Perception of Sound Quality of City Streets: Comparison of German and Swedish Subjects

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Introduction

In the past four years, the interdisciplinary SVEN project (Sound Quality of Vehicle Exterior Noise) funded by the European Union has studied pass-by noises of single cars as well as complex traffic noises with respect to their sound quality [1]. Major aims were finding appropriate methods for describing the perceived sound quality of environmental noise and identifying factors explaining these perceptions.

In a series of laboratory experiments carried out at the University of Duesseldorf and at Chalmers University in Gothenburg, recordings of traffic noise of different streets of Paris were presented to naïve subjects in order to decide on suitable descriptors and to establish reliable methods of assessment for the perception of environmental sound quality [2]. The results of these experiments reported here deal with the evaluation of sound quality by questionnaires.

Methods

Sound Stimuli

28 traffic noise recordings were taken by the project partners in streets in Paris which were representative for common urban situations in terms of traffic load, traffic flow, architectural aspects etc. From this compilation, four pairs of streets were selected for laboratory experiments with respect to the following criteria: The stimuli of a pair should differ in one specific feature and otherwise resemble each other as much as possible. The differentiating feature should be relevant in terms of acoustical characteristics, e.g. the reflection caused by differences in building or differences in traffic regulation. One pair is discussed here. Two city streets with medium traffic load (1200 vh/h) but with different traffic control: intersection with traffic lights vs. roundabout.

The Experiments

These noise stimuli were used with minor methodological differences in the following three laboratory experiments:

- **DUS** (Institute of Occupational Medicine and Social Medicine, University of Duesseldorf): all the sounds were presented with a raised sound level (L_{eq} = 83 dBA); 24 subjects; parameters: subjective evaluation and physiological measurements
- **GOT** (Acoustical Department of the Chalmers Technical University Gothenburg): the same noises with raised sound level (L_{eq} = 83 dBA); 30 subjects; parameters: subjective evaluation
- **ORI** (also Chalmers Technical University): the same noises, but with *original sound levels* ranging from 60 to 68 dBA; 52 subjects; parameters: subjective evaluation

Subjects

All the subjects were taken from the university population. For the Duesseldorf experiment, Ss had to be male and younger than 30 years. Among the Swedish samples, there were some females and some subjects were older than 30 years. All the Ss were compensated for participation.

Subjective Evaluation

The subjective evaluation was assessed by several questionnaires which had to be filled in by the Ss after each sound stimulus. This paper deals only with the *adjective list* consisting of 27 items qualifying the characteristics of the noises. The ratings were taken on 9-step linear scales and condensed to factors by Principal Component Analysis (PCA).

Results

Principal Component Analysis

The results reported here are based on the data of all three studies with 106 subjects. The PCA was calculated from 848 noise ratings. The extracted factors were checked and optimized with regard to their inner consistency and to the explanation of total variance of the PCA. After reduction of the adjective list to 20 items, finally a solution with four factors with Eigenvalues > 1,0 was found by Varimax rotation accounting for 64.4 % of the total variance. Table 1 depicts the factor loadings for the 20 items.

The first factor contains items referring to emotional effects or responses such as annoying, unpleasant, (not) acceptable and (not) relaxing as well as to general negative characteristics of a noise such as loud, intrusive, and strenuous. In general, *annoyance* might be an appropriate description of this factor. Three items with positive emotional connotations (pleasant, acceptable, relaxing) had to be recoded in a reverse scale for the assessment of their inner consistency so that the factor is now unipolar with high values meaning a high degree of annoyance. The inner consistency of this factor is high as expressed by Cronbach's alpha: $\alpha = 0.9160$.

The second factor is unipolar emphasizing a feeling of a threatening, dangerous and uproaring situation as suggested by the emotional connotations of the items "surprising", "alarming", "dangerous" and "attention demanding" as well as by the acoustical characteristics "sharp" and "roaring".

