (N=2,070). Without testing for interaction you get a zero relationship (larger group with chronic illness).

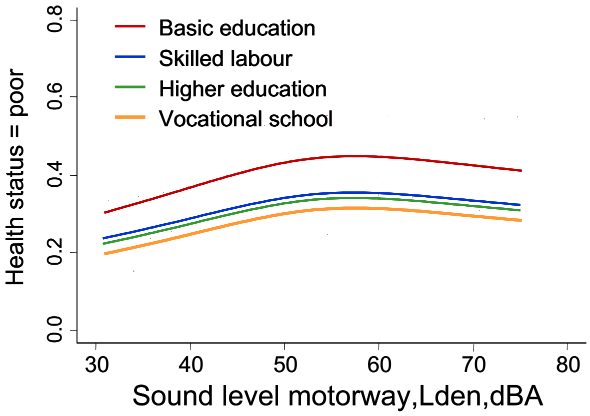

Figure 1: Exposure effect relationship for poor health status by motorway and different levels of education (left N=3,630)

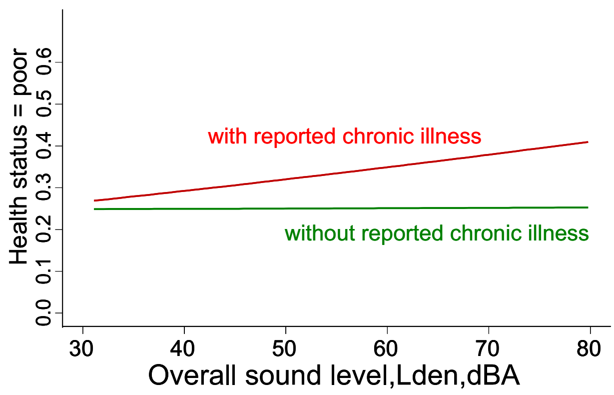

Figure 2: Exposure effect relationship for poor health status by overall sound exposure (right N=2,070) by reported chronic illness status (95 % confidence intervals omitted)

The relation between depression and combined noise exposure (road & rail) shows a stronger departure of the slope particularly for people with poor health status (Figure 3) and with persisting trauma experience (Figure 4) in the phone study.

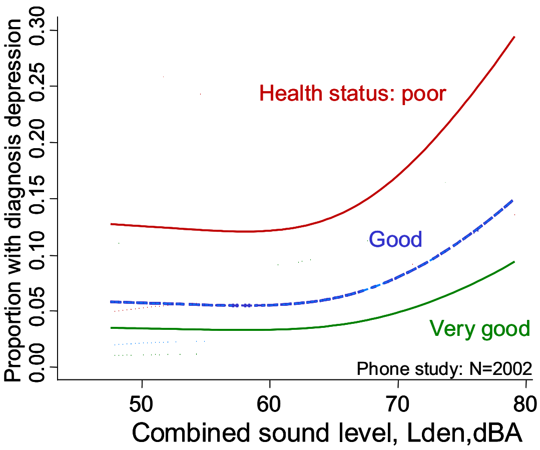

Figure 3: Exposure effect relationship: proportion with depression diagnosis related to sound level from combination of all sources by health status

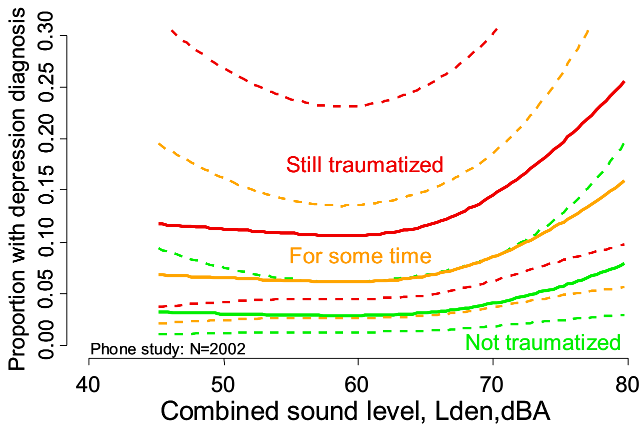

Figure 4: Exposure effect relationship: proportion with depression diagnosis related to sound level from combination of all sources by trauma status

