Community response to military shooting noise immissions - preliminary results

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INTRODUCTION

The assessment of the impact of noise exposure on the population is a fundamental step in noise abatement. It includes the establishment of exposure-response relationships with the use of empirical studies and the setting of an exposure limit that specifies the protection level for the population and eventually triggers mitigating measures to reduce noise exposure. Exposure-response relationships are common for most kinds of traffic or industrial noise. They usually relate noise exposure to the percentage of highly annoyed persons (%HA). As military shooting noise (as a result of military training activities in times of peace) is less of a problem for the majority of the population, there are relatively few studies investigating its effects to be found in the literature and hence the impact of military shooting noise from training grounds of armies is far less well understood than effects of traffic or industrial noise.

Background and study objectives

Noise abatement in Switzerland started in the early sixties with a parliamentary proposal to deal with the increasing noise exposure of the population and its negative effects on public health. An environmental protection law was established 1983 including regulations for noise protection that were later laid down in the Noise Abatement Ordinance in 1987 (Schweizerische Eidgenossenschaft 1986). In the following years this policy was supplemented with exposure limits for roads, railways, civil shooting ranges, industry and trade installations, civil and military airports. While all the effort in noise abatement in the last decades has remarkably reduced noise exposure from the most dominant sources, there are still missing exposure limits as well as actions plans for military shooting grounds. Military shooting noise annoyance is not among the most widespread in Switzerland, even though gun shots from light and sometimes heavy weapons can be frequently heard in some mountain valleys. The biggest part of military shooting takes place on eight important shooting grounds that contain small infantry shooting ranges as well as expanded artillery and tank training facilities. Every year, the shooting training of the army consists of about 120'000 large caliber shots (>50mm) and over 25 million small caliber shots. Despite of, or maybe even because of (rifle) shooting, which is closely related to the militia army system, has a long standing tradition in Switzerland, no systematic studies have so far been carried out that researched the impact of military shooting noise on the population. The present study aimed at filling this knowledge gap. The main study goals were the following:

1. Establish a statistical model that explains as most as possible variation of annoyance by acoustical and/or operational factors

2. Provide an exposure-effect function for high annoyance among residents in the vicinity of the eight largest military training/shooting grounds in Switzerland

3. Provide the decisional basis for defining an exposure limit value by policy

METHODS

Sampling procedure

Eight large training grounds of the Swiss army that were located sufficiently close to inhabited areas to potentially evoke annoyance reactions from shooting noise were selected as study sites. At each of these sites, the exposure contours from preliminary exposure calculations (without detailed modeling of terrain, elevation above ground, and shadowing effects) from the year 2006 were used to assign exposure values to building addresses which were derived using a geographical information system (GIS). The yearly exposure at each address was calculated as sound exposure level L_{EA}, expressing the total acoustic energy resulting from shooting activity. Over all eight sites, a total of 5,901 building addresses within the 104 dB(A) contour were identified. Buildings not serving a residential purpose were deleted from the dataset. The remaining addresses were aligned with a commercially available address database to yield all available telephone numbers of private households. These telephone numbers were stored together with their exposure level category and served as the primary sample. The survey was carried out by computer assisted telephone interviews that were commissioned to a market research bureau. Within each household, one person over 16 years of age was randomly selected to be interviewed. The CATI software was configured to try to sample equal amounts of subjects in the different exposure categories, as far as possible. A total of 1,002 interviews could be realized.

Telephone interviews

Interviews lasted about 15 to 20 minutes and took place during the evening hours of September, October and November 2007. Interviewers were blind to the pre-calculated exposure levels of the interviewees. Interviewers had to confirm the address and, if applicable, their floor if they lived in a multi-storeyed building. This information was later used for the exact calculation of exposure levels that accounted for the elevation above ground and shading effects from neighboring buildings.

