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CHARACTERIZATION OF COMPLEX TRANSPORTATION NOISE WITH PSYCHOACOUSTICAL PARAMETERS

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1. INTRODUCTION

In the course of an interdisciplinary project on noise immissions in residential areas, the interaction and the effects of immitting noises on the daily life of inhabitants has been analysed in a kind of microscopic approach in two residential quarters of Oldenburg (approx. 150.000 inhabitants).
One motivation for the study is the following reason: In field investigations it has been stated that noise related level parameters are able only to explain about a third of the total variance of the reported annoyance that is referred to the noise immissions [1].
Physicists specialised in acoustics and psychoacoustics and sociologists (socioacousticiens) are involved in the project whose character is exploratory. A number of methods are developed and applied to the various tasks and in the course of the project the methods are permanently under discussion and improved if necessary [2].
This paper shows how the acoustic landscape in the quarters is measured and assessed with objective and subjective methods. The objective and subjective description of the immitting noises can be regarded as an objective and subjective characterization of the acoustic stimulus that causes a variety of effects in the daily life of the inhabitants.

2. DESCRIPTION AND CHARACTERISATION OF NOISE IMMISSIONS

The description of the noise immissions is performed by a combination of objective and subjective methods. Subjective assessments are carried out in a nearly laboratory-like manner by a group of test persons. At the same time the immissions at the places where the subjective judgements take place are simultaneously recorded by a single microphone and by an

artificial head. The artificial head recordings are to be used in a later phase of the project to perform retests in the laboratory.
These assessments of only short time intervals are completed by long-term measurements which last for seven days.

3. SOUND RECORDING AND DETERMINATION OF OBJECTIVE ACOUSTICAL AND PSYCHOACOUSTICAL PARAMETERS

During the assessment intervals noises are recorded by a 1/2" condenser microphone and an artificial head on a DAT-tapes The recordings are transferred to a hard disk of a computer and the following intensity related parameters are calculated from consecutive 100 ms frames of the stored signal: the unweighted level in dB, the A, B and C weighted levels, the loudness in soneG and phonG. Further more quality oriented psychoacoustical parameters are determined: sharpness, roughness and fluctuation strength [3]. Sharpness after Aures [4] is calculated from the specific loudness distributions from the standardised loudness calculation [DIN 45631]]. In distinction to von Bismarck's proposal [6] who modelled sharpness only as the first moment of the correctly weighted specific loudness distribution the sharpness Aures [4] additionally takes into account the loudness dependency of the sharpness. Roughness is calculated with an optimised roughness model [7] that has originally been proposed by Aures [5]. Nicolas Chouard and Ernst Kabot coded the algorithm for the fluctuation strength [3]. All psychoacoustical parameters are calculated every 100 ms, so that a 1-min-interval which is normally used for subjective assessments requires 600 values for each parameter processed.

4. CORRELATION AMONG OBJECTIVE PARAMETERS

Crosscorrelation between all kind of levels and psychoacoustic parameters of each assessment interval are calculated to check which independent parameters are useful for the description of the noises.
In this paper the results of the correlation calculations will be given for an assessment session during which nine different 1-min-time-intervals are assessed by ten test persons. They are standing at the side of a busy street near a protected railway line cross. The nine 1-min-Leq-values of the assessment intervals range from 68 to 80 dBA.
As the A-weighted sound pressure level is the accepted international compromise for noise measurements the correlation factors are discussed with regard to the dBA-values (see table 1)
It is not surprising that the correlation coefficients between the differently weighted sound pressure levels are highest between the A- and B-

weighted levels and worst between the A-weighted and the unweighted level.

As an important result it turns out that the correlation coefficients between the A-weighted level and the loudness in soneG and phonG are very high and that the coefficients for the logarithmic loudness in phonG is still slightly higher than the coefficients for the ratio scaled loudness in soneG. Thus the A-weighted sound pressure level and the loudness in phonG and soneG are equivalent for the noise intervals investigated.

As the sharpness calculation after Aures [5] considers the contribution of the loudness to the sharpness sensation rather high correlation between the dBA-level and the sharpness is obtained. If one is interested in independent noise descriptors it is recommended to use the sharpness as proposed by von Bismarck [6].

	Crosscorrelation coefficients between L/dBA and							
Noise number	L/dB(lin)	L/dBB	L/dBC	N/soneG	N/phonG	S/acum	R/asper	F/vacil
2	0,74	**0,97**	0,86	**0,99**	**1,00**	0,87	0,15	-0,18
3	0,82	0,97	**0,89**	**0,95**	1,00	0,87	0,01	-0,01
4	0,52	**0,76**	0,54	0,97	0,98	0,68	0.06	-0,42
5	0,74	0,93	0,78	0,97	0,99	0,85	0,05	-0,11
6	0,30	0,88	0,57	0,98	0,98	**0,87**	**0,37**	**0,01**
7	0,72	0,90	0,76	0,98	0,99	0,85	0,19	-0,35
8	0,63	0,94	0,77	0,98	0,99	0,77	**0,00**	**-0,46**
9	**0,11**	0,76	**0,28**	0,87	**0,97**	0,84	-0,03	-0,32
10	**0,84**	0,96	0,85	0,95	0,98	**0,91**	0,15	-0,25

Table 1: Crosscorrelation coefficients between the A-weighted sound pressure level L/dBA and further differently weighted levels [L/dB(lin), L/dBB, L/dBC] as well as psychoacoustical parameters [loudness N/soneG, loudness N/phonG, sharpness after Aures S/acum, roughness R/asper, fluctuation strength F/vacil] for the different noise intervals. The parameters are calculated every 100 ms; so about 600 values per parameter belong to each noise interval. Bold numbers indicate minimum or maximum cofficients within a column.

