A Further Test of the Relevance of ASEL and CSEL in the Determination of the Rating Sound Level for Shooting Sounds

Joos Vos

TNO Human Factors Research Institute, P.O. Box 23, 3769 ZG Soesterberg, The Netherlands

Abstract: In a previous study the annoyance, as rated indoors with the windows closed, could be predicted from outdoor ASEL of the shooting sounds. With the product (CSEL-ASEL)(ASEL) as a second variable, the predictability further increased. In that study just one facade attenuation (FA) type was used. In the present study the benefit of this second predictor could be convincingly demonstrated for five conditions in which FA varied from low to very high.

INTRODUCTION

In a previous study (1), it was shown that an almost perfect prediction of the annoyance, as rated indoors with the windows closed, was obtained on the basis of the weighted sum of the outdoor A-weighted and C-weighted sound exposure levels [ASEL (LAE) and CSEL (LCE)] of the shooting sounds. The annoyance (y) was given by y = c + αLAE + βΔL_ASE, in which ΔL = LCE - LAE. On the basis of ASEL only, the explained variance, r², in the mean ratings was already as high as 0.85. With ΔL-ASEL as the second predictor, (multiple) r² further increased to 0.97. The term ΔL-ASEL implies 1) that the annoyance increases with the 'heaviness' of the sound (ΔL is small for sounds with relatively little energy in the low frequency bands, such as those produced by pistols and rifles, and ΔL is high for sounds with relatively much energy in the low frequency bands, such as those produced by mortars and howitzers), and 2) that the additional annoyance due to the 'heaviness' of the sound increases with ASEL. In the previous study, a typical facade attenuation (FA) was used. In the present study it was investigated to which extent the additional contribution of ΔL-ASEL to the annoyance is also relevant for conditions with alternative FAs.

METHODS

As in the previous study (1) the sounds were produced by firearms ranging in calibre from 7.62 to 155 mm. The indoor annoyance was determined for five FA types that varied from low to very high. For each FA type the degree of attenuation is shown in Fig. 1. In the two FA conditions with relatively little attenuation (Fig. 1), 55 impulses were presented (11 sound types x 5 levels). In the other three FA conditions the total number of impulses presented was lower: as a result of FA, several sounds were no longer audible. Outdoor ASEL of the impulse sounds ranged from 47 to 75 dB, outdoor CSEL ranged from 48 to 97 dB. After each stimulus presentation the subjects responded to the question "How annoying would you find the sound if you heard it at home on a regular basis?"

![Figure 1: Frequency dependent outdoor-to-indoor sound reduction for five conditions.](image-url)
RESULTS AND DISCUSSION

Fig. 2 shows the annoyance ratings (averaged across 20 subjects) as a function of outdoor ASEL for four of the five FA types (the differences between the high and the very high FA types were negligibly small). In each panel, the results are based on two representative impulse sounds for each of the three firearm types included. From a comparison of the ratings in each panel (Figs. 2a-2d) it must be concluded that the effect of FA type was large and consistent. Within each FA type significant main effects of outdoor ASEL and sound type were obtained. Moreover, for each FA type, the differences among the three firearm categories significantly increased with sound level.

For each FA condition separately, the mean annoyance ratings were subjected to (stepwise) multiple linear regression analyses with outdoor ASEL, CSEL, ΔL, and ΔL·ASEL as potential predictors. In all conditions, ASEL was selected as the first, and ΔL·ASEL as the second predictor. Regression weights and $r^2$-values are shown in Table 1. In all FA conditions, addition of the second predictor resulted in a (highly significant) increase in the predictability of the annoyance. The benefit of the second predictor ranged from 2.5% to 55% and increased with the degree of FA. The relatively small increase in $r^2$ found in the very high FA condition is explained by the homogeneity of the stimuli included: here, only a few sounds produced by medium-large and large firearms were investigated. It was concluded that for the determination of the rating sound level, the acoustic parameters ASEL and CSEL are very powerful.

TABLE 1. Regression weights and $r^2$-values for analyses with one or two predictors, for five facade attenuation types.

<table>
<thead>
<tr>
<th>window condition</th>
<th>$y = c + \alpha L_{AE}$</th>
<th>$y = c + \alpha L_{AE} + \beta \Delta L \cdot L_{AE}$</th>
<th>increase in $r^2$</th>
</tr>
</thead>
<tbody>
<tr>
<td>wide open</td>
<td>0.21 0.954</td>
<td>0.21 0.0007 0.979</td>
<td>0.025</td>
</tr>
<tr>
<td>slightly open</td>
<td>0.19 0.896</td>
<td>0.19 0.0011 0.968</td>
<td>0.072</td>
</tr>
<tr>
<td>closed (modal isolation)</td>
<td>0.15 0.705</td>
<td>0.17 0.0015 0.970</td>
<td>0.265</td>
</tr>
<tr>
<td>closed (high isolation)</td>
<td>0.11 0.402</td>
<td>0.16 0.0014 0.949</td>
<td>0.547</td>
</tr>
<tr>
<td>closed (very high isolation)</td>
<td>0.14 0.864</td>
<td>0.14 0.0011 0.967</td>
<td>0.103</td>
</tr>
</tbody>
</table>

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REFERENCES