Considering that directly asking people about their perception of military noise exposure and annoyance could bias their responses, the description of the interview to follow given by the interviewers was not about "military shooting noise" but it was announced as being about "factors influencing living quality". For the interviews, a questionnaire was used that first asked about various factors of living quality of the respondent, among them, noise exposure and annoyance from different sources (5-point verbal scale, including military shooting noise). These were asked in random order, followed by the questions of the short form of the "Lärmempfindlichkeitsfragebogen" by Zimmer and Ellermeier (Zimmer & Ellermeier 1998) to assess noise sensitivity. In the middle of the interview was placed the main block about military shooting noise immissions and annoyance. This main block of questions included the German version of the 11-point annoyance scale from 0 to 10 recommended by ICBEN (Fields et al. 2001), a question about self-assessment of the intensity of exposure by military shooting noise, a question about strategies to cope with the noise, and several questions about the respondent's attitude towards the army. In an open question, respondents could – if they wanted – indicate characteristics of the shooting noise they thought were particularly annoying.

Exposure assessment

After the selection of the eight shooting grounds at which the study took place, the input data for the noise exposure calculation were collected from army officials responsible for the respective training facilities. Exposure calculations were performed separately for the years 2004, 2005, and 2006. For each single respondent's place of living, the exposure from all emplacement/weapon/ammunition combinations for each of the three years were calculated using a new calculation model being developed at Empa. The yearly sound exposure levels were calculated for the most exposed facade of the respondents dwelling, using the sum of the energetic products of each weapon/ammunition exposure level with their corresponding number of shots fired in the respective year. For many decades, the C-weighting was widely used in conjunction with shooting noise, but evidence exists, that A-weighted levels better reflect community annoyance due to shooting noise (Buchta & Vos 1998; Meloni & Rosenheck 1995; Vos 2001). Therefore, no calculations using the C-weighting were performed and all calculations presented here use the A-weighting. Exposure values were calculated separately for daytime and evening shootings although the time periods for day and evening were not strictly defined. The relevant factor for the assignment of a particular amount of ammunition used during either the "day" or "evening" period is the amount of light. Therefore – depending on season – during wintertime all shootings after about 17:00 h are usually considered "evening", in summertime the evening period starts at about 20:30 h, amounting to an average beginning of the "evening" of 18:45 h. Shootings in the night past 23:00 h are very rare, as are shootings during weekends.

RESULTS

Sample description and distribution of exposure values

A total of 460 male and 542 female participants constituted the sample of 1,002 residents. 232 interviews were made in the French speaking part of Switzerland. Respondents were in the age range from 16 to 94 years and experienced military shooting noise exposure levels between 91 and 128 dB L_{AE}.

Table 1 shows the yearly average number of shots as well as the average L_{AE} exposure value per weapon class.

Table 1: Number of shots fired and average L_{AE} of a single shot in the sample of 1002 inhabitants around eight army shooting grounds (yearly average between 2004 and 2006)

Type of weapon/ammunition	# shots fired (Day)	# shots fired (Evening)	Average $L_{AE,Day}$	Average $L_{AE,Evng}$
Large caliber/tank	5,088	179	74 dB	75 dB
Middle caliber	336,351	11,808	62 dB	65 dB
Small caliber	8,554,533	532,128	46 dB	49 dB
Practice ammunition	32,650	4,862	27 dB	32 dB
Grenades and explosive charges	17,163	1,065	64 dB	68 dB
Mortars	6,443	583	66 dB	70 dB

Distribution of annoyance ratings

The usefulness of a dose measure such as L_{AE} or $L_{A,eq}$ to predict shooting noise annoyance has repeatedly been demonstrated in the literature (Buchta 1990; Schomer 1985; Vos 2001). Therefore the first noise metric we analyzed in some detail is the energetic average L_{AE} over three years (further referred to as L_{AE}).

The degree of annoyance among residents was assessed in two ways: The first time during the interview using a 5-point verbal scale with the marks ("not at all", "slightly", "moderately", "very", "extremely") within a block of noise annoyance questions for different noise sources, the second time later during the interview using an 11-point numerical scale (both scales are described in Fields et al. 2001). Figure 1 shows the distribution of annoyance ratings in each level class.

