Annoyance responses to military shooting noise in Switzerland

Final Report

On behalf of the Swiss Federal Office for the Environment (BAFU)

Final Version 1.01

12. November 2009

Authors: Mark Brink[1]
Jean-Marc Wunderli[2]

1 ETH Zürich, MTEC-ZOA Public and Organizational Health, CH-8092 Zürich

2 Empa Swiss Federal Laboratories for Materials Testing and Research, Laboratory of acoustics, CH-8600 Dübendorf

Abstract

We report a social survey on noise annoyance from military shooting activities with small, mid-size, and heavy weapons that was carried out in late summer 2007 at eight different study sites located near military training grounds in Switzerland. The primary goal of the study was to collect up to date information about the exposure-annoyance relationship of military shooting noise in order to provide the foundations for defining legal exposure limits that have so far not been established in Swiss legislation. The extent of noise annoyance was determined among 1002 residents by carrying out a telephone survey that included standard questions recommended by the international commission on biological effects of noise (ICBEN). Shooting noise exposure was calculated for the years 2004, 2005, and 2006 from source models of all weapons used by the army and the numbers of shots fired, as reported in detail in the shooting activity records from each ground. Noise annoyance predictor variables investigated were L_{AE}, L_{CE}, L_{CE}-L_{AE}, L_{max}, number of shots above threshold as well as individual moderators such as noise sensitivity. Exposure-annoyance relationships were modeled by means of linear and logistic regression analysis. We propose a rather simple logistic prediction model for the probability of high annoyance (P_{HA}) that relies on the energy principle. The L_E of shooting noise (integrated over an average year) revealed to better explain variations in annoyance than other operational and/or acoustical predictors. Annoyance ratings on the 5-point verbal scale were more closely related to noise exposure than annoyance expressed on the 11-point numerical scale. L_{AE} turned out to be the better annoyance predictor than L_{CE}. The inclusion of the C-A frequency weighting difference as a second explaining variable, as it was suggested earlier, did not substantially enhance the predictability of high annoyance.

Keywords: shooting noise, community response, annoyance, heavy weapon noise.

Version 1.01

12. November 2009

D-MTEC Public and Organizational Health, Ergonomics and Environment

WEP H17, CH-8092 Zürich

Citation:

Brink, M. & Wunderli, J.-M. (2009). Annoyance responses to military shooting noise in Switzerland (Final Report). ETH Zürich, D-MTEC POH, 8092 Zürich

CONTENTS

1. INTRODUCTION

The assessment of the impact of noise exposure on the population is a fundamental step in noise abatement. The latter includes the establishment of exposure-response relationships with the use of empirical studies and the setting of an impact threshold that specifies the protection level for the population and eventually triggers mitigating measures to reduce noise exposure. Exposure-response relationships are commonly used to rate many kinds of traffic or industrial noise. In their most pure form, they 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. Hence the impact of military shooting noise from training grounds of armies is far less well understood than effects of traffic or industrial noise.

1.1 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 in 1983 [1] including regulations for noise protection that were later laid down in the Noise abatement ordinance [2]. In the following years this policy was supplemented with exposure limits for roads, railways, civil shooting ranges, industry, and civil and military airports. While the efforts in noise abatement in the last decades have reduced noise exposure from the most dominant sources, there are still missing exposure limits as well as actions plans for military shooting grounds.

In Switzerland, with roughly two thirds of the country's surface being covered with mountains, plain space is very scant, which increases the pressure of building densely, and to that effect we find several multipurpose training grounds in Switzerland where military shooting activity comprises small, middle, and heavy weapon shooting activities at one and the same place, and often in close vicinity to inhabited areas. The biggest part of military shooting takes place on a few medium-large 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 fires about 120'000 large caliber shots (>50mm) and over 25 million small caliber shots. Apart from the military training there is considerable civil shooting activity with over 75 million small caliber shots per year. Because no reliable information about the noise impact of military shooting activity on the population was at hand, the Swiss federal office for the environment (BAFU) commissioned the authors to investigate the extent of the noise annoyance problem due to military shooting and to provide the decisional basis for military shooting noise regulation.

The three main study goals were the following:

1. Establish a statistical model that explains variation of community annoyance by operational and acoustical descriptors of military shooting activity
2. Provide an exposure-effect function for high annoyance (%HA) among residents in the vicinity of military training grounds
3. Provide the decisional basis for defining an exposure limit by policy

1.2 Exposure-effect relationships for shooting noise annoyance

Shooting with firearms on multipurpose training grounds with different combinations of small to very large caliber weapons creates a site-specific and quite complex blend of different sounds. It therefore appears that the construction of generalized exposure-effect relationships regarding military shooting noise is much more difficult than for other, more uniform noise types. Despite a relatively large body of literature, which mostly pertains to laboratory studies, there have only few generalized exposure-effect functions for (military) shooting noise been published so far [e.g. in 3]. The purpose of reviewing past military shooting noise annoyance literature was to seek guidance for regulatory decisions and to prepare the current study. With few exceptions, as it seems, the published exposure-effect functions are not currently used for regulatory purposes, e.g. for defining exposure limits. While exposure assessment following the equal energy principle has been adopted for the most distinctive noise sources, at least pertaining to annoyance as dependent variable, no commonly accepted noise descriptor for assessing community annoyance to shooting noise has successfully established itself to date.

1.2.1 Shooting noise descriptors

In the annoyance literature, noise descriptors that were identified to yield the highest degrees of explained variance of annoyance from impulsive sounds vary from accumulated peak level [4], maximum sound pressure level [5], A-weighted FAST maximum sound pressure level [6], Number of shots above a C-weighted threshold level [7], C-weighted average Day-Night level L_{CDN} [3], Schomers [8] "new descriptor for high-energy impulsive sounds" [9], the L_{Aeq}, to even surrogate measurements of ground vibration in the case of blast noise from surface mines [10]. Most of these studies investigated the noise effect from particular source (weapon) types, either from e.g. rifle shooting ranges or from large weapon training facilities. Depending on weapon type, one or the other noise descriptor probably better predicts community annoyance. Therefore, the question which predictor best accounts for the variation of (military) shooting noise annoyance *in general*, that means for any kind and combination of weapons, can not easily be answered. The studies mentioned above do not allow the derivation of a generalized exposure-effect function for a multitude of military weapons. There are no field surveys published, where a mixture of small, middle, and large caliber weapons account for the overall shooting noise exposure.

1.2.2 Frequency weighting

The question of the choice of frequency weighting to best predict impulsive or weapon noise annoyance respectively, has received considerable attention in the literature. It is of particular importance for the current project as it is desired to derive a unified exposure-effect relationship for all kinds of weapons, small and large. Insights into the relationship between shots of weapons and annoyance, especially with regard to impulse correction and frequency weighting have been collected in a series of laboratory studies [11; 12; 13; 14; 15].

The use of the A-weighting is widespread in the evaluation of gunfire noise from small arms, usually including a penalty correction of between 5 and 12 dB for the added annoyance of impulsive sounds [14; 16]. However, for the assessment of large caliber or high energy weapon noise, the C weighting and the measure L_{CE} (or L_{CDN}) have been suggested in the past [17] or are recommended in ISO 1996-1 [18]. For the whole set of impulse sound types produced by various firearms ranging in caliber from 7.62 to 155 mm, the annoyance rating in the laboratory study of Vos [13] was almost entirely determined by the outdoor L_{AE} of the impulses, as long as the artificial laboratory situation reflected a scenario with open windows. Similar results were reported by Meloni and Rosenheck [11] who found that if shooting noise is predominantly heard through open windows, the A-weighted sound exposure level is appropriate for predicting annoyance and no weapon-specific level correction (penalty) for small, medium or large weapons is needed.

Vos suggests to implement the difference between the C and A-weighted level as a second predictor alongside the A-weighted level the principal annoyance predictor [13]. Because the addition of the C-weighted level in the regression equations in most instances only very slightly increased the explained variance of the exposure-effect relationship, it remains arguable, whether the additional effort of C-weighted measurements and/or calculations is justified, particularly for the assessment of the "outside situation", as Vos demonstrated in his laboratory studies [13; 19]. However, as Vos pointed out – there seems to be no need to develop separate procedures to describe different categories of firearm calibers and the only relevant acoustic measures to predict shooting noise annoyance are L_{AE} and L_{CE}.

As the owners (i.e. governments) of facilities which emit noise can only partially be made responsible for *indoor* levels at residents homes, noise regulations normally specify a measurement point *outdoors* (e.g. the Swiss Noise Abatement Ordinance dictates measurements to be made with the microphone placed in the middle of the open window of the most exposed facade). In a study on aircraft noise annoyance in Switzerland, Oliva [20] concludes that annoyance responses to "outside" questions are comparable to a more general form of questioning, without specific location reference. Confirming this, it was found that respondents in (aircraft) noise annoyance surveys also seem to judge their *general* noise annoyance based on the outside or with other words, "in front of the house" situation [21]. As long as the low frequency content of the noise is marginal (e.g. with some types of traffic noise), one can assume that the facade attenuation is in most instances high enough – at least in Switzerland with its relatively high building quality standards – to keep noise exposure levels with closed windows so low, that no noteworthy indoor annoyance can result. However, this general rule of thumb might not work with impulsive sounds with strong low frequency content as those components more easily pass through walls and windows. In this light, the "indoor proportion" of the individual general annoyance rating might be considerably higher with low frequency weapon noise than with other noise types. It is therefore desirable to empirically test the advantage of the incorporation of C-weighted measurements not only in the laboratory, but also within the scope of community reaction surveys in the field, such as the present one.

1.2.3 Laboratory versus field

The amount of explained variance in annoyance by acoustical factors appears to be much higher in laboratory studies than in the field. A speculative and not yet empirically proven explanation for this would be that subjects not regularly annoyed by shooting sounds in their everyday environment might have a tendency in acoustical laboratory experiments to rather rate loudness instead of annoyance, even if instructed differently. This provides a strong rationale to investigate noise effects where they really happen, that means, in the field, at the homes of the affected population. In the real-world situation, people use adaptive mechanisms that try to ignore noise as much as possible whereas in a laboratory setting they do the opposite and inevitably concentrate on the noise, which might lead to a different meaning of the noise. Furthermore, potential lack of realism and real life experience of living near a shooting ground raises doubts about the feasibility of deriving policy-relevant exposure-effect curves from laboratory experiments, such as the ones discussed above. Of the few field studies on community annoyance due to weapon noise at hand [5; 6; 7; 9; 10; 12; 22], no generalized exposure-effect function covering *all kinds of weapons* emerged that could be used for policy purposes. The current field survey aims at overcoming some of the restrictions of the studies discussed above.

2. METHODS

2.1 Sampling procedure

In field studies of weapon noise and annoyance, the respondents are required to give annoyance ratings on the basis of long time periods and the stimulus conditions to which they respond are usually very complex [13]. Depending on the site-specific combinations of weapons/ammunition used, average distances of dwellings from the shooting ground, visible vs. non-visible army activities in the surrounding neighborhood, involvement with the army (e.g. as employee), and many other factors, we would expect exposure-effect relationships to show a rather wide variation. As the primary goal of the research reported about in this article is collecting data for constructing an exposure-effect relationship to be used by Swiss noise regulation policy, we chose to sample a representative amount of residents near some of the largest shooting grounds that are in operation. This sample therefore represents a considerable part of the area that will later be affected by the new legislation when it becomes enforced.

Eight large training grounds of the Swiss army that were located sufficiently close to inhabited areas to potentially evoke annoyance reactions from noise were selected as study sites. The sites were Bière, Thun, Wangen an der Aaare, Gehren-Erlinsbach, Krähtal-Riniken, Walenstadt, Herisau-Gossau, and Chur (Figure 1). At each of these sites, the exposure contours from preliminary exposure calculations that did not account for elevation above ground and shielding effects from neighboring buildings were used to assign exposure values to building addresses. The exposure for the year 2006 was calculated at each address as the yearly sound exposure level L_{AE}, i.e. the total acoustic energy resulting from shooting activity during a year. Over all eight sites, a total of 5901 building addresses within the 104 dB(A) contour were identified. These addresses were aligned with a commercial address database to yield all available (landline) telephone numbers of private households. 5851 individual telephone numbers were identified. The 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 (CATI) that were commissioned to a market research bureau. Within each household, one person over 16 years of age was selected using a modified Troldahl-Carter method [23]. This method semi-randomly selects a household member based on the distribution of age and gender in the population and generates a request to speak to an individual that best complements the already collected answers in the response set so that the distribution of age and gender in the response set is at each stage of data gathering as close as possible to the distribution in the population. The CATI software was configured to try to sample equal amounts of subjects in the different exposure categories, as far as possible. E.g. it repeatedly tried to reach residents within the particularly high exposure level categories whose telephone was not answered upon the first attempts. 5851 individual numbers were called. A total of 1002 interviews could be realized. 2137 calls were either never answered or were not valid due to technical reasons (e.g. a FAX device at the other end of the line). Of the 3714 remaining calls that resulted in a personal contact, the following statistics apply: Valid interviews conducted: 27%; Interview scheduled, but did not take place for unknown reasons: 8%; Communication or language problems make interview impossible: 4%; No target person living in household: 2%; Person called refused interview: 59%.

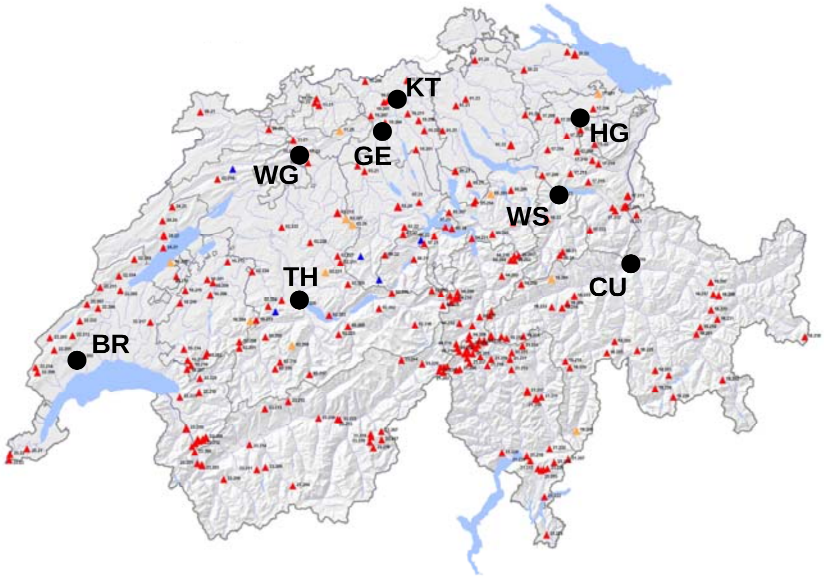


Figure 1: Geographical location of army shooting ranges in Switzerland (triangles) and sites in the present study (large dots; BR: Bière; TH: Thun; WG: Wangen an der Aaare; GE: Gehren-Erlinsbach; KT: Krähtal-Riniken; WS: Walenstadt; HG: Herisau-Gossau; CU: Chur)

2.2 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. As a first step, interviewees had to confirm their address and floor if they lived in a multi-story building. This information was later used for the calculation of exposure levels that accounted for the elevation above ground and shading effects from neighboring buildings.

