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IMPULSE DURATION AND TEMPORARY THRESHOLD SHIFT

(Interim Report)

by

Michel Loeb, Ph. D.
and
Lt Colonel John L. Fletcher, MSC

25 September 1968

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IMPULSE DURATION AND TEMPORARY THRESHOLD SHIFT

(Interim Report)

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ABSTRACT

IMPULSE DURATION AND TEMPORARY THRESHOLD SHIFT

OBJECTIVE

To determine the effect on temporary threshold shift of varying the duration of impulses.

METHODS

Subjects were exposed on different test days to 166 dB (peak, normal incidence) impulses 34, 58, 72, or 96 μsec duration, 1 sec apart. Pre- and post-exposure thresholds were compared to determine TTS produced by the exposure.

SUMMARY

At the longest pulse duration, a median of only four impulses was required to reach the criterion TTS. The frequency of maximum TTS appears relatively independent of impulse duration. Maximum shift occurs at very high test frequencies (11-16 KHz) with appreciable loss at 3-4 KHz.

CONCLUSIONS

It is obvious that TTS will be greater following exposure to impulses of the same sound pressure level by having longer durations. Such TTS is not confined to the frequency regions typically tested with conventional audiometers (125 - 8,000 Hz), but might very well be considerably greater at higher frequencies, e.g., up to 16 KHz.

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INTRODUCTION

In recent times there has been increasing agreement on the hazards to hearing posed by continuous noise, but there are no generally accepted standards for exposure to impulsive noise. In order to perform research such that standards of this kind may be formulated, it is necessary to generate and measure intense impulses varying in duration, amplitude, spacing, rise and decay time, reverberant characteristics, etc., and these instrumentation and measurement problems are not completely solved. As many have observed, one cannot simply put the appropriate electrical wave forms into speakers and expect faithful reproduction. With very short electrical inputs (with durations characteristic of gunshots, e.g.), speakers ring, and therefore the result output is determined primarily by the transducer rather than the input.

In the past, investigators have generated impulses by discharging a capacitor across a speaker (10), by using an intense impulse into a speaker at the ear (1), by opening and closing toy "crickets" (10, 11), or by using an electrical spark gap (4, 9). In these studies, the duration of impulses was either much longer or much shorter than that of gunshots, and the intensity was generally lower. In the last two studies, the intensity was comparable, but pulse duration was shorter.

The alternative to working with these laboratory sources is to work directly with small arms. A number of researchers (2, 7) have employed actual weapons. It may be, in fact, that this will prove to be the most practical approach and the only way to attain the desired physical characteristics. However, it is not easy to assemble the appropriate weapons so that one can independently vary different pulse parameters—e.g., peak intensity, number, spacing, rise time and duration.

PROCEDURE

Initially, a number of enlisted volunteers assigned to the US Army Medical Research Laboratory were screened on a Rudmose ARJ-5 diagnostic audiometer and a specially built high frequency Rudmose audiometer manufactured by Tracor, Inc. (see (13)). If hearing levels at or below 8 KHz equalled or exceeded 30 dB (ISO), or, if high frequency thresholds at or below 16 KHz were so high that a measurable shift would not be feasible (i.e., if the threshold were less than 40 dB from the maximum measurable), the S was dropped from the experiment. Seventy-two subjects met the criteria imposed.

The $\underline{S}$s were placed in an anechoic chamber and exposed to four durations of impulsive noise presented once per second. For each, the peak was 166 dB—as measured (grazing incidence) with an LTV microphone; but the duration of the first positive impulse (and of successive ones) was different for each impulse. Impulses were generated with a multiple spark-gap generator devised by R. W. Benson and Associates. Four durations of positive peak were generated—approximately 34, 58, 72, and 96 μsec. Subjects were positioned so that the incidence of the impulse on the ear was normal. Tracings of the oscilloscope recordings from the LTV microphone* are given in Figures 1-4 (below and following pages).

