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A PILOT STUDY OF TEMPORARY THRESHOLD SHIFTS RESULTING FROM EXPOSURE TO HIGH-INTENSITY IMPULSE NOISE

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human ENGINEERING LABORATORIES

ABERDEEN PROVING GROUND, MARYLAND

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A PILOT STUDY OF TEMPORARY THRESHOLD SHIFTS RESULTING FROM EXPOSURE TO HIGH-INTENSITY IMPULSE NOISE

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ABSTRACT

This investigation was a pilot study to determine the temporary threshold shifts resulting from exposure to high-intensity impulse noise. The threshold shifts induced were of a temporary nature, i.e., there were no instances of permanent hearing losses among any of the experimental subjects. The purpose of the study was to explore various physical parameters of a sound source and relate them to any decrements they may have on auditory acuity.

Thirty enlisted men received audiometric tests both before and after exposure to a high-intensity impulse noise generated by an M-14 rifle. Rate and number of impulses were varied separately and examined at three test frequencies. Due to inter-subject differences, only general implications are indicated. Recommendations are included for future research.

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A PILOT STUDY OF TEMPORARY THRESHOLD SHIFTS

RESULTING FROM EXPOSURE TO HIGH-INTENSITY IMPULSE NOISE

INTRODUCTION

The purpose of this report is to present an interim progress statement in the area of noise exposure, and in particular, exposure to high-intensity impulse noise. The problem arises from the fact that, while new weapon systems have increased the destructive capabilities of the individual soldier, the weapons have also increased the magnitude and the incidence of hazardous noise exposure. The direction of research, therefore, will be to relate some of the physical characteristics of the sound source with their effects on the auditory acuity of the user.

There are a number of important physical parameters of the sound source. These include: (1) intensity (sound pressure level), (2) characteristics of the energy spectrum, (3) rise time, (4) decay time, (5) total duration, (6) total energy, (7) repetition rate, (8) number of impulses, and (9) location of exposure. In addition, environmental parameters must be included such as: (1) temperature, (2) humidity, (3) wind velocity, and (4) sound field. Finally, subject parameters to be considered are: (1) previous noise exposure, (2) medical history, and (3) acuity requirements of the task.

When investigating these parameters, a procedural difficulty arises in that the parameters are not necessarily mutually exclusive. It was not technically feasible to manipulate each variable independently, and since they may be reasonably assumed to interact with each other, certain decisions were made on which parameters would be studied immediately; that is, those variables that would be experimentally held constant and those that would be manipulated. This rather arbitiary choice of variables points to the necessity for further research into the area of impulse noises. In general, little or no research has been reported on some of the variables. Therefore, this study was designed to eliminate any methodological problems as well as to determine the range of values that are encountered in research in the area of impulse noises.

METHOD

Subjects

Forty enlisted personnel from Headquarters and Headquarters Company, Companies A and B, Special Troops at Aberdeen Proving Ground, Maryland, served as subjects (S). Of the 40 Ss, data on 30 were used. One S was rejected because of an unintentional interruption in the sound source (rifle misfire) and nine Ss were rejected because their audiograms indicated that their hearing acuity could not be considered under the Army's category of Class A; i.e., they deviated by 15 db or more in one or more of the 11 test frequencies. This, it may be noted, is a 22.5% rejection rate. The mean age of the Ss was 23 years, 8 months, ranging from 17 to 36 years. The mean time-in-service was 3 years, 1 month, ranging from 2 months to 15 years.

A pre-test interview disclosed the following information:

a. The medical history of each subject.

b. A family history of any deafness.

c. The pre-service and active service occupational speciality.

d. Extent, if any, of combat and overseas duty.

e. Previous noise exposure, especially while in service (firing range, vehicle noise, etc.).

Apparatus

The impulse noise was generated by a U. S. Army 7.62mm M-14 rifle using ball ammunition and fired from a fixed rifle mount (Fig. 1). There were two reasons why this weapon was selected as the sound source. First, both the rate of impulse and the number of impulses could be controlled separately, and secondly, this weapon is replacing the Garrand M1 as the Army's standard individual rifle.

A detailed description of the physical measurements made on the sound source will be presented in a later report (HEL Tech Memo 15-61). The sound pressure level at firing position was 158 db (re. 0.0002 dyne/cm^2) with a $\pm$ 3 db reliability. Included in the Appendices of this report (Appendices A and B) are an octave band analysis and a diagram of the constant sound-pressure contours of the sound field.

The auditory thresholds were determined by a standard Maico audiometer (H-1B). The two experimenters, both trained in audiometric techniques, administered the tests.

PROCEDURE

Each day three Ss were tested separately. Each S was given a pretest audiogram on his right ear. This audiogram, and all succeeding audiograms, were given at the experimental site (Fig. 2). In the experimental position the S was seated 3' 9" to the left and 1' 4½" to the rear

