Noise annoyance and distance perception

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Introduction

Noise produced by source located farther from a listener is assessed as less annoying than noise produced by source of the same type that is located closer. It sounds pretty trivial but the satisfactory explanation of this phenomenon is not easy to achieve. Apparent explanations correctly point that increase in distance of the source of noise causes decrease in loudness but falsely assume that this decrease in loudness is the only factor that causes the decrease in annoyance. In such explanations neither ground effect nor air absorption phenomena are taken into account. Their occurrence changes not only the sound level of the stimulus but also its spectral content. It is the change in the spectral content that helps to estimate the distance of the sound source and contributes to the annoyance judgment. The aim of the present paper is to answer two questions: (1) what change in distance of sound source location evokes the change in noise annoyance assessment, and (2) how the annoyance assessment of the passing car depends upon the estimation of its distance.

Method

Two independent psychoacoustic experiments were performed. In Experiment I subjects were asked to assess the difference in annoyance of noises produced at different distances. In Experiment II two signals were presented in a pair and subjects were asked to assess the difference in distance of the sources of these signals. Both experiments were controlled by the computer and the adaptive procedure-two-alternative forced-choice method was used.

Stimuli and apparatus

The original reference stimulus was the genuine car noise recorded binaurally at 7.5m from the moving source. Its sound pressure level was 80dB averaged over 2s duration. It was artificially modified (by using the Matlab Tools) to represent car noise recorded at 15m, 30m and 60m respectively. So, there were four reference stimuli representing noise sources located at 7.5m, 15m, 30m and 60m. The spectra of these stimuli were calculated according to the ISO standard (ISO9613-1 Acoustics-Attenuation of sound during propagation outdoor-Part I: Calculation of absorption of sound by the atmosphere).

During the experiments subjects were exposed to pairs of noises. One signal in a pair was a reference noise, the other represented noise source located farther or closer to the source of the reference noise. The spectra of these other stimuli were calculated on-line in the same way as the reference stimuli.

Subjects

In both experiments subjects were two female and two male university students, 21-26 years of age. They were paid for their participation. All subjects had normal hearing (defined as no more than 15 dB above the ISO zero threshold) according to an audiometric test taken before the experiment.

Procedure

The 70.7% transformed up-down procedure was used as a measure of differential sensitivity (DL) for annoyance in Experiment I and differential sensitivity (DL) for distance in Experiment II. In the adaptive procedure, using the 1-2 stepping rule, a run continued until eight reversals had occurred and DL was estimated by averaging the stimulus values at the 8 reversal points. In total, the annoyance and distance of each stimulus was judged 5 times. The final DL value obtained for each stimulus was the average of 40 reversal points (8x5). This value was found for 4 subjects and for 4 reference stimuli. During one experimental session each subject judged the annoyance or distance of one reference stimulus five times. A session lasted about 30 minutes. Subjects participated in 8 sessions: 4 sessions for annoyance and 4 sessions for distance judgements. Subjects participated in one session per day. They were seated in a sound-isolated booth.

Results

Results obtained are presented as DL values in meters and DL values in dB. In the Table 1 the DLs in meters for all stimuli used in Experiment I and Experiment II and for 4 subjects are presented. DLs for annoyance perception expressed in meters are presented in Fig.1.

Table 1. DL for annoyance and distance perception expressed in differences in meters between the judged signals

Distance [m]	DL – Annoyance in [m]				DL – Distance in [m]			
	Subject				Subject			
	PP	MM	KB	AD	PP	MM	KB	AD
7.5	0.62	0.35	0.46	0.56	0.44	0.71	0.80	0.57
15	1.05	0.99	1.48	0.73	0.85	2.11	0.60	1.21
30	2.02	1.55	1.99	2.65	2.18	2.53	3.98	1.70
60	3.21	6.68	2.53	4.04	4.97	5.83	7.38	3.80

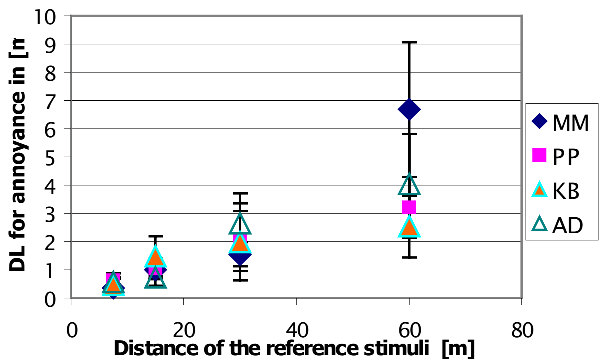

Figure 1. Individual DLs values and standard deviations for annoyance judgements for 4 subjects expressed in meters.