Bearing in mind, 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". The schedule moved gradually from questions about the satisfaction with the immediate environment to the topic of military shooting noise. The true aim of the survey was disclosed to all interviewees after the interview was finished and they were given the opportunity to withdraw, an option no one exercised.

For the interviews, a questionnaire was used that first asked about various criteria of living quality of the respondent, among them, noise exposure and annoyance from different sources (5-point verbal scale, including military shooting noise) with the marks "not at all", "slightly", "moderately", "very", "extremely". These were asked in random order of the sources, followed by the questions of the short form of the "Lärmempfindlichkeitsfragebogen" (LEFK; English: "Noise sensitivity questionnaire") by Zimmer and Ellermeier [24] 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 [25], a question about self-assessment of the intensity of exposure by military shooting noise, a question about strategies to cope with the noise, and three items about the respondent's attitude towards the army (these items were "Switzerland does need an army", "The Swiss army sufficiently cares for the environment", and "Military shooting noise is a necessary evil") that had do be answered on a 1 to 5 scale with the end points "totally agree" and "totally disagree". As part of this block, respondents could indicate three different time periods during which they considered themselves particularly annoyed by military shooting noise.

2.3 Exposure assessment

After the selection of the eight study sites, the input data for the noise exposure calculations were collected from army officials that were in command of the respective training grounds. Their task basically encompassed the reporting of the weapons and ammunitions used, the corresponding number of shots and shooting days, as well as the distribution of shots fired between day and evening (night shootings are usually very rare). Since the army rigorously controls and records delivery, use and retraction of ammunition, the obtained figures can be considered very reliable. Each weapon/ammunition combination was assigned one of the following categories: small caliber (<=10 mm); middle caliber (10-50 mm); large caliber/tank (>=50 mm); grenades and explosive charges; mortars; practice ammunition. For all receiver points in the sample, the exposure from every emplacement/weapon/ammunition combination of the respective study site was calculated using the "WL04" source and propagation model (described in more detail in the appendix). The calculations were performed for up to 16 distinct weather conditions that were derived for each study site based on long-term weather statistics. Receiver points were set on the façade of the building aiming at the shooting ground. The height of the receiver points was set to 1.8 meters for detached houses and ground floor apartments. For each additional floor the height was increased by 2.6 meters. The calculation model delivers L_{AE}, L_{CE} as well as the distribution of the $L_{AF,max}$ exposure values at the most exposed facade. The L_{AE} and L_{CE} calculations account for reverberating parts (echoes) of shooting sounds which can be considerable, given the topography (nearby mountains) at some of the study sites. Echoing sounds are particularly annoying [26]. Exposure calculations were performed separately for the years 2004, 2005, and 2006 and separately for daytime and evening shootings although the exact time periods for "day" and "evening" shootings could not be obtained according to any strict pre-set definition. However, it was assured by the army, that the reported shooting activity data that were assigned to "day" and "evening" did not overlap. The relevant factor for the assignment of a particular amount of ammunition used during either the "day" or "evening" period was usually the amount of light. Therefore – depending on season – during wintertime all shootings after about 17:00 h were 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 extremely rare, as are shootings during weekends.

The total yearly exposure levels were calculated as the sum of the energetic products of each emplacement/weapon/ammunition sound exposure level with their corresponding number of shots fired in the respective year.

As the timely distribution of the intensity of shooting often varies considerably across a year, with some shooting grounds and/or emplacement being used only a few months per year, a (daily) average exposure value such as e.g. a 12h-L_{eq} or a 24h-L_{eq} does in most cases not necessarily reflect a representative description of the noise exposure residents are affected with. Dose values in this article are therefore simply given as L_E values, representing the total (integrated) energy of shooting noise exposure in a year (or, as the average over three years). A corresponding energy equivalent continuous level over a particular time period can be obtained by transforming the given L_E value, e.g. using

$$L_{eq} = L_E - 10 \times \log(N_{SD} \times N_{HD} \times 3600) \tag{1}$$

where:

L_{eq}	Equivalent sound level for a particular number of hours of a particular number of days (within a year)
N_{SD}	Number of days in a year when shootings/trainings take place
N_{HD}	Number of hours per day for which the average sound level should be calculated [e.g. 12]

E.g. the average daily 12h-L_{eq} would thus be L_E - 10×log(365×12×60×60).

3. RESULTS

3.1 Sample description

A total of 460 male (46%) and 542 female (54%) participants constituted the sample of 1002 residents. Shooting noise exposure was calculated for 918 distinct receiver points. For a small number of the receiver points, more than 1 respondent were interviewed (e.g. more than one family member living in the same apartment; i.e. 43 receiver points with 2 respondents, 4 receiver points with 3 respondents, 5 receiver points with 4 respondents, 2 receiver points with 5 respondents, 2 receiver points with 6 respondents). 232 interviews were made in the French speaking part of Switzerland. Respondents were in the age range from 16 to 94 years. The average age of the respondents was 50 years. The age class distribution was as follows (in brackets the percentage of the population older than 16): between 16 and 20 years: 5% (5%); 20–40: 25% (34%); 40–60: 37% (34%), and older than 60 years: 33% (26%).

TABLE 1: Number of interviews conducted at each site and yearly average exposure level category

Study site	**90-95 dB [L_{AE}]**	**95-100 dB [L_{AE}]**	**100-105 dB [L_{AE}]**	**105-110 dB [L_{AE}]**	**110-115 dB [L_{AE}]**	**115-120 dB [L_{AE}]**	**120-125 dB [L_{AE}]**	**125-130 dB [L_{AE}]**
Bière (BR)	14	21	50	42	51	42	10	
Chur (CU)	1	15	62	56	23	2		
Gehren-Erlinsbach (GE)		2	6	11	8	2		
Herisau-Gossau (HG)		11	25	20	7		1	2
Krähtal-Riniken (KT)	1	5	25	16	10	1		
Thun (TH)		7	27	59	92	52	34	8
Wangen an der Aare (WG)		15	10	8	12	3		
Walenstadt (WS)		25	28	46	34			
Total	16	101	233	258	237	102	45	10
Percent	1.60	10.08	23.25	25.75	23.65	10.18	4.49	1.00

The respondents experienced yearly military shooting noise exposure levels between 92 and 130 dB L_{AE} or 98 and 141 dB L_{CE} respectively. Unlike the (quite simple) preliminary calculations that were used for sample stratification and definition of the address sampling areas, the definitive exposure calculation for each respondent accounted for elevation and shielding effects from other buildings, thus yearly L_{AE} levels down to 92 dB were reached in the sample. The sound exposure values of *single* shots, accounting for all meteorological situations in the sample, went up to 98.4 dB L_{AE} and up to 113.1 dB L_{CE} at the receiver points respectively. Table 1 shows the distribution of the number of telephone interviews that were realized per L_{AE} exposure level category (as three-year energetic average) and study site. Table 2 shows the yearly average number of shots as well as the number of shots above the 50, 60, 70, and 80 dB L_{AE} thresholds per weapon type, as experienced at the 918 receiver points in the sample. The figures given in the last four columns represent the average number of shots above the respective threshold, which is defined as the average A-weighted sound exposure level of a distinct source (more clearly the emplacement/weapon/ammunition-combination) at the receiver points within the study sample, as the average of the three years 2004, 2005, and 2006. Besides their illustration of the frequency and magnitude of sound exposure levels of single shots, that are a property the receiver points in the sample, these numbers have no other particular meaning.

The average shooting activity per year was about the same for all three years and no substantial changes have occurred at any of the eight grounds between 2004 and 2006.

TABLE 2: Number of shots and number of shots above threshold at the 918 receiver points in the study sample (all values represent the yearly average over the years 2004, 2005, and 2006)

Type of weapon/ammunition	# shots during day	# shots during evening	# shots > L_{AE}=50 dB	# shots > L_{AE}=60 dB	# shots > L_{AE}=70 dB	# shots > L_{AE}=80 dB
Large caliber/tank	5088	179	2119	1701	834	207
Middle caliber	336351	11808	38141	18954	17194	14699
Small caliber	8554533	532128	303277	179902	73783	0
Practice ammunition	32650	4862	0	0	0	0
Grenades / explosive charges	17163	1065	2356	1712	816	471
Mortars	6443	583	1514	1271	1266	737

3.2 Annoyance ratings

The degree of annoyance among residents was assessed in two ways: The first time during the interview using the mentioned 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 the 11-point numerical scale. For all quantitative analyses, the verbal answer alternatives of the 5-point scale have been transformed to the numerical values 1-5 and treated as continuous. Different exposure metrics (noise descriptors) could be calculated from the available operational data. Table 3 shows the correlation coefficients of a range of noise descriptors with the annoyance rating of the 5-point and the 11-point rating scales. The threshold for calculating the number of shots above a particular exposure in Table 3 was set in order that 90% of all shooting events of the particular weapon class were below the threshold. In the case of small caliber shots, this threshold was at 50 dB L_{AE}, in the case of large caliber shots, it was at 98 dB L_{CE}.

TABLE 3: Correlations of different acoustical noise descriptors with annoyance ratings on the 11-point numerical and the 5-point verbal scale

Noise Descriptor	11-point scale		5-point scale	
	r	p	r	p
Arithmetic average sound exposure level [L_{AE}] over three years	0.20	<.0001	0.29	<.0001
Energetic average sound exposure level [L_{AE}] over three years	0.20	<.0001	0.29	<.0001
Energetic average sound exposure level [L_{AE}] over three years during day	0.19	<.0001	0.28	<.0001
Energetic average sound exposure level [L_{AE}] over three years during evenings	0.07	.0189	0.16	<.0001
Arithmetic average sound exposure level [L_{CE}] over three years	0.21	<.0001	0.27	<.0001
Energetic average sound exposure level [L_{CE}] over three years	0.22	<.0001	0.28	<.0001
Energetic average sound exposure level [L_{CE}] over three years during day	0.22	<.0001	0.28	<.0001
Energetic average sound exposure level [L_{CE}] over three years during evenings	0.07	.03	0.15	<.0001
Energetic average sound exposure level [L_{AE}] of small caliber shots	0.11	.0005	0.22	<.0001
Energetic average sound exposure level [L_{CE}] of large caliber shots	0.02	.6	0.02	.43
Number of small caliber shots over 50 dB L_{AE}	0.13	<.0001	0.16	<.0001
Number of large caliber shots over 98 dB L_{CE}	0.08	.008	0.09	.005

From Table 3 it becomes evident that energetic dose measures – accounting for all shooting events in a year – in particular the yearly average exposure, expressed as L_{AE} and L_{CE} appear to be the best predictors for shooting noise annoyance.

TABLE 4: Annoyance reactions for different degrees of exposure. The categories are defined based on the L_{AE} metric, the average exposure values ∅-L_{AE} and ∅-L_{CE} pertain to the arithmetic average of all cases within the category boundaries.

Level Category [Range of L_{AE} values]	Scale	Mean Annoyance	CI – 95%	CI +95%	St. Dev.	%HA
90-95 (N=16)	11-point [0...10]	3.38	2.12	4.63	2.36	6.25
∅-L_{AE}=93.64, ∅-L_{CE}=114.87	5-point [1...5]	1.81	1.46	2.16	0.66	0.00
95-100 (N=101)	11-point [0...10]	2.83	2.27	3.40	2.86	7.92
∅-L_{AE}=98.07, ∅-L_{CE}=111.50	5-point [1...5]	2.10	1.89	2.31	1.05	7.92
100-105 (N=233)	11-point [0...10]	3.83	3.47	4.19	2.77	10.73
∅-L_{AE}=102.67, ∅-L_{CE}=116.37	5-point [1...5]	2.41	2.26	2.55	1.12	15.45
105-110 (N=258)	11-point [0...10]	4.14	3.77	4.51	3.00	16.28
∅-L_{AE}=107.53, ∅-L_{CE}=119.66	5-point [1...5]	2.53	2.38	2.68	1.20	23.26
110-115 (N=237)	11-point [0...10]	4.65	4.26	5.03	3.03	22.78
∅-L_{AE}=112.30, ∅-L_{CE}=123.77	5-point [1...5]	2.97	2.82	3.13	1.24	32.07
115-120 (N=102)	11-point [0...10]	5.35	4.78	5.92	2.91	28.43
∅-L_{AE}=117.32, ∅-L_{CE}=129.21	5-point [1...5]	3.41	3.18	3.65	1.20	43.14
120-125 (N=45)	11-point [0...10]	5.09	4.30	5.88	2.63	22.22
∅-L_{AE}=122.21, ∅-L_{CE}=131.40	5-point [1...5]	3.11	2.78	3.44	1.09	35.56
125-130 (N=10)	11-point [0...10]	3.90	1.68	6.12	3.11	10.00
∅-L_{AE}=127.74, ∅-L_{CE}=134.09	5-point [1...5]	2.60	2.00	3.20	0.84	10.00

In light of the different approaches to define *high annoyance* and for reasons of comparability, we used both scales to describe high annoyance in the respondent – following the suggestions of ICBEN [25]. Concerning the 5-point verbal scale, ICBEN's recommendation is to use the upper two categories (the verbal marks "very" and "extremely") as indicators of "high annoyance". This corresponds to a cutoff point at 60% of the scale. No recommendation is given for the 11-point scale, but according to common understanding, the upper three points on the numerical scale (8, 9, 10) indicate the presence of "high annoyance" in the respondent. In this case, the cutoff lies at 72.7% [cp. 27]). In total, on the 11-point numerical scale, 170 of 1002 respondents qualified as "highly annoyed", on the 5-point scale 241 of 1002.

Table 4 tabulates the mean annoyance rating per exposure level category as well as the percentage of highly annoyed persons (%HA) in each category, according to the above stated "highly annoyed" cutoff points (60% and 72.7%) on the scales. Annoyance is an increasing function of the sound exposure level up to the exposure level category of 115-120 dB L_{AE}. The mean annoyance ratings per level category and the corresponding percentage highly annoyed (%HA) are plotted in Figure 2.

