UNCLASSIFIED

AD NUMBER:	AD0449855

LIMITATION CHANGES

TO:

Approved for public release; distribution is unlimited.

FROM:

Distribution authorized to U.S. Gov't. agencies and their contractors; Administrative/Operational Use; 1 Oct 1964. Other requests shall be referred to Office of the Surgeon General, Washington, DC 20315

AUTHORITY

20190516 - OSG ltr 1966

THIS PAGE IS UNCLASSIFIED

AD 449855

BOLT BERANEK AND NEWMAN INC

MD 985

CONSULTING • DEVELOPMENT • RESEARCH

Report No. 1159
Job No. 110072

AD-449855

A STUDY OF THE ACOUSTIC REFLEX IN INFANTRYMEN

~~Kryter file~~

1 October 1964

Submitted to:

Headquarters
U.S. Army Medical Research and
Development Command
Office of the Surgeon General
Washington, D. C. 20315

CAMBRIDGE NEW YORK CHICAGO LOS ANGELES

Report No. 1159 Bolt Beranek and Newman Inc.

A STUDY OF THE ACOUSTIC REFLEX IN INFANTRYMEN

Michael H. L. Hecker and Karl D. Kryter
Bolt Beranek and Newman Inc.
50 Moulton Street
Cambridge, Massachusetts 02138

1 October 1964

Contract Number DA-49-007-MD-985

Supported by:

U.S. Army Medical Research and Development Command
Office of the Surgeon General
Washington, D. C. 20315

ABSTRACT

AD NO.__________________ ACCESSION NO.__________________

1. Preparing Institution: Bolt Beranek and Newman Inc.
50 Moulton Street
Cambridge, Massachusetts 02138

2. Title of Report: A STUDY OF THE ACOUSTIC REFLEX IN INFANTRYMEN

3. Principal Investigators: Michael H. L. Hecker and Karl D. Kryter

4. Number of Pages: 22
Number of Illustrations: 5
Date: 1 October 1964

5. Contract Number: DA-49-007-MD-985

6. Supported by: U.S. Army Medical Research and Development Command
Office of the Surgeon General
Washington, D. C. 20315

The degree of reflex response to monaurally presented white noise (100 dB SPL) was measured and graphically recorded at the contralateral ear for 40 career infantrymen with an acoustic bridge. These soldiers had been exposed to controlled amounts of weapon noise, and pre- and post-exposure audiograms were obtained. The results show that subjects with a high pre-exposure HL are less susceptible to TTS than subjects with normal hearing. The results further indicate that a strong acoustic reflex is associated with high rather than low pre-exposure HL for subjects having no appreciable conductive hearing impairment. Subjects with suspected middle-ear disorders exhibited no reflex response to the same stimulus.

Note: Copies of this report are filed with the Defense Documentation Center (DDC), Building 5, Cameron Station, Alexandria, Virginia, and may be obtained from that agency by qualified investigators.

INTRODUCTION

Although the nature of the acoustic reflex is by no means fully understood, the many experiments that have been carried out during the past decade suggest that the reflex phenomenon may be practically valuable in at least three respects. First, there is evidence that the action of the middle-ear muscles attenuates certain kinds of intense acoustic signals and thus protects the cochlea from acoustic trauma. Both animal[4,13] and human ears[3,16] have been studied in this respect. Second, the reflex action can provide useful information in the clinical diagnosis of hearing disorders. A difference of less than 70-90 dB between the threshold of hearing and the reflex threshold (lowest intensity of a tone that will elicit the reflex) indicates the presence of recruitment.[2,11,15] And finally, recent research suggests that the acoustic reflex should be considered in explaining the results of various psychoacoustic experiments, particularly those involving masking and loudness scaling.[10]

Because it has been demonstrated that the reflex serves to protect the inner ear when subjects are exposed to a rapid succession of intense acoustic transients (such as gunfire), the hypothesis has been formulated that in a population of subjects who are constantly exposed to such transients those individuals with a strong reflex will tend to have less noise-induced hearing loss than individuals with a weaker reflex. In order to investigate possible general relations between a measure of reflex activity, auditory fatigue, and permanent hearing loss, an experiment was performed in which 40 U.S. Army infantrymen participated as subjects.

These soldiers were made available following a government program for the evaluation of new weapons.[8] In this program the men had been exposed to controlled amounts of weapon noise, and audiograms had been obtained prior to and just after exposure. The earlier program thus provided pre-exposure hearing level (HL) and temporary threshold shift (TTS) data for both ears of the test subjects.

The acoustic reflex of each infantryman was measured by means of an acoustic bridge that was developed by Zwislocki[17] and is manufactured by the Grason-Stadler Company (Model E8872A). With this instrument the acoustic impedance of the eardrum can be measured at various frequencies. When the acoustic reflex is elicited by means of a noise presented to the opposite ear, the impedance measurement in the near ear will change from its previous value. The degree of this change is an indication of the amount of middle-ear muscle activity. It is possible to elicit the reflex in one ear and to measure it in the other ear (contralateral measurement) because the reflex is normally a bilateral response to a unilateral stimulus.

The acoustic impedance method of measuring the reflex also permits the taking of measurements in the same ear where the reflex is elicited (homolateral measurement), but this technique increases the complexity of the instrumentation and was not used in the present study.* Another method of measuring the acoustic reflex

---

* Møller has demonstrated that the degree of reflex activity is somewhat greater for homolateral than for contralateral measurement of the reflex.[12] However, techniques employing contralateral measurement are valid and more practical whenever normal subjects are being tested. (