inter.noise 2000
The 29th International Congress and Exhibition on Noise Control Engineering
27-30 August 2000, Nice, FRANCE

I-INCE Classification: 6.3

QUANTIFICATION OF CONTEXT EFFECTS IN THE DETERMINATION OF SOURCE-SPECIFIC ANNOYANCE RATINGS FOR SHOOTING AND ROAD-TRAFFIC SOUNDS

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Keywords:
CONTEXT EFFECTS, COMMUNITY RESPONSE, AMBIENT NOISE, NOISE ZONING

ABSTRACT
Specific analyses of field survey data suggest that the context in which a sound is heard may substantially influence the reaction to it. In the present paper, the relevance of the effect of context on the community response to single sources is estimated from the data obtained in two separate field surveys. By means of multiple linear regression analyses, it was verified to which extent the predictability of the source-specific annoyance caused by a target sound (road-traffic or shooting sounds) from its noise dose could be enhanced by adding the noise dose of a non-target source (shooting or road-traffic sounds) as a second predictor. Overall, a 10 dB increase in the noise exposure of a second source resulted in a decrease in the annoyance of the target sound that was equivalent to a shift in its noise dose of 0.5-1 dB.

1 - INTRODUCTION
It has frequently been assumed that the community response to a target sound source will be reduced if there are other environmental sound sources present. In a study on context effects reported by Job et al. [1], the individual annoyance ratings for aircraft sounds were related to those for road-traffic sounds. From the significant correlation coefficient of about 0.30, they concluded that the context in which a sound is heard may substantially influence reaction to it. It is not excluded, however, that this conclusion is based on a spurious correlation: the correlation might be partly due to a main effect of respondents, i.e., a portion of the respondents tends to give low, and a portion of the respondents tends to give high annoyance ratings, irrespective of the actual sound exposure. Moreover, since the context effect discussed in Job et al. [1] is not related to the noise dose of the target and the non-target sound sources, it is impossible to evaluate to which extent context effects are relevant to noise zoning, land-use planning and so on.
In the present paper, the relevance of the effect of context on the community response to single sources is estimated from the data obtained in two separate German field surveys [2, 3].

2 - SURVEY RESULTS FOR SMALL FIREARMS AND ROAD TRAFFIC

2.1 - Brief description of the survey
Two military shooting sites of Resse and Schepsdorf, and three civil shooting sites of Bottrop, Datteln, and Troisdorf were included in the investigation. For the military sites, about 80% of the impulse sounds were single shots produced by 7.62-9 mm caliber rifles, guns, and pistols. The remaining impulses were produced by machine guns and machine pistols. For the civil sites, about 80% of the impulse sounds were produced by shotguns firing at clay pigeons; the remaining reports were produced by sporting guns and short-distance weapons. To allow the determination of dose-response relationships, three to four residential areas at different distances from each shooting site were selected for interviews and acoustical measurements. The distance between the borders of the residential areas and the centers of the shooting

sites varied from 150 to 650 m. About 80 personal interviews were completed per site (392 interviews in total). Although road-traffic sounds were present, the shooting sounds were clearly audible in the greater part of each zone most of the time. The interviews were carried out between May and October 1980, or in April 1981.

From extensive measurements of the impulse sounds, the A-weighted equivalent sound level (ALEQ) was determined for the various locations in the residential areas on a yearly basis. Determination of ALEQ of the road-traffic sounds was based on measurements and countings between 6 and 22 h for various time periods ranging from 15-30 min.

The questionnaire consisted of over 200 questions. Two types of questions are relevant to the present analyses. The first type read "Could you please indicate to which extent you are disturbed in your residential area by... (A1) the bangs from the shooting site and... (B1) the sounds from road traffic." In the second type it was emphasized to rate the sounds heard in the daytime. For all four questions, the respondents had to indicate their degree of disturbance by selecting the relevant answers from "not disturbing" (0) to "unbearably strongly disturbing" (6). More details may be found in [2].

2.2 - Dose-response relationships

On the basis of their corresponding ALEQs of shooting sounds, the individual annoyance ratings given for the two separate questions (A1 and A2) were assigned to one of ten ALEQ classes. Since in the last four classes the number of respondents was less than or equal to 6, the data for these classes were combined into one class.

