Multidimensional scaling of road and railway noise in a 5.1 surround situation

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Introduction

The effect of combined road and railway noise on the listener is one of the topics of the German project *Leiser Verkehr*. Currently a joint study is performed by three laboratories (IfADo, Dortmund; IUG, Eichstätt; SASS, Essen) to find out whether the combination of these noises has specific effects on the listener or not. Within the context of this project two experiments were performed in our laboratory to clarify methodological issues related to the establishment of a representative catalogue of traffic sounds. Previous data based on car interior noise showed that the perception of these noises is primarily related to four factors: pleasantness, power, timbre and impulsiveness [1]. As a working hypothesis for the present study it is assumed that (exterior) road and railway noise may be classified in a similar way. Taking this assumption as a starting point the major objective of the study is the development of a valid strategy for the psychometric classification of traffic sounds**.** Two methods are compared to each other. Method 1 (experiment 1) has the advantage that more sounds can be presented to the subject during an experimental session as compared to method 2 (experiment 2). On the other hand data gained with method 2 may be more specific and reliable as subjects are allowed to better concentrate on the various perceptual aspects of traffic sounds.

Experiment 1

Experimental noises

Road and railway noises (duration: three minutes) were varied in their LAeq from 40 - 82 dB in steps of 6 dB. Figure 1 shows the stereo time-level plot of the two noises.

Procedure

The presentation of the sounds and the input of responses were controlled by a computer in a single-subject situation. (N= 29 normal hearing subjects, males: N=13, females: N=16; mean age: 28,3 years; standard deviation: 9,9 years). The task of the subjects was to scale six attributes using the method of categorical subdivision [2]: pleasant, annoying, loud, dynamic, high-pitched, impulsive. At the beginning of the experiment six different (artificial) sounds were presented to the subject to exemplify the meaning of each attribute. For instance, the meaning of the attribute *impulsive* was demonstrated by a random series of short pink noise pulses. To avoid possible carry over time effects the sounds were presented in a random order having a different order of presentation for each individual subject. Following a sound all attributes were scaled one after another, then the next sound was presented, etc.

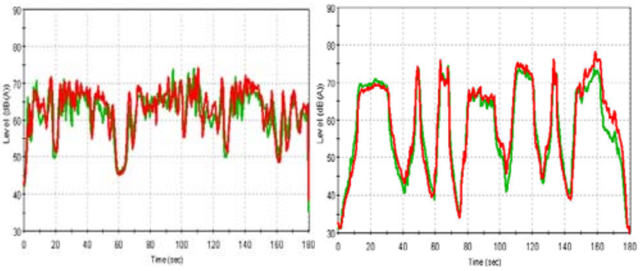

Figure 1: Stereo-level plot of the road (left) and the rail noise (right). LAeq of both noises: 64dB.

Listening conditions

Figure 2 shows the loudspeaker arrangement according to ITU-R BS.775-1 [3] and the position of the subject (reference point). According to ITU-R BS.1116-1 [4] the recommended area of listening is defined as a circle with a radius of 0,7 m around the reference point. The distance between the position of the subject and the directional loudspeakers was 2m. Relative to size and reverberation the room was designed such as to fulfil the specifications of ITU-R BS.1116-1. For the directional presentation of the sounds Genelec 1030A loudspeakers were used.

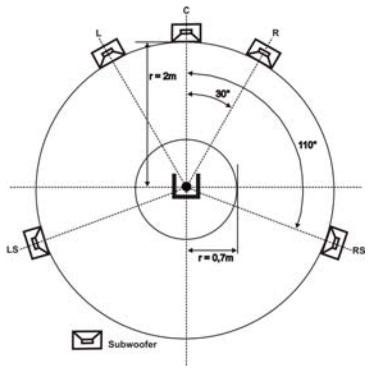

Figure 2: Positions of loudspeakers and subject (experiment 1)

