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DESIGN OF A FIELD STUDY ON THE EFFECTS OF RAILWAY NOISE AND ROAD TRAFFIC NOISE

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1. INTRODUCTION

People complain most frequently about noise which interferes with activities during the state awake but they regard noise as most deleterious if it causes or prolongs the state of consciousness either by preventing sleep onset or by premature awakenings.

Dependent on the duration of unvoluntary periods awake and on the difficulty to fall asleep (or to return to sleep) these states are recalled in the morning, they determine subjective sleep quality, mood, actual well-being and performance. In the long run, the resulting psychosocial stress may contribute into the genesis of chronic health disorders, particularly of cardiovascular diseases.

Most studies on noise-induced sleep disturbances were carried out in the laboratory and a very few were executed in the field. Numerous various and even obscure noises were studied but the main interest concerned traffic noise. Among the latter aircraft noise was in the beginning almost exclusively studied, but during the last few years, the interest turned more and more to road traffic noise. Noises from railways, however, were rather neglected.

Summarizing the various papers it is evident that at least two acoustic situations must be considered:

- continuous noise as produced by high density road traffic where the maximum levels vary in a rather limited range and do not exceed the equivalent sound pressure level by more than 10 dBA.
- intermittent noise as produced by low density road traffic, by air and by railway traffic.

Where the equivalent sound pressure level is a suitable predictor for the effects of high density road traffic noise on sleep, the effects of intermittent noises are better predicted by the maximum levels, the num-

ber of noises etc.. Accordingly, special measures were developed for aircraft noise. Their predictive power, however, seem to be questionable regarding the almost countless number of noise indices especially developed for this purpose.

Though the acoustic stress from railway traffic is clearly intermittent, no special indices are used for this type of noise and the equivalent sound pressure level is calculated instead. Several social surveys were directed to the comparison of noises produced by road and by railway traffic. But these studies were mainly focussed to daytime noise, mainly to noise-induced annoyance and only a very few questions concerned sleep.

Overall, these studies revealed an advantage of railway noise, meaning that the same rating levels are less annoying in areas with railway traffic than in areas where road traffic noises dominate. In the Federal Republic of Germany, the maximum admissible limit is 5 dBA higher for noises from railways than for noises from road traffic. However, this advantage is increasingly debated within the last years. Sleep researchers, in particular, argue that the advantage for nighttime bases on questions answered during the day and not on sleep recordings and they are convinced that the equivalent sound pressure level is not suitable for the assessment of railway noise.

A definite statement presupposes extended field studies where numerous subjects exposed to largely varying sound pressure levels are observed during several nights each and where acoustical, psychosocial, and physiological parameters are carefully regarded. Therefore, researchers experienced in these 3 disciplines founded a team to scrutinize the assumed advantage of railway noise. These are

- acousticians (Möhler & Partner, Obermeyer GmbH, both in Munich)
- psychologists (ECoR/Bochum, Schümer-Kohrs/Hagen)
- physiologists (Institute for Occupational Physiology/Dortmund)

2. AIMS OF THE STUDY, HYPOTHESES

The aim of the project is to scrutinize the advantage of railway noise or to compare the extents and the frequencies of sleep disturbances related to railway traffic and to road traffic. Among others, the following hypotheses are proofed:

- assuming the same rating levels, railway noises disturb less than road traffic noises,
- sleep disturbances increase with maximum levels, durations and numbers of railway noises,
- sleep disburbances are more frequent in the early morning than during the beginning of the night,
- sleep disturbances increase with age.

3. METHODS AND MATERIAL

Independent, dependent and intervening variables
According to the hypotheses three types of variables were defined:
The independent acoustic situation are described by
- the dominant type of noise (railway, road),
- the number of noise events,
- the maximum and the equivalent sound pressure levels.

Dependent variables are
- body movements (primary reactions),
- subjective assessment of sleep quality (secondary reactions),
- sensumotor performance (after-effects).

Among others, the main intervening variables are
- age,
- gender,
- climate,
- residential time,
- noise sensitivity.

Study design
Regarding railway noise (T) 4 areas were determined where ever 2 areas are exposed to high resp. to low traffic density (60-100 resp. 30-60 passages per night) and where the amount of goods trains varies between 50 and 80 %. Based on their rating levels during the night 4 areas with the same acoustical load were determined at roads.

frequencies of train passages per night	Train	Road
30-60 (low density)	$T_{low}1$ & $T_{low}2$	$R_{low}1$ & $R_{low}2$
60-100 (high density)	$T_{high}1$ & $T_{high}2$	$R_{high}1$ & $R_{high}2$

Due to varying distances between the noise sources (railways, roads) and the locations of the houses and/or the locations of the sleeping rooms within the houses (front, rear) the maximum and rating levels vary accordingly in a large range within each area which is essential for the determination of dose-response-relations and for the assessment of the supposed benefit for railway noise. As road traffic almost ever occurs in areas where railway noises dominate, these areas are compared with those, where noise from road traffic (R) dominates but where additionally some railway traffic occurs.

Size of the sample, durations of the recordings
The usual situation in the field is not well controlled. The acoustic situaions vary hourly, nightly, weekly and monthly and sleep behavior is influenced by numerous exogenic and endogenic factors as well. So, valid results presuppose sufficiently large samples and sufficiently long observation periods. Therefore, in each of the 8 areas 50 persons shall be observed during 10 nights each.