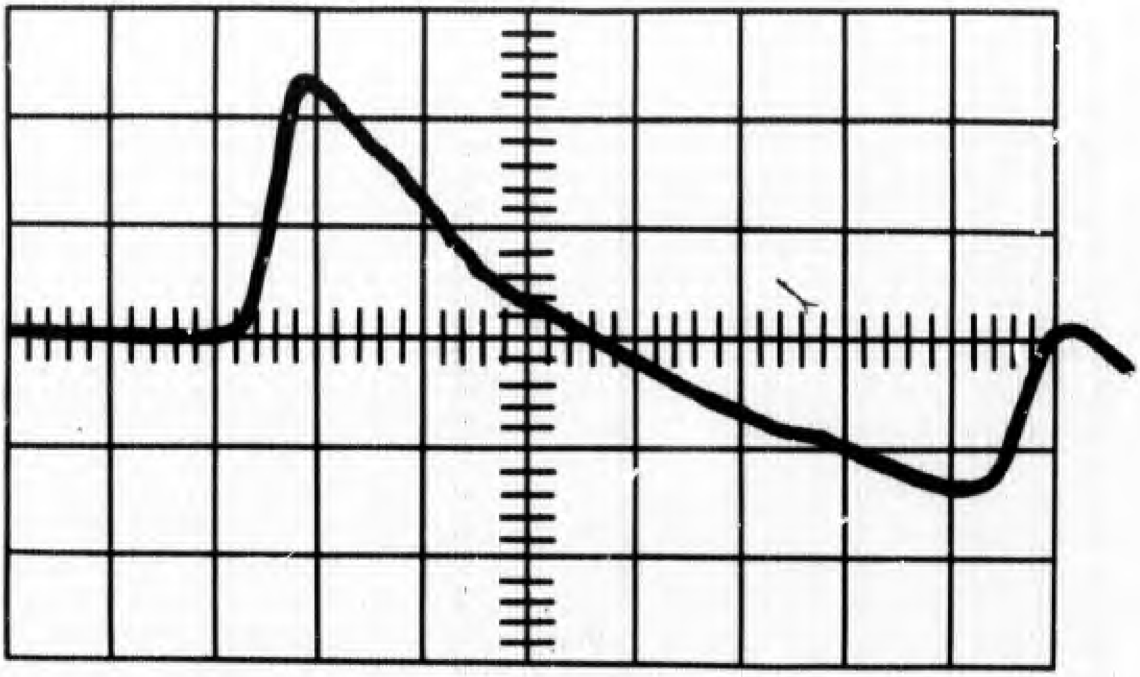

Fig. 1. Oscilloscope tracing of 3-gap impulses. (Time base = 10 μsec/div.)

*The impulses have recently been re-measured with a Brüel and Kjaer Model 4136 microphone, since there is some evidence, according to R. W. Benson, that it may be more suitable for impulse noise measurement. The overall level so measured was 167 dB peak and durations for 3-, 4-, 5-, and 6-gap were 32, 56, 72, and 96 μsec, respectively. It is felt that these values do not differ sufficiently from those previously measured to merit reconsideration of the analysis and conclusions presented in this report.