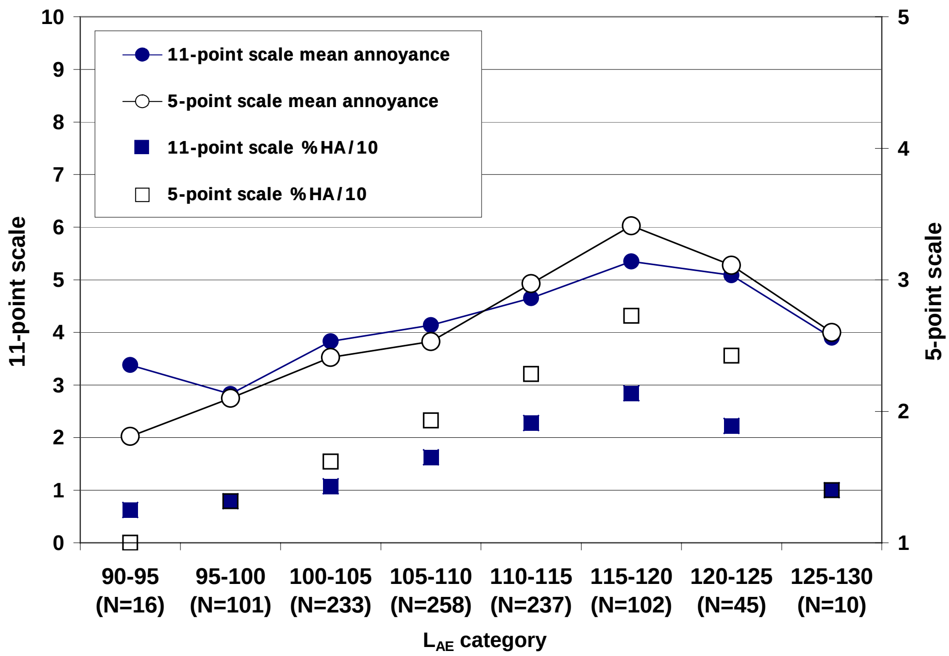
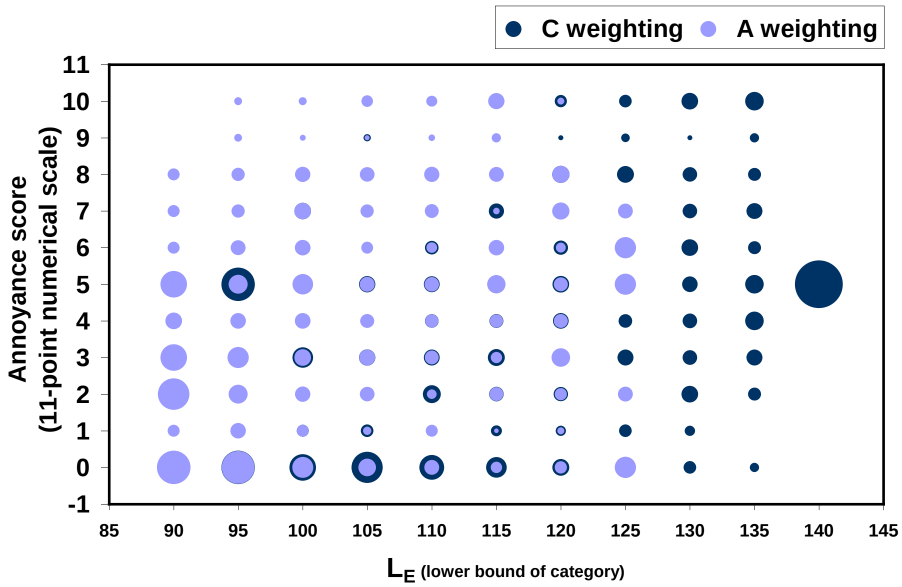


Figure 2: Mean annoyance (dots) and %HA/10 (squares) from military shooting noise on the 11- and 5-point scale per category of LAE values. Left axis: 11-point scale and %HA/10; right axis, 5-point scale.

Contrary to expectation, within the higher level categories (120-125 dB L_{AE} and 125-130 dB L_{AE}), mean annoyance as well as the percentage of highly annoyed persons (%HA) again drops to a level close to the level reported by respondents that are 15 or even 20 dB less exposed. This could be explained by some type of self selection process being at work insofar as people not being annoyed by military shooting noise are overrepresented in areas close to military shooting grounds, maybe because they are less sensitive to noise and/or have a more positive attitude towards the army, e.g. because they are army employees living in the vicinity of their employer. This explanation appears feasible since: (1) In linear regression analysis of L_{AE} as dependent variable, noise sensitivity (as measured by the LEFK) is a significant predictor [β=-0.11, t(1000)=-2.33, p=0.02], thus supporting the self selection hypothesis. (2) Annoyance, as measured using the 5-point verbal scale, and attitude towards the army (an index value between 1 and 5 with higher values denominating a more positive attitude, derived from items of the questionnaire, see section II B) are negatively correlated within the sample [r=-0.28; p<.0001]. (3) Furthermore, in general linear modeling of annoyance (5-point verbal scale), both L_{AE} and attitude independently predict annoyance [L_{AE}: F(1)=94.23, p<.0001; attitude: F(1)=89.64, p<.0001], whereas attitude is negatively related to annoyance in this model.



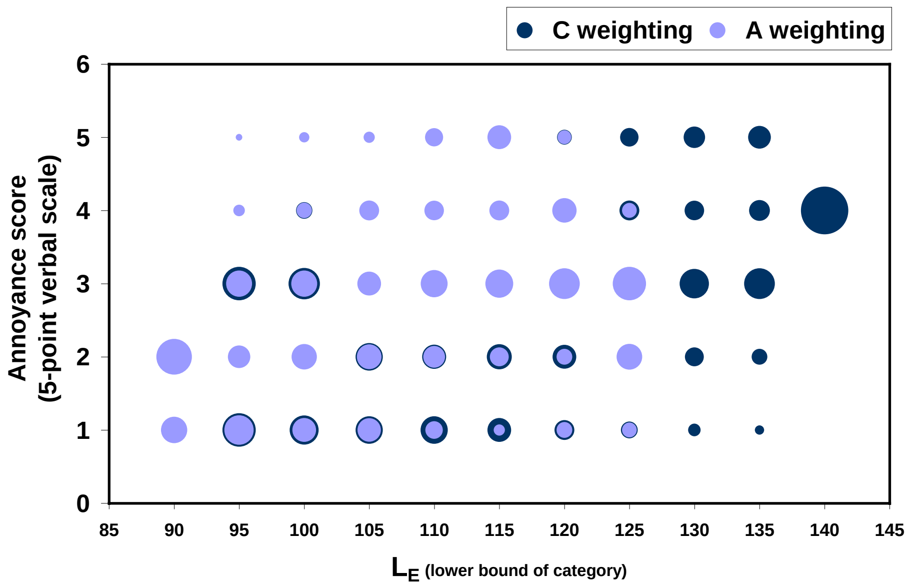


Figure 3: Distribution of annoyance ratings in the different exposure level categories of L_{AE} and L_{CE} (the category denomination on the x-axis refers to the lower boundary of the category). The diameter of the bubbles at a respective annoyance score value reflects the fraction of annoyance ratings per level category. Top: 11-point numerical scale; Bottom: 5-point verbal scale with scale values 1="not at all", 2="slightly", 3="moderately", 4="very", 5="extremely".

Figure 3 shows the distribution of annoyance ratings in each level category as bubble plots with two series - one representing the level category as yearly average L_E with A weighting (L_{AE}), and the other as L_E with C weighting (L_{CE}). As becomes evident from Figure 3, the data show considerable variability of annoyance ratings for both the 11-point numerical and the 5-point verbal scales. Linear regression results of the individual sample data (not the grouped data!) for the 11-point numerical scale yielded R^2 values of less than 0.05, the 5-point verbal scale yielded an adjusted R^2 value of 0.08 for both L_{AE} and L_{CE} as predictor. The limitations of mere acoustical noise metrics in explaining variance in annoyance is a widespread phenomenon. While with transportation noise, on the individual level, R^2 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.

3.3 Exposure-effect relationships for L_{AE} and L_{CE} as principal predictors

The method to establish noise exposure limits, the primary goal of this study, can be broken up into four steps: exposure assessment, impact assessment, establishing dose-response relationships and setting exposure limits according to predefined protection criteria. In many instances, a predefined proportion of *highly annoyed* persons (e.g. 25%) is used as the criterion for setting an exposure limit value. It is noteworthy that the percentage agreed upon (e.g. 25%) is basically a political criterion regardless of any kind of scientific justification. Some of the reasons, why the percentage of the population that strongly reacts to the noise within an exposure category is a better measure of community reaction than the average of the rating scale, are listed in the seminal paper by Schultz [27].

The derivation of a fitting function requires a practical as well as theory-based choice about the functional form with which the observed exposure-effect relationship can be represented in a pertinent and useful way. Since the relevant effect in the current study – being highly annoyed or not – is binary by nature, we prefer the logistic form. To predict the proportion of highly annoyed people at any given L_E level, a sound statistical model must prevent of predicting values that are theoretically inadmissible – the statistical analysis must therefore account for the binomial nature of the distribution of the dependent variable. This is achieved with logistic regression analysis.

Logistic regression analyses on the probability of high annoyance (P_{HA}) using the L_{AE} and L_{CE} predictor were calculated with the SAS STAT system (SAS version 9, SAS Institute, Cary, NC, USA). The 95% confidence bounds that are shown in Figure 4 were calculated using the standard errors and the estimated variance-covariance matrices of the models. To roughly asses the degree of explained variance in the model building process, the pseudo-R^2 statistic according to McKelvey & Zavoina [28] was calculated.

First, it was assessed which nonacoustic factors exert influence on the probability of high annoyance P_{HA} (on the 5-point verbal scale). The study sites (shooting grounds), which were distributed all over Switzerland (cp. Figure 1), did not have an independent significant effect on annoyance as a sole predictor. Neither did the language in which the interview was conducted (French or German). Also, no significant effect of gender on annoyance could be found in a range of models. There could be found an influence of age in a few models though, insofar as elderly persons were less annoyed than younger. No effect was found with the duration of living near the shooting ground, nor did house owner's annoyance significantly differ from the annoyance of tenants. Altogether, findings of this kind are quite advantageous for policy purposes.

The strongest logistic model comprised the predictors L_{AE}, *Attitude towards the army* and *Noise sensitivity* (as measured by the LEFK). To permit the readers to gauge the relative impact of these variables in a composite model, the parameter estimates are given in Table 5.

TABLE 5: Logistic regression results of P_{HA} explained by exposure and individual moderators. Noise Sensitivity was assessed using the LEFK questionnaire and is expressed on a scale from 0 to 27, Attitude towards the army is expressed on a scale from 1 to 5.

Dependent	Parameter	Coefficient (B)	Standard Error	Wald Stat.	p
P_{HA}	Intercept	-10.12	1.36	55.81	<.0001
	L_{AE}	0.09	0.01	52.81	<.0001
	Noise Sensitivity	0.08	0.02	20.75	<.0001
	Attitude towards Army	-0.45	0.07	46.31	<.0001
		McKelvey & Zavoina R^2: 0.45			

Since individual moderators of noise annoyance can not be accounted for within the scope of defining exposure limits, and also because no other operational characteristics of shooting appear to be relevant in their influence on annoyance, we propose a set of logistic models which solely rely on either the L_{AE} or L_{CE} dose measure as main predictor. The logistic curves of these models are plotted in Figure 4, the corresponding parameters are given in Table 6.

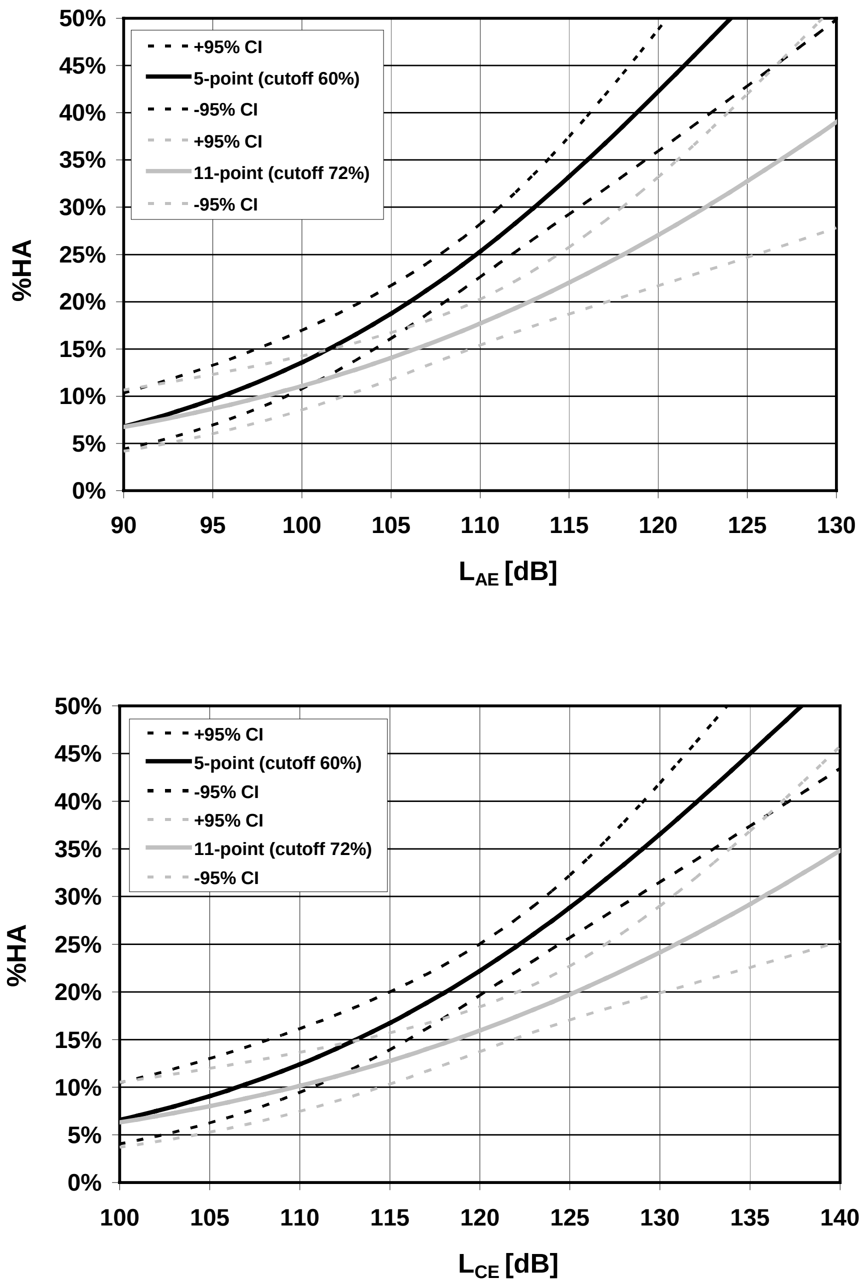


Figure 4: Dose-response curves and 95% confidence intervals for high annoyance due to military shooting noise as predicted by logistic regression models. Top: exposure expressed as L_{AE}; Bottom; exposure expressed as L_{CE}

As mentioned, in the current study, we employed two different scales to measure annoyance and consequently, two different derivations (definitions) of the occurrence of high annoyance in the resident, both of which have been discussed by ICBEN [25] and are widely used. The finding, that the two measurements do not lead to congruent logistic curves (cp. Figure 4) is rather unsatisfying. It points to the fact that the numerical and the verbal scales and their most commonly used cutoff-points for the HA definition (upper 2 categories in the case of the 5-point scale, upper 3 categories in the case of the 11-point scale) obviously do not measure the same thing. There have been successful attempts to attain congruent curves in other studies [e.g. 29] by statistically raising the cutoff-point of the 5-point scale to 72% by weighting the response category "very" on the 5-point scale as proposed by Miedema and Vos [30]. A similar attempt was not very successful with the current data (cp. Figure 5). The weighted curve (with cutoff 72%) is displaced by about 10 dB, but has a more steep characteristic than the dose-response curve from the 11-point scale, the two curves are still not congruent. The parameters of the corresponding weighted logistic regression are tabulated in the last rows in Table 6.