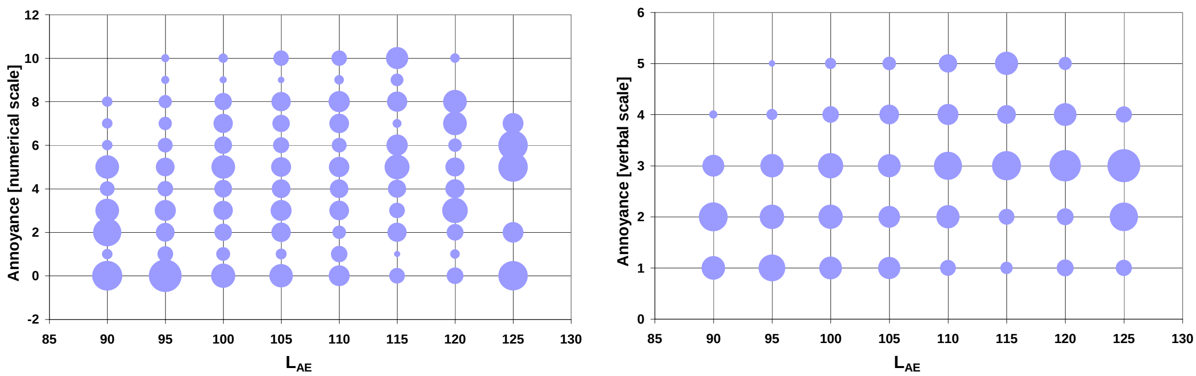

Figure 1: Proportional distribution of annoyance ratings in the different exposure level classes (the class description on the x-axis refers to the lower boundary of the class) as bubble-plot. The diameter of the bubbles is proportional to the proportion of annoyance ratings for a particular level class. Left: 11-point numerical scale; Right: 5-point verbal scale

Data show considerable variability of annoyance ratings and the degree of explained variance was very limited. Linear regression results for the numerical scale yielded an adjusted R square value of 0.04, the verbal scale yielded an adjusted R square value of 0.08. The limitations of different noise metrics in explaining variance in annoyance is a widespread phenomenon. While with transportation noise, on the individual level, R square values between 0.1 and 0.3 are common, the marginal relationship found with military shooting noise is no surprise, assuming that individual moderators (such as the attitude towards the army) more strongly influence the annoyance rating than would be the case with transportation noise. In our case, a simple regression model using L_{AE}, noise sensitivity, and a social image variable reflecting the attitude towards the army (numerical index) explained about 17 % of the variation of the annoyance rating. Since, when it comes to setting a limiting value, individual factors and moderators of noise annoyance can not be accounted for, such type of variables will not be dealt with within the scope of this paper.

However, the low levels of explained variance could to some degree also be caused by having used an inadequate noise descriptor as predictor. Therefore, we computed several other potential exposure-related descriptor variables for each respondent. The following table shows the correlation coefficients of a range of noise descriptors with the annoyance rating of the 5-point and the 11-point ICBEN rating scales.

Table 2: Correlations of different acoustical noise descriptors with annoyance ratings on the 5-point verbal and the 11-point numerical scale