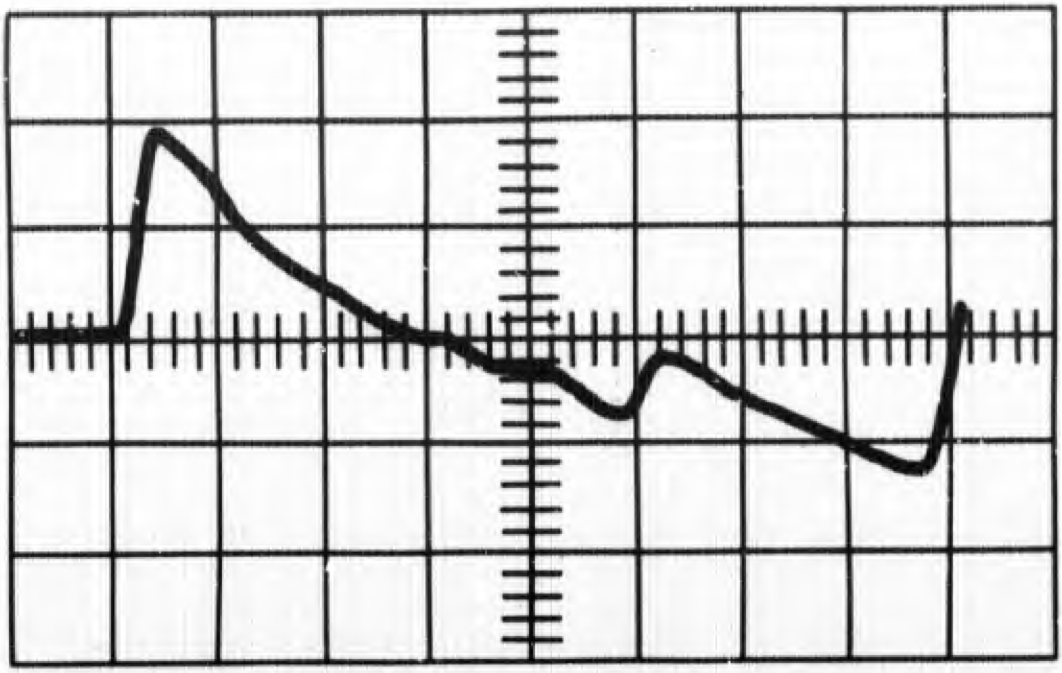

Fig. 2. Oscilloscope tracing of 4-gap impulse. (Time base = 20 μsec/div.)

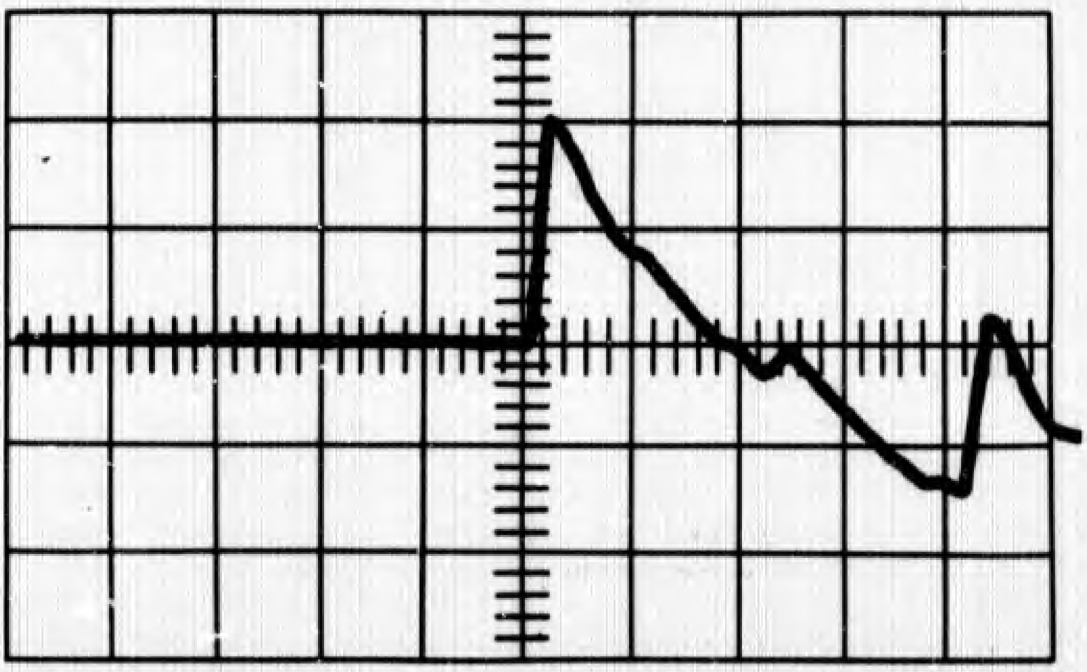

Fig. 3. Oscilloscope tracing of 5-gap impulse. (Time scale = 40 μsec/div.)

