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HEARING DAMAGE AND ANNOYANCE FROM CLAY PIGEON SHOOTING

J.C. Goodchild

Acoustics Group, Department of Physics, Liverpool Polytechnic

1. A survey of hearing damage amongst persons who fire shotguns

Identifying groups of people who have, over a number of years, been exposed to high levels of short duration impulsive noise presents some difficulties. Constabulary firearm instructors are possible subjects and although when approached in 1979 many helpful replies were received from Chief Constables, including a number of audiometric records, the history of exposure was varied and difficult to establish. Many instructors had undergone military training or were members of shooting clubs etc., and in recent years whilst employed as constabulary instructors, were meticulously careful about wearing hearing protection. Use of hearing protection is also widespread amongst competitors in clay pigeon shooting competitions, and recent unprotected exposure amongst serious CPSA competitors is unlikely.

Gamekeepers, farmers and game shooters however are less likely to protect their hearing, and in 1980 an opportunity arose to carry out audiometric tests on a number of such people. A clay pigeon shooting competition was organised at the principle agricultural shows for gamekeepers and others who use 'side by side' shotguns rather than for serious clay shooting competitors, who usually use 'over and under' guns. In order to promote the use of hearing protection competitors attending the Three Counties Show, the Royal Show and the Game Fair were invited to have their hearing tested, and a questionnaire was completed to ascertain their suitability for inclusion in the survey and to estimate their history of exposure, in terms of years and number of shots per year.

Hearing tests were carried out in a caravan, using a Kampex Model BA2, Bekesy Audiometer. No attempt was made to isolate the subjects from intrusive noise, other than using a noise excluding head set, and there is evidence of masking at low audiometric test frequencies for many of the subjects. However, at the frequencies at which threshold shifts due to noise damage might be expected, background noise had little effect.

After elimination of subjects who said that they had been exposed to high noise within a 36 hours period prior to the audiometric test, and who might therefore have a temporary hearing loss, 78 subjects remained. They were all male, they ranged in age from 15 to 63 years, had fired shotguns for between 1 and 48 years, on between 4 and 350 days per year, averaging between 3 and 100 rounds per day. 10 subjects claimed to have always worn hearing protection, others only recently and some never.

It became apparent whilst carrying out the hearing tests that right handed subjects generally showed more hearing damage in the left ear than the right and vice versa. Figure 1 shows the average hearing thresholds for the 66 right handed subjects and separately for the 12 left handed subjects. In addition to the average levels the ± 1 standard deviation levels have been plotted.