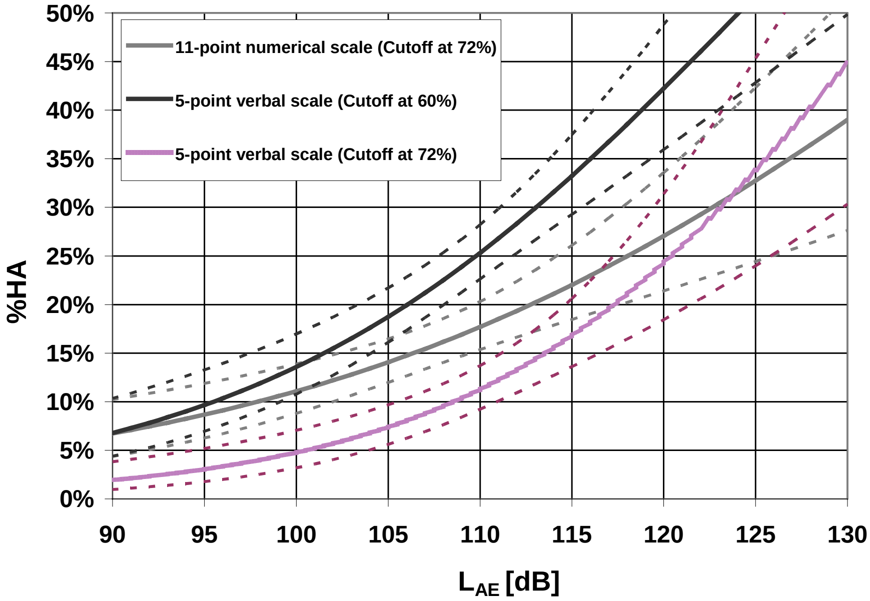


Figure 5: Logistic dose-response curves and 95% confidence intervals for three different methods of defining the proportion of "highly annoyed" persons in the current sample. The curve on the 5-point verbal scale using a cutoff point of 72% was generated by weighting the cases, where the respondent chose the "very" modifier on the scale, with 0.4 in the logistic regression analysis.

Although the issue of non-congruent exposure-effect curves from scales that are both designed to express "high annoyance" is very important for noise effects research and for noise policy in general, it cannot be investigated any further within the scope of the current article. The question about which of the three displayed curves better serves the intention of the study will be discussed in Part 4.

The confidence intervals of the dose-effect functions in Figure 4 and 5 and the standard errors reported in Table 6 pertain to the uncertainty of the annoyance measurement in the sample, not the uncertainty of noise exposure calculations. Therefore, the true confidence boundaries are most probably wider. We did not calculate the extended uncertainty of the exposure-effect relationship since the nonconsideration of acoustic uncertainty is a shortcoming of almost all annoyance studies of this kind, and accounting for acoustic uncertainty would possibly compromise the comparability of the confidence intervals in this study with the ones from other studies.

TABLE 6: Results of the logistic regression models

Predictor	Dependent	Parameter	Coefficient (B)	Standard Error	Wald Stat.	p
L_{AE}	P_{HA} (11-point numerical)	Constant	-7.53	1.34	31.74	<.0001
		L_{AE}	0.05	0.01	20.15	<.0001
			McKelvey & Zavoina R^2: 0.10			
L_{AE}	P_{HA} (5-point verbal)	Constant	-9.54	1.23	60.49	<.0001
		L_{AE}	0.08	0.01	47.68	<.0001
			McKelvey & Zavoina R^2: 0.23			
L_{CE}	P_{HA} (11-point numerical)	Constant	-7.88	1.50	27.72	<.0001
		L_{CE}	0.05	0.01	17.96	<.0001
			McKelvey & Zavoina R^2: 0.11			
L_{CE}	P_{HA} (5-point verbal)	Constant	-9.67	1.36	50.43	<.0001
		L_{CE}	0.07	0.01	39.79	<.0001
			McKelvey & Zavoina R^2: 0.19			
L_{AE}	P_{HA} (5-point verbal, cutoff at 72%)	Constant	-12.28	1.78	47.83	<.0001
		L_{AE}	0.09	0.02	34.00	<.0001
			McKelvey & Zavoina R^2: 0.28			

3.4 Accounting for low frequency components in L_{AE} based models

The sound exposure spectra of large caliber weapons such as cannons or tanks are dominated by the energy in the low frequency bands. In contrast to small caliber shots these sounds can excite noticeable vibration of dwellings and they more easily pass through walls and windows owing to a reduced attenuation of lower frequencies. For this kind of shooting events, C-weighted measures might better predict annoyance. In the present study, L_{AE} and L_{CE} almost equally well (or bad, for that matter) predict annoyance and both descriptors can basically be used interchangeably as main predictor. L_{AE} and L_{CE} correlate with r=.8 (p<.0001) in the sample, which potentially leaves room for some additional variance explanation by accounting for both measures in some (combined) way. In the literature, e.g. in Vos [13], there have been discussed models which account for both A-weighted as well as C-weighted properties of shooting sounds. The aim of such kind of modeling is to arrive at one single rating procedure for both small and medium-large weapon sounds.

The following analyses were performed to test the benefits of the inclusion of C-weighted measures in the annoyance prediction of principally L_{AE} based models.

It must be noted that (L_{CE}-L_{AE}) is strongly dependent on weapon type. With small arms, the difference is near 0 dB, and increases with increasing caliber, as the low frequency energy becomes more and more determining. In the current sample, the arithmetic average C-A level differences at the receiver points for the different weapon categories were as follows (rounded to full null numbers): Large caliber/tank: 19 dB, Middle caliber: 10 dB, Small caliber: 3 dB, Practice ammunition: 5 dB, Grenades/explosive charges: 16 dB, Mortars: 16 dB.

3.4.1 Linear models

First, we modeled the annoyance reaction on the 11 and 5-point scales with linear regression analysis (using the GLM Module of STATISTICA, Stat Soft Inc.) with the predictors L_{AE} and the difference between the C-weighted and the A-weighted level (L_{CE}-L_{AE}), as has been suggested by Vos [13]. The inclusion of this second predictor is based on the idea that for large weapons with considerable low frequency content, the A-weighted level alone does not sufficiently account for the variation in annoyance. For the purpose of modeling, the 5-point verbal scale variable was transformed to numeric values 1…5 with the scale end points "not at all"=1 and "extremely"=5. The results are presented in Table 7.

TABLE 7: Linear regression results with L_{AE} and (L_{CE}-L_{AE}) predictors

Dependent	Parameter	B	Beta	F	df	p	Whole Model Statistics
Annoyance rating (11-point scale)	Intercept	-7.36		21.06	1	0.0001	R^2 adj.=0.05; F(2)=26.08, p<0.0001
	L_{AE}	0.10	0.23	50.89	1	<.0001	
	(L_{CE}-L_{AE})	0.07	0.10	10.42	1	0.0013	
Annoyance rating (5-point scale)	Intercept	-3.70		33.01	1	<.0001	R^2 adj.=0.09; F(2)=50.59, p<0.0001
	L_{AE}	0.06	0.03	101.15	1	<.0001	
	(L_{CE}-L_{AE})	0.02	0.03	8.11	1	0.0045	

Both predictors L_{AE} and (L_{CE}-L_{AE}) account for the variance in annoyance. The inclusion of (L_{CE}-L_{AE}) as a second predictor slightly improved the explained variance (R^2 adjusted) of both the models by about 0.01 points. Also, as can be learned from Table 7, the 5-point verbal scale, treated as continuous variable, better predicted the annoyance rating than did the 11-point numerical scale.

Vos proposes a rating sound level (L_r) for impulse noise events to be calculated as follows, taking into consideration both the A-weighted and C-weighted outdoor sound exposure level of the noise:

$$\begin{aligned} L_r &= L_{AE} + 12\text{dB} + \beta(L_{CE} - L_{AE}) \times (L_{AE} - \alpha) \\ L_{r'} &= L_{AE} + \beta(L_{CE} - L_{AE}) \times (L_{AE} - \alpha) \end{aligned} \quad (2)$$

where:

L_r	Rating sound level for impulsive sounds that are equally annoying than traffic sounds with the same energy [13]
$L_{r'}$	Rating sound level for impulsive sounds, omitting the penalty of 12 dB
β, α	Parameters of the linear regression

In Equation 2, the term "+12 dB" represents the "added annoyance" of impulsive noise as compared to the annoyance of road traffic noise of the same energy. The term "$\beta(L_{CE}$-$L_{AE})\times(L_{AE}$- α)" represents the "added annoyance" for heavy firearms, in Decibels. This term is, as one can see, level-dependent. For L_r (including the 12 dB impulse penalty) Vos reckons the optimum parameter values to be α=45 and β=0.015 for the "indoor" condition and α=57dB and β=0.015 for the "outdoor" condition. As we do not primarily seek a model that takes into account the annoyance difference to a reference noise source (like road traffic noise), we can omit the impulse penalty of 12 dB. The annoyance rating is then a function of Lr':

$$\text{Annoyance rating} = a + b \times Lr' \quad (3)$$

where:

$L_{r'}$	Rating sound level from Equation 2
a, b	Parameters of the linear regression to be estimated

To derive the estimates for a and b in Equation 3, one needs to calculate $L_{r'}$, which in turn demands an estimation of the parameters β and α in Equation 2. This was accomplished using the Generalized Reduced Gradient Method implemented in Microsoft Excel Solver. First, the starting values for β and α in Equation 2 were estimated by maximizing the correlation between the annoyance rating and Lr‘. Done so, the annoyance rating was predicted with Equation 3. β, α, b and a were optimized by minimizing the sum of the squared differences between the original annoyance rating and the prediction according to Equation 3. The same estimation was also carried out with the NLIN procedure of SAS by running the Gauss-Newton Method and using the Solver results as start values. Both methods yielded the same parameter estimations which were: For the 11-point numerical scale: β=0.00014; α=-4956; a=-7.34; b=0.0989; for the 5-point verbal scale: β=0.055; α=93.94; a=-1.31; b=0.0339. With these α and β parameter values, linear regression analysis on annoyance with Lr‘ as only predictor yields the statistics given in Table 8. For comparison, the regression analysis results for the model with the L_{AE} predictor are shown also.

TABLE 8: Linear regression results using the Lr' and L_{AE} predictor

Model / Dependent	Parameter	B	Beta	F	df	p	Whole Model Statistics
Annoyance rating (11-point scale)	Intercept	-7.34		21.04	1	0.0001	R^2 adj.=0.05; F(1)=52.22, p<0.0001
	Lr'	0.10	0.22	52.22	1	<0.0001	
Annoyance rating (5-point scale)	Intercept	-1.30		11.21	1	0.0001	R^2 adj.=0.09; F(1)=105.00, p<0.0001
	Lr'	0.03	0.31	105.00	1	<0.0001	
Annoyance rating (5-point scale)	Intercept	-2.88		24.83	1	<0.0001	R^2 adj.=0.08; F(1)=92.42, p<0.0001
	L_{AE}	0.05	0.29	92.42	1	<0.0001	

As can be derived from Table 8, in case of the annoyance rating using the 5-point scale, the model using the rating level Lr' as predictor slightly enhances the explained variance compared to the model using just L_{AE} as predictor.

Albeit the most important components determining annoyance due to military shooting noise most probably are not to be found in the acoustic domain (but rather considering individual moderators such as noise sensitivity, attitude towards the army etc., see Section III.C), the results at hand confirm the predictive value of incorporating the difference between C and A-weighted measurements (in the next section, it is tested whether this is the case also with binary logistic modeling of the probability of high annoyance P_{HA}). However, in light of the comparatively small effect of acoustic predictors anyway, the additional variance explanation contained in the Lr' rating level appears negligible.

3.4.2 Binary logistic models

Two binary logistic models that predict the probability of high annoyance (P_{HA}) with L_{AE} and (L_{CE}-L_{AE}) as independent variables were estimated using PROC LOGISTIC of SAS. The results are presented in Table 9.

In contrast to linear modeling of the annoyance rating (cp. Table 7), the inclusion of (L_{CE}-L_{AE}) in the binary logistic models did not significantly contribute to the prediction of the probability of high annoyance (P_{HA}). It therefore appears not necessary to implement C-weighted measurements or a difference between the C and A-weighted level in the modeling of exposure-effect functions for policy purposes. In all conscience, the inclusion of (L_{CE}-L_{AE}) does not degrade the power of the models, but likewise the (L_{CE}-L_{AE}) predictor also offers no specific benefit that would warrant the effort of additional calculation or measurement of C-weighted exposure levels. It is likely, that accounting for low frequency components is much less important in the field than in the laboratory.

TABLE 9: Logistic regression models on P_{HA}

Dependent	Parameter	Coefficient (B)	Standard Error	Wald Stat.	p
P_{HA} (11-point numerical)	Intercept	-8.30	1.51	30.34	<.0001
	L_{AE}	0.06	0.01	21.23	<.0001
	(L_{CE}-L_{AE})	0.02	0.02	1.27	0.2592
		McKelvey & Zavoina R^2: 0.14			
P_{HA} (5-point verbal)	Intercept	-10.36	1.38	56.79	<.0001
	L_{AE}	0.08	0.01	48.65	<.0001
	(L_{CE}-L_{AE})	0.02	0.02	1.84	0.1753
		McKelvey & Zavoina R^2: 0.22			

4. DISCUSSION

As military shooting noise as resulting from 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. The current study therefore investigated shooting noise annoyance of communities near eight large military training grounds in Switzerland, yielded insights to the exposure-annoyance relationship, and provides the foundations for defining an exposure limit by policy.

In the following, we briefly review and discuss the findings of the study and then conclude this article with some policy recommendations.

Exposure-effect relationship. The relationship between the reactions of the respondents and exposure was not very strong for any exposure measure. The weak exposure-annoyance link was expected and is quite in line with previous attempts of deriving exposure-effect relationships of shooting noise annoyance in field studies [e.g 4]. However, the reduced ability of the exposure measures in explaining variability of annoyance is rather detrimental when it comes to justifying a particular exposure limit.

Annoyance scales and cutoff points. Schultz in the seventies already observed that the largest uncertainties in deriving his influential dose-effect curve were associated with the judgment as to which respondents are counted as "highly annoyed" [27]. Obviously, this is a statement that still prevails today. We found that when applying the most commonly used cutoff points (60% and 72.7%) on both the verbal and numerical annoyance scales suggested by ICBEN [25], the two resulting logistic curves are non-congruent and predict different amounts of highly annoyed persons (%HA), especially within higher exposure level categories. Our data also demonstrate, that statistically aligning (weighting) the cut-off points of both scales might not be a sound basis for comparing the two scales. Since a proper definition of "high annoyance" (and its impact on the fitting of a function curve) is decisive within the framework of setting exposure limits by policy, this is all the more an issue which must be tackled by the scientific community soon.