Results

Figure 3 show the dose-response curves for the two noises

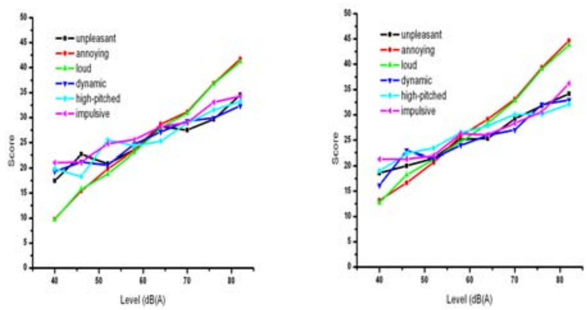

Figure 3: Road (left) and rail noise (right) dose-response curves for the six scales (experiment 1)

relative to the six scales. For both types of noise ANOVA showed (with no exception) a highly significant increase for the six scales ($p<0.001$). The rail noise was scaled as somewhat louder and more annoying than the road noise ($p < 0.05$).

Conclusion

All six scales uniformly show a significant increase due to level. Annoyance and loudness scores show a steeper increase as compared to the other scales. Overall there is no clear differentiation between the scales. This is surprising as at least for some scales, e.g. high-pitched or dynamic, no such strong and uniform dependency on level was to be expected. This observation was supported by factor analysis showing that for both noises all attributes primarily load on one factor (annoyance), i.e. are strongly interrelated to each other. Obviously subjects did not differentiate very well between the various perceptual aspects of the noises with this kind of experimental procedure

Experiment 2

Experimental noises

The same road and railway noises were used as in the first experiment. Levels, however, were varied in only three degrees ranging from 46 - 82 dB in steps of 18 dB.

Procedure

Groups of up to four subjects took place in the experiment simultaneously. (N= 19 normal hearing subjects, males: N=11, females: N=8; mean age: 27 years; standard deviation: 8,5 years). Again six attributes were scaled using categorical subdivision: pleasant, loud, powerful, dynamic, high-pitched, impulsive (note that *annoying* was omitted and *powerful* was added to the list). Again six example sounds were presented to the subject at the beginning of the experiment. Different to experiment 1 following the presentation of a sound only one attribute was scaled at a time, thus each sound was presented six times (instead of one single presentation as in the first experiment).

Listening conditions

Figure 4 shows the set up of the listening room. The distance between the reference point and the loudspeakers was 2.5m. The seating positions of the subjects were arranged along a circle having a radius of 0.6 m around the reference point. The two seats on the left side were separated from the seats on the right side by a screen of 1m height.

Results

Figure 5 depicts the results. With the exception of high-pitched the analysis of variance revealed significant increases for all other scales ($p<0.001$). Significant higher scores relative to rail noise ($p<0.05$) were found with *loud*, *powerful* and *impulsive*.

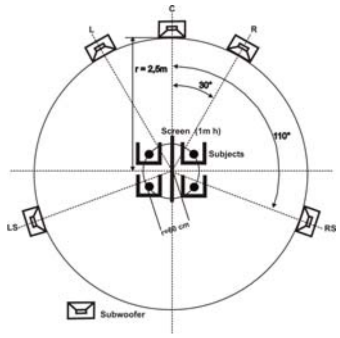

Figure 4: Positions of loudspeakers and of subjects (experiment 2)

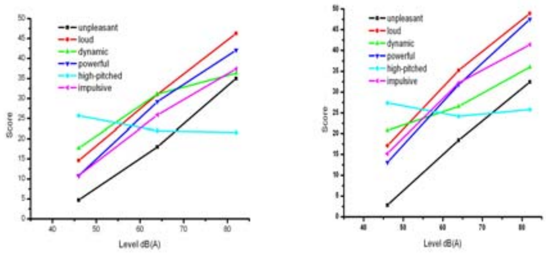

Figure 5: Road (left) and rail noise (right) dose-response curves for the six scales (experiment 2)

General conclusion

As figure 5 demonstrates the scaling pattern of experiment 2 is considerably more differentiated and less homogeneous, i.e. dependent on level effects, as compared to the experiment 1 data (figure 3). Moreover, the internal stability of scaling results, i.e. the correlation matrix of the repeated measurements, was found to be much higher than those of experiment 1. Thus, despite the fact that the experiment 2 approach is more time consuming than the method used in experiment 1 this method will be chosen for further experiments related to traffic noise classification.

References

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Acknowledgement

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