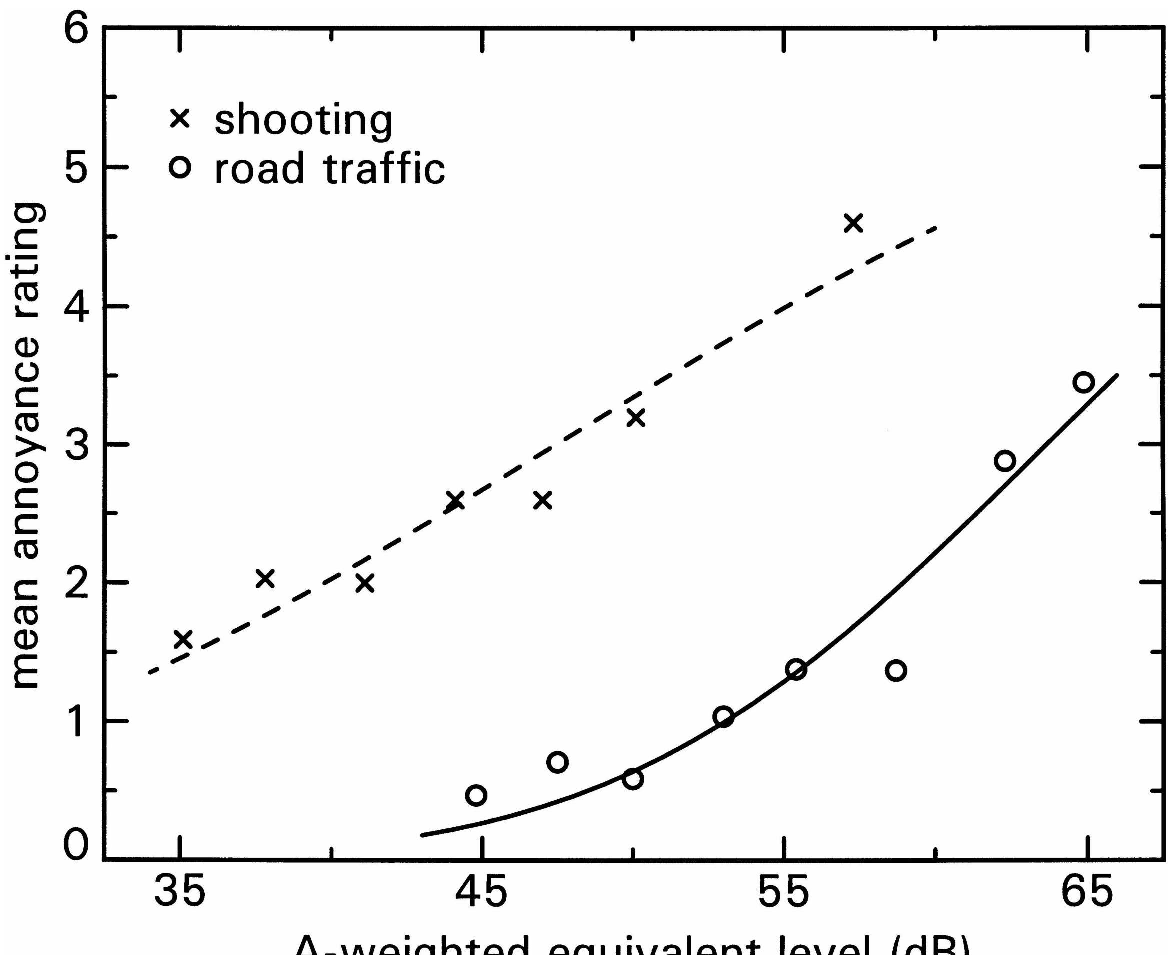


Figure 1: Mean annoyance ratings as a function of ALEQ for shooting and road-traffic sounds.