Noise Descriptor	5-point scale		11-point scale	
	r	p	r	p
Arithmetic average sound exposure level [L_{AE}] over three years	0.29	<.0001	0.20	<.0001
Energetic average sound exposure level [L_{AE}] over three years	0.29	<.0001	0.20	<.0001
Energetic average sound exposure level [L_{AE}] over three years during day	0.28	<.0001	0.19	<.0001
Energetic average sound exposure level [L_{AE}] over three years during evenings	0.15	<.0001	0.07	0.0189
Sound exposure level [L_{AE}] in 2004	0.29	<.0001	0.20	<.0001
Sound exposure level [L_{AE}] in 2005	0.29	<.0001	0.20	<.0001
Sound exposure level [L_{AE}] in 2006	0.27	<.0001	0.19	<.0001
Energetic average sound exposure level [L_{AE}] of small caliber shots	0.22	<.0001	0.11	0.0005
Energetic average sound exposure level [L_{AE}] of middle caliber shots	0.13	<.0001	0.08	0.0095
Energetic average sound exposure level [L_{AE}] of large caliber shots	0.03	0.4000	0.02	0.5814
Energetic average sound exposure level [L_{AE}] of other weapons	0.14	<.0001	0.08	0.0149
Energetic average maximum level [$L_{A,max}$] of shots during day	0.24	<.0001	0.17	<.0001
Energetic average maximum level [$L_{A,max}$] of shots during evenings	0.24	<.0001	0.17	<.0001
Energetic average maximum level [$L_{A,max}$] of shots	0.24	<.0001	0.17	<.0001
Number of small caliber shots over 50 dB L_{AE} during day	0.19	<.0001	0.13	<.0001
Number of small caliber shots over 50 dB L_{AE} on evenings	0.16	<.0001	0.11	0.0004
Number of small caliber shots over 50 dB L_{AE}	0.20	<.0001	0.13	<.0001
Number of shots of other weapons/calibers over 50 dB L_{AE} during day	0.10	0.0020	0.09	0.0062
Number of shots of other weapons/calibers over 50 dB L_{AE} on evenings	0.10	0.0020	0.09	0.0062
Number of shots of other weapons/calibers over 50 dB L_{AE}	0.10	0.0020	0.09	0.0062

We will not report about the model building process in more detail here. The energetic average sound exposure level L_{AE} over the three years before the survey took place resulted as being the best acoustic/operational predictor for noise annoyance. It will further be used as main predictor for defining dose-response relationships with high annoyance.

Dose-response relationships with high annoyance (%HA)

The method to establish noise exposure limits can be broken up into four steps: impact assessment, exposure assessment, establishing dose-response relationships and setting exposure limits according to predefined health protection criteria. In most instances, a predefined proportion of *highly annoyed* persons (e.g. 25 %) is used as the criterion for setting an exposure limit value. However, there are different ways to assess high annoyance. According to the recommendations set forth by ICBEN (Fields et al. 2001), two basic rating scales should be integrated in annoyance questionnaires: (1) the already mentioned 5-point verbal scale, and (2) a numerical scale with scale points ranging from 0 to 10. Following common understanding, the upper three points on the numerical scale (8, 9, 10) indicate the presence of high annoyance in the respondent. The 11-point scale and the corresponding definition of high annoyance is in fact a Swiss "invention" dating back to the early seventies (Arbeitsgemeinschaft für sozio-psychologische Fluglärmuntersuchungen 1974) and seemingly also influenced Schultz's work (Schultz 1978) on noise annoyance. The 11-point scale has so far been the preferred measurement scale for noise annoyance surveys in Switzerland. For a multilingual country like Switzerland, the use of a numeric instead of a 5-point verbal scale is further justified by the fact, that equidistance between the scale points of the verbal scale across the country's languages can not be taken for granted, especially considering the verbal marks in Italian language for which no standard recommendation has been formulated so far.

Concerning the 5-point verbal scale, ICBEN's recommendation is to use the two upper categories (the verbal marks "very" and "extremely") as indicators of high annoyance. In light of the different approaches to measure high annoyance and for reasons of comparability, we defined two binary variables expressing high annoyance. The first accounting for the upper three categories on the 11-point numerical scale, the second accounting for the upper two categories on the 5-point verbal scale. Logistic regression models on these variables were calculated with the SAS STAT system (SAS version 9, SAS Institute, Cary, NC, USA) using L_{AE} and a site-specific indicator as predictors. The sites, which were scattered around Switzerland, did not have a significant effect, therefore this predictor was removed and only L_{AE} remained in the models. The logistic functions of the two models are plotted in Figure 2, the corresponding parameters are given in Table 3.