Criteria for the determination of the 8 areas

Architectural criteria
- predominantly residential area,
- homogenuous buildings (basement and ≤3 floors),
- condominiums and rented flats, own and rented houses,
- not near railway stations,

Traffic criteria
- for each source 2 areas with high/low traffic density,
- extensions of roads/railway tracks are neither planned nor recently executed,
- no other dominant noise sources,
- mixed goods and passenger transports,
- both road and railway noise are present but one source dominates clearly,
- *Railway traffic:* no other track-dependent transport,
- *Road traffic:* continuously flowing traffic, no red-light or train crossings

Acoustic criteria
- comparability of areas according to the L_{eq} during the night,
- sound pressure levels vary according to the distance between L_{eq} = 50 and 75 dBA.

Subjects
- 18 to 70 years,
- equal number of men and woman,
- residential time at least 12 months,
- no chronic diseases usually accompanied with sleep disturbances,
- no regular intake of remedies which influence sleep,
- no significant hearing loss,
- no shiftwork.

Sleep disturbances

In the present study primary effects of noise on sleep are recorded by means of actigrams, after-effects are registered by means of short questionnaires and by reaction time tests.

Movements, actigrams. Sleep depth including the state awake is reliably assessed by the electroencephalogram (EEG). However, due to the need of personnel for fixation and removal of electrodes, for maintainance and calibration of the apparatus as well as for evaluation, due to the costs of technical equipment and the time required for recordings and evaluation this method cannot be applied in extended field studies.

Though the EEG is often regarded as the only valid indicator for sleep, there are some serious disadvantages. On the one hand, its registration induces a laboratory situation thus sensitizing the subjects and increasing their alertness and readiness to awake. On the other hand awakenings are not necessarily associated with consciousness. Therefore, small actimeters which are fixed to the wrist and which scarcely impair sleep are used to record body movements. This method was recently applied in the most extended field study on the effects of aircraft noise on sleep at four airports in the UK.

Though awakenings are usually accompanied by body movements, the reverse is not true. The thresholds for noise-induced body movements are much lower than for awakenings, but their density and durations are greater during the state awake. So, if these parameters are sufficiently regarded they may reliably indicate awakenings. To achieve this, requires a statistical calibration and the registration of the EEG of as many subjects as possible during one night simultaneously with the actigram.

The low specifity found in other studies is probably related to the low sample rates for movements which were set to one epoch (30 s). The binary code only indicates that at least 1 movement had taken place which might have endured 1-30 s. In the present study, movements are registered every second which allows the determination of the densities and the durations of movements.

Questionnaires. For the people concerned individually experienced sleep quality is probably most decisive and this is registered every morning using short questionnaires. The items comprize tension, tiredness, bedtime, subjective sleep quality, intermittent awakenings, and position of the windows (open, closed). A questionnaire in the evening comprizes actual tension and tiredness, physical, mental and emotional stress, tension and tiredness during the day, intake of alcohol or remedies.

Sensumotor performance. Ever 25 subjects complete a sensumotor performance tests every evening and every morning during either the first or the second week. The test instrument is basically a conventional 4-choice reaction time test, where one out of 4 LEDs arranged in a square light up randomly. After one out of four keys below the LEDs is pressed the next signal occurs after a defined time. After 3 minutes the

admissible response time is shortened if the preceding 3 answers are correct and prolonged if at least 1 answer is false. The total test procedure endures 5 minutes and the test is completed every evening and every morning.

Procedure

Prior to the sleep recordings during 2 times 5 nights, the daily estimation of experienced sleep quality, and actual well-being appropriate areas were carefully selected and a representative sample of the residents were interviewed.

Determination of suitable areas. First, the acousticians evaluated the traffic density maps for railway and for road traffic in Northrhein Westfalia. Based on these data they estimated the equivalent sound pressure levels and determined areas which are similar with respect to buildings and the number of residents living in these areas. Acoustic measurements were then completed during several nights. The final decision to accept an area for the study was made after inspection by the 3 teams (acousticians, psychologists, physiologists).

Social survey: The psychologists constructed an extended questionnaire, which comprizes a large number of items such as personal data (age, sex, education), actual health state, occupation (profession, working hours), items concerning housing conditions (size, sleeping rooms, ownership, family size), residental area (facilities, satisfaction). The most extended part concerned environmental noise (sensitivity, annoyance, attitudes, noise abatement) and sleeping habits (bedtimes, position of windows etc.) The questions are asked by well trained interviewers. At the end of the interview the subjects are asked whether they are interested to participate in the sleep recording phase.

Sleep recordings: Those subjects interested to participate in the recording phase are called up to fix a date where a coworker of the physiological team explains the procedure in detail and demonstrates the equipment (actimeter, questionnaires, reaction time test, EEG-equipment).

During the recording phase of 2 times 5 nights the actigrams are registered during each night, the questionnaires are completed every evening and every morning. Performance tests are executed during one week, again every evening and morning. Recordings of the EEG are completed during one night only but of as many subjects as possible. The instruments are distributed every evening and collected the next morning. The data of the actimeters and of the performance tests are daily transmitted and secured.

The acoustic data are continuously recorded during each night at the dominant noise source (railway track, road). To assess the damping effects of walls and windows indoor noise in the sleeping rooms and outdoor levels in front of the respective house are recorded in one night.

At present, 2 out of 8 areas are studied. 2 areas will be investigated this autumn. The 4 remaining areas are studied in 1997, again ever 2 in spring and in autumn.