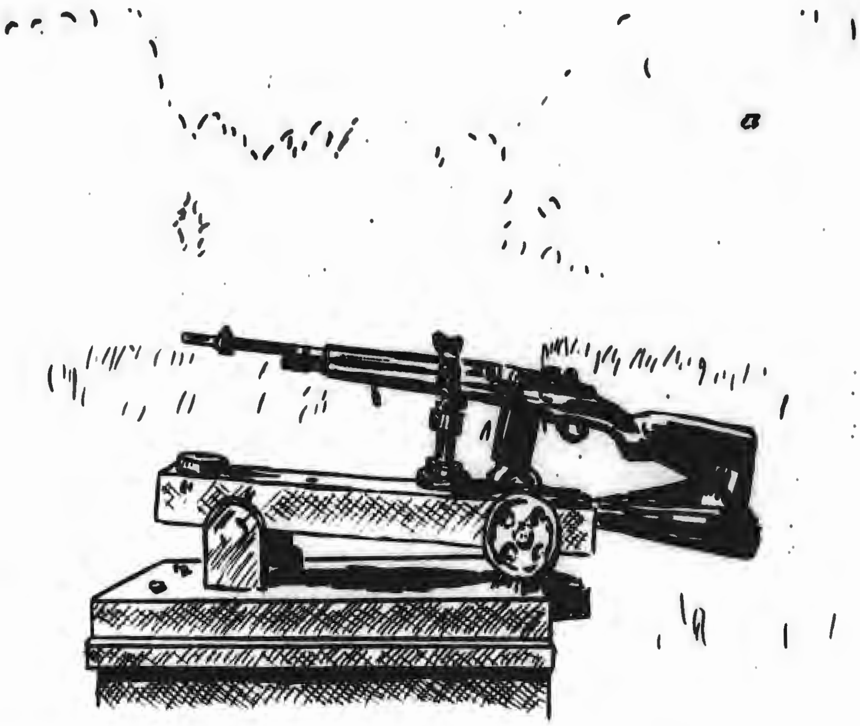


Fig. 1. M-14 in Fixed Rifle Mount

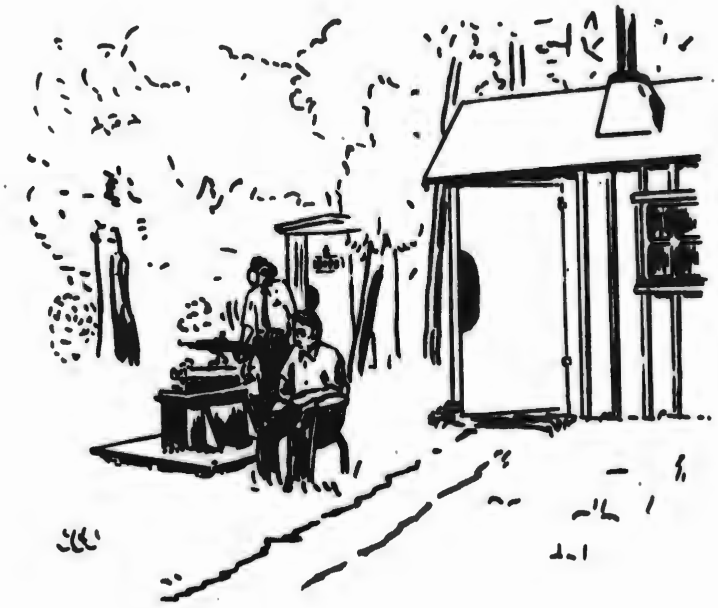


Fig. 2. Experimental Test Site

of the breech of the rifle, facing in the direction of fire. At this position the S received the same impulse that he would have received if he had actually fired the weapon (Appendix B). However, this position gave the experimenters greater control over the application of the independent variables. The S wore earphones; the left earphone was positioned over the left ear throughout the experiment, while the right earphone was positioned just in front of the right ear, over the S's temple during the firing. The S was alerted of the impending fire immediately before the experimental condition. After fire, he was immediately tested by replacing the right earphone over his ear. A three-frequency check was then administered. The frequencies, 3000 cps, 4000 cps, and 6000 cps were chosen in order to determine which frequency, if any, was the most sensitive to temporary threshold shifts (TTS). Previous research has shown these three test-frequencies to be the most sensitive; Murray and Reid, 1946; Ward, Senders, and Glorig, 1961.

The exact number of audiograms that were administered depended upon the individual S's recovery rate. Seventeen were administered for the slowest recovery rate. The first audiogram was a complete check of all frequencies and was used as a selection device. Only the three chosen test-frequencies were used on the subsequent audiograms in order to obtain as much useful information as possible in the shortest period of time. The actual time schedule of the audiograms was as follows:

a. Initial complete audiogram

b. Three-frequency checks:

    1. Immediately before firing
    2. Immediately (0) after firing
    3. One minute after firing
    4. Two minutes after firing
    5. Five minutes after firing
    6. Ten minutes after firing
    7. Twenty minutes after firing
    8. Thirty minutes after firing
    9. Forty-five minutes after firing
    10. One hour after firing
    11. One and one-half hours after firing
    12. Two hours after firing

13. Three hours after firing

14. Four hours after firing

15. Twenty-four hours after firing

16. Forty-eight hours after firing

During the testing of one S, the other two Ss were physically removed from the immediate test vincinity and as added precaution against uncontrolled exposure they were required to wear ear protectors. The order in which the treatments were administered and the assignment of treatments to Ss was randomly determined. The time period between the testing of successive Ss was determined by the preceding S.

Experimental Design

The independent variables were: (1) rate of impulse - there were two rates of impulse, single fire (one round per second) and rapid fire (760 rounds per minute or 12.7 rounds per second) (2) total number of impulses - there were three levels of total impulses (20, 25, and 30 rounds). Preliminary work had indicated that levels of at least 20 impulses were necessary in order to produce temporary threshold shifts of meaningful decrement, both in extent and duration. The dependent variable was the magnitude of temporary threshold shifts.

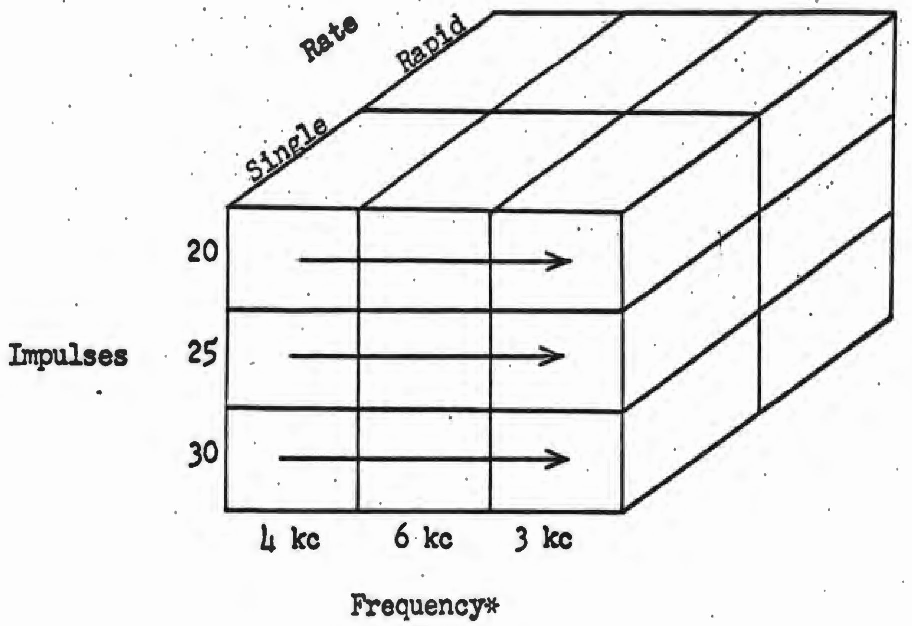
Since all Ss were tested over all three test-frequencies, the design resulted in a 2 x 3 x 3 factorial with non-independence in the frequency treatment and five Ss per group (Fig. 3).

RESULTS AND DISCUSSION

Difference scores were computed for each S by comparing his pre-exposure with each post-exposure audiogram. The data in means are presented in Table 1 and in medians in Table 2 according to experimental conditions and recovery intervals.

The mean difference scores were then analyzed by an analysis of variance design (Lindquist, 1956) Type III. The shorter recovery intervals (0, 1, 2, 5 min.) were each analyzed separately, while the longer intervals (10 min., 20 min., .. 4 hours) were not analyzed. The rationale for this cut-off was that with increasing recovery intervals there were progressively more Ss who returned to their pre-exposure thresholds, therefore the assumption of normality could not be met.