Table 3: Results of the logistic regression models A and B

	Parameter	Coefficient (B)	Standard Error	Wald Stat.	p
Model A (11-point numerical)	Constant	-6.95	1.27	30.09	<.0001
	L_{AE}	0.05	0.01	18.27	<.0001
Model B (5-point verbal)	Constant	8.59	1.15	55.56	<.0001
	L_{AE}	-0.07	0.01	42.48	<.0001

Assuming policy decides on a 25 % protection level, the limiting values for military shooting noise immissions would be around 118 dB based on the numerical scale, and about 109 dB according to the definition of high annoyance on the verbal scale. The difference between the two measurements is quite considerable as becomes evident from Figure 2.

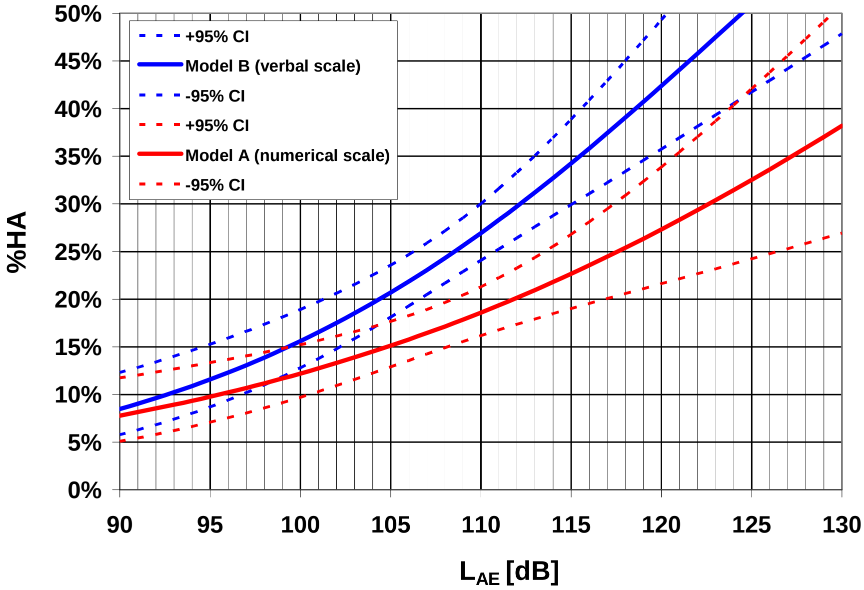

Figure 2: Dose-response curves and 95 % confidence intervals for high annoyance due to military shooting noise as predicted by logistic regression models A & B

Particularly annoying characteristics of military shooting noise

In order to identify further characteristics of military shooting noise that are particularly annoying and therefore may need to be considered when defining exposure limits, respondents were asked about the most annoying characteristics of military shooting noise, as they experienced it subjectively. 22 % of the respondents answered this question. The (free) answers were collected and categorized. The most prominent factor determining shooting noise annoyance refers to the time shootings take place. Within this category, evening shootings were most often mentioned as being a particularly annoying factor. 15 % of the respondents that answered this question complained about vibrations elicited by large weapons and another 10 % declared that they had doubts about the necessity of shooting and/or expressed a general anti-army attitude. Figure 3 shows a pie chart of the distribution of answers.