However, the observation, that the %HA predictions from the two scales do not match and the ratings on the 5-point scale are higher might also be the result of an order effect and not necessarily an effect of the underlying scale: The question using the 5-point verbal scale was asked first and early in the interview, after a few non-noise related data like particulars were asked. The noise issue was raised the first time within a block of (randomized) annoyance rating questions for different noise types. On the contrary, the 11-point numerical scale was presented after the interview dealt with several military shooting and noise related questions. The cognitive occupation with the noise topic could have lead to a relativization of the noise annoyance issue and may prevented the respondents to give extreme answers.

The 11-point numerical scale has so far been the preferred measurement method for noise annoyance surveys in Switzerland and has already been used in an aircraft noise annoyance survey in the early seventies, in a study which in fact established the "3/11 standard" of assigning people who respond to the upper three categories on a 0-10 scale to the group of *highly annoyed* [31]. This definition was later adopted by Schultz in his synthesis on noise annoyance [27]. For a multilingual country like Switzerland, the use of a numeric instead of a 5-point verbal scale was justified by the fact, that "semantic 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.

Indeed, with the current data, we found quite strong evidence, that the 5-point scale better explains variance in (shooting noise) annoyance than the 11-point scale. The explained variance of the 5-point scale is even higher when applying a cutoff-point at 72% instead of the usual 60%.

Comparison with existing literature. The current study is an attempt to derive an exposure-effect relationship for annoyance from gathering both independent predictor data as well as dependent effects from the real world, combined with an exactitude of exposure assessment over a large time span (three years) that was not reported in the literature before. As the "overall annoyance" in this study is caused by an unknown combination of noise intrusions experienced in- and outdoors, with open and closed windows, possibly only partly at home and partly away from home, and by a particular combination of weapons, small and large, it is not easily possible to relate our findings to previous research which most often concentrated on one particular type of shooting activity (e.g. artillery firing) only. In light of the fact that only a few field studies on community reactions to military noise have been carried out so far, and many of the studies applied an exposure quantisation methodology whose accuracy is at best questionable (e.g. short-term measurements instead of calculation), or did not publish a statistically derived exposure-effect function at all, any attempt to compare our findings with previous research was very difficult. To obtain at least an idea for the extent to which the annoyance in our sample is in line with previous research, we tried to find as many studies as possible that allowed to compare the exposure needed to elicit 25% HA. The only study that allowed a more or less direct comparison was the one from Buchta and Vos [9]. They conducted a field study on annoyance from artillery firing and found 25% HA at a L_{CDN} of about 57 dB. Since in our case, night and evening shootings are very rare, the L_{DN} is practically equal to the $L_{eq,24h}$. The L_{CDN} level of 57 dB roughly corresponds to a yearly L_{CE} level of 132 dB. In Figure 4 we find 25% HA (using the 11-point scale and cutoff-point at 72 %) at a L_{CE} of about 131 dB. The two field studies thus correspond very well.

Frequency weighting. The observations made in previous (laboratory) studies [e.g. 13], that explained variability of annoyance (slightly) rises when including the difference between the C and A-weighted levels as an additional predictor, could be confirmed in linear regression analyses. However, the additional variance explanation through incorporation of the C-A difference was rather small and almost disappeared within the scope of binary logistic modeling of the probability of high annoyance. We therefore conclude that the use of L_{AE} as the sole predictor of high annoyance in most cases captures as much variation as is appropriately derivable from operational and acoustical data, at least in the vicinity of military shooting grounds that are typical for Switzerland. As the C-A difference becomes larger with larger calibers, the incorporation of C-weighted measurements might lead to a better prediction of annoyance at grounds with more heavy weapon shooting activities and/or considerably higher levels of exposure, or, in countries with usually more permeable building envelopes. But these are issues that remain to be investigated in further field surveys. It was clearly shown in the current study, that a laboratory-derived rating procedure does not necessarily lead to a better annoyance prediction than a function that omits the C-A difference as predictor. We currently have ample reason to believe that there are no shooting grounds in Switzerland where additional C-weighted measures would considerably sharpen up the annoyance prognosis.

In contrast to experimental laboratory studies where a specific listening situation (indoors or outdoors) of shooting sounds is deliberately created by the experimenter, it generally remains unknown to which particular situation or blend of recalled situations respondents in community surveys react when asked about their annoyance. The data found in this study rather suggest that the interviewees implicitly reported their annoyance based on the outdoor situation, as – in accordance with previous laboratory research employing an outdoor [13] or open windows listening situation [11] – their annoyance ratings were best determined by L_{AE} and the incorporation of L_{CE} only added a limited amount of explained variance.

Penalty corrections for evening shootings. In this study we also tried to elucidate the impact of different timely distributions of shootings across a day and to provide the foundations for defining a penalty for evening shootings. However, because the timely resolution of the shooting activities on the grounds was not recorded in detail and could therefore not be reported accurate enough by army officials to be able to calculate hour-by-hour exposure level values, there was no method of responsibly deriving a penalty value for evening shootings with the current data at hand. Although the respondents were asked which times they considered themselves as being particularly highly annoyed, the questionnaire was lacking a generic question as to the degree of annoyance during "evenings", an admittedly dissatisfactory weakness of the study design. However, the fraction of the number of shots during evenings amounted to less than 6% of the total number of shots. Considering the fact, that likely 99% of shots fired fall within a rather short time period of roughly 12 hours per day, beginning at 08:00 h, it would still be difficult to statistically derive a stable estimate for an evening penalty to be adopted. In contrast to e.g. aircraft noise, which is often particularly intense during shoulder hours [32] and therefore calls for apt integrated noise measures, military shooting noise in Switzerland is mostly confined to office hours. But there is no reason to believe that peoples sensitivity to shooting noise during shoulder hours differs from what has been found with other noise types. This assumption is further supported by the many times during the interviews, respondents mentioned evening shootings as being particularly annoying [cp. 33]. It can be assumed that a penalty correction for the evening time should be in the range of about 5 to 10 dB, as is the case with other noise types. The *rating level* for military shooting noise exposure (Lr), based on a yearly calculation, can then be defined as a composite of the yearly sound exposure level during day ⊕ the level during night, with the latter including the penalty correction.

Policy recommendations. Establishing the criteria for rating weapon noise has proven to be a quite difficult task as annoyance ratings from residents were strongly influenced by non-acoustic, but quite powerful moderating factors such as the attitude towards the army and the individual noise sensitivity. It appears that shooting noise exposure itself is only a moderate determinant of people's propensity for annoyance. Especially within the scope of noise abatement policy, this should always been kept in mind. For reasons of comparability and because of its relatively high degree of explained variance, we suggest further studies of community noise annoyance to basically rely on the 5-point verbal scale and the corresponding cutoff for the definiton of "high annoyance" as suggested by Fields et al. [25]. Consequently, our general recommendation for military shooting noise regulation purposes is to employ the black exposure-effect curve in the top panel of Figure 4. This curve can be expressed as 2nd or 3rd order polynomial with sufficient accuracy between 90 and 130 L_{AE}, with P_{HA} expressing the fraction of highly annoyed persons for a given L_{AE} value, as follows:

$$\begin{aligned} P_{HA} &= 1.40 - 0.0348 \times L_{AE} + 0.00022 \times L_{AE}^2 \\ P_{HA} &= 4.53 - 0.121 \times L_{AE} + 0.00101 \times L_{AE}^2 - 0.0000023978 \times L_{AE}^3 \end{aligned} \quad (4)$$

This curve represents military shooting noise annoyance which predominantly occurs with (1) most of the shootings taking place during day, (2) a fraction of about 5-10% of the shootings taking place during the evening hours, and (3) no shootings during the core night hours. Furthermore, the curve rather represents an exposure situation with a considerable fraction of small caliber shots (cp. Table 2), whose exposure values, at least in the current case, also better correlated with annoyance than the exposure from large caliber weapon shootings (cp. Table 3). With the advent of more sophisticated training simulators for mainly heavy weapon systems (e.g. for tanks) which will more and more replace the training with real weapons, heavy weapon noise will most probably be less of a problem in the future, hence, the proposed exposure-effect relationship for small caliber dominated shooting activity appears to be well suited to forecast shooting noise annoyance also in the future.

The generalizability of the current results for certain shooting noise situations, particularly for shooting grounds with a possibly 'atypical' distribution of small and large weapon noise exposure, is of course, somewhat reduced. However, for Switzerland, the reported results are representative as the largest military training grounds, covering a large part of the population of people potentially benefiting from the introduction of new shooting noise regulations, were chosen as study sites. Thus, in light of the study goals exposed in Section I.A, the results seem to describe the shooting noise annoyance situation in Switzerland quite well and might be applicable to other countries as well.

Acknowledgements

This study was funded by the Swiss federal office for the environment to which we are very grateful. We thank the Swiss federal statistical office for their collaboration with address sampling and the IHA GfK company for carrying out the telephone interviews for us. We also thank the Swiss army for providing operational data in order to make the exposure calculations. We wish to express our gratitude to Rainer Guski and Christian Maschke for commenting an early version of this report as well as to Hans Boegli and Kurt Heutschi for other helpful contributions. Finally, MB would like to acknowledge the valuable discussions, in particular with Joos Vos, but also with Jim Fields and Dick Botteldooren about several aspects of this study during the 9^{th} ICBEN conference at Foxwoods, CT in 2008.

5. REFERENCES

[1] Schweizerische Eidgenossenschaft. (1983). *Bundesgesetz über den Umweltschutz (Umweltschutzgesetz, USG) [Swiss Federal Law on the Protection of the Environment]*. Retrieved 20 August 2008, from http://www.admin.ch/ch/d/sr/814_01/index.html

[2] Schweizerische Eidgenossenschaft. (1986). *Lärmschutz-Verordnung vom 15. Dezember 1986 (LSV) [SR 814.41]*. Retrieved 20 August 2008, 2008, from http://www.admin.ch/ch/d/sr/8/814.41.de.pdf

[3] Schomer, P. D. (1985). Assessment of Community Response to Impulsive Noise. *Journal of the Acoustical Society of America, 77*(2), 520-535.

[4] Bullen, R. B., Hede, A. J., & Job, R. F. S. (1991). Community Reaction to Noise from an Artillery Range. *Noise Control Engineering Journal, 37*(3), 115-128.

[5] Levein, B., & Ahrlin, U. (1988). Annoyance Caused by Shooting Range Noise. *Journal of Sound and Vibration, 127*(3), 589-592.

[6] Sorensen, S., & Magnusson, J. (1979). Annoyance Caused by Noise from Shooting Ranges. *Journal of Sound and Vibration, 62*(3), 437-442.

[7] Rylander, R., & Lundquist, B. (1996). Annoyance caused by noise from heavy weapon shooting ranges. *Journal of Sound and Vibration, 192*(1), 199-206.

[8] Schomer, P. D. (1994). New Descriptor for High-Energy Impulsive Sounds. *Noise Control Engineering Journal, 42*(5), 179-191.

[9] Buchta, E., & Vos, J. (1998). A field survey on the annoyance caused by sounds from large firearms and road traffic. *Journal of the Acoustical Society of America, 104*(5), 2890-2902.

[10] Fidell, S., Horonjeff, R., Schultz, T., & Teffeteller, S. (1983). Community Response to Blasting. *Journal of the Acoustical Society of America, 74*(3), 888-893.

[11] Meloni, T., & Rosenheck, A. (1995). Choice of Frequency-Weighting for the Evaluation of Weapon Noise. *Journal of the Acoustical Society of America, 97*(6), 3636-3641.

[12] Schomer, P. D., Wagner, L. R., Benson, L. J., Buchta, E., Hirsch, K. W., & Krahe, D. (1994). Human and Community Response to Military Sounds - Results from Field-Laboratory Tests of Small-Arms, Tracked-Vehicle, and Blast Sounds. *Noise Control Engineering Journal, 42*(2), 71-84.

[13] Vos, J. (2001). On the annoyance caused by impulse sounds produced by small, medium-large, and large firearms. *Journal of the Acoustical Society of America, 109*(1), 244-253.

[14] Vos, J. (1990). On the Level-Dependent Penalty for Impulse Sound. *Journal of the Acoustical Society of America, 88*(2), 883-893.

[15] Schomer, P. D., & Wagner, L. R. (1995). Human and Community Response to Military Sounds .2. Results from Field-Laboratory Tests of Sounds of Small Arms, 25-Mm Cannons, Helicopters, and Blasts. *Noise Control Engineering Journal, 43*(1), 1-14.

[16] Buchta, E. (1990). A Field Survey on Annoyance Caused by Sounds from Small Firearms. *Journal of the Acoustical Society of America, 88*(3), 1459-1467.

[17] Schomer, P. D. (1986). High-Energy Impulsive Noise Assessment. *Journal of the Acoustical Society of America, 79*(1), 182-186.

[18] International Standards Organisation. (2003). ISO 1996-1:2003 (Acoustics - Description, measurement and assessment of environmental noise Part 1).

[19] Vos, J. (2003). A- and C-weighted sound levels as predictors of the annoyance caused by shooting sounds, for various facade attenuation types. *Journal of the Acoustical Society of America, 113*(1), 336-347.

[20] Oliva, C. (1998). *Belastungen der Bevölkerung durch Flug- und Strassenlärm*. Berlin: Duncker&Humblot.

[21] Wirth, K. (2004). *Lärmstudie 2000. Die Belästigungssituation im Umfeld des Flughafens Zürich*. Aachen: Shaker Verlag.

[22] Bullen, R. B., & Hede, A. J. (1982). Assessment of Community Noise Exposure from Rifle Shooting. *Journal of Sound and Vibration, 82*(1), 29-37.

[23] Troldahl, V. C., & Carter, R. E. (1964). Random Selection of Respondents within Households in Phone Surveys. *Journal of Marketing Research, 1*(2), 71-76.

[24] Zimmer, K., & Ellermeier, W. (1998). Ein Kurzfragebogen zur Erfassung der Lärmempfindlichkeit. *Umweltpsychologie, 2*(2), 54-63.

[25] Fields, J. M., De Jong, R. G., Gjestland, T., Flindell, I. H., Job, R. F. S., Kurra, S., et al. (2001). Standardized general-purpose noise reaction questions for community noise surveys: Research and a recommendation. *Journal of Sound and Vibration, 242*(4), 641-679.

[26] Rosenheck, A., & Meloni, T. (1995). *Die Störwirkung von Seriefeuer, Salven und Schüssen mit Echoanteilen.* Paper presented at the DAGA 95, Saarbrücken.

[27] Schultz, T. J. (1978). Synthesis of social surveys on noise annoyance. *Journal of the Acoustical Society of America, 64*, 377-405.

[28] McKelvey, R. D., & Zavoina, W. (1975). Statistical-Model for Analysis of Ordinal Level Dependent Variables. *Journal of Mathematical Sociology, 4*(1), 103-120.