An analysis of variance (Two way ANOVA) was performed on the results presented in Table 1. It revealed that there was no significant difference between the DL values obtained for perceived annoyance and perceived distance [F(1,3)=2.20; p<0.2350]. In addition, there was no significant difference between the DL values for each reference distance [F(3,9)=0.61; p<0.6253].
The result of this analysis is presented in Fig.2. The DL values obtained for annoyance judgement expressed in meters are plotted against the DL values obtained for distance judgments in meters. There is a linear relation between the annoyance and distance judgements. It means that at least for the cases analyzed in the present paper, the annoyance DL values can be predicted based on the distance perception.

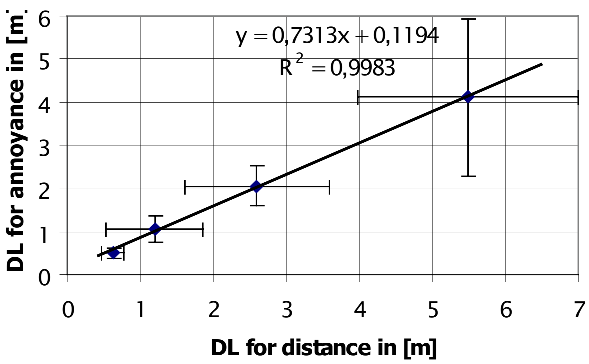

Figure 2. Relationship between annoyance and distance perception expressed in meters.

In Table 2 the DLs in dB for all stimuli used in Experiment I and Experiment II and for 4 subjects are presented. DLs for annoyance perception expressed in dB are presented in Fig.3.

Table 2. DL for annoyance and distance perception expressed in differences in sound pressure levels between the judged signals.

Distance [m]	DL – Annoyance in [dB]				DL – Distance in [dB]			
	Subject				Subject			
	PP	MM	KB	AD	PP	MM	KB	AD
7.5	0.69	0.40	0.52	0.63	0.50	0.79	0.88	0.63
15	0.59	0.56	0.82	0.41	0.48	1.14	0.34	0.67
30	0.57	0.44	0.56	0.74	0.61	0.70	1.08	0.48
60	0.45	0.92	0.36	0.57	0.69	0.81	1.01	0.53

An analysis of variance (Two way ANOVA) was performed also on the results presented in the Table 2. It revealed that there was no significant difference between the DL values obtained for perceived annoyance and perceived distance

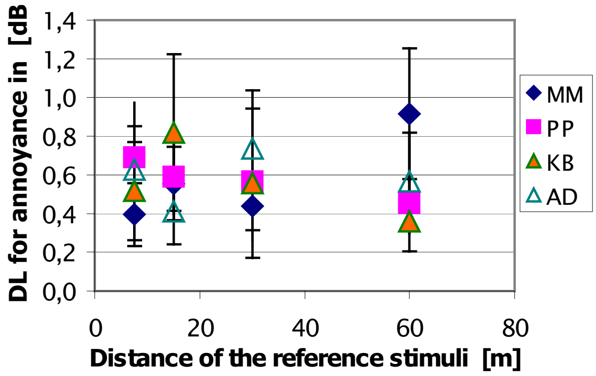

Figure 3. Individual DLs values and standard deviations for annoyance judgements for 4 subjects expressed in dB values.

[F(1,3)=2.78; p<0.1938]. In addition there was no significant difference between the DL values for each reference distance [F(3,9)=0.07; p<0.9733]. Finally, the DL values do not depend on the distance [F(3,9)=0.12;p<0.9476].
The result of this analysis is presented in Fig. 4. The DL values obtained for annoyance judgements expressed in dB are plotted against the DL values obtained for distance judgments in dB. As can be seen, the DL value is almost the same for all investigated reference distances and both types of judgements. In most cases the obtained DL values are smaller than 1 dB SPL. It means, that although the DL values between signals in a pair were smaller than 1 dB SPL the differences in their spectra were perceived by the subjects both in annoyance and in distance judgments.

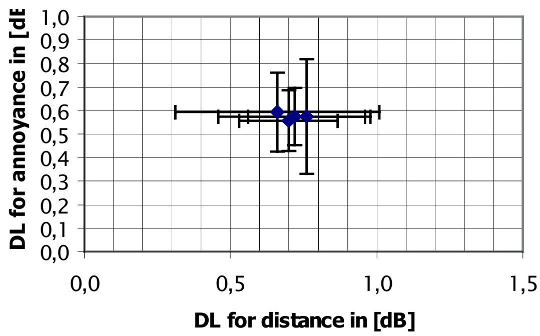

Figure 4. Relationship between annoyance and distance perception expressed in dB.

Conclusions
The results obtained in this study show that car noise stimuli used in the experiments were judged analogously both in annoyance and distance perceptions. It means that at least for the investigated stimuli the annoyance judgments can be represented by the distance judgements. If these results could be extended to other types of stimuli it would mean that annoyance of noise could be predicted by studying the distance perception.

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