The summary tables for each analysis of variance are presented in Appendix C, while a summary of the significant findings is presented in Table 3.



*The frequency variable is not an independent measure as all subjects served in the three frequency conditions.

Fig. 3. Diagram of Experimental Design

In general, the various error terms of the analyses of variance were rather large. Thus, in order to examine the variability of Ss within treatment conditions and the variability of the Ss x frequency interaction within treatment conditions, Bartlett tests for homogeneity of variance (Edwards, 1960) were computed. The S variances for the different treatment groups proved highly significant ($F = 16.84$, $P < .01$). Examination of the raw data shows the S variance under the single rate-25 impulses treatment to be at least 2-3 times greater than the S variance under any other treatment. The S x frequency variances did not prove to be significantly different ($F = 7.29$, $P < .20$) for the various treatment conditions. This indicates that the variability of the Ss' pattern of scores across frequency within each treatment condition does not vary with different treatment conditions. Since homogeneity of variance was only partially present, the hypothesis of random sampling from a common population variance was rejected. Close scrutiny of the original data indicates that of the five Ss in the single rate-25 impulse group, three had a TTS at the 0-interval in the range of 55-60 db, one S had a very short transient TTS of 20 db for one minute, while the fifth S had only a small TTS (5 db) at 4000 cps which was recovered immediately.

The extreme variance that any one group contributed is not totally unexpected. The sensitivity of individual Ss to TTS is quite well documented (Ward, et al., 1961); there seems to be a proportion of the population who will have large shifts almost regardless of the magnitude of the impulse. Thus, without prior knowledge of a S's susceptibility to TTS, it seems quite possible that by a chance occurence three Ss who were quite sensitive were randomly placed in the same experimental group. Subjects in other groups had indications of high susceptibility, e.g., the single -30 and the rapid-30 groups each had a S who showed a disproportionate TTS, in fact, one S in the single-30 group had upwards of a 55 db TTS which required 48 hours for total recovery.

Since further investigations may also have similar variance problems, a discussion of the transformations that can be used seems appropriate. This discussion is included in Appendix D. In this study the means of the various treatments tended to be proportional to the standard deviations. Therefore, a logarithmic transformation was applied to the data ($\log X+1$). For purposes of general interest, both a square root ($\sqrt{X+.5}$) and a reciprocal transformation ($1/X+5$) were also applied. The summary tables for each analysis of variance are presented in Appendix C, while a summary of the significant findings is presented in Table 3.

The mean data has been plotted graphically and is presented in Figs. 4-7 although the values suffer from the data of extreme individuals. Median values were not plotted because of the rapid recovery to pre-exposure thresholds for the majority of the Ss.

In Fig. 4 the mean TTS across all Ss was plotted against recovery interval. The curve, it may be noted, is a classic example of a recovery curve with a large initial threshold shift followed by a rapid recovery in the first few minutes which, in turn, is followed by a slow recovery over a long period of time. Within the first two minutes after exposure there is almost 50% recovery.

TABLE 1

MEAN TEMPORARY THRESHOLD SHIFT IN DECIBELS *

Recovery Interval	Frequency			Impulses			Rate		Total TTS
	3KC	4KC	6KC	20	25	30	Single	Rapid	
0 min.	6.2	15.3	9.8	5.3	18.1	7.8	13.6	7.3	10.4
1 min.	5.5	9.2	9.0	3.5	13.5	6.7	10.1	5.7	7.9
2 min.	3.0	6.5	7.7	3.0	9.8	4.3	7.1	4.3	5.7
5 min.	1.5	4.2	6.3	1.2	7.3	3.5	4.9	3.1	4.0
10 min.	1.2	2.7	5.3	.5	6.0	2.7	3.7	2.4	3.1
20 min.	.8	2.7	4.7	.3	5.7	2.2	3.4	2.0	2.7
30 min.	.8	2.5	3.3	.3	4.8	1.5	2.8	1.7	2.2
45 min.	1.0	2.2	3.3	.2	4.8	1.5	2.9	1.4	2.2
1 hr.	.5	1.8	2.8	.0	3.7	1.5	2.3	1.1	1.7
$1\frac{1}{2}$ hrs.	.3	1.0	2.3	.0	2.7	1.2	1.7	.8	1.2
2 hrs.	.3	1.3	2.0	.0	2.7	1.0	1.8	.7	1.2
3 hrs.	.3	1.3	1.7	.0	2.3	1.0	1.6	.7	1.1
4 hrs.	.3	1.0	1.8	.0	2.3	.8	1.6	.6	1.1
OBSERVATIONS	30	30	30	30	30	30	45	45	90

* For purposes of analysis the total of 90 observations has been partitioned three ways: frequency, number of impulses, and rate. This is also the case for Table 2.

TABLE 2

MEDIAN TEMPORARY THRESHOLD SHIFT IN DECIBELS

Recovery Interval	Frequency 3KC	4KC	6KC	Impulses 20	25	30	Rate Single	Rapid	Total TTS
0 min.	0	7.5	5	5	5	0	5	5	5
1 min.	0	5.0	0	0	5	0	0	0	0
2 min.	0	0	0	0	2.5	0	0	0	0
5 min.	0	0	0	0	0	0	0	0	0
10 min.									
20 min.									
30 min.									
45 min.									
1 hr.									
1½ hrs.									
2 hrs.									
3 hrs.									
4 hrs.									
OBSERVATIONS	30	30	30	30	30	30	45	45	90

TABLE 3

SUMMARY OF ANALYSES OF VARIANCE

Recovery Interval	Rate	Impulses	Frequency	Rate x Impulses	Frequency x Impulses	Frequency x Impulses	Frequency x Rate	Frequency x Imp x Rate
1. Non-transformed								
0 min.			**	*				
1 min.			*	*				
2 min.			*	*				*
5 min.			*					*
2. Logarithmic transformation								
0 min.			**					
3. Square root transformation								
0 min.			**					
4. Reciprocal transformation								
0 min.			**					