[29] Schreckenberg, D., & Meis, M. (2006). *Belästigung durch Fluglärm im Umfeld des Frankfurter Flughafens [Endbericht; Langfassung]*, from http://www.dialogforum-flughafen.de/fileadmin/PDF/Presse/Belaestigungsstudie_Langfassung.pdf

[30] Miedema, H., & Vos, H. (1998). Exposure-response relationships for transportation noise. *Journal of the Acoustical Society of America, 104*(6), 3432-3445.

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

[32] Brink, M., Wirth, K., Thomann, G., Bauer, G., & Schierz, C. (2008). Annoyance responses to stable and changing aircraft noise exposure. *Journal of the Acoustical Society of America, 124*(5), 2930-2941.

[33] Brink, M., Wunderli, J.-M., & Boegli, H. (2008, 30 May-1 June 2008). *Community response to military shooting noise immissions - preliminary results.* Paper presented at the 9th International Congress on Noise as a Public Health Problem (ICBEN), Foxwoods, CT.

[34] International Standards Organisation. (2005). ISO 17201-1 (Acoustics - Noise from shooting ranges - Part 1: Determination of muzzle blast by measurement).

[35] International Standards Organisation. (2006). ISO 17201-4 (Acoustics - Noise from shooting ranges - Part 4: Prediction of projectile sound).

[36] International Standards Organisation. (2006). ISO 17201-2 (Acoustics - Noise from shooting ranges - Part 2: Estimation of muzzle blast and projectile sound by calculation).

[37] Wunderli, J. M., Acta Acustica united with Acustica. (2004). Modeling the source strength of explosions under consideration of the ground influence. *Acta Acustica united with Acustica, 90*, 690-701.

[38] International Standards Organisation. (1993). ISO 9613-1 (Acoustics - Attenuation of sound during propagation outdoors, Part 1: Calculation of the absorption of sound by the atmosphere).

[39] International Standards Organisation. (1993). ISO 9613-2 (Acoustics - Attenuation of sound during propagation outdoors, Part 2: General method of calculation).

[40] Chessell, C. I. (1977). Propagation of Noise Along a Finite Impedance Boundary. *Journal of the Acoustical Society of America, 62*(4), 825-834.

[41] Chien, C. F., & Soroka, W. W. (1975). Sound-Propagation Along an Impedance Plane. *Journal of Sound and Vibration, 43*(1), 9-20.

[42] Chien, C. F., & Soroka, W. W. (1980). A Note on the Calculation of Sound-Propagation Along an Impedance Surface. *Journal of Sound and Vibration, 69*(2), 340-343.

[43] Hothersall, D. C., & Harriott, J. N. B. (1995). Approximate Models for Sound-Propagation above Multi-Impedance Plane Boundaries. *Journal of the Acoustical Society of America, 97*(2), 918-926.

[44] Delany, M. E., & Bazley, E. N. (1970). Acoustical properties of fibrous absorbent materials. *Applied Acoustics, 3*(2), 105-116.

[45] Hofmann, J., & Heutschi, K. (2005). An engineering model for sound pressure in shadow zones based on numerical simulations. *Acta Acustica United with Acustica, 91*(4), 661-670.

[46] Polster, G. (1969). Erfahrungen mit Strahlungs-, Temperaturgradient- und Windmessungen als Bestimmungs-grössen der Diffusionskategorien. *Meteorologische Rundschau, 22*, 170-175.

[47] Wunderli, J. M., & Salomons, E. (2008). Reflection of sound from a forest: Effective tree spacing for a scattering model with a single line of cylinders. *Journal of the Acoustical Society of America, 123*(5), 3821.

Appendix A: Annoyance questions wordings

To determine the degree of annoyance, the following original question wordings were used by the telephone interviewers.

(The English version of these questions [including answer alternatives] can be extracted from [Fields et al., Reference 25]. The Italian version is not included here because no standard wording for the Italian language has been proposed in [25], and because no Italian language interviews were carried out in this study.)

5-point scale: (German) "Wenn Sie einmal an die letzten 12 Monate hier bei Ihnen denken, wie stark haben Sie sich durch die folgenden Lärmarten insgesamt gestört oder belästigt gefühlt? Sie können mir jeweils sagen 'überhaupt nicht', 'ewas', 'mittel', 'stark' oder 'äusserst'". (French) "Si vous repensez aux 12 derniers mois, à quel point avez-vous été dérangé ou perturbé, dans votre logement, par les différents types de bruits que je vais vous citer? Vous pouvez me répondre par 'pas du tout', 'légèrement', 'moyennement', 'fortement' ou 'extrêmement'."

11-point scale: (German) "Stellen Sie sich eine Messlatte vor von 0 bis 10, auf der Sie angeben können, wie sehr Sie der Schiesslärm hier bei Ihnen im vergangenen letzten Jahr insgesamt gestört oder belästigt hat. Wenn Sie nun an die letzten 12 Monate hier bei Ihnen denken, welche Zahl zwischen 0 und 10 gibt am besten an, wie stark Sie sich durch den Schiesslärm insgesamt gestört oder belästigt fühlten? 0 bedeutet 'Der Schiesslärm hat mich überhaupt nicht gestört oder belästigt' und 10 bedeutet 'Der Schiesslärm hat mich äusserst gestört oder belästigt', mit den Werten dazwischen können Sie Ihr Urteil abstufen." (French) "Imaginez-vous une échelle d'opinion graduelle de zero à dix. Vous devez spécifier sur cette échelle la façon dont le bruit de tirs vous gêne lorsque vous êtes ici, chez vous: M'indiquez-vous zero si le bruit ne vous gêne pas du tout et dix si le bruit vous gêne extremement. Si vous êtes entre ces deux situations, choisissez une note intermédiaire entre zero et dix. Maintenant, si vous pensez aux douze derniers mois, quand vous êtes ici, chez vous, quelle note comprise entre zero et dix exprime le mieux à la façon dont le bruit des coups de feu vous gêne?"

The complete questionnaires in German, French, and Italian are in Appendix C1-C3.

Appendix B: Exposure calculation

The calculation model for weapon noise (abbreviated "WL04") used in this study was developed at the Laboratory of Acoustics of Empa and is the standard working tool for shooting noise calculations for military shooting grounds in Switzerland. The calculation model predicts the A-weighted single-event sound exposure level L_{AE}. As the calculation is performed in third-octave-bands from 25 Hz to 5 kHz, other frequency weightings can be applied as well. The model delivers sound exposure spectra in octave-bands from 31.5 Hz to 4 kHz of direct and reflected sound as well as for each source and receiver combination and each defined weather condition.

Sound sources: The WL04 data pool of sound sources distinguishes three types of sources: muzzle blasts, sonic booms and detonations. The source data for muzzle blasts is gathered based on measurements according to ISO 17201-1 [34], including information on the directivity pattern. Sonic boom emission levels are not measured but calculated on the basis of the projectile length and width (the caliber) and the projectile speed according to ISO 17201-4 [35]. The ballistic curve is calculated with a sophisticated algorithm provided by the Defense Procurement Agency of Switzerland. The third source type covers all kinds of explosions. The sound emission data are calculated based on the type of explosive and the charge weight according to ISO 17201-2 [36]. The corresponding height above ground of the source is derived according to Wunderli [37].

Sound propagation: The propagation calculation is based on ISO 9613, Part 1 and 2 [38; 39] with several extensions: *Ground-effect* - The ground effect model calculates spherical reflection coefficients for homogeneous, level ground according to Chessell, and Chien and Soroka [40; 41; 42], combined with an extension for inhomogeneous, uneven terrain that is based on a Fresnel-zone-approach [43]. The frequency-dependent ground impedance is derived from the flow resistance of the ground using the one-parameter model of Delaney and Bazley [44]. *Shielding effects* - In situations with shielding effects, ground reflections are calculated for two sound paths: the path source-ground-barrier edge-receiver and source-barrier edge-ground-receiver. Generally, the propagation calculation takes place in the vertical plane between source and receiver including terrain and obstacles. For artificial barriers as buildings, firing sheds or noise barriers, an additional analysis is performed in the horizontal plane. If the dominating sound path does not lead over the barrier but around it, the resulting shielding effect is reduced accordingly. *Meteorological effects* - Meteorological influences on sound propagation are accounted for by two aspects: On one hand the change of shielding effects and on the other, the evolution of acoustical shadow zones is modeled [45]. A ray tracing algorithm is implemented that identifies the sound path from source to receiver including possible barrier edges for arbitrary sound speed profiles. Information on meteorology is provided as vertical profiles of wind speed, temperature and humidity given at heights from 0 to typically 100 m above ground in a resolution of 0.1 m. For each shooting ground a representative station of the measurement net of the Swiss federal office of meteorology and climatology (MeteoSwiss), was chosen. For these meteorological stations, statistical weather data over at least five years was gathered containing information on wind speed and direction in combination with an allocation to atmospherical stability classes according to Polster [46]. An analysis was performed yielding the frequency of occurrence for three wind speed classes (< 2 m/s, 2 – 4 m/s, > 4 m/s), three stability classes (stable, neutral, unstable) and the three dominating wind directions in each class, separately for day and night. For each shooting ground the most frequent situations were chosen to cover at least 70 % of the weather conditions at day and at night. Depending on the situation this could be achieved by choosing between 13 and 16 distinct weather conditions. The sound propagation calculations were performed for each of these conditions using standardized vertical profiles of wind speed, temperature and humidity. For the calculation of long-term average sound exposure level several meteorological conditions can be defined within one project. *Diffuse reflections* - As shooting grounds in Switzerland are often situated in forested and mountainous areas, reflections from forests and cliffs are taken into account as well. For that purpose forest edges and cliffs are divided into segments, each representing a scattering reflector. Cliffs are assumed to exhibit a frequency independent reflectivity. The reflection attenuation of a forest edge is set equal to the reflection of a vertical cylinder with the height and diameter of an average tree. For both types of scatterers a free parameter was introduced to adjust the total amount of reflected energy to match measurement results [47]. *Sonic boom* - The sound propagation for sonic boom sources is calculated according to ISO 17201-4 and thus features several additional deviations from the procedure described in ISO 9613.

Input data: *Topography and surface properties* - As information on topography, data sets of the digital terrain model (DTM) of the Swiss federal office of topography (Swisstopo) were used. This terrain model provides heights above sea level in a grid of 2 meters. The default surface type was set to grassland, featuring a flow resistivity of 300 Rayl (needed for ground effect calculations) and a roughness height of 0.15 m (needed for the vertical sound speed profiles). *Characterization of shooting activities* - A single shooting event is defined by the position and height above ground of the muzzle and the target together with information on the weapon system and the ammunition used. *Modeling of buildings and reception points* - Swisstopo operates a model called VECTOR25 that encompasses the footprints of all buildings in Switzerland. However, information on the shape and height of the buildings is missing. Therefore it was decided to model all buildings as flat roofed. The height of the buildings was derived by comparing the digital terrain model (DTM) with the digital surface model (DOM). While the first only yields the height above sea level of the ground, the latter features the same information including artificial objects such as houses, bridges etc.

Exposure calculation: In a database, A- and C-weighted sound exposure level (L_{AE} and L_{CE}) were stored of the direct sound of muzzle blast, sonic boom and detonation and the sum of the reflections of the three primary sources for each source and receiver combination and weather condition on a shooting ground. As an additional quantity, the A-weighted maximum level with an averaging time of 125 ms ($L_{AS,max}$) was derived based on the sound exposure levels. As the calculation model yields no information on the run-time of the different signals, estimations of the time of arrival of the different contributions were made.

Uncertainty of the sound propagation model: Comparisons with extensive measurement data up to propagation distances of 2 km yielded a standard deviation of 3 dB(A) for single situations where meteorological data as well as the other input parameters where known in detail. The accuracy of the calculation model is to a large extent independent of the propagation distance, the type of source, the amount of direct and reflected sound and the meteorological conditions. The calculated levels are composed of the contributions of various sound sources under different propagation conditions during a longer period of time. This averaging automatically leads to a reduction of the stochastic calculation error as compared to the uncertainty of a single event. Consequently, it can be concluded that the uncertainty of a calculated level, expressed as a standard deviation, is likely to be considerably smaller than 3 dB(A).

Appendix C1: Survey questionnaire (German version)

E.01 Als erstes möchte ich gerne Ihre Adresse überprüfen. Wir brauchen diese Information lediglich zu statistischen Zwekken. Ihre Angaben werden völlig anonym behandelt.
E.02 Auswahl der Zielperson **E.02a:** Wie viele Personen ab 16 Jahren leben in Ihrem Haushalt? **E.02b:** Bitte geben Sie mir Ihren Vornamen und Ihr jetziges ALTER an . **E.02c:** Können Sie mir bitte alle Personen ab 16 Jahren aufzählen, wo in Ihrem Haushalt leben, Sie inbegriffen? Fangen Sie bitte mit der ältesten Person an und sagen Sie mir den Vornamen, das Alter und das Geschlecht! **E.02d:** Der Computer hat jetzt für die Fortsetzung vom Interview folgende Person ausgewählt:

1. Fragen zur Lebenssituation

1.01 Wie lange wohnen Sie schon an Ihrem jetzigen Wohnort?
1.02 In welchem Stockwerk wohnen Sie? ☐ Erdgeschoss bzw. EFH ☐ ...... Stock
1.03 Ich lese Ihnen verschiedenen Lebenssituationen vor. Welche trifft am ehesten auf Sie persönlich zu? • Wohngemeinschaft • Einpersonenhaushalt / Singlehaushalt • Familienhaushalt • Paar alleine • Paar mit Kind(ern) • Elternteil mit Kind(ern) • Einzelperson mit Elternteil (ältere Erwachsene mit Eltern) • Nichtfamilienhaushalte
1.04 Sind Sie Mieter/in oder Eigentümer/in von der Wohnung / vom Haus in welchem Sie aktuell wohnen? ☐ 1 Eigentümer/in☐ 2 Mieter/in oder Untermieter/in

2. Fragen zum Wohnen und zur Wohnqualität

2.01 Im Folgenden lese ich Ihnen einige Eigenschaften vor, wo für das Wohnen wichtig sind. Wie zufrieden sind Sie damit bei Ihnen zu Hause? Sie können mir eine Zahl nennen von 1, das bedeutet „nicht zufrieden“ bis 5, das bedeutet „sehr zufrieden“. Mit den Werten dazwischen können Sie Ihr Urteil abstufen. • Distanz zum Arbeitsplatz • Distanz zur nächsten Stadt • Öffentliche Verkehrsmittel • Einkaufsmöglichkeiten • Schulmöglichkeiten für Kinder • Nähe zur Natur • Gute Nachbarn • Ruhige Wohngegend
2.02 Gibt es hier in Ihrer Wohnung / Ihrem Haus irgendwelche Lebensbedingungen, woSie stören? ☐ 1 nein => Frage 2.03 ☐ 2 ja => Frage 2.02a **2.02a** Welche sind das?
2.03 Wie stark sind Sie persönlich in Ihrer Wohngegend durch folgende Sozial- und Umweltprobleme betroffen? Sie können mir eine Zahl nennen von 1, das bedeutet „gar nicht“ bis 5, das bedeutet „sehr stark“. Mit den Werten dazwischen können Sie Ihr Urteil abstufen. • Umweltverschmutzung • Lärm • Arbeitslosigkeit • Kriminalität • Ausländerproblematik

2.04 Wenn Sie an ihre nähere Wohnumgebung denken, gibt es etwas, was Ihre Gesundheit oder die von Ihrer Familie nachteilig beeinflussen könnte?
☐ 1 nein => Frage 3.01 ☐ 2 ja => Frage 2.04a

2.04a Was könnte Ihre Gesundheit oder die von Ihrer Familie nachteilig beeinflussen?