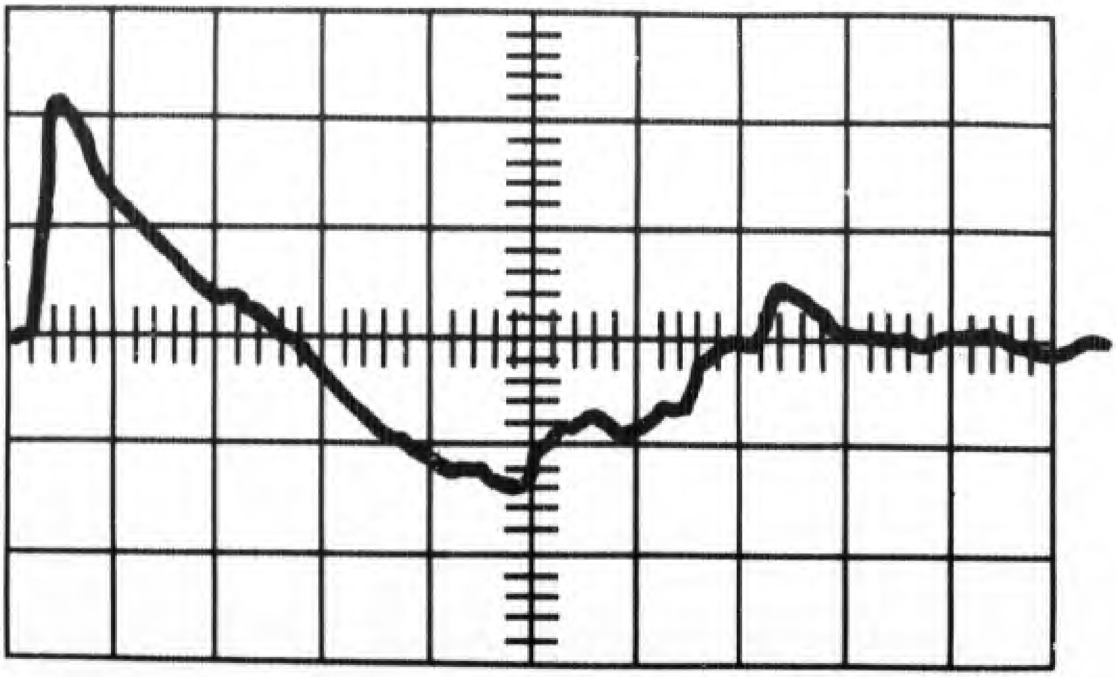

Fig. 4. Oscilloscope tracing for 6-gap impulses. (Time scale = 40 μsec/div.)

Note here that after the initial positive pulse there is a longer but less intense negative pulse. (Duration was a little less than twice as long and peak pressure a little more than half as great as that of the original pulse.) The positive pulse following the extended negative one was down approximately 14 dB from the peak level of the first positive pulse.

Order of the four exposure conditions was counterbalanced. Since some of the 72 subjects were lost during the course of the experiment (due to illness, etc.) counterbalancing was not perfect.

At each spark-gap setting, Ss were exposed on their first test day to only one impulse. On successive days the number was doubled—to 2, 4, 8, 16, 32, etc. When the number of impulses exceeded 512 (as it did with one or two subjects at the lower pulse durations), then instead of doubling to 1024, an intermediate setting at 722 (the geometric mean of 512 and 1024) was employed before going on to 1024.

Ss were tested before and after each exposure at 250, 500, 750, 1,000, 1,500, 2,000, 3,000, 4,000, 5,000, 6,000, 7,000, and 8,000 KHz with a Rudmose ARJ-5 audiometer and at higher frequencies (9, 10, 11, 12, 13, 14, 15, 16, and 18 KHz) with the high frequency

Rudmose audiometer. Post-exposure testing was initiated 90 sec after exposure. Temporary threshold shifts (TTSs) were computed and data converted to estimates of TTS 2 min after exposure (TTS_2) (see (6)). Subjects were dropped from a particular exposure condition (i. e., not run at the next highest number of impulses) whenever the TTS (uncorrected) exceeded 30 dB at any frequency. Almost invariably this occurred at a high test frequency—at or between 10 and 16 KHz—though appreciable shifts were noted as low as 4 KHz for some Ss. The average HLs of subjects employed in each exposure condition are given in Table 1, below.

TABLE 1

Mean and Median Hearing Levels (ISO) for Each Exposure Condition

34 μsec	250	500	750	1000	1500	2000	3000	4000	5000	6000	7000	8000
N = 66												
Mean	2.98	2.56	-1.14	-1.17	.73	.58	2.29	-2.61	2.85	8.11	10.14	1.56
Median	4.00	2.0	-2.0	-2.0	1.0	0.0	2.0	-5.0	3.00	8.0	10.5	-1.00
58 μsec												
N = 67												
Mean	1.63	1.82	-1.66	1.31	-.030	-.70	1.36	-2.73	2.53	9.12	10.90	1.00
Median	3.00	2.00	-2.00	-2.00	-2.00	0.0	1.00	-4.00	2.00	9.00	10.00	0.0
72 μsec												
N = 71												
Mean	3.99	2.17	-.59	-1.82	-.14	0	1.28	-4.66	3.46	8.03	11.39	1.65
Median	4.0	2.0	-1.0	-2.0	-1.0	0	1.0	-5.0	1.0	8.0	11.0	1.0
96 μsec												
N = 65												
Mean	3.91	2.38	-1.03	-1.28	-.046	.013	.123	-5.43	1.48	8.12	9.45	1.05
Median	4.00	2.0	-2.0	-2.0	-.050	0	0	-7.0	2.00	8.0	9.0	0