The relation between overall sound exposure (all sources) and hypertension (Figure 5) exhibits a mixed picture: The face to face study shows a linear trend (OR=1.28 (1.03-1.58 (for 50 to 60 dBA) and reaches a plateau around 60 dBA. The phone study levels off strongly around 60 dBA (OR=1.43 (1.05-1.95 (65 to 75 dBA) and the analysis for the main valley nearly reaches significance (OR=1.14(0.98-1.31) (for 60 to 70 dBA). The non-linear relation of hypertension medication (Figure 6) with rail noise is quite strong (OR=1.63 (1.12-2.36) (for 60 to 70 dBA) while the face to face study shows no relation and the analysis for the inhabitants of the main valley is also not significant.

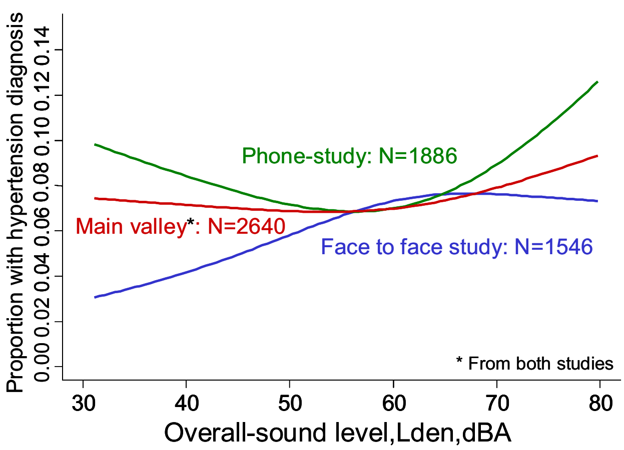

Figure 5: Exposure effect relationship: proportion with hypertension diagnosis related to overall sound level by study type and area

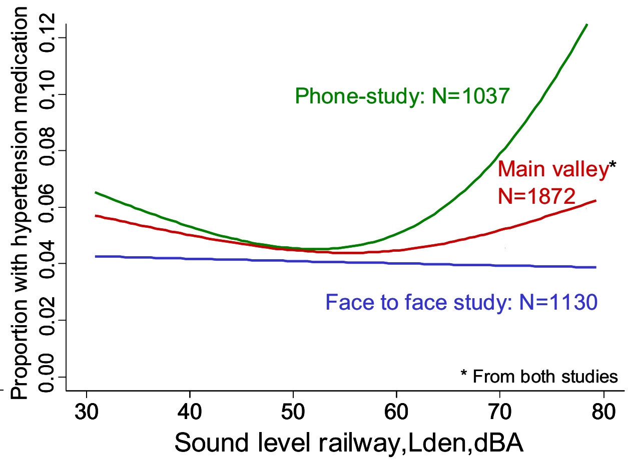

Figure 6: Exposure effect relationship: proportion with hypertension diagnosis related to overall sound level by study type and area

The same analysis conducted in the phone study by source (Figure 7) reveals a significant relation only with railway and main road but not with motorway noise. Against a reference level of 55 dBA the relative risk (OR) increases to 1.84 (1.15-2.95) for rail and 1.83 (1.17-2.86) for main road at 70 dBA. In contrast to the previous results the combined endpoint angina pectoris/myocardial infarction is significantly associated in the phone study (OR 1.70 (1.16-2.47)(for 60 to 70 dBA) and the main valley analysis (OR=1.34(1.05-1.71) with motorway noise (Figure 8) – but not in the face to face study.