3. Fragen zur Lärmbelästigung und Lärmempfindlichkeit

3.01 Im nun folgenden Themenblock geht es um verschiedene Aspekte von der Wohnqualität. Zunächst geht es um den Lärm. Wenn Sie einmal an die letzten 12 Monate hier bei Ihnen denken, wie stark haben Sie sich durch die folgenden Lärmarten insgesamt gestört oder belästigt gefühlt? Sie können mir jeweils sagen überhaupt nicht, es bitzli, mittelmässig, stark oder äusserst - gestört oder belästigt. (random list)

- Strassenlärm
- Eisenbahnlärm
- Fluglärm Zivil
- Fluglärm Militär
- Schiesslärm (Gewehre, Kanonen, Panzer usw.)
- Industrie/Gewerbe/Baustellen
- Beizen/Musik/Veranstaltungen
- Lärm von Nachbarn
- Lärm von Kirchenglocken

3.02 Als nächstes möchte ich Sie bitten, Aussagen zu verschiedenen Geräuschen zu machen. Versuchen Sie, sich in die jeweilige Situation hineinzuversetzen und antworten Sie spontan und ohne lange zu überlegen. Uns interessiert Ihre ganz persönliche Meinung zu den Aussagen. Sie können mir jeweils sagen stimmt genau,stimmt eher, stimmt eher nicht oder stimmt gar nicht.

(1) Sich unterhalten macht keinen Spass, wenn nebenbei das Radio läuft.
(2) Ich bemerke störende Lärmquellen später als andere.
(3) Ich vermeide laute Freizeitveranstaltungen wie z.B. Fussballspiele oder Jahrmärkte.
(4) Ich wache beim geringsten Geräusch auf.
(5) Ich kann auch in lauter Umgebung schnell und konzentriert arbeiten.
(6) Wenn ich in der Stadt bin und einkaufe, überhöre ich den Strassenlärm.
(7) Nach einem Abend in einem lauten Lokal fühle ich mich wie ausgelaugt.
(8) Wenn ich einschlafen will, stört mich kaum ein Geräusch.
(9) Am Wochenende bin ich gerne an ruhigen Orten.

3.03 Nächste Frage: Wenn es darum geht, mit gesetzlichen Massnahmen den Lärm zu bekämpfen, um welchen Lärm soll man sich da besonders kümmern?

- Strassenlärm
- Eisenbahnlärm
- Fluglärm Zivil
- Fluglärm Militär
- Schiesslärm
- Industrie/Gewerbe/Baustellen
- Beizen/Musik/Veranstaltungen
- Lärm von Nachbarn
- Lärm von Kirchenglocken
- anderes:

3.04 Wir möchten gern von Ihnen zu einer von den verschiedenen Lärmarten ein paar Detailangaben sammeln. Die Auswahl von der Lärmart haben wir per Zufall bestimmt. Bei Ihnen wird es um Schiesslärm (also Lärm von Gewehren, Kanonen, Panzern usw.) gehen. Stellen Sie sich eine Messlatte vor von 0 bis 10, auf der Sie angeben können, wie sehr Sie der Schiesslärm hier bei Ihnen im vergangenen letzten Jahr insgesamt gestört oder belästigt hat.

Wenn Sie nun an die letzten 12 Monate hier bei Ihnen denken, welche Zahl zwischen 0 und 10 gibt am besten an, wie stark Sie sich durch den Schiesslärm insgesamt gestört oder belästigt fühlten? 0 bedeutet „Der Schiesslärm hat mich überhaupt nicht gestört oder belästigt“ und 10 bedeutet „Der Schiesslärm hat mich äusserst gestört oder belästigt“, mit den Werten dazwischen können Sie Ihr Urteil abstufen.

3.05 Wie ist die Intensität vom Schiesslärm (Gewehre, Kanonen, Panzer) im Verlaufe von der letzten Woche gewesen?

- Er ist wie immer gewesen
- Er ist stärker als sonst gewesen
- Er ist schwächer als sonst gewesen
- Weiss nicht

3.06 Was belästigt Sie am Schiesslärm besonders?

- Auftretenshäufigkeit
- Art des Geräusches („Knall")
- Unvorhersehbarkeit / Überraschungseffekt
- Dass man davor erschrickt
- Nähe oder Intensität des Lärms („es tönt wie im Krieg")
- Die „tiefen Töne"
- Anderes:

3.07 Werden Sie durch Schiesslärm unter der Woche besonders stark belästigt?
☐ 1 nein => Frage 3.08☐ 2 ja=> Frage 3.07a

3.07a Zu welchen Tageszeiten ist das (0 – 24 Uhr)?von ...... bis ......Uhrund von ...... bis ......Uhr
und von ...... bis ......Uhr

3.08 Werden Sie durch Schiesslärm am Wochenende besonders stark belästigt?
☐ 1 nein => Frage 3.09☐ 2 ja, => Frage 3.08a

3.08a Zu welchen Tageszeiten ist das (0 – 24 Uhr)?von ...... bis ......Uhrund von ...... bis ......Uhr
und von ...... bis ......Uhr

3.09 Haben Sie gegen den Schiesslärm schon mal etwas unternommen?

- Nein

- Beim Militär/Waffenplatz beklagt
- Politische Betätigung
- Eindringen des Lärms bekämpft (Fenster schliessen, Schallschutzfenster eingebaut etc.)
- Von zu Hause weggegangen
- Anderes:

3.10 Hat der Schiesslärm in den letzten 3 Jahren zugenommen oder abgenommen oder ist er gleich geblieben?

- Gleich geblieben
- Stark abgenommen
- Eher abgenommen
- Eher zugenommen
- Stark zugenommen
- Weiss nicht

3.11 Was denken Sie, wie wird sich bei Ihnen die Belästigung durch Schiesslärm in Zukunft entwickeln? Wird die Belästigung abnehmen oder schlimmer werden? 1 heisst: viel geringer, 5 heisst: viel schlimmer. Mit den Werten dazwischen können Sie Ihr Urteil abstufen.

3.12 Ich lese Ihnen nun einige Aussagen über die Schweizer Armee vor. Sie geben mir jeweils an, wie sehr Sie diesen Aussagen zustimmen. 1 bedeutet „stimme gar nicht zu", 5 bedeutet „stimme sehr zu", mit den Werten dazwischen können Sie Ihr Urteil abstufen.

- Die Schweiz braucht eine Armee
- Die Schweizer Armee tut genügend für den Umweltschutz
- Militärischer Schiesslärm ist ein notwendiges Übel

4. Allgemeine Angaben

Jetzt kommen noch einige Fragen zu ihrer Person.

4.01 Welche von den folgenden Schulen haben Sie zuletzt abgeschlossen?
- Primar-/Oberschule
- Real-/Sekundar-/Bezirksschule
- Berufsschule
- Berufsmittelschule/Gymnasium
- Fachhochschule/Universität/Hochschule

4.02a Um welche Uhrzeit gehen Sie unter der Woche (Mo-Fr) normalerweise aus dem Haus und wann kommen Sie zurück?

☐ ich bleibe unter der Woche mehrheitlich zuhause (z.B. Mütter mit Kleinkindern, Pensionierte...)
Aus dem Haus: .... [hh:mm]
zurück: .... [hh:mm]

4.02b Wie sieht es am Wochenende (Samstag/Sonntag) aus?

☐ ich bleibe am Wochenende mehrheitlich zuhause (mit allenfalls kurzen Abwesenheiten, Einkaufen etc.., Verwandtenbesuch).
☐ ich bin am Wochenende meist dauernd ausser Haus (z.B. für Reisen, Hobby, Freizeitaktivitäten...) und übernachte auswärts.
☐ ich bin am Wochenende tagsüber meist ausser Haus (z.B. für Hobby, Freizeitaktivitäten...), übernachte aber zuhause.

anderes:

4.03 Haben Sie einen Gartensitzplatz oder einen Balkon/Terrasse?

ja => Frage 4.03
nein => ENDE

4.03a Wie lange halten Sie sich dort im Durchschnitt pro Tag auf? Wie ist das ...

a) im Sommer: ....hh:mm
b) im Winter: .... hh:mm

Appendix C2: Survey questionnaire (French version)

E.01 Tout d'abord je souhaite vérifier votre adresse. Cette information sera exclusivement utilisée à des fins statistiques. Toutes vos données seront traitées de manière strictement anonyme.
E.02 Choix du répondant **E.02a:** Combien de personnes de plus de 16 ans vivent dans votre ménage? **E.02b:** Quel est votre prénom? Et votre âge? **E.02c:** Pourriez-vous me dire quelles personnes de plus de 16 ans vivent dans votre ménage, vous compris(e)? Commencez par la personne la plus âgée, en me donnant son prénom, son âge et son sexe. **E.02d:** L'ordinateur a choisi … pour poursuivre l'interview.

1. Environnement de vie

1.01 Depuis combien de temps habitez-vous dans votre logement actuel?
1.02 À quel étage habitez-vous? ☐ rez de chaussée/maison ☐ .... étage
1.03 Parmi les types d'habitations et de ménages que je vais vous citer, quel est celui qui vous correspond le mieux? • Colocation • Ménage à une personne • Famille • Couple seul • Couple avec enfant(s) • Parent avec enfant(s) • Personne seule avec parent (adulte avec père et/ou mère)
1.04 Êtes-vous locataire ou propriétaire de l'appartement/la maison que vous habitez actuellement? ☐ 1 propriétaire ☐ 2 (sous-)locataire

2. Habitation et qualité de vie

2.01 À présent, je vais vous citer une série de critères sur la base desquels vous me donnerez votre degré de satisfaction. Vous pouvez répondre en utilisant une échelle de 1 à 5, où 1 signifie signife « pas satisfait » et 5 « très satisfait ». Les notes intermédiaires permettent de nuancer votre réponse. • Distance du lieu de travail • Distance de la ville la plus proche • Transports publics • Commerces • Ecoles • Proximité de la nature • Voisins • Quartier calme
2.02 Y a-t-il dans votre appartement/votre maison, des conditions qui vous dérangent? ☐ 1 non => Question 2.03 ☐ 2 oui => Question 2.02a **2.02a** Lesquelles?
2.03 À quel point votre logement est-il touché par les facteurs sociaux ou environnementaux suivants? Vous pouvez répondre en utilisant une échelle de 1 à 5, où 1 signifie « pas touché » et 5 « très touché ». Les notes intermédiaires permettent de nuancer votre réponse. • Pollution • Bruit • Chômage • Criminalité

• Différences culturelles
2.04 Y a-t-il, à proximité directe de votre logement, des facteurs qui pourraient nuire à votre santé ou à celle de votre famille? ☐ 1 non => Question 3.01 ☐ 2 oui => Question 2.04a **2.04a** Lesquels?

3. Pollution sonore et sensibilité aux bruits

3.01 Dans cette partie, nous aborderons divers aspects de la qualité de vie. . Commençons par le bruit. Si vous repensez aux 12 derniers mois, à quel point avez-vous été dérangé ou perturbé, dans votre logement, par les différents types de bruits que je vais vous citer? Vous pouvez me répondre par « pas du tout », « légèrement », « moyennement », « fortement » ou « extrêmement ». (random list) • Bruit de la route • Bruit des voies de chemin de fer • Bruit de l'aviation civile- • Bruit de l'aviation militaire • Bruit de tirs (fusils, canons, tank, etc.) • Bruit de l'industrie/de l'artisanat/des chantiers • Bruit des bars, des manifestations (musique…) • Bruit des voisins • Bruit du clocher de l'église
3.02 À présent, je vais vous demander, pour chacune des situations suivantes, de me dire si l'énoncé correspond « tout à fait », « plutôt », « plutôt pas » ou « pas du tout ». Merci de répondre spontanément, sans réfléchir trop longuement. (1) Je n'apprécie pas une conversation lorsque la radio est allumée à proximité. (2) Je remarque la présence d'une source de bruit dérangeante plus tard que les autres personnes. (3) J'évite les manifestations bruyantes comme les matchs de foot ou les marchés annuels. (4) Je me réveille au moindre bruit. (5) Je suis capable de travailler rapidement et de rester concentré(e) même dans dans un environnement bruyant. (6) En ville, lorsque je fais des achats, je ne perçois pas le bruit de la route. (7) Après une soirée dans un lieu bruyant, je suis épuisé(e). (8) Le bruit me dérange à peine pour m'endormir. (9) J'aime passer le week-end dans un lieu calme.
3.03 Si l'on devait mettre en œuvre des mesures législatives pour lutter contre le bruit, à quel(s) type(s) de bruit donneriez-vous la priorité? ☐ 1 Bruit de la route ☐ 2 Bruit des voie de chemin de fer ☐ 3 Bruit de l'aviation civile ☐ 4 Bruit de l'aviation militaire ☐ 5 Bruit de tirs ☐ 6 Bruit de l'industrie/de l'artisanat/des chantiers ☐ 7 Bruit des bars, des manifestations (musique…) ☐ 8 Bruit des voisins ☐ 9 Bruit du clocher de l'église ☐ 10 Autres:...
3.04 À présent, nous souhaiterions avoir quelques détails concernant un type de bruit, choisi au hasard. Dans votre cas, il s'agit du bruit de tirs (fusils, canons, tanks, etc.). Imaginez-vous une échelle d'opinion graduelle de zero à dix. Vous devez spécifier sur cette échelle la façon dont le bruit de tirs vous gêne lorsque vous êtes ici, chez vous: M'indiquez-vous zero si le bruit ne vous gêne pas du tout et dix si le bruit vous gêne extremement. Si vous êtes entre ces deux situations, choisissez une note intermédiaire entre zero et dix. Maintenant, si vous pensez aux douze derniers mois, quand vous êtes ici, chez vous, quelle note comprise entre zero et dix exprime le mieux à la façon dont le bruit des coups de feu vous gêne?
3.05 Avec quelle intensité avez-vous perçu le bruit de tirs (fusils, canons, tanks) au cours de la semaine dernière? ☐ 1 comme d'habitude ☐ 2 plus fort que d'habitude ☐ 3 moins fort que d'habitude ☐ 4 je ne sais pas
3.06 Qu'est-ce qui vous importune le plus dans le cas du bruit de tirs?