* Significant at the .05 level

** Significant at the .01 level

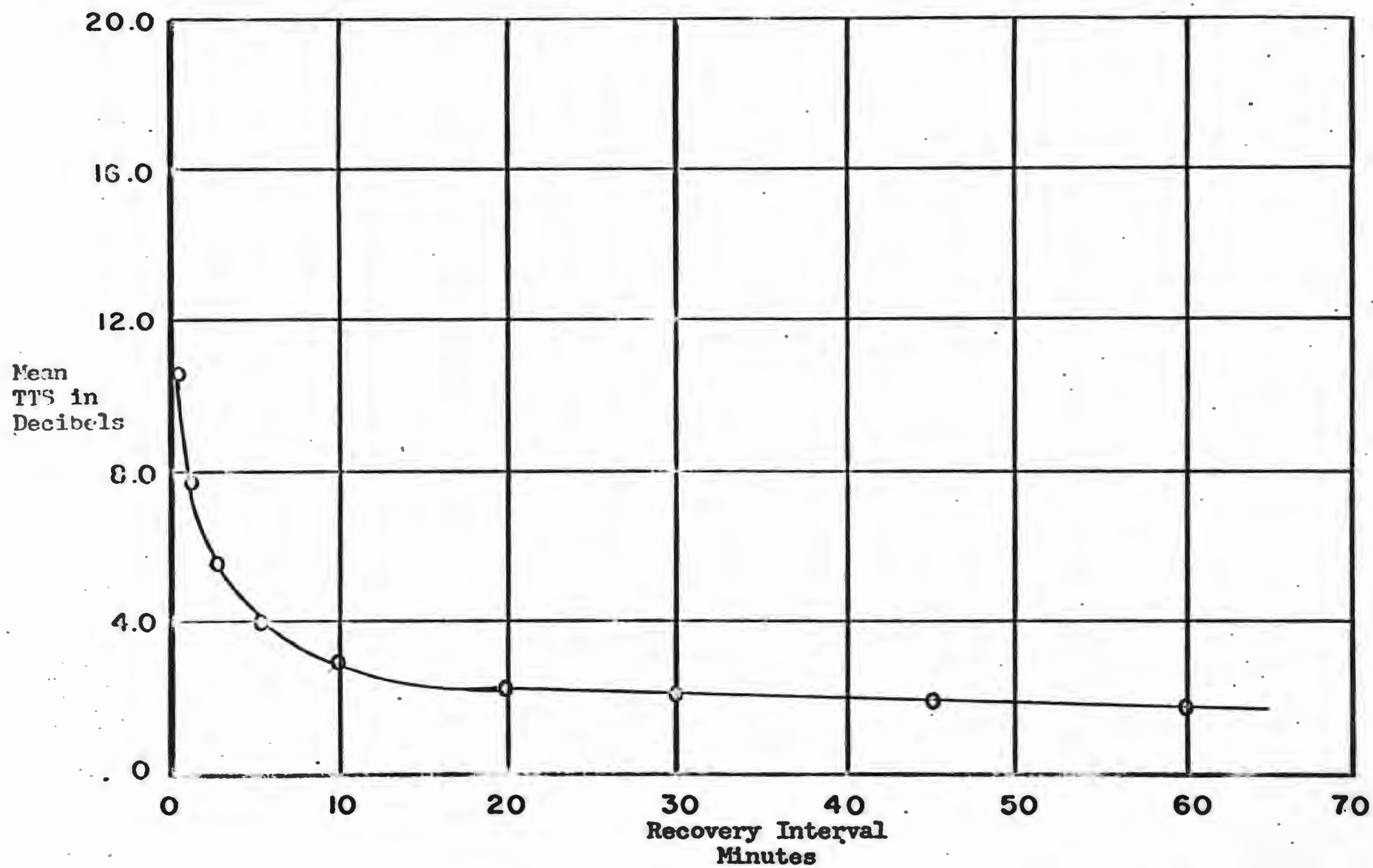


Fig. 4. Mean Temporary Shift Over All Treatments

In Fig. 5 the rate of impulse is plotted with mean TTS in decibels and recovery interval (RI) as the axes. For the two impulse rates, a comparison of the heights of the ordinate at each abscissa point indicates that the single-fire rate is always numerically more adverse to auditory acuity than is the rapid-fire rate. These differences are not statistically significant when analyzed either at each recovery interval separately or when tested across all intervals. The error terms in the analyses of variance were too large to detect small differences. Therefore, if valid differences exist, but were not detected, they can probably be accounted for by the acoustic reflex (Fletcher, 1960). The rapid rate of fire (12.7/sec) is well within the activation period of the acoustic reflex (AR), and therefore, some degree of attentuation of the impulse may be present.

In Fig. 6 the total number of impulses is plotted with the mean TTS in decibels again on the ordinate and the recovery interval on the abscissa. It may be noted that the greatest TTS is associated with the median number of impulses (25). The least number of impulses (20) caused the smallest TTS while the greatest amount of impulses (30) caused an effect which fell between the 20 and 25 impulse curves. These differences between the curves at the various recovery intervals are not statistically significant, as indicated by the analyses of variance. Here again, large error terms (between Ss, within groups) prevent detection of differences.

In Fig. 7 the three test-frequencies are plotted with mean TTS in decibels on the ordinate and recovery interval on the abscissa. The differences between the test-frequencies at each recovery interval were analyzed by "t" tests for correlated measures. Table 4 presents the findings. It may be noted from Fig. 7 that the 6000 cps test-frequency is numerically more sensitive to TTS at all points on the abscissa beyond the one-minute recovery interval. When significance testing was applied, the differences between the 4000 cps and 6000 cps frequency were significant only at the 0 minute recovery interval (4000 cps was more sensitive), never at any other recovery interval. From Table 4 it may also be noted that the 3000 cps frequency was always statistically significantly different from 4000 cps at all recovery intervals while it is significant from 6000 cps only at the 0 and 2 minute recovery interval. Therefore, when the greatest amount of information is to be obtained in the shortest period of time, it may be of value to eliminate the 3000 cps check, since either 4 kc or 6 kc is the most sensitive.