Fig. 1 shows the mean annoyance ratings as a function of mean ALEQ in the seven relevant class intervals. The function

$$S\,(L_{Aeq}) = 1 + 5 \cdot \Phi[\,(L_{Aeq} - \mu)\,/\sigma] \tag{1}$$

was fitted to the mean ratings. $S(L_{Aeq})$ and $\Phi(z)$ denote the mean annoyance ratings and the cumulative (Gaussian) distribution, respectively.
For the shooting sounds the optimal values of μ and σ, as estimated by a least-squares fit to Eq. (1), were equal to 47.4 and 17.8 dB, respectively ($r^2 = 0.94$). For the road-traffic sounds, the data (ALEQ values and the individual responses to questions B1 and B2) are similarly assigned to one of eight class intervals. The optimal values of μ and σ were equal to 63.7 and 11.0 dB ($r^2 = 0.94$). From the two regression functions shown in Fig. 1, an adjustment for shooting sound can be derived. For mean annoyance ratings between 2.5 and 3.5, corresponding with $44 < L_{Aeq,shot} < 51$ dB, the adjustment ranged between 18 and 15 dB.

2.3 - Context effects

The annoyance (y) caused by the road-traffic sounds was significantly related to ALEQ of these sounds. For Question B1, with 392 individual cases, $y = -6.67 + 0.15L_{Aeq,traf}$ ($r^2 = 0.35$); for Question B2, $y = -5.71 + 0.13L_{Aeq,traf}$ ($r^2 = 0.32$). Multiple linear regression analyses showed that neither for the responses to Question B1, nor for those to Question B2, the predictability of the annoyance was significantly enhanced by adding ALEQ of the shooting sounds as a second predictor.
Similarly, the annoyance caused by the shooting sounds was significantly related to the ALEQ of the impulses. For Question A1, $y = -2.13 + 0.11L_{Aeq,shot}$ ($r^2 = 0.13$); for Question A2, $y = -2.39 + 0.11L_{Aeq,shot}$ ($r^2 = 0.13$). The predictability of the annoyance determined with Question A1 was slightly enhanced by adding ALEQ of the road-traffic sounds as a second predictor: $y = -0.67 + 0.11L_{Aeq,shot} - 0.0245L_{Aeq,traf}$ (multiple $r^2 = 0.14$; $p = 0.05$). Overall, an increase of 10 dB in the ALEQ of road traffic resulted in a decrease in the annoyance of the shooting sounds that was equivalent to a 2.2 dB-shift in its ALEQ. The variance in the annoyance ratings determined with Question A2, however, was not significantly enhanced by adding ALEQ of road traffic as a second predictor.

3 - SURVEY RESULTS FOR LARGE FIREARMS AND ROAD TRAFFIC

3.1 - Brief description of the survey

Seventeen residential areas (zones) at different distances from the military training fields of Bergen and Munster were selected for interviews. In 16 of the 17 zones, the exposure to the shooting sounds was to a large extent determined by the bangs from detonating grenades and explosions. In most zones, the muzzle bangs from the 120 mm cannon and the 155 mm howitzer contributed significantly as well. In total, 433 personal interviews were completed. The interviews were carried out in the summer of 1991.
Again, the respondents in each zone were also exposed to local road-traffic sounds. The levels of these traffic sounds were measured between 6 and 22 h for various time periods ranging from 15-30 min. On the basis of these data ALEQ for the daytime was computed. Since ALEQ in the nighttime was typically 10 dB lower than ALEQ in the daytime, the A-weighted day-night level (ADNL, L_{Adn}) was equal to ALEQ as determined between 6 and 22 h.
From detailed information about the ammunition spent in 1989 and 1990, the number of shots fired in a representative calender year was computed for the daytime and the nighttime separately. In the present paper, the annoyance caused by the shooting sounds is related to an adjusted ADNL and, as an alternative, to CDNL. The calculation of the adjusted ADNL was based on the A-weighted and C-weighted sound exposure levels (ASEL and CSEL; L_{AE} and L_{CE}). For all relevant impulsive sources, the ASELs and CSELs received in the various residential areas were determined for 27 different sound speed profiles [4, 5]. Meteorological information relevant to the Bergen/Munster area, such as wind speed, wind direction, and cloud cover, enabled the calculation of the statistical weights of the various profiles, separately for the day- and for the nighttime. For single events in each meteorological condition, the adjusted or rating sound level, L_r, is given by