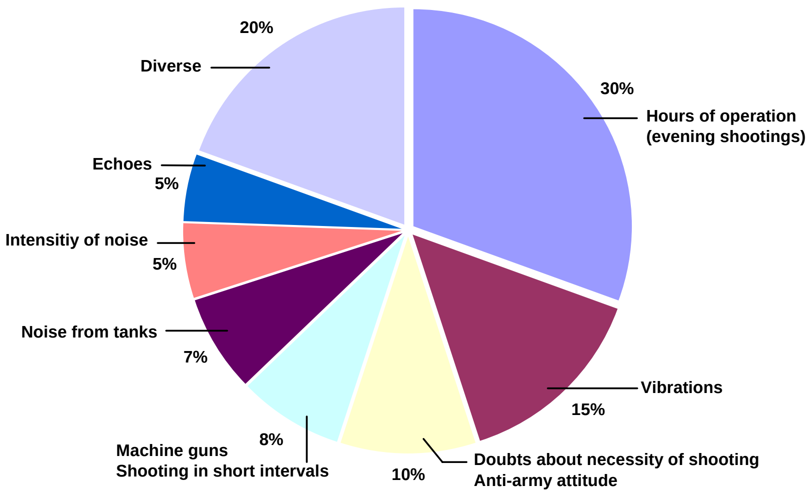

Figure 3: Distribution of reasons why respondents considered military shooting noise as particularly annoying

A penalty for evening shootings?

The calculation of a penalty value for evening shootings appears to be rather difficult in the current case, because on one hand, the exposure data was not strictly related to specific time periods and on the other hand, evening shootings usually take place rather seldom (roughly about 8-10 times fewer shots fired than during day) and therefore the empirical basis appears to be too weak for a sound statistical estimation of the time-of-day effect. However, due to the fact that evening shootings were rated among the top particularly annoying features of military shooting noise (cp. Figure 3), a penalty for the time evening shootings take place seems to be justified.

CONCLUDING REMARKS

The present study assessed the degree of military shooting noise annoyance around eight different shooting grounds in Switzerland. The reported results are to be termed "preliminary", as suggested by the title of this paper. Scientific experience as well as the body of literature concerning this kind of noise annoyance is rather scarce and the results therefore call for further discussion with experts in the field. Results showed a large variability among the annoyance responses for any given exposure class, adding to the complexity of the task of defining an exposure limit value. Total sound energy (L_{AE}) appeared to be the best predictor for high annoyance.

The current study established two preliminary exposure-response relationships as a basis for setting a limiting value. Abatement measures for all military shooting grounds will be enforced as soon as the exposure limits are legally fixed in the Swiss noise abatement ordinance.

REFERENCES

Arbeitsgemeinschaft für sozio-psychologische Fluglärmuntersuchungen (Ed.) (1974). Sozio-psychologische Fluglärmuntersuchung im Gebiet der drei Schweizer Flughäfen Zürich, Genf, Basel. Bern: Eidgenössisches Luftamt.

Buchta E (1990). A field survey on annoyance caused by sounds from small firearms. J Acoust Soc Am 88: 1459-1467.

Buchta E, Vos J (1998). A field survey on the annoyance caused by sounds from large firearms and road traffic. J Acoust Soc Am 104: 2890-2902.

Fields JM, de Jong RG, Gjestland T, Flindell IH, Job RFS, Kurra S, Lercher P, Vallet M, Yano T, Guski R, Felscher-Suhr U, Schumer R (2001). Standardized general-purpose noise reaction questions for community noise surveys: research and a recommendation. J Sound Vibr 242: 641-679.

Meloni T, Rosenheck A (1995). Choice of frequency-weighting for the evaluation of weapon noise. J Acoust Soc Am 97: 3636-3641.

Schomer PD (1985). Assessment of community response to impulsive noise. J Acoust Soc Am 77: 520-535.

Schultz TJ (1978). Synthesis of social surveys on noise annoyance. J Acoust Soc Am 64: 377-405.

Schweizerische Eidgenossenschaft (1986). Lärmschutz-Verordnung vom 15. Dezember 1986 (LSV) [SR 814.41], http://www.admin.ch/ch/d/sr/8/814.41.de.pdf.

Vos J (2001). On the annoyance caused by impulse sounds produced by small, medium-large, and large firearms. J Acoust Soc Am 109: 244-253.

Zimmer K, Ellermeier W (1998). Ein Kurzfragebogen zur Erfassung der Lärmempfindlichkeit. Umweltpsychologie 2: 54-63.