- Fréquence d'occurence
- Type de bruit (détonation)
- Imprévisibilité / effet de suprise
- Le fait de sursauter
- Proximité ou intensité du bruit (bruit de guerre)
- Bases féquences
- Autres:______________________

3.07 Le bruit de tirs vous importune-il particulièrement <u>en semaine</u>?
☐ 1 non => Question 3.08   ☐ 2 oui=> Question 3.07a

3.07a À quelles heures (0 – 24 h)? de ...... a ...... et de ...... a .....

3.08 Le bruit de tirs vous importune-il particulièrement <u>le week-end</u>?
☐ 1 non => Question 3.09   ☐ 2 oui, => Question 3.08a

3.08a À quelles heures (0 – 24 h)? de ...... a ...... et de ...... a .....

3.09 Avez-vous déjà entrepris quelque chose contre le bruit de tirs?

- Non
- Plainte auprès de la place d'armes/de l'armée
- Action politique (réunions de riverains, manifestations, courrier des lecteurs, etc.)
- Minimisation du bruit à l'intérieur (fermeture des fenêtres, installation de fenêtres antibruit, etc.)
- Absence de chez soi
- Autres:____________________________

3.10 Au cours de ces <u>3 dernières années</u>, le bruit s'est-il intensifié, a-t-il diminué ou est-il resté pareil?

- Est resté pareil
- A fortement diminué
- A plutôt diminué
- S'est plutôt intensifié 4
- S'est fortement intensifié
- Je ne sais pas

3.11 Comment estimez-vous l'évolution future des nuisances sonores? Pensez-vous que les nuisances vont diminuer ou augmenter? 1 correspond à une forte diminution, 5 à une forte augmentation. Les notes intermédiaires permettent de nuancer votre réponse.

3.12 Je vais vous lire plusieurs affirmations sur l'armée suisse. Veuillez me dire, sur une échelle de 1 à 5, si l'énoncé correspond à la réalité. 1 correspond à « pas du tout » et 5 à « tout à fait ». Les notes intermédiaires permettent de nuancer votre réponse.

- La Suisse a besoin d'une armée
- L'armée suisse fait suffisament d'efforts pour protéger l'environnement
- Le bruit de tir militaire est un mal nécessaire

4. Données personnelles

Pour terminer, je vais vous poser quelques questions au sujet de votre personne.

4.01 Quel est le dernier niveau scolaire que vous avez atteint?
- école primaire
- école secondaire
- école professionnelle
- école prof. sup./gymnase
- école spécialisée/université/haute école

4.02a À quelle heure quittez-vous votre logement et à quelle heure êtes-vous de retour, <u>en semaine</u> (lu-ve)?

Je quitte la maison vers................ [hh:mm]
Je rentre vers: .... [hh:mm]

☐ En semaine, je reste à la maisin la plupart du temps (p. ex. mère au foyer, retraité...).

4.02b Et le <u>week-end</u> (sa et di)?

Je quitte la maison vers................. [hh:mm]
Je rentre vers: .... [hh:mm]

☐ Le week-end, je reste à la maison la plupart du temps (courtes absences, courses, etc…, visite de la famille).
☐ Le week-end, je suis presque toujours absent(e) (p. ex. voyages, hobby, loisirs), et ne passe pas la nuit chez moi.
☐ Le week-end, je suis souvent absent durant la journée (p. ex. hobby, loisirs), mais je passe la nuit chez moi.

autres:...

4.03 Avez-vous un balcon ou une terrasse?

oui => Question 4.03
non => FIN

4.03a Combien de temps y passez-vous en moyenne par jour?

a) en été: ....hh:mm
b) en hiver: .... hh:mm

Appendix C3: Survey questionnaire (Italian version)

E.01 Innanzitutto vorrei verificare il Suo indirizzo: questa informazione ci serve unicamente a scopo statistico. Inoltre, tutte le risposte che ci fornirà durante l'intervista saranno trattate in maniera completamente anonima.

E.02 Scelta della persona target

E.02a: Quante persone di più di 16 anni vivono con Lei nella stessa economia domestica?

E.02b: La prego ora di indicarmi il Suo nome di battesimo e la Sua età attuale.

E.02c: Potrebbe ora per favore elencarmi tutte le persone di più di 16 anni che vivono con Lei nella stessa economia domestica, Lei compreso/a? Inizi con la persona più vecchia e mi indichi, per ognuno, nome di battesimo, età e sesso!

E.02d: Per la continuazione di questa intervista, il computer ha scelto a caso la seguente persona:

1. Domande sulle condizioni abitativi

1.01 Da quanto tempo vive al Suo domicilio attuale?

1.02 A quale piano abita?
☐ piano terra/casa monofam.
☐ .... piano

1.03 Ora Le elencherò diverse situazioni abitative. Quale corrisponde meglio al Suo caso?

- comune
- economia domestica composta da una sola persona o da un/a single
- economia domestica di una famiglia
- coppia da sola
- coppia con figlio/figli
- un genitore solo con figlio/figli
- una persona sola con genitore/i (persone adulte che vivono con i genitori)
- economia domestica di tipo non famigliare

1.04 È in affitto oppure è proprietario/a dell'appartamento/della casa in cui abita attualmente?
☐ 1 proprietario/a ☐ 2 affittuario/a o suabaffittuario/a

2. Domande sulla situazione abitativa e sulla qualità residenziale

2.01 Qui di seguito Le elencherò alcune caratteristiche importanti che determinano la situazione abitativa. Qual è la sua soddisfazione in merito? Ad ogni caratteristica La prego di indicarmi un punteggio da 1 (non soddisfatto/a) a 5 (molto soddisfatto/a): si serva pure anche dei valori intermedi per graduare la Sua valutazione.

- distanza dal luogo di lavoro
- distanza dalla città più vicina
- mezzi pubblici di trasporto
- possibilità per fare le compere
- offerta di scuole per i figli
- prossimità alla natura
- buoni vicini
- tranquillità della zona

2.02 Nell'appartamento/nella casa in cui vive ci sono forse delle condizioni che La disturbano?
☐ 1 no => Domanda 2.03 ☐ 2 si => Domanda 2.02a

2.02a Se sì, quali?

2.03 Nella zona in cui abita, in quale misura è toccato/a personalmente dai seguenti problemi sociali e ambientali? Mi indichi per cortesia un punteggio da 1 ("affatto") a 5 ("moltissimo"): si serva pure anche dei valori intermedi per graduare la Sua valutazione.

- inquinamento ambientale
- rumore

- disoccupazione
- criminalità
- problematiche legate agli stranieri

2.04 Se ora pensa ai paraggi dove abita, c'è forse qualcosa in grado di influire negativamente sulla Sua salute o sulla salute della Sua famiglia?

☐ 1 no => Domanda 3.01 ☐ 2 si => Domanda 2.04a

2.04a Se sì, che cosa potrebbe influire negativamente sulla Sua salute o sulla salute della Sua famiglia?

3. Domande sul disturbo causato dal rumore e sulla sensibilità al rumore

3.01 Nel seguente blocco tematico tratteremo diversi aspetti relativi alla qualità residenziale. Dapprima parliamo di rumore. Se Lei ripensa agli scorsi 12 mesi all'interno del Suo appartamento/della Sua casa, in quale misura si è sentito/a in generale infastidito/a o disturbato/a dai seguenti tipi di rumore? Per definire il grado di disturbo che ha provato, La invito a usare le seguenti categorie: affatto, un poco, moderatamente, molto, tantissimo. (random list)

- rumore della strada
- rumore della ferrovia
- rumore da traffico aereo civile
- rumore da traffico aereo milit.
- rumore determinato da attività di tiro (fucili/cannoni/carriarmati ecc.)
- industria/artigianato/cantieri edili
- locali pubblici/musica/manifestazioni
- rumore da vicinato
- rumore delle campane

3.02 Ora vorrei chiederLe di fare delle affermazioni su vari tipi di rumore. Quando Le descrivo una situazione, Lei provi a mettersi in tale condizione e risponda spontaneamente senza troppo riflettere. Quello che mi interessa è la Sua opinione del tutto personale sulle seguenti affermazioni. Per esprimere il Suo giudizio personale, si può servire delle seguenti categorie: vero, abbastanza vero, poco vero o per nulla vero.

(1) Parlare non è piacevole con la radio accesa in sottofondo.
(2) Noto dopo gli altri i rumori che disturbano.
(3) Nel tempo libero evito di andare a manifestazioni rumorose, come partite di calcio o fiere annuali.
(4) Mi sveglio per il minimo rumore.
(5) Riesco a lavorare veloce e concentrato/a anche in un contesto rumoroso.
(6) Quando sono in città a fare compere non mi accorgo neppure del rumore della strada.
(7) Dopo una serata trascorsa in un locale pubblico rumoroso mi sento sfinito/a.
(8) Quando sto per addormentarmi, nessun rumore riesce a disturbarmi.
(9) Durante il fine settimana mi piace stare in luoghi tranquilli.

3.03 Prossima domanda: Quando si tratta di combattere il rumore con misure di legge, secondo Lei quale o quali rumori vanno presi maggiormente in considerazione?

☐ 1 rumore della strada
☐ 2 rumore della ferrovia
☐ 3 rumore del traffico aereo civile
☐ 4 rumore del traffico aereo militare
☐ 5 rumore determinato da attività di tiro
☐ 6 industria/artigianato/cantieri edili
☐ 7 locali pubblici/musica/manifestazioni
☐ 8 rumore da vicinato
☐ 9 rumore delle campane
☐ 10 altro:..

3.04 Adesso Le chiederò qualche informazione più dettagliata sul rumore. A questo scopo abbiamo scelto a caso solo un tipo di rumore: desideriamo parlare del rumore determinato da attività di tiro (cioè del rumore di fucili, cannoni, carriarmati ecc.): usando una scala di valutazione da 0 a 10, mi indichi in quale misura il rumore determinato da attività di tiro L'ha infastidito/a o disturbato/a in generale nell'appartamento o nella casa dove abita sull'arco dell'ultimo anno.

Se ripensa agli scorsi 12 mesi all'interno del Suo appartamento o della Sua casa, quale punteggio, da 0 a 10, sceglierebbe per indicare la misura in cui il rumore determinato da attività di tiro l'ha infastidito/a o disturbato/a nel complesso? Il punteggio 0 significa "Il rumore determinato da attività di tiro non mi ha affatto infastidito/a né disturbato/a"; il punteggio 10 significa "Il rumore determinato da attività di tiro mi ha infastidito/a o disturbato/a moltissimo": si serva pure anche dei punteggi intermedi per graduare la Sua valutazione.

3.05 Nell'ultima settimana, quale intensità ha avuto il rumore determinato da attività di tiro (fucili, cannoni, carriarmati)?

☐ 1 è stato come al solito
☐ 2 è stato più forte del solito
☐ 3 è stato più debole del solito
☐ 4 non saprei dire

3.06 Cosa La disturba in particolare del rumore determinato da attività di tiro?

- la sua frequenza
- il tipo particolare di rumore (è come uno scoppio o un'esplosione)
- la sua imprevedibilità ("effetto sorpresa")
- il fatto che mi fa spaventare
- la vicinanza o l'intensità del rumore (acusticamente è "come in guerra")
- i suoi "suoni bassi"
- Altro:________________________

3.07 Dal lunedì al venerdì viene disturbato/a in maniera notevole dal rumore determinato da attività di tiro?

☐ 1 no => Domanda 3.08 ☐ 2 sì => Domanda 3.07a

3.07a In quali fasce orarie capita (dalle ore 0 alle ore 24)? dalle ore ...... alle ore ...... e dalle ore ...... alle ore .....

3.08 Durante il fine settimana viene disturbato/a in maniera notevole dal rumore determinato da attività di tiro?

☐ 1 no => Domanda 3.09 ☐ 2 sì => Domanda 3.08a

3.08a In quali fasce orarie capita (dalle ore 0 alle ore 24)? dalle ore ...... alle ore ...... e dalle ore ...... alle ore .....

3.09 Ha già intrapreso qualcosa contro il rumore determinato da attività di tiro?

- No
- mi sono lamentato con i militari/alla piazza d'armi/allo stand di tiro
- ho agito politicamente (iniziative di protesta dei cittadini, dimostrazioni, lettere ai giornali ecc.)..☐
- ho cercato di impedire che il rumore penetri in casa (finestre chiuse, installazione di vetri antirumori, ecc.)
- sono andato/a via di casa
- Altro:______________________________

3.10 Negli ultimi 3 anni il rumore determinato da attività di tiro è aumentato, diminuito o rimasto uguale?

- è rimasto uguale
- è molto diminuito
- è un po' diminuito
- è un po' aumentato
- è molto aumentato
- non saprei dire

3.11 Come crede che si svilupperà in futuro, nel Suo appartamento o nella Sua casa, il disturbo dovuto al rumore determinato da attività di tiro? Secondo Lei, il fastidio potrà diminuire oppure peggiorare? Il punteggio 1 significa: sarà molto ridotto; il punteggio 5 significa: sarà molto peggio. Si serva pure anche dei punteggi intermedi per graduare la sua valutazione.

3.12 Le formulo ora alcune affermazioni relative all'esercito svizzero. Lei mi dice come concorda con queste affermazioni. 1 significa 'non sono per niente d'accordo', 5 significa 'sono completamente d'accordo'. Con i valori compresi tra 1 e 5 Lei può dare una scala al Suo giudizio.

- La Svizzera ha bisogno di un esercito
- L'esercito svizzero fa abbastanza per la protezione dell'ambiente
- Il rumore di tiro militare è un male necessario

4. Indicazioni generali

Ora vorrei porLe ancora alcune domande sulla Sua persona.

4.01 Qual è l'ultima scuola che ha frequentato?

- Scuola elementare
- Scuola media
- Scuola professionale
- Liceo/Scuola con maturità prof.
- Scuola universitaria professionale/Università/Politecnico

4.02a Dal lunedì al venerdì di solito a che ora esce di casa e a che ora rientra?

esco di casa alle ore: .... [hh:mm]
rientro alle ore: .... [hh:mm]

☐ durante la settimana resto quasi sempre a casa (ad es. madri con figli piccoli, pensionati...)

4.02b E durante il fine settimana (sabato/domenica), a che ora esce di casa e a che ora rientra?

esco di casa alle ore: .... [hh:mm]
rientro alle ore: .... [hh:mm]

☐ durante il fine settimana, resto quasi sempre a casa (con sporadiche brevi assenze ad esempio per fare le compere, visite a parenti, ecc.).
☐ durante il fine settimana, di solito sono quasi sempre assente (ad es. per viaggi, hobbies, attività del tempo libero...) e dormo anche fuori casa.
☐ durante il fine settimana, di solito sono fuori casa durante il giorno (ad es. per hobbies, attività del tempo libero...), ma rientro a casa la sera per dormire.
Altro ....

4.03 Dispone di un terrazzo in giardino oppure di un balcone/terrazza?

si => Domanda 4.03
no => FINE

4.03a Quanto tempo vi trascorre ogni giorno in media? Quanto tempo...

a) en été: ....hh:mm
b) en hiver: .... hh:mm