$$L_r = L_{AE} + \beta\,(L_{CE} - L_{AE})\,(L_{AE} - \alpha) + 12\ \text{dB}$$

(See [6, 7] for details). The yearly energy average adjusted levels in the day- and the nighttime were computed from the single event rating sound levels as defined above. The adjusted ADNL of the shooting sounds was computed from these two average adjusted levels.
The computation of CDNL for the shooting sounds was based on the CSELs as predicted by "LARM-LAST." For details, see [3].
The questionnaire consisted of about 100 questions. A question that is very relevant to the present analyses read "Could you please indicate to which extent you are disturbed in your residential area by... (A) the noise from cannons, grenades, and explosions, and... (B) the sounds from road traffic." For both sound sources there were two such questions. In the first type (A1 and B1) the respondents had to

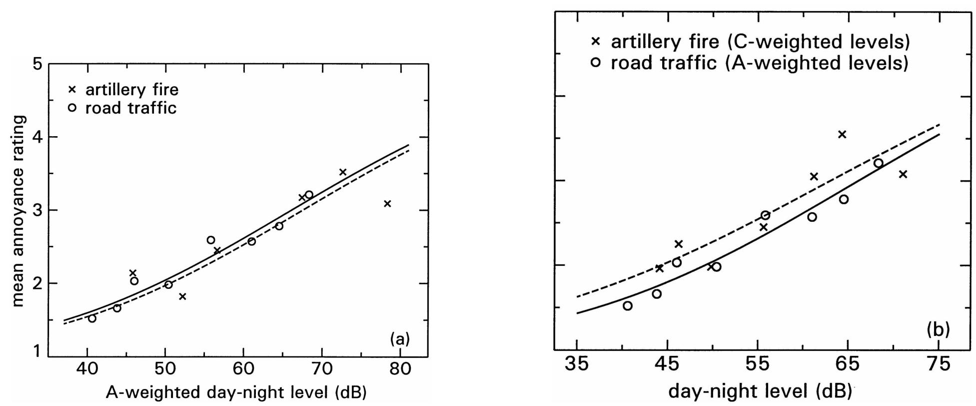
select their answers from verbally labeled 5-point rating scales; in the second type (A2 and B2) a 9-point rating scale was used. To enable a direct comparison between the responses, the scores obtained with the 9-point scale were converted to a 5-point rating scale. For more details, the reader is referred to [3].

3.2 - Dose-response relationships

On the basis of their corresponding ADNLs of the road-traffic sounds, the individual annoyance ratings given for the two separate questions (B1 and B2) were assigned to one of eight ADNL classes.
Fig. 2a shows the mean annoyance ratings as a function of mean ADNL in the various class intervals. The function

$$S\,(\mathrm{L_{Adn}}) = 1 + 4 \cdot \Phi[\ (\mathrm{L_{Adn}} - \mu)\ /\sigma] \qquad (2)$$

was fitted to the mean ratings. For the road-traffic sounds the optimal values of μ and σ, as estimated by a least-squares fit to Eq. (2), were equal to 66.1 and 25.1 dB, respectively ($r^2 = 0.94$). For the shooting sounds, the data (adjusted ADNL values and the individual responses to questions A1 and A2) were similarly assigned to one of six class intervals. With σ fixed at 25.1 dB, the optimal value of μ was equal to 67.5 dB ($r^2 = 0.78$). The two regression functions are shown in Fig. 2a. The function for the shooting sounds does not exactly coincide with that for the road-traffic sounds. The small discrepancy of about 1 dB is explained by the fact that in the calculation of the adjusted ADNLs, α- and β-values had been used that were optimized with the community response expressed as percentages "highly annoyed" respondents [7], rather than expressed as mean annoyance ratings. For the analyses in the next section, however, the results are insensitive to a constant shift in the noise dose.
For the noise dose of the shooting sounds expressed as CDNL, the mean ratings are shown in Fig. 2b. Here, the optimal values of μ and σ were equal to 63.0 and 27.8 dB, respectively ($r^2 = 0.77$). As a reference, the dose-response relationship for road-traffic sounds from Fig. 2a is reproduced in Fig. 2b.