RESULTS

Number of impulses required to achieve the 30 dB criterion TTS_2 was computed for every subject. Since in every case the exact criterion had been somewhat exceeded, this required interpolation between settings. As Ward (12) and others have reported, the range of susceptibilities (as reflected in number of pulses to criterion shift) was immense, being 0.5 to 2745 impulses at the highest pulse duration and 11 to 2304 at the lowest pulse duration. The data were skewed, with only a few Ss requiring a large number of impulses to achieve criterion shift. Because of this skewness, it was felt that median number of impulses to criterion best represented group shift. In Figure 5 (below) the relationship between impulse duration and median impulses to criterion shift is plotted.

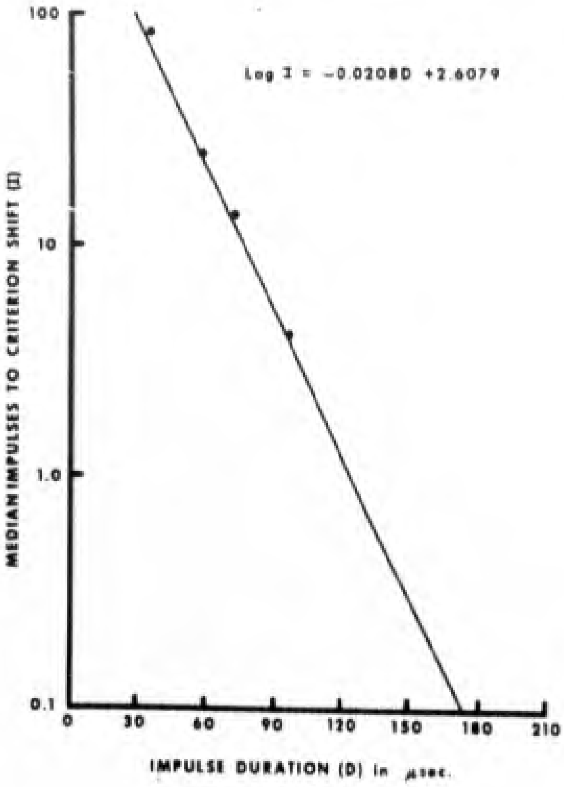

Fig. 5. The relationship between median impulses to criterion and impulse duration.

Note that there appears to be a good linear relationship between the logarithm of number of impulses to criterion and duration (of the first positive component). Note also that criterion shift is reached with a rather small number of impulses, especially at longer pulse durations.

Table 2 (next page) shows the computed median TTS_2 at each test frequency when criterion shift is attained. Note here that the frequency of maximum shift appears relatively independent of impulse duration. This is somewhat in conflict with earlier findings, based on less data,

TABLE 2

Mean and Median TTS_2's (30 dB or greater)

Test Frequencies

	250	500	750	1000	1500	2000	3000	4000	5000	6000	7000	8000	9000	10,000	11,000	12,000	13,000	14,000	15,000	16,000	18,000
3 GAP (34 μsec)																					
Mean	1.3	2.3	2.1	2.0	2.1	2.6	5.9	10.8	12.5	13.6	18.0	20.0	22.0	26.6	28.1	28.2	28.0	28.7	24.6	24.6	19.6
Median	1.0	2.0	1.0	3.57	1.0	2.2	5.0	8.25	10.6	11.95	17.5	18.75	21.0	26.5	28.0	29.0	29.0	30.0	24.0	25.7	18.1
4 GAP (58 μsec)																					
Mean	2.3	2.9	2.0	3.2	3.2	4.4	12.1	17.2	17.9	19.6	20.6	21.6	21.4	23.0	28.6	28.1	29.6	27.0	24.7	23.5	18.0
Median	2.0	2.0	1.0	4.08	2.0	3.2	9.5	15.0	16.5	19.5	20.5	20.75	20.0	23.5	30.0	28.0	30.0	26.0	25.0	21.7	18.1
5 GAP (72 μsec)																					
Mean	1.8	2.2	1.7	2.0	3.0	4.1	10.5	15.5	17.5	18.05	17.6	20.0	20.8	24.3	27.4	26.6	27.8	27.9	25.3	23.1	18.2
Median	2.0	2.0	1.0	3.36	2.0	3.3	10.0	13.75	16.5	15.5	17.5	15.5	16.0	26.0	29.0	25.0	29.0	29.0	28.0	22.7	22.8
6 GAP (96 μsec)																					
Mean	1.3	1.6	0.6	1.3	2.9	3.6	9.6	13.15	12.5	13.6	13.0	14.9	20.2	22.2	27.0	28.0	29.9	28.0	24.0	24.6	16.6
Median	1.0	1.0	0	2.95	1.0	2.2	8.5	11.75	12.1	9.8	11.6	13.0	16.5	20.5	29.0	30.0	30.0	29.0	23.5	24.7	16.1