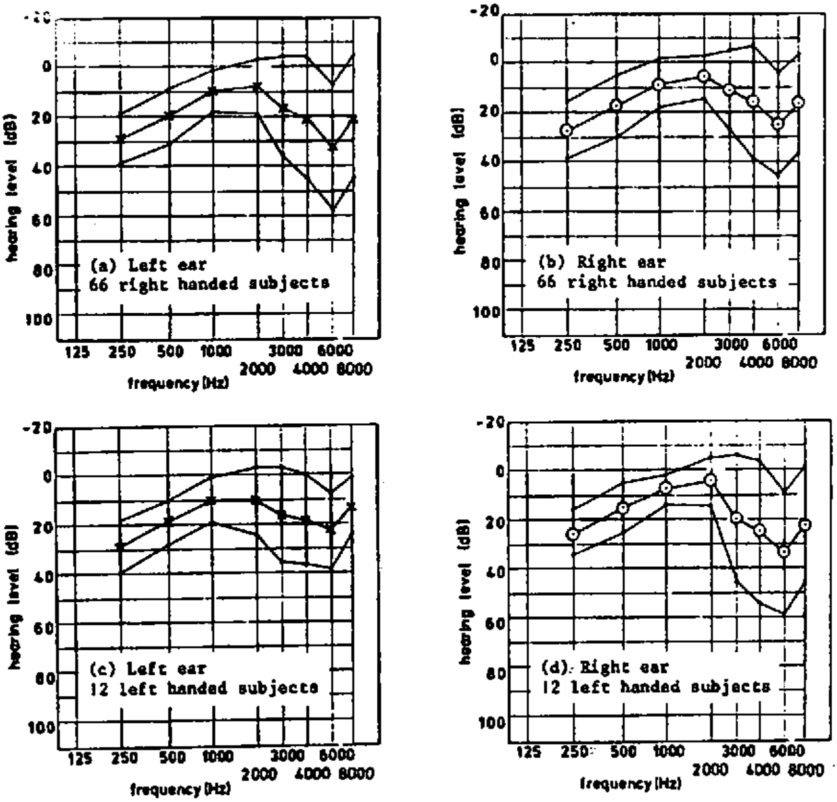

Figure 1. (a) and (b). Average hearing thresholds for 66 right handed subjects
(c) and (d). Average hearing thresholds for 12 left handed subjects

This evidence of differential hearing loss would suggest that the damage was in consequence of exposure to the subjects own gun rather than exposure as spectators, or from other industrial or agricultural noise sources.

In Figure 2 the 78 subjects are divided into age groups and hearing thresholds are shown for the 'more exposed' and 'less exposed' ears rather than right or left ears. It is noticeable from Figure 2 that even the 30 subjects in the 15 to 25 year age group show considerable evidence of damage. The average hearing loss is greater for the 26-40 year age group and the 40+ group shows some evidence of presbycousis as well as noise-induced hearing loss.