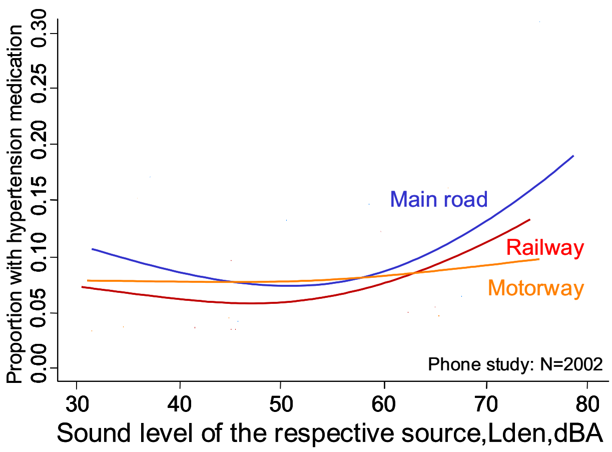

Figure 7: Exposure effect relationship: proportion with hypertension medication related to sound level by study type and area

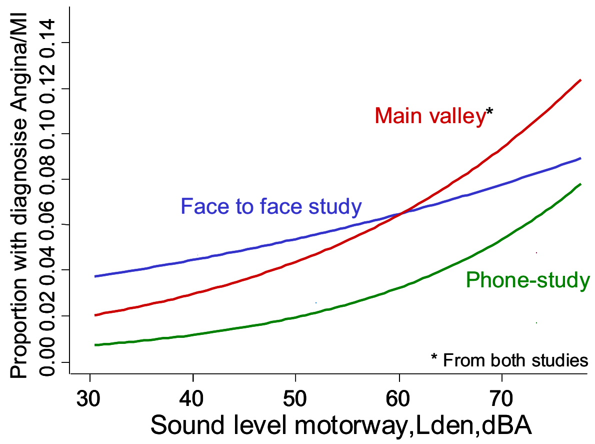

Figure 8: Exposure effect relationship: proportion with diagnosed angina/myocardial infarction related to motorway sound by study type and area

Inntal (ALPNAP-study)

The observations for overall noise (Figure 9) show a significant increase in the prevalence of persons with poorer health which is paralleled by a decrease in population prevalence with very good health when the sound level increases.

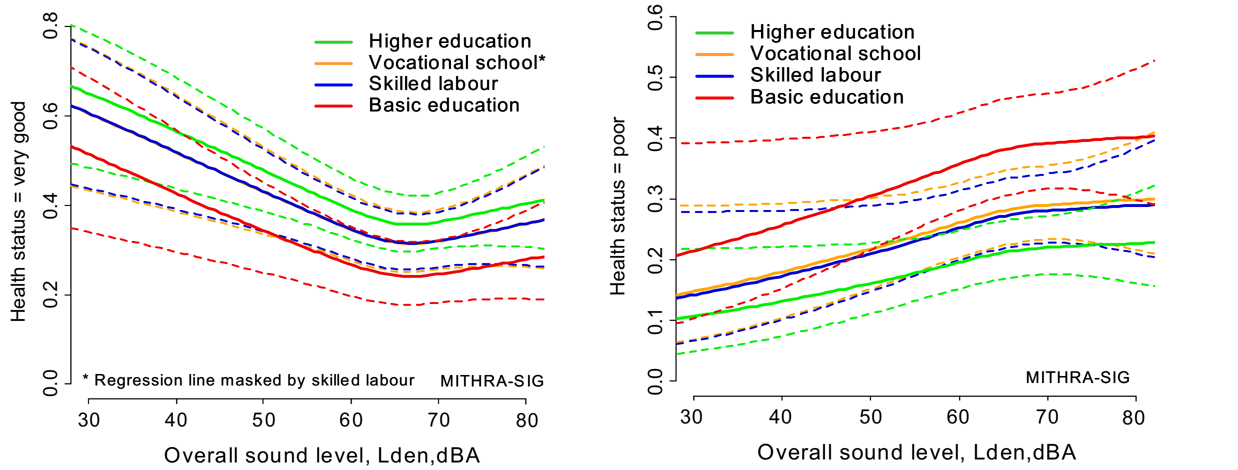

Figure 9: Proportion with very good (left) and poor (right) health status and overall sound level by educational status (MITHRA-SIG modeling)

In order to evaluate the possible effect of air pollution, a model without and with adjustment for a specific noise indicator was evaluated. The curves show a small non-significant trend for an increase in poor health with higher level of particulate pollution when noise is not adjusted for (Figure 10 left). However, when an adjustment for overall noise exposure is made, the air pollution effect disappears completely (Figure 10 right). Hence, at higher noise levels, 65 versus 45 dBA, the proportion of persons with poor health is higher, completely independent of the level of air pollution.