reported by Fletcher and Loeb (4). Although the maximum shift occurs at very high test frequencies (11-15 KHz), there is appreciable loss (on the order of 10 dB) at 3 to 4 KHz.

Table 3 (below) shows the correlations between numbers of impulses to criterion shift for the four different conditions. Correlations are based on the subjects run in all four exposure conditions. Of interest here is the fact that there appears to be a systematic tendency for correlations to be highest between exposure conditions most similar in duration.

TABLE 3

Correlations Between Impulses to Achieve Criterion Shift at Different Durations of First Positive Impulse

Durations (μsec)	34	58	72	96
3		0.87	0.67	0.30*
4			0.86	0.47
5				0.60

*Significant beyond 0.05 level. All other correlations significant beyond 0.01 level.

DISCUSSION

The most surprising finding in this experiment was the large shifts associated with relatively small numbers of impulses. The median shifts at 3 and 4 KHz in our experiment following exposure to a median of 4 impulses (at the largest duration) were not greatly less than shifts at the same test frequencies following exposure to approximately 100 impulses of similar peak level but twice the duration in Kryter and Garinther's experiment (7).

The reason for this discrepancy is not apparent, though some differences would be expected. Incidence of the impulsive noise in the present experiment was normal, whereas in Kryter and Garinther's it was grazing. (It was felt that employing a normal incidence is a more conservative procedure, as on the firing range it is not uncommon for a firer or observer to encounter a normal-incidence impulsive noise from another's rifle, though a firer probably receives a grazing-incidence impulse from his own rifle.) It has been suggested by Coles, Garinther, Hodge, and Rice (3) that a normal-incidence impulse is approximately equal in its effects to a grazing-incidence impulse 5 dB more intense. There was also an apparent difference in the ears of the Ss in the present study and in Kryter and Garinther's. The HLs of the ears in the firing condition discussed were of the order of 7-11 dB (ASA) at 3 and 4 KHz; in our case, the HLs approached 0 dB (ISO) (see Table 1). In other words, our Ss, fresh from basic training, were approximately 20 dB more sensitive than Kryter and Garinther's subjects. As they, Ward (12), and others have pointed out, with lower HLs, greater TTSs are to be expected. Kryter and Garinther attempted to take this into account by adding initial HL and TTS_2 to obtain a HL_2 hopefully indicative of the TTS_2 to be expected from 0 dB HL subjects.

It could be argued that since our subjects had HLs less than the ASA 0 dB HLs on which the original criteria for TTS were based (see (8)), that the application of such criteria (20 dB at 3 KHz at above, 15 at 2 KHz, 10 at 1 KHz or below) may be too stringent a procedure in this case. While this may be true, Kryter and Garinther noted in their article that at very high intensities small changes in intensity may have unexpectedly large effects on TTS.

In the past, little attention has been paid to TTS above 4 KHz and even less to TTS above 8 KHz, in part because these frequencies are considered unimportant for speech comprehension, and in part because most audiometers are limited in high frequency capability. The large shifts noted at high frequencies in this experiment would appear to pose a dilemma for the researcher. Losses at 4 KHz and below were approximately a third (in dB) of the losses noted at very high frequencies. If, as has been suggested (12), losses of greater than 40 dB may sometimes involve some permanent loss, then when we perform experiments which produce TTS of 20 dB in the range at or below 4 KHz, we may be risking permanent high frequency loss. This problem has not really existed for continuous noise, as the losses generally have been maximum in or near the speech frequency. It is possible that high frequency loss is typical only for short impulses.