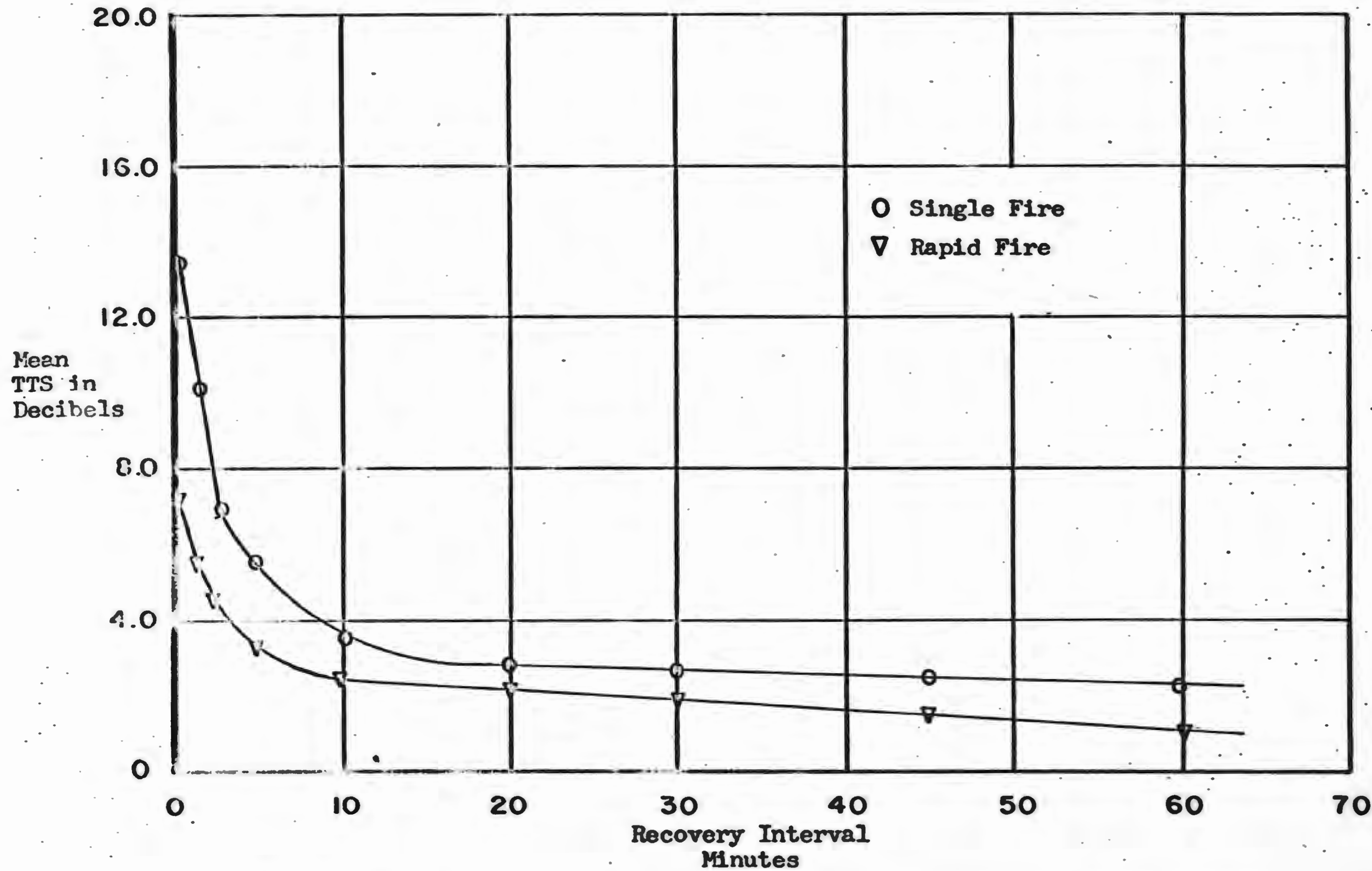


Fig. 5. Mean Temporary Threshold Shift as a Function of Rate of Impulse

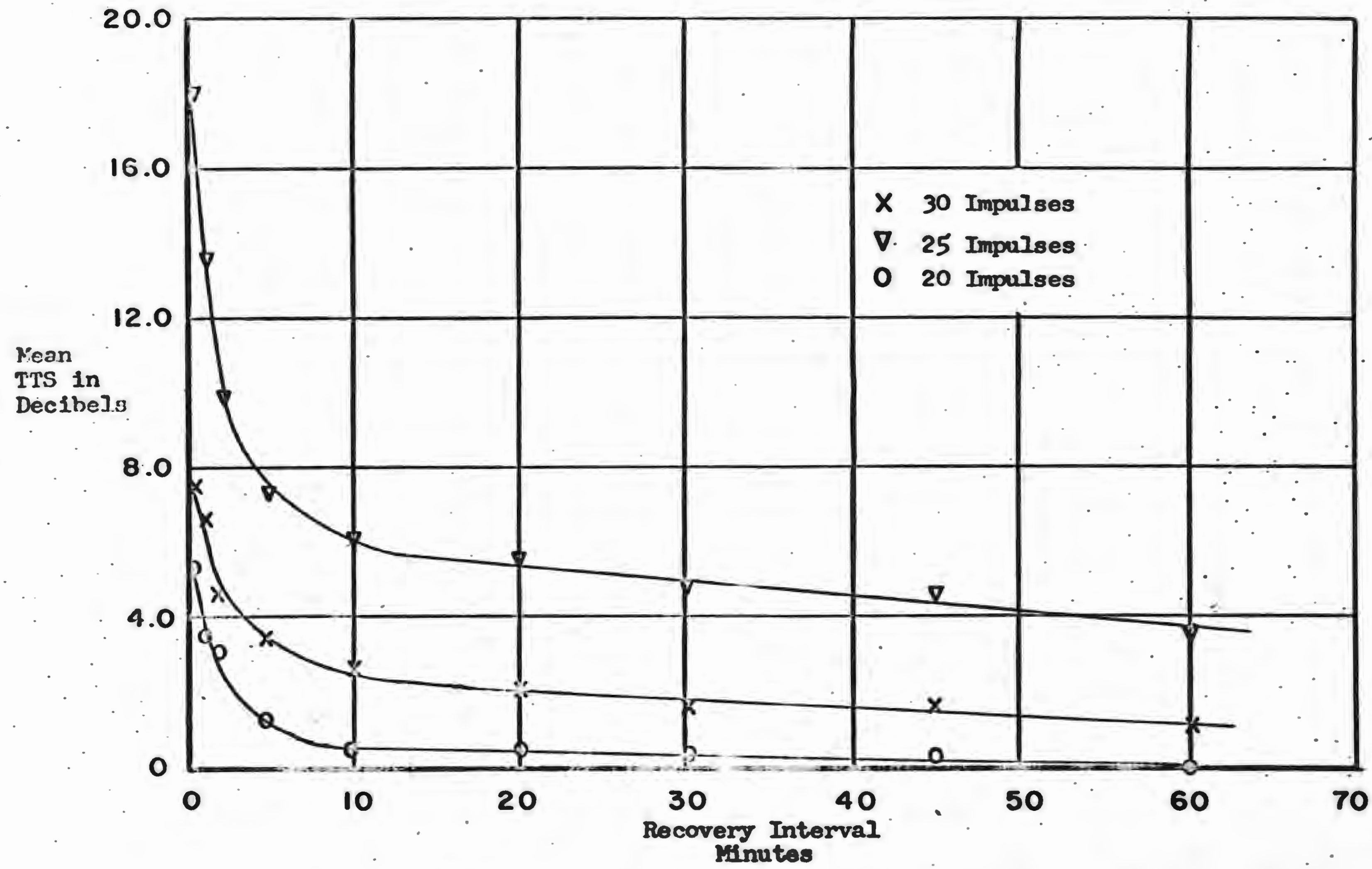


Fig. 6. Mean Temporary Threshold Shift as a Function of Number of Impulses

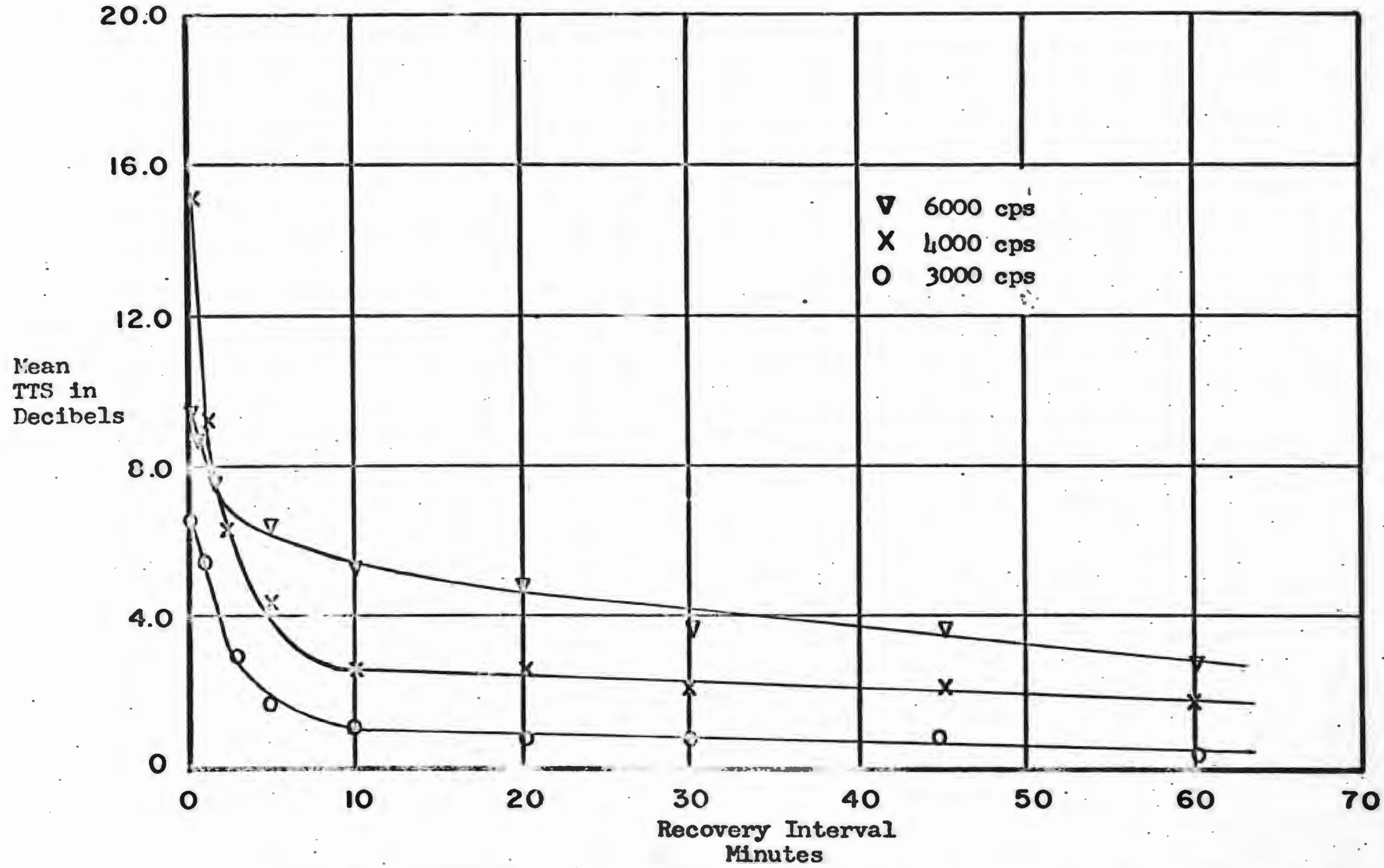


Fig. 7. Mean Temporary Threshold Shift as a Function of Test Frequency

TABLE 4

SUMMARY OF "t" ANALYSES

		Test Frequency		
		3000 cps	4000 cps	6000 cps
0 min.	3000			
	4000	.01*		
	6000	.05	.01	
1 min.	3000			
	4000	.02		
	6000	.10	.15	
2 min.	3000			
	4000	.01		
	6000	.02	.50	
5 min.	3000			
	4000	.02		
	6000	.10	.20	
10 min.	3000			
	4000	.05		
	6000	.10	.20	

* Table entries refer to probability levels.

SUMMARY AND CONCLUSIONS

This investigation was a pilot study to determine the effects of exposure to high-intensity impulse noise on auditory acuity. Thirty enlisted men were tested before and after exposure to the firing of an M-14 rifle (158-SPL). Both rate of fire (1/sec. and 12.7/sec.) and number of impulses (20, 25, and 30) were varied independently and the effects were tested at three test-frequencies (3000, 4000, and 6000 cps).

The conclusions and recommendations resulting from the investigation are:

a. Research in the area of audition suffers from several experimental design difficulties, of which the between-subjects variance is the most important. While the type of design used in this study is quite efficient in many other areas, it has not been in this study. For this reason any final conclusions drawn from the data must be treated as tenuous and only indicative at best.

b. The inter-subject variance problem can be controlled by large samples, or be repeated measurements on the same subject, or by a selection and/or matching procedure.

c. After the first few minutes both the 4000 cps and 6000 cps are equally sensitive for detecting temporary threshold shifts while 3000 cps is rather insensitive. Therefore, if time is crucial, this latter test frequency may be eliminated.

d. The independent variables, rate of impulse, and total number of impulses resulted in statistically unreliable differences.

e. Implications for further research were noted.