The analyses for depression did not reveal a direct relationship with noise indicators.

Overall, significant associations with noise exposure were seen only in people with poor health status (not shown), psychological trauma experience (Figure 11 left) or higher noise sensitivity (Figure 11 right). Noise exposure from main roads did exhibit the strongest associations (similar to the annoyance results).

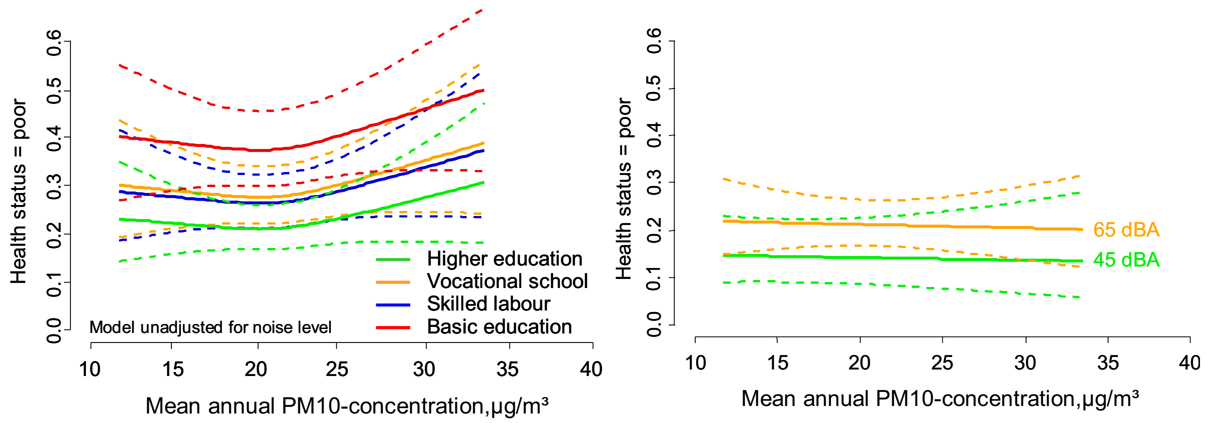

Figure 10: Proportion with poor health status by education and mean annual PM10 concentration (left) and stratified by high versus low overall noise exposure (right). PM10 modeling by TU-Graz

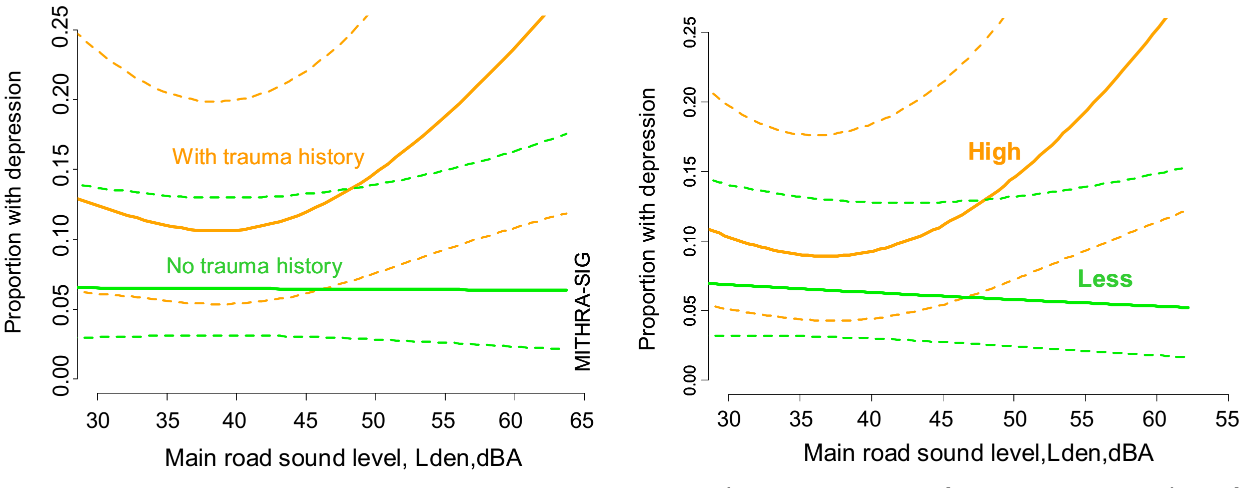

Figure 11: Proportion with depression by trauma status (left) and noise sensitivity (right) and main road sound level