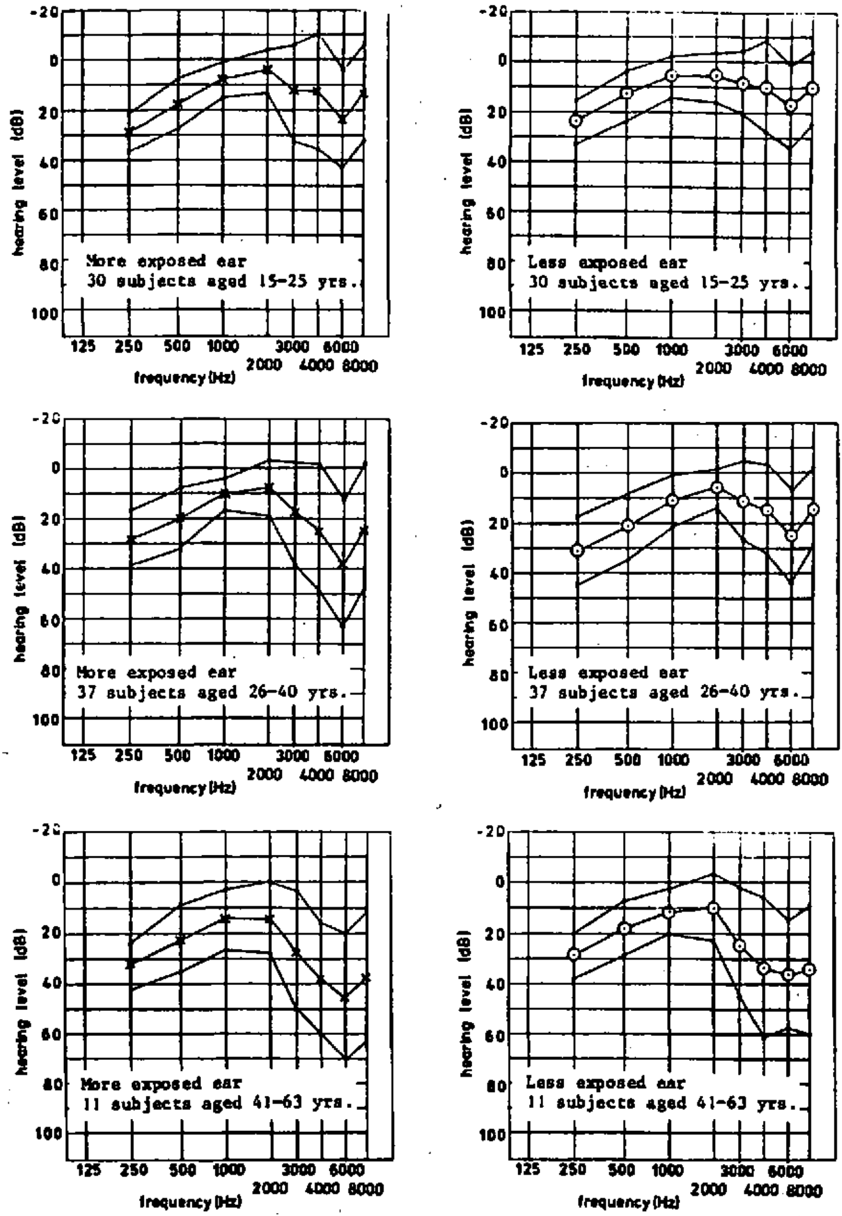

Figure 2. Average hearing levels. 78 subjects divided into age groups

2. Prediction of hearing damage risk associated with firing shotguns

Burns and Robinson [1] showed that permanent hearing loss for persons exposed to industrial noise is a function of the A weighted sound energy to which they are exposed. Atherley and Martin [2] and others have extended this energy immission principle to include exposure to impact and impulse noise, but recent standards and codes of practice concerned with hearing protection set upper limits of instantaneous sound pressure above which the unprotected ear should not be exposed and above which the energy immission principle should not be applied. In America, damage risk from gunfire noise is assessed in terms of instantaneous peak sound pressure and impulse duration by the CHABA criteria [3].

Harris [4] in an undergraduate project under the author's supervision assessed the hearing damage risk associated with firing shotguns by using a digital capture technique to measure instantaneous sound pressure, impulse duration and also integrated energy content for shotgun noise. He used Bruel and Kjaer 1/4 inch microphones, either mounted on a headband or on a stand 25 to 30cms from the shooter's ear, and a Type 2033 Real Time Analyser, interfaced to a Hewlett Packard HP85 microcomputer programmed to integrate up the energy content and to calculate an L_{AX} level for the impulses. The four microphone positions that he used are shown in Figure 3, and typical excess pressure versus time plots, which show considerable difference between right and left ear exposure, are reproduced in Figure 4. In Table 1 the important parameters for the shotgun noise impulses are summarized. It should be noted that no A weighting has been applied in the measurement system and subsequent computation of L_{AX} values.

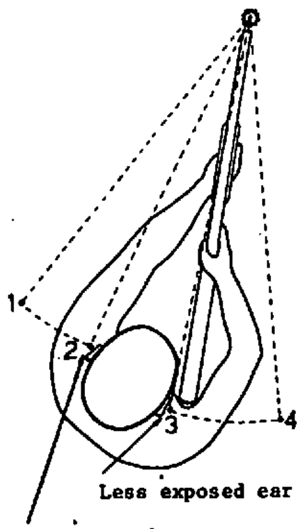

Figure 3. The four microphone positions. Positions 2 and 3 on head band. Positions 1 and 4 on stand.

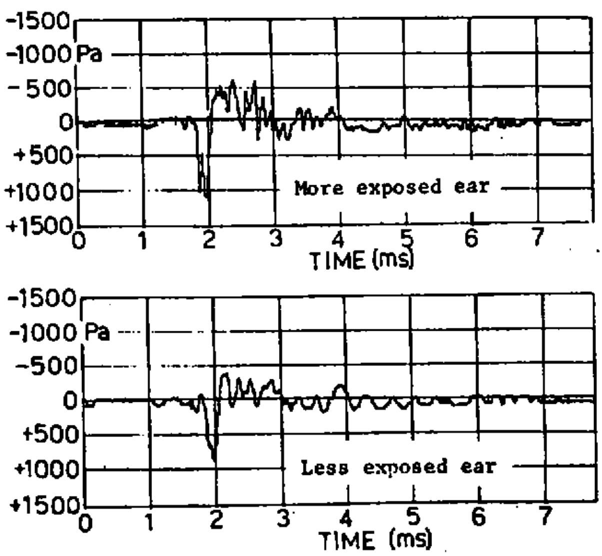

Figure 4. Excess pressure versus time for shotgun noise. Microphones on head band. (Eley International Trap Cartridges)