However, it is questionable that TTS at high frequencies would not be produced by exposure to small arms fire. One study (5), in which the noise was produced by an M-14 rifle, suggests that mean TTS would be maximum at moderately high frequencies (10 and 12 KHz). However, the average peak was smaller (158 dB) than in the present experiment, exposure was grazing, and in some cases Ss did not have a measurable threshold at some high frequencies. Further studies on TTS produced by exposure to conventional impulse noise seem advisable.

High frequency acuity may have practical significance for some purposes (e.g., localization, or identification of certain sounds), and in any event, it probably has aesthetic utility. If, by requiring personnel exposed to impulse noise to use ear protective devices we could prevent high frequency permanent loss, there would appear to be little reason not to do so under most training or recreational conditions.

At this point it would appear that relaxation of standards for exposure to impulse noise would be premature.

LITERATURE CITED

1. Ball, J. Instrumentation for a study of temporary threshold shift caused by high-intensity acoustic transients. Report No. 785, Bolt, Beranek, and Newman, Inc., Cambridge, Mass., 1961.

2. Coles, R. R. A. and C. G. Rice. High intensity noise problems in the Royal Marines. J. Roy. Med. Serv. 51: 2-3, 1965.

3. Coles, R. R. A., G. R. Garinther, D. H. Hodge, and C. G. Rice. Hazardous exposure to impulse noise. J. Acoust. Soc. Amer. 43: 336-343, 1968.

4. Fletcher, J. L. and M. Loeb. The effect of pulse duration on TTS produced by impulse noise. J. Aud. Res. 7: 163-167, 1967; USAMRL Report No. 680, 1967 (DDC AD No. 647540).

5. Hodge, D. C. and R. B. McCommons. Further studies of the reliability of temporary threshold shift from impulse-noise exposure. Tech. Memo. 3-66, Human Engineering Labs., Aberdeen, Md., 1966.

6. Kryter, K. D. Steady state noise and impairment of hearing. J. Acoust. Soc. Amer. 35: 1515-1525, 1963.

7. Kryter, K. D. and G. R. Garinther. Auditory effects of acoustic impulses from firearms. Acta Otolaryngol., Suppl. 211, 1966.

8. Kryter, K. D., W. D. Ward, J. D. Miller and D. H. Eldredge. Hazardous exposure to intermittent and steady-state noise. J. Acoust. Soc. Amer. 39: 451-464, 1966.

9. Loeb, M., J. L. Fletcher, and R. W. Benson. Some preliminary studies of temporary threshold shift with an arc-discharge impulse noise generator. J. Acoust. Soc. Amer. 37: 313-318, 1965; USAMRL Report No. 631, 1965 (DDC AD No. 467139).

10. Ward, W. D., W. Selters, and A. Glorig. Exploratory studies on temporary threshold shift from impulses. J. Acoust. Soc. Amer. 33: 781-793, 1961.

11. Ward, W. D. Studies in the aural reflex. III. Reflex latency as inferred from induction of temporary threshold shift from impulses. J. Acoust. Soc. Amer. 34: 1132-1137, 1963.

12. Ward, W. D. Auditory fatigue and masking. In: Modern Developments in Audiology. J. Jerger (Ed.), New York: Academic Press, 1963.

13. Zislis, T. and J. L. Fletcher. Relation of high frequency thresholds to age and sex. J. Aud. Res. 6: 189-190, 1966; USAMRL Report No. 702, 1966 (DDC AD No. 645082).

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13. ABSTRACT

Subjects were exposed, on different test days, to 166 dB (peak, normal incidence) impulses 34, 58, 72, or 96 μsec in duration spaced 1 sec apart. For each pulse duration the subjects were first exposed to one pulse, then the number of pulses was doubled on successive days until the temporary threshold shift (TTS) following exposure exceeded 30 dB. Intercorrelations of numbers of impulses required to reach criterion TTS at each duration were obtained; they were highest when durations were similar. At the largest pulse duration a median of only four impulses was required to achieve criterion, some individuals exceeded criterion at one impulse, while others required hundreds. No evidence was seen of a 4 KHz notch; maximum shift was at high frequencies (10-15 KHz) and relatively independent of impulse duration. There is reason to believe that if one exceeds allowable TTS in the speech range frequencies with this kind of impulse noise, there is a chance of producing permanent high frequency loss. (U)

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14. KEY WORDS	LINK A		LINK B		LINK C	
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Impulse Duration						
Temporary Threshold Shift Correlations						
Susceptibility						
Criteria for Hazardous Exposure						
Traumatic Noise						

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