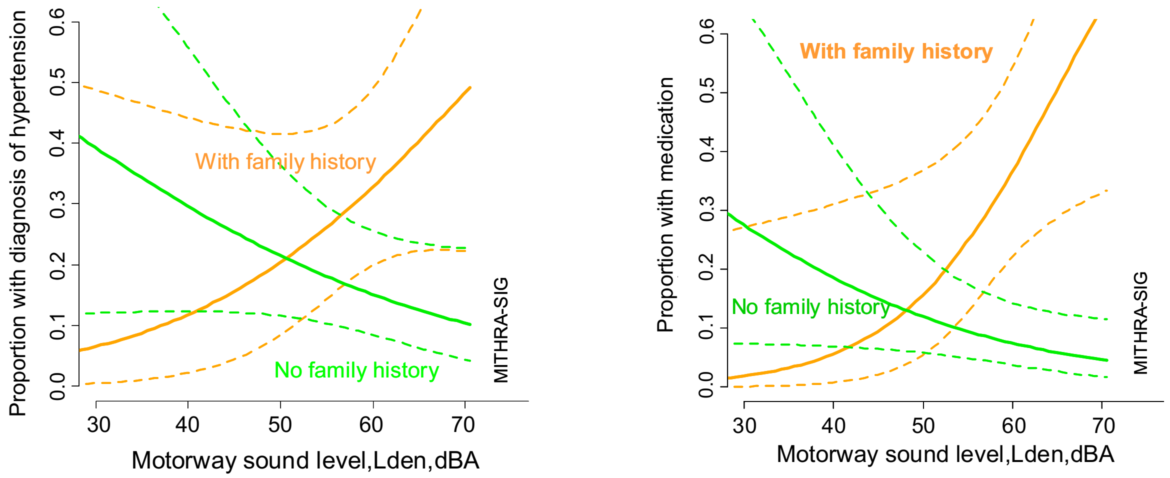

Figure 12: Proportion with hypertension diagnosis (left) and medication (right) by family history and motorway sound level

The relationship of hypertension with motorway noise exhibits significance only when potential moderators are considered (Figure 12).

DISCUSSION

For a broad range of possible health outcomes significant (mostly non-linear) relationships were observed in three larger studies in alpine valleys with continuously increasing exposure to mixed traffic sources (rail, main road, motorway) over the last 25 years. The sources often run in parallel and therefore the noise exposure can be characterized as combined exposure – mostly a combination of two or even three sources. The sources can be perceived quite well by the receptors, since the sources have distinct noise characteristics and time pattern and the existing background levels are low, particularly during night (Heimann et al. 2007). Furthermore, many noise abatement measures have been implemented over the last years – but the implementation was not coordinated across areas. Hence in the BBT study areas were significant differences between the northern and southern area regarding the implementation of counter-measures. In an earlier communication (Lercher & Botteldooren 2006) we have reported different relationships for the noise-health relationships in the northern and southern part. It is, therefore, not surprising that the relations of the various health outcomes with the calculated noise exposure do not always agree in the summary analyses which reflect only the average result over the full area or the two studies. However, some results are consistent across analyses:

The relation of health status with noise exposure is valid across educational levels adjusted for age, sex, BMI, noise & weather sensitivity, trauma and emotional coping. Within the range of the observed levels air pollution in the studied areas did not make a significant contribution when noise exposure indicators were introduced in the adjusted models. All tests for interaction with noise failed also to reach significance. This is in line with the hitherto only peer reviewed study which has evaluated air pollution in addition to noise with respect to hypertension (de Kluizenaar et al. 2007). This observation is further strengthened by similar experience with other health endpoints (health status, depression, heart disease) in this study.