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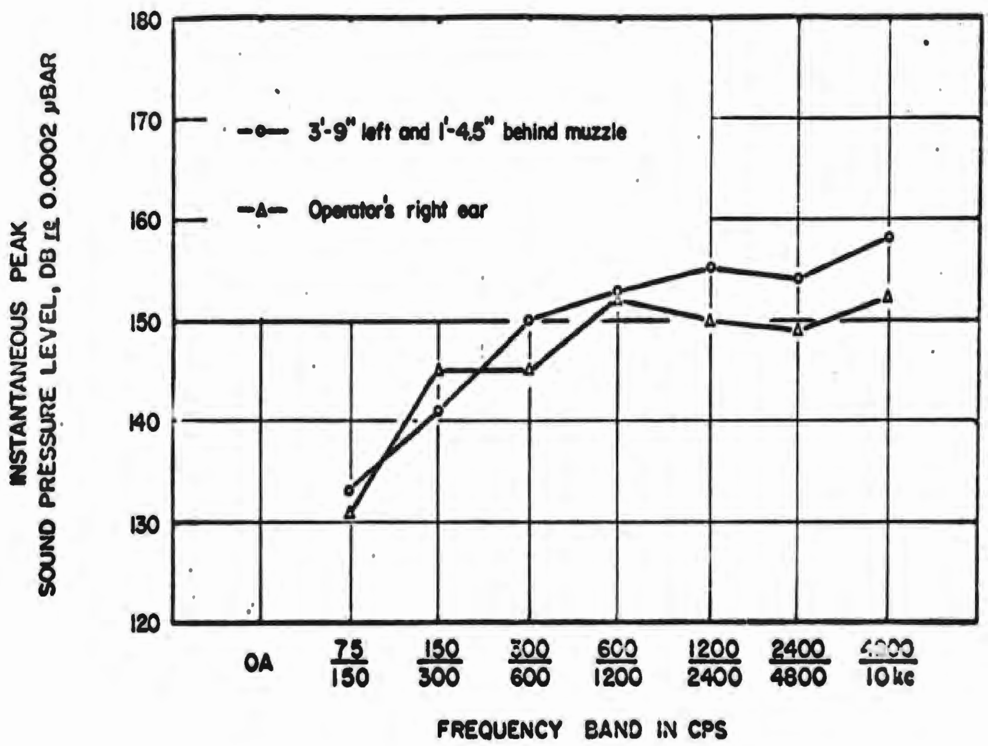
APPENDICES

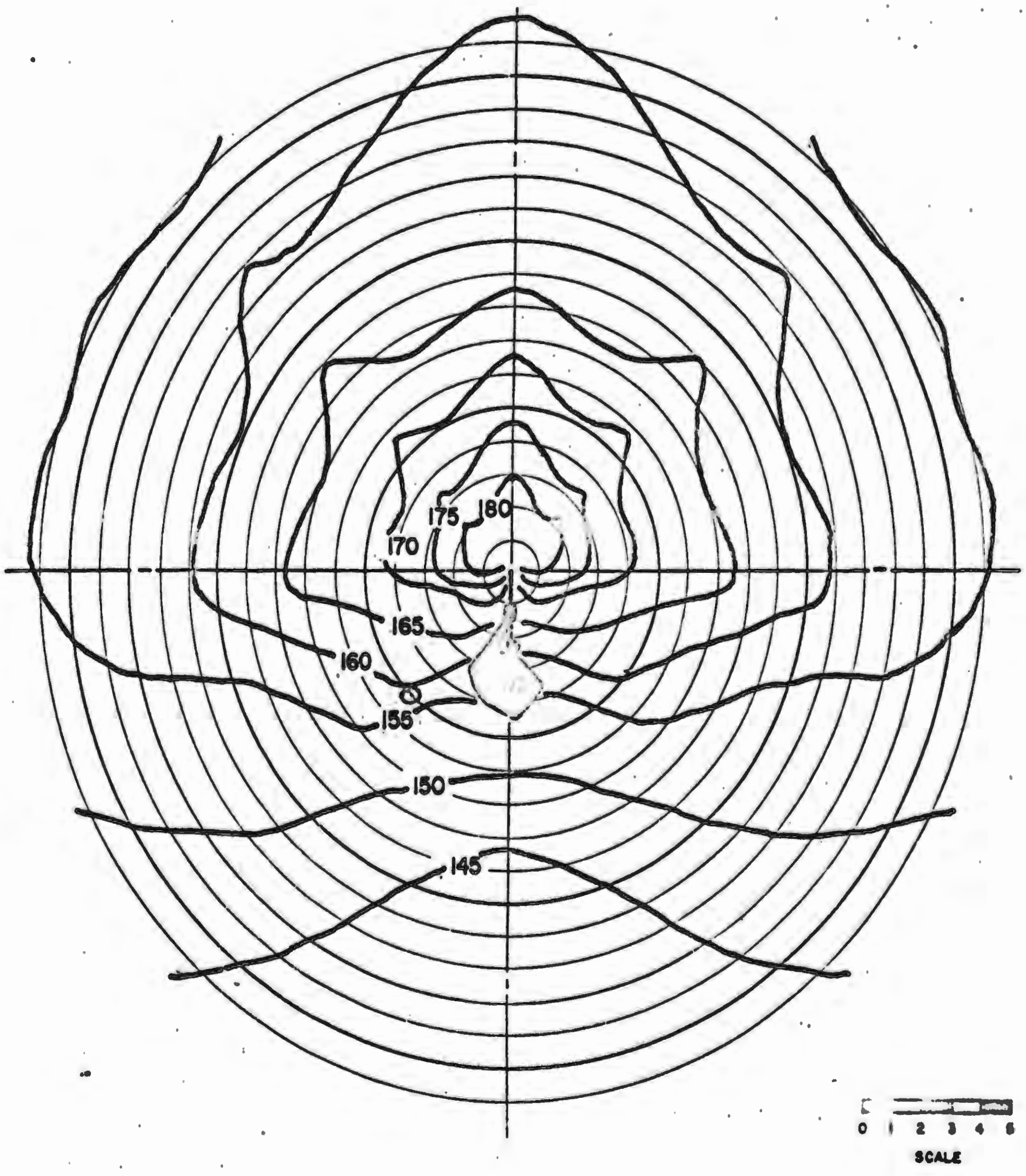
APPENDIX A

OCTAVE BAND ANALYSIS OF M-14



APPENDIX B

CONSTANT SOUND-PRESSURE CONTOURS OF SOUND FIELD



APPENDIX C

SUMMARY TABLES OF ANALYSES OF VARIANCE

ANALYSIS OF VARIANCE OF DIFFERENCE SCORES
FOR
0 MINUTE RECOVERY INTERVAL

Source	SS	df	MS	F
Rate	871	1	871	2.11
Impulses	2,777	2	1,389	3.36
Rate X Impulses	3,612	2	1,806	4.37*
Between Ss, within Grps. (Error 1)	9,922	24	413	
Total between Ss	17,182	29		
Frequency	1,371	2	685	16.00**
Frequency x Rate	34	2	17	- -
Frequency x Impulses	114	4	29	- -
Frequency x Rate x Impulses	283	4	71	1.67
Ss x Frequency, within Grps. (Error 2)	2,048	48	43	
Total within Ss	3,850	60		
Total	21,032	89		

* Beyond .05 level of significance

** Beyond .01 level of significance

ANALYSIS OF VARIANCE OF DIFFERENCE SCORES
FOR
1 MINUTE RECOVERY INTERVAL

Source	SS	df	MS	F
Rate	350	1	350	- -
Impulses	1,472	2	736	1.15
Rate x Impulses	2,985	2	1,493	3.75*
Between Ss, within Grps. (Error 1)	9,547	24	398	- -
Total between Ss	14,354	29		
Frequency	233	2	117	3.47*
Frequency x Rate	44	2	22	- -
Frequency x Impulses	154	4	37	1.15
Frequency x Rate x Impulses	306	4	76	2.28
Ss x Frequency, within Grps. (Error 2)	1,613	48	33	
Total within Ss	2,350	60		
Total	16,704	89		