Normally the roughness is not correlated with the intensity entities as well as the fluctuation strength, which is quite reasonable. Significant crosscorrelation coefficients obviously appear only by accident in the last two columns.

5. PARAMETERS FOR NOISE CHARACTERIZATION

Statistical entities as the L_x (the level which is exceeded in x% of the time considered) are chosen besides the Leq as possible indicators to characterize acoustical and psychoacoustical properties of the 1-min-noise-intervals.

Four different x-values are selected: 1%, 5%, 50% and 95%, where the first two denote peak or very high parameter values, the third is the median and the last entity gives information about the background. These statistical entities are derived from the distributions of the parameters for each noise interval seperately. In the case of levels the difference between the 5%- and the 95%-value is taken as a measure for the dynamic range within the interval. For ratio-scaled parameters as loudness in sone, sharpness, roughness and fluctuation strength the ratio between the 5%- and the 95%-value is used for dynamic information.
As can be expected from the correlation calculus in table 1 the level loudness and sharpness indicators are highly correlated. A typical coefficient is higher than 0,95. No correlation can be found for the relation between the intensity entities and the roughness and fluctuation strength.
The indicators chosen now have to be correlated with subjective assessments in order to figure out which indicator is related to the subjective assessments of the noises.

6. CATEGORICAL SUBJECTIVE NOISE ASSESSMENTS

Subjective assessments of the acoustic environment in the quarters are performed by a team of acoustic experts. The assessments allow a human related subjective characterization of the acoustic situation in the quarters in addition to objective noise measurements.
Three different properties of the sounds have to be assessed: loudness, pleasantness and attention attractiveness. During a time interval of 1 min the assessing persons are asked to concentrate on the noise and to give overall assessments after the end of the interval. They are also asked to write down what is going through their mind in order to obtain additional information about their assessment criteria. The experimenter acoustically announces the begin and the end of the assessment interval.
The noise ratings are made with the aid of three categorical scales because categorical rating is the most common way of judgement in daily life. And it is planned to involve also residents of the quarter into these assessments. The categorical loudness scale is a unipolar scale with the categories *not, slightly, medium rather* and *very loud* which are supposed to be equally distant on an interval scale [8]. The two scales about the pleasantness and the attention attraction are bipolar category scales. All scales can be used in analog manner which means that every position on the 12 cm long scale can be used for an answer. In former experiments it has turned out that such a combination of categorically divided scales with the possibility of giving an analog answer is quite appropriate for such kind of assessments [9].

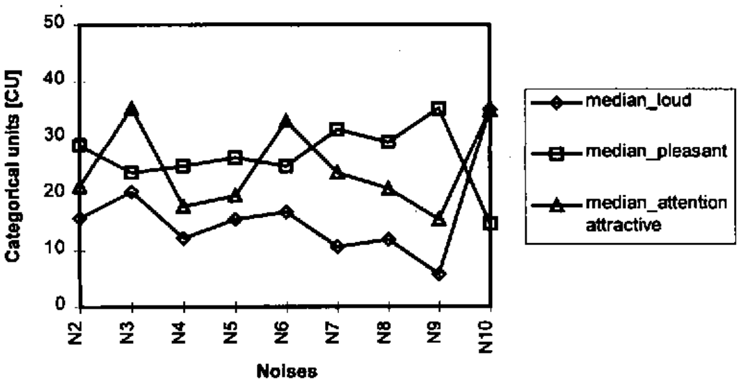

Fig.1: Individual categorical judgements of 10 test persons and their median on nine different time intervals lasting for 1 minute each. Categorical assessments are given on the loudness, pleasantness and attention attractiveness. Any position on the category scales can be used to answer.

The assessment procedure in the field is very similar to a laboratory experiment where the subjects are also asked to concentrate on the noises and to perform specific tasks related to them. This is different to the situation in daily life where noise is not the usual focus of attention unless it is disturbing by which means ever. Of course there are some important exceptions: listening to a concert or listening to all kinds of verbal or musical communication.

Results are given in Fig. 1 where the medians of the categorical loudness, pleasantness and attention attractiveness are plotted for 9 assessment intervals of 1 min each. The correlation coefficients between the categorical loudness and pleasantness equals -0,95, between loudness and attention attractiveness 0,77 and between pleasantness and attention attractiveness -0,72.

It turns out that the pleasantness assessment is mainly just the inverse of the categorical loudness rating and that the attention attractiveness assessment exhibits a certain relation to the loudness judgement. But their is no strong linearity between these two entities.

7. COMPARISON BETWEEN OBJECTIVE PARAMETERS AND SUBJECTIVE ASSESSMENTS

The medians of the loudness judgements in the field correlate highly with the 1 min Leq (r = 0,95). Approximately this hold also for the relation to the other intensity indicators. The correlation between the pleasantness and the Leq yields a coefficient of -0,91. The correlation between the attention attractiveness and the Leq (r = 0,65) is only significant at a 5% level. No significant dependency of the subjective data on the roughness and fluctuation strength has been found in this set of assessments. There is not yet an explanation for the attention attractiveness.

8. CONCLUSIONS

In an interdisciplinary study the characterization of noises with psychoacoustical parameters has been investigated in order to look for parameters which might be more suited to account for the subjective effects of noise. A correlation analysis among the objective parameters shows that sound intensity related entities as differently weighted levels and loudness measures are highly correlated. In the nine 1 min long time noise intervals it is by possilble to substitute the the A-weighted levels by the loudness measures and vice versa. Subjective loudness, pleasantness and attention attractiveness assessments exhibit a clear interdependency and show a relationship with objective intensity indicators. In the set of noise situation investigated no relation between subjective ratings and roughness and fluctuation strength can be observed.

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