Furthermore, the strong importance of modifying factors receives further support. The analyses have repeatedly shown moderation on the noise-health relation across studies and areas of health status, noise sensitivity, trauma experience. Further effects on the observed noise-health relationship were seen by study type (phone vs face to face) and area layout with respect to the traffic sources in terms of exposure combinations. This observation was more visible in the BBT-studies, where more variation in exposure-mix occurred across the studied area than in the ALPNAP-study, where exposure was more homogeneous along the valley due to a more uniform topographic layout and implementation of noise abatement measures. Eventually, these findings support the adoption of a contextual approach in risk assessment and prevention (Staples 1996; Lercher 1996, 1998, 2002, 2007) and follow up on results reported from earlier surveys in these valleys (Lercher & Kofler 1993, 1996; Lercher et al. 2000).

CONCLUSION

In spite of the implementation of noise control measures in the study areas significant relations with exposure to single and combined noise sources could be observed. Strong moderation components often lead to the typical large spread and prevent the detection of significant noise-health relationships when not considered in design and analysis. The additional consideration of air pollution did not weaken the noise-health relations. Health status is a very accurate predictor of future mortality and morbidity and should be further utilized in noise studies, since very stable relations with noise exposure could be established in these investigations.

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REFERENCES

Almbauer RA, Öttl D, Bacher M, Sturm PJ (2000). Simulation of the air quality during a field study for the city of Graz. Atmos Environ 34: 4581-4594.

Babisch W (2006). Transportation noise and cardiovascular risk: Updated review and synthesis of epidemiological studies indicate that the evidence has increased. Noise & Health 8: 1-29.

Babisch W (2008). Road traffic noise and cardiovascular risk. Noise & Health 10: 27-33.

Babisch W, Beule B, Schust M, Kersten N, Ising H (2005). Traffic noise and risk of myocardial infarction. Epidemiology 16: 33-40.

Belojevic G, Saric-Tanaskovic M (2002). Prevalence of arterial hypertension and myocardial infarction in relation to subjective ratings of traffic noise exposure. Noise & Health 4(16): 33-37.

Bluhm GL, Berglind N, Nordling E, Rosenlund M (2007). Road traffic noise and hypertension. Occup Environ Med 64: 122-126.

Botteldooren D, Lercher P (2004). Soft-computing base analyses of the relationship between annoyance and coping with noise and odor. J Acoust Soc Am 115: 2974-2985.

de Greve B, de Muer T, Botteldooren D (2005). Outdoor beam tracing over undulating terrain. In:Proceedings of Forum Acusticum 2005, Budapest, Hungary.

de Greve B, van Renterghem T, Botteldooren D (2007). Outdoor sound propagation in mountainous areas: comparison of reference and engineering models. In: Proceedings of ICA on CD-ROM. Madrid, Spain.

de Kluizenaar Y, Gansevoort RT, Miedema HME, de Jong PE (2007). Hypertension and road traffic noise exposure. J Occup Environ Med 49: 484-492.

Harrell FE Jr (2001). Regression modeling strategies. New York: Springer.

Herbold M, Hense H-W, Keil U (1989). Effects of road traffic noise on prevalence of hypertension in men: results of the Lübeck blood pressure study. Soz Praeventivmed 34: 19-23.

Ibald-Mulli A, Stieber J, Wichmann HE, Koenig W, Peters A (2001). Effects of air pollution on blood pressure: a population-based approach. Am J Public Health 91: 571-577.

Ising H, Lange-Asschenfeldt H, Eilts M (2005). Bronchitis in children exposed to road traffic noise and exhaust fumes. Somnologie 9: 105-110.

Jarup L, Babisch W, Houthuijs D, Pershagen G, Katsouyanni K, Cadum E, Dudley M, Savigny P, Seiffert I, Swart W, Breugelmans O, Bluhm G, Selander J, Charalampidis AS, Dimakopoulou K, Sourtzi P, Velonakis M, Vigna-Taglianti F (2007). Hypertension and exposure to noise near airports - the HYENA study. Environ Health Perspect 116: 329-333.

Job RSF (1988). Community response to noise: A review of factors influencing the relationship between noise exposure and reaction. J Acoust Soc Am 83: 991-1001.