(a) **(b)**

Figure 2: Mean annoyance ratings as a function of ADNL for road-traffic sounds and as a function of (a) adjusted ADNL or (b) CDNL for shooting sounds.

3.3 - Context effects

The annoyance (y) caused by the road-traffic sounds was significantly related to ADNL of these sounds. For Question B1, with 433 individual cases, $y = -0.73 + 0.054\mathrm{L_{Adn,traf}}$ ($r^2 = 0.13$); for Question B2 (original ratings), $y = -2.48 + 0.116\mathrm{L_{Adn,traf}}$ ($r^2 = 0.161$). Multiple linear regression analyses showed that both for the responses to Question B1, and for those to Question B2, the predictability of the annoyance was slightly enhanced by adding the adjusted ADNL of the shooting sounds as a second predictor. For Question B1, $y = 0.091 + 0.0544\mathrm{L_{Adn,traf}} - 0.014\mathrm{L_{Adn,shot}}$ (multiple $r^2 = 0.148$; $p = 0.0025$). For Question B2, $y = -1.50 + 0.117\mathrm{L_{Adn,traf}} - 0.017\mathrm{L_{Adn,shot}}$ (multiple $r^2 = 0.168$; $p = 0.06$).
Adding CDNL of the shooting sounds resulted in an increase of the explained variance as well.
For Question B1, $y = 0.18 + 0.054\mathrm{L_{Adn,traf}} - 0.016\mathrm{L_{Cdn,shot}}$ (multiple $r^2 = 0.145$; $p = 0.005$). For Question B2, $y = -1.34 + 0.116\mathrm{L_{Adn,traf}} - 0.02\mathrm{L_{Cdn,shot}}$ (multiple $r^2 = 0.168$; $p = 0.06$).
For the results obtained with Questions B1 and B2, an increase of 10 dB in the ADNL of the shooting sounds resulted in a decrease in the annoyance of the road-traffic sounds that was equivalent to a 2.5-dB shift or a 1.4-dB shift in its ADNL, respectively. For a 10-dB increase in CDNL of the shooting sounds, the respective values were 3.0 and 1.7 dB.

Similarly, the annoyance caused by the shooting sounds was significantly related to the adjusted ADNL or CDNL of the impulses. With the adjusted ADNL, the functions were y = -0.15 + 0.044$L_{Adn,shot}$ (r^2 = 0.14) for Question A1, and y = -1.17 + 0.09$L_{Adn,shot}$ (r^2 = 0.19) for Question A2.
With CDNL, the functions were y = -0.47 + 0.052$L_{Cdn,shot}$ (r^2 = 0.13) for Question A1, and y = -1.84 + 0.107$L_{Cdn,shot}$ (r^2 = 0.17) for Question A2.
Neither for the responses to Question A1, nor for those to Question A2 was the predictability of the annoyance (either by the adjusted ADNL or by CDNL) significantly enhanced by adding ADNL of the road-traffic sounds as a second predictor.

4 - GENERAL CONCLUSION

Averaged across the results obtained in the relevant conditions (two separate questions in each of two surveys), an increase of 10 dB in the noise exposure of road-traffic sounds resulted in a decrease in the annoyance of the shooting sounds that was equivalent to about a 0.5-dB shift in its noise exposure. A similar 10-dB increase in the noise exposure of shooting sounds resulted in a decrease in the annoyance caused by the road-traffic sounds that was equivalent to about a 1-dB shift in its noise exposure. On the basis of the data from more than 30 field surveys, Fields [8] concluded that, overall, a 10-dB increase in ambient noise exposure has no more impact than approximately a 0.5-dB decrease in the target noise exposure. It must be concluded that the context effect studied in the present paper could be found in part of the conditions only, and that it was hardly different from the mean effect obtained by Fields.

ACKNOWLEDGEMENTS

This research was financed by the Netherlands Ministry of Defence.

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