Danger might be an appropriate denotation of this factor (Cronbach's alpha: $\alpha = 0.8690$).

Item	F. 1	F. 2	F. 3	F. 4
Not* Pleasant	,818			
Annoying	,790			
Not* Acceptable	,771			
Not* Relaxing	,753			
Loud	,683			
Intrusive	,673			
Strenuous	,668			
Unpleasant	,604			
Surprising		,766		
Alarming		,757		
Dangerous		,693		
Sharp		,682		
Roaring		,666		
Attention demanding		,587		
Hectic		,577		
Rhythmic			,794	
Pulsating			,727	
Reverberant			,594	
Non-traffic sounds				,833
Natural				,800

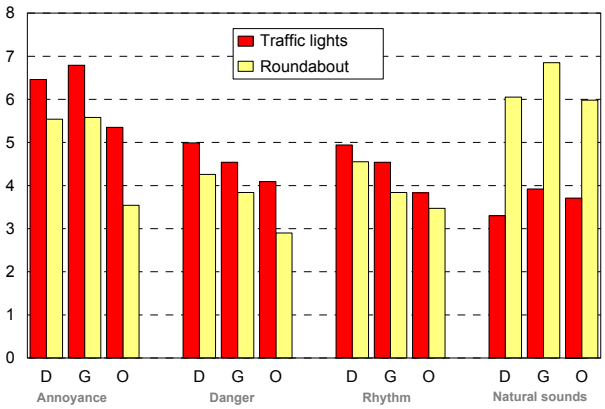
* Items were recoded to a reverse scale to calculate inner consistency

Table 1: Results from the Principal Component Analysis – 20 items related to 4 factors according to their loading

The third factor might be called *rhythm* because it is clearly related to the time structure of the soundscape including the items "rhythmic", "pulsating", and "reverberant" (Cronbach's alpha: $\alpha = 0.6084$). Finally, the fourth factor which includes only the items "non-traffic sounds" and "natural" is called *natural sounds* (Cronbach's alpha: $\alpha = 0.5941$). For further analysis four *index variables* were created by calculating the mean of the subjects' votes over all the items belonging to one factor.

Evaluation of Traffic Lights vs. Roundabout

Figure 1 shows the means of the four index variables based on the complete data of all three experiments comparing traffic noise from the two streets with differences in traffic control. It is obvious that the factors *annoyance, danger,* and *rhythm* are much more attributed to the traffic lights situation and that the judgements of the subjects exposed to the recordings with original sound levels are always lower than the corresponding judgements of the two other samples. The fourth factor *natural sounds* is represented clearly stronger in the roundabout situation. The multivariate analysis of variance (MANOVA procedure in SPSS) yields highly significant effects ($p < 0.001$) for the type of noise as well as for the different subject groups on the mean differences for each factor.



Experiments: D = Duesseldorf, G = Gothenburg, O = Original recordings Sweden

Figure 1: Means of the index variables for each factor in the three studies; comparison of city streets with intersections: traffic light vs. roundabout

Discussion

Results from other measurements for this specific pair of noises have already been reported [3], and they are concordant with the results from the PCA showing unanimously a more positive response of the subjects to the roundabout traffic noise. Thus, the reliability of the whole set of measurements for assessing the sound quality of traffic noises is confirmed once more.

The three samples show a remarkable correspondence in their judgements on the two noises in each factor of the PCA, and it is also noteworthy that the group with the original recordings is more positive in its votes as was to be expected because of the lower sound pressure levels. But we have to add from our knowledge on the complete series of experiments that other pairs of noises were judged more controversial [4, 5].

With regard to the four dimensions of the PCA, a comparison of only two noises cannot unfold so much additional information in terms of a "sound profile". The sound of the roundabout situation is just too clearly preferred in any respect. A wider use of this questionnaire with a greater variety of traffic noises would be desirable to get a still better understanding of different aspects in the evaluation of sound quality.

References

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