Jonasson HG (2007). Acoustical source modeling of road vehicles. Acta Acust Acust 93: 174-183.

Lercher P (1996). Environmental noise and health: An integrated research perspective. Environ Int 22: 117-129.

Lercher P (1998). Context and coping as moderators of potential health effects in noise-exposed persons. In: Prasher D, Luxon L (eds.): Advances in noise series, Vol. 1: Biological effects (pp 328-335). London: Whurr.

Lercher P (2002). The association between transportation noise and hypertension in an alpine area: A comparison of two approaches. Epidemiology 13: S89.

Lercher P (2007). Environmental noise: A contextual public health perspective. In: Luxon L, Prasher D (eds.): Noise and its effects (pp 345-377). London: Wiley.

Lercher P, Botteldooren D (2006). General and/or local assessment of the impact of transportation noise in environmental health impact studies ? In: Proceedings of Euronoise 2006, CD-ROM edition. Tampere: European Acoustics Association.

Lercher P, Kofler W (1993). Adaptive behavior to road traffic noise: Blood pressure and cholesterol. In: Vallet M (ed.). Noise as a public health problem, Vol. 2 (pp 465-468). Nice: Institut National de Recherche sur les Transports et leur Sécurité.

Lercher P, Kofler WW (1996). Behavioral and health responses associated with road traffic noise exposure along alpine through-traffic routes. Sci Total Environ 189/190: 85-89.

Lercher P, Widmann U, Kofler WW (2000). Transportation noise and blood pressure: the importance of modifying factors. In: Casserau D (ed.): Proceedings of InterNoise 2000, Vol. 4 (pp 2302-2307). Nice: Sociéte Francaise d'Acoustique.

Öttl D, Almbauer R, Sturm PJ (2001). A new method to estimate diffusion in low wind, stable conditions. J Appl Meteorol 40: 259-268.

Öttl D, Sturm P, Pretterhofer G, Bacher M, Rodler J, Almbauer R (2003a). Lagrangian dispersion modeling of vehicular emissions from a highway in complex terrain. J Air Waste Managem Assoc 53: 1233-1240.

Öttl D, Almbauer RA, Sturm PJ, Pretterhofer G (2003b). Dispersion modelling of air pollution caused by road traffic using a Markov Chain - Monte Carlo model. Stochastic Environ Res Risk Assess 17: 58-75.

Öttl D, Goulart A, Degrazia G, Anfossi (2005). A new hypothesis on meandering atmospheric flows in low wind speed conditions. Atmos Environ 39: 1739-1748.

Öttl D, Sturm P, Anfossi D, Trini Castelli S, Lercher P, Tinarelli G, Pittini T (2007). Lagrangian particle model simulation to assess air quality along the Brenner transit corridor through the Alps; Air Pollution Modelling and its Applications XVIII (pp 689-697). New York: Elsevier. (Developments in environmental science, Vol. 6).

R Development Core Team (2006). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. http://www.R-project.org.

Rexeis M, Hausberger S (2005). Calculation of vehicle emissions in road networks with the model "NEMO". In: Conference Proceedings of the 14th Symposium on Transport and Air Pollution 1-3 June 2005, Graz (pp 118-127).

Romberg E, Bösinger R, Lohmeyer A, Ruhnke R, Röth E (1996): NO-NO2-Umwandlung für die Anwendung bei Immissionsprognosen für Kfz-Abgase. Gefahrstoffe - Reinhaltung der Luft 56: 215-218.

Seinfeld JH, Pandis SN (1997). Atmospheric chemistry and physics: From air pollution to climate change. New York: Wiley-Interscience.

Staples SL (1996). Human response to environmental noise. Psychological research and public policy. Am Psychologist 51: 143-150.

van Renterghem T, Botteldooren D, Lercher P (2007). Comparison of measurements and predictions of sound propagation in a valley-slope configuration in an inhomogeneous atmosphere. J Acoust Soc Am 121: 2522-2533.

von Eiff AW, Neus H (1980). Verkehrslärm und Hypertonierisiko. 1. Mitt. Münch Med Wschr 122: 894-896.

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