Microphone position	P_{max} (db)	L_{AX} (db)	β-DURATION (ms)	'N' CHABA	'N' Equal Energy
on headband left ear	155.2 ± 0.4	121.7 ± 0.2	3.4 ± 0.3	0.1	19
on headband right ear	152.2 ± 0.4	120.7 ± 0.1	5.3 ± 0.3	0.3	24
on tripod left ear	156.0 ± 0.3	121.7 ± 0.7	4.2 ± 0.7	0.1	20
on tripod right ear	154.0 ± 0.7	120.7 ± 0.6	3.6 ± 0.2	0.2	24

Table 1. Summary of instantaneous peak sound levels P_{max}, L_{AX} levels and β durations for shotgun noise. Included are the number of shots per day allowed according to the CHABA and the 90db(A)L_{eq} equal energy criteria. (Eley International Trap Cartridges)

Harris [4] then assessed the hearing damage risk using the energy immission principle, based on a maximum noise dose corresponding to 90dB(A) for eight hours, and using the CHABA criteria by calculating the number of shots that the two methods would allow per day, and these numbers are also included in Table 1. In all cases not even one unprotected shot per day would be allowed according to the CHABA damage risk criteria, whereas the equivalent of 90dB(A) for 8 hours was between 10 and 25 shots per day. This would seem to be consistent with the inclusion of an instantaneous sound pressure limit of 150db in 'Protection of Hearing at Work' [5].

3. Prediction of hearing damage for the 78 subjects of the audiometric survey

An attraction of the energy immission principle is that methods based on it have been developed to allow prediction of noise induced hearing loss from the accumulated exposure, calculated in terms of a noise immission level.

BS 5330 [6] provides a method of estimating the probability of an individual suffering a hearing handicap based on information about noise exposure and age. According to this standard Harris [4] estimated that the handicap percentage of the 78 subjects should be less than 1%, whereas 18 of the 78 subjects were handicapped, according to the way in which a hearing handicap is defined in BS 5330.

A report by Robinson and Shipton [7] provides tables for the estimation of noise-induced hearing loss as a function of noise immission and age. Harris [4] applied these tables to the noise exposures for the 78 subjects, dividing them again into age groups. Taking an average noise immission level and age for each of the three groups he plotted the predicted hearing levels exceeded by 50% of populations corresponding to each of the three groups (Figure 5). Also shown in Figure 5 are measured average hearing thresholds for the age groups, separated into 'more exposed' and 'less exposed' ears.

It must be stressed that because of the way in which the audiometric testing was conducted and the inevitable inaccuracy of the information relating to noise exposure, in particular since no consideration has been given to whether the subjects wore hearing protection, only the most general conclusions can be drawn