* Beyond .05 level of significance

ANALYSIS OF VARIANCE OF DIFFERENCE SCORES
FOR
2 MINUTE RECOVERY INTERVAL

Source	SS	df	MS	F
Rate	174	1	174	- -
Impulses	839	2	420	1.78
Rate x Impulses	1,628	2	814	3.45*
Between Ss, within Grps. (Error 1)	5,670	24	236	
Total between Ss	8,311	29		
Frequency	354	2	177	4.02*
Frequency x Rate	10	2	5	- -
Frequency x Impulses	43	4	11	- -
Frequency x Rate x Impulses	470	4	118	2.68*
Ss x Frequency, within Grps. (Error 2)	2,090	48	44	
Total within Ss	2,967	60		
Total	11,278	89		

* Beyond .05 level of significance

ANALYSIS OF VARIANCE OF DIFFERENCE SCORES
FOR
5 MINUTE RECOVERY INTERVAL

Source	SS	df	MS	F
Rate	71	1	71	- -
Impulses	582	2	291	1.91
Rate x Impulses	904	2	452	2.97
Between Ss, within Grps. (Error 1)	3,653	24	152	
Total between Ss	5,210	29		
Frequency	352	2	176	4.29*
Frequency x Rate	0	2	0	- -
Frequency x Impulses	76	4	19	- -
Frequency x Rate x Impulses	495	48	123	3.00*
Ss x Frequency, within Grps. (Error 2)	1,977		41	
Total within Ss	2,900	60		
Total	8,110	89		

* Beyond .05 level of significance

ANALYSIS OF VARIANCE OF THE DIFFERENCE SCORES
WHEN TRANSFORMED TO A LOGARITHMIC SCALE
FOR
0 RECOVERY INTERVAL

Source	SS	df	MS	F
Rate	0.3679	1	0.3679	- -
Impulses	3.0382	2	1.5191	2.10
Rate x Impulses	3.8377	2	1.9189	2.65
Between Ss, within Grps. (Error 1)	17.3936	24	0.7247	
Total between Ss	24.6374	29		
Frequency	2.7447	2	1.3724	11.89**
Frequency x Rate	0.6912	2	0.3456	2.99
Frequency x Impulses	0.4115	4	0.1029	- -
Frequency x Rate x Impulses	0.5977	4	0.1494	1.29
Ss x Frequency, within Grps. (Error 2)	5.5399	48	0.1154	
Total within Ss	9.9850	60		
Total	34.6224	89		

** Beyond .01 level of significance

ANALYSIS OF VARIANCE OF THE DIFFERENCE SCORES
WHEN TRANSFORMED TO A RECIPROCAL SCALE
FOR
O RECOVERY INTERVAL

Source	SS	df	MS	F
Rate	2,924	1	2,924	- -
Impulses	35,627	2	17,814	1.85
Rate x Impulses	42,808	2	21,404	2.23
Between Ss, within Grps. (Error1)	230,517	24	9,605	
Total between Ss	311,876	29		
Frequency	37,167	2	18,584	10.36**
Frequency x Rate	10,667	2	5,334	2.97
Frequency x Impulses	6,348	4	1,587	- -
Frequency x Rate x Impulses	10,884	4	2,721	1.52
Ss x Frequency, within Grps. (Error 2)	86,046	48	1,793	
Total within Ss	157,112	60		
Total	462,988	89		

** Beyond .01 level of significance

ANALYSIS OF VARIANCE OF THE DIFFERENCE SCORES
WHEN TRANSFORMED TO A SQUARE-ROOT SCALE
FOR
O RECOVERY INTERVAL

Source	SS	df	MS	F
Rate	95,193	1	95,193	1.17
Impulses	420,509	2	210,255	2.58
Rate x Impulses	555,494	2	277,747	3.40
Between Ss, within Grps. (Error 1)	1,959,519	24	81,647	
Total between Ss	3,030,715	29		
Frequency	285,959	2	142,980	16.10**
Frequency x Rate	34,421	2	17,211	1.94
Frequency x Impulses	20,100	4	5,025	- -
Frequency x Rate x Impulses	59,043	4	14,761	1.66
Ss x Frequency, within Grps. (Error 2)	426,215	48	8,879	
Total within Ss	825,738	60		
Total	3,856,453	89		

** Beyond .01 level of significance

APPENDIX D

DISCUSSION OF TRANSFORMATIONS

The F test of the analysis of variance is a robust test under a variety of violations of the assumptions (Edwards, 1960, pp 132). Evidence has been accumulated that in experimental work, where the number of observations is the same for the various treatments, the F test for the means in the analysis of variance is little influenced by hetrogeneity of variance (Box, 1954). Box has indicated that, since the F test is quite insensitive to nonnormality, and since with equal n's it is also insensitive to variance inequalities, it may be safely used under most conditions.

The relationship between variances and means of the treatments is one indication of departure from normality, and this is likely to be associated with hetrogeneity of variance. Since Bartlett's test has indicated hetrogeneity of variance, the data was examined to determine the relationship between the means and variances of the experimental groups. If a relationship is indicated, then a transformation of the raw data to a new scale may reduce the hetrogeneity of variance. A transformation has two desirable effects; one, it will tend to stabilize the variance, and two, it will tend to decrease the skewness or nonnormality of the variable.

The relationship of the means to the variances will dictate which transformation is applicable. If the means and variances of the original data are correlated, a square root transformation is the best choice (Bartlett, 1936). If the means and the standard deviations of the original data tend to be proportional, then a transformation to a logarithmic scale is recommended (Bartlett, 1947). A discussion of use of various other transformations may be found in Edwards, 1960; Bartlett, 1947; or Mueller, 1949.

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H. Glenn Smith, Gerald Goldstone, Technical Assistance of Ray Donley

Tech Memo 19-61 Unclassified

This investigation was a pilot study to determine the temporary threshold shifts resulting from exposure to high-intensity impulse noise. The threshold shifts induced were of a temporary nature, i.e., there were no instances of permanent hearing losses among any of the experimental subjects. The purpose of the study was to explore various physical parameters of a sound source and relate them to any decrements they may have on auditory acuity.

Thirty enlisted men received audiometric tests both before and after exposure to a high-intensity impulse noise generated by an M-14 rifle. Rate and number of impulses were varied separately and examined at three test frequencies. Due to inter-subject differences, only general implications are indicated. Recommendations are included for future research.

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