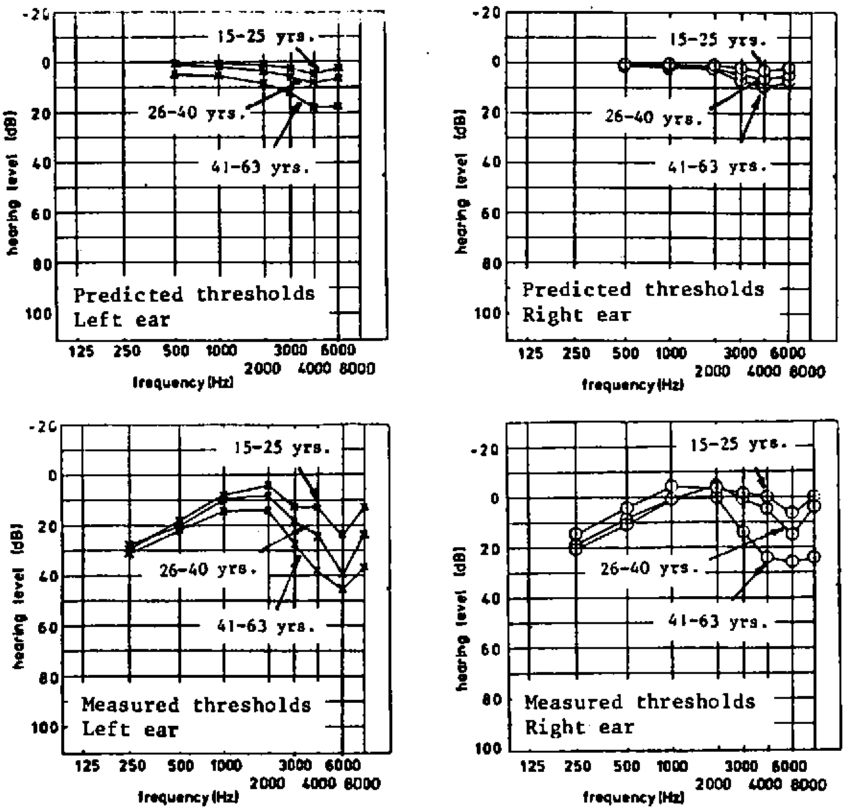

Figure 5. (a) and (b). Predicted hearing thresholds for the three age groups.
(c) and (d). Measured average hearing thresholds for the three age groups.

from this work. It would seem clear however that prediction of hearing damage amongst persons exposed to short duration impulse noise, using procedures, based on the energy immission principle, developed for fairly steady industrial noise exposure, significantly underestimates the likely hearing damage. The standards and reports that give the prediction methods make it clear that they should not be applied to situations that receive high noise exposure on perhaps only a few days per year, and as stated earlier impulses exceeding 150dB are excluded from consideration in terms of the equal energy principle in 'Protection of Hearing at Work' [5]. The audiometric survey reported here would seem to confirm these reservations about the applicability of the equal energy principle to short duration high level impulse noise.

4. Annoyance from clay pigeon shooting

In recent years clay pigeon shooting has increased in popularity as a recreational activity and there appears to be a corresponding increase in the incidence of complaints about noise from shooting grounds. In common with the official bodies for a number of potentially noisy sporting activities the Clay Pigeon Shooting Association is presently considering adopting a Code of Practice aimed at minimizing the impact of noise on the environment. When considering ways in which annoyance from existing grounds can be reduced the need for practical information about the propagation of shooting noise has become apparent. Particular questions arising include:

1. Indices for rating noise annoyance from shooting.
2. Attenuation with distance from the firing position, under different atmospheric conditions.
3. How the direction of firing affects noise levels.
4. The variation of noise levels between the same type of cartridge and between different types.
5. The attenuation provided by purpose built barriers and partial enclosures and temporary barriers made from straw bales etc.
6. Reflection and screening effects of woodlands.

In another undergraduate project at Liverpool Polytechnic Gilbert [8] carried out some preliminary measurements on the effects of distance and shooting direction on noise from shotguns, and this work, extended to cover a wider range of conditions could provide useful information for inclusion in the proposed Code of Practice. After a brief discussion of ratings and indices for shooting noise the results of these measurements are presented.

5. Indices for noise from shooting

At Inter-noise 81 Smoorenburg [9] summarized the results of a number of studies on the evaluation of impulse noise with regard to annoyance. From these studies he concluded that the A weighted impulse noise level ($L_{A,imp}$) was the most adequate index. Referring to earlier work by Meurers, Hediger, Kryter and Carter he proposed a rated sound level (L_r), the sound level of a steady noise which is assumed to cause the same community response, that is a function of both the impulse level of a single shot and the number of impulses per day, according to:

$$L_r = L_{A,imp} + 10 \log N - 42\text{dB}$$

6. Variation of impulse sound level with distance for shotgun noise

Using B and K ½ inch microphones at head height with horizontal diaphragm, A weighted noise levels were obtained for groups of approximately 8 shots at distances ranging from 5m to 400m from the gun. Eley Olympic Trap cartridges were used throughout and propagation was over level grass land and although there were some trees and low buildings in the area there was a clear line of sight between gun and microphone. The direction of firing was perpendicular to the microphone direction. In Figure 6 the average A weighted impulse noise level is plotted against distance with the sound propagation assisted and opposed by wind speeds of 7.5 and 19 Km/hour. The attenuation with distance appears to exceed 6 dB per doubling of distance even with wind assisted propagation. For some of the close microphone positions the scatter of levels within each group of 8 shots was low (standard deviation $\sigma \sim 0.5$ dB) but at greater distances, in gusty winds, σ increased to approximately 3 dB. Wind speed measurements quoted refer to the average wind over approximately a two hour period, obtained using a Casella Type

W1204 rotating cup anemometer.

One of the practical difficulties was wind noise generated at the microphones even though wind muffs were used. A weighting the signal partly overcame this difficulty but prevented 'Linear' tape recording and subsequent laboratory analysis of the signals.

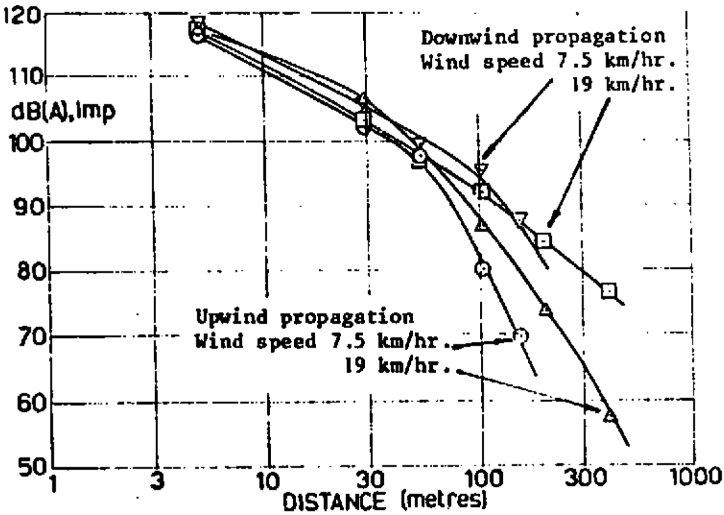

Figure 6. Shotgun noise propagation over grassland (Eley Olympic Trap Cartridges)

7. The effect of the direction of firing on noise levels. The measurements described in the previous section were obtained with the gun elevated by between 30 and 45°, and with the direction of firing perpendicular to the microphone direction. Figure 7 shows the results of repeating the impulse noise measurements taken at a distance of 55m with 4 different firing directions. Rotating the firing direction through 90° produced a reduction of about 7 dB(A) compared to firing directly over the microphone and a further rotation of 90° can produce an additional 2/3 dB(A).

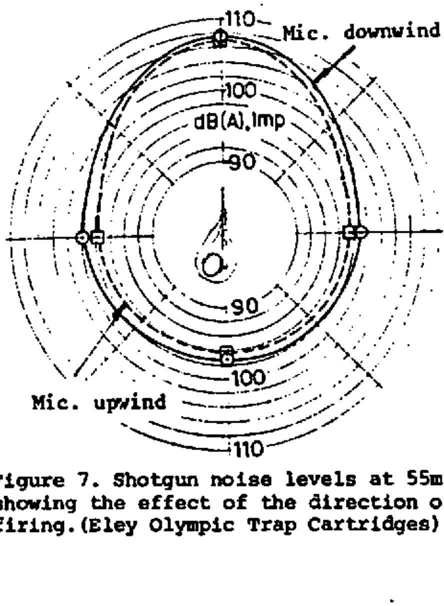

Figure 7. Shotgun noise levels at 55m, showing the effect of the direction of firing.(Eley Olympic Trap Cartridges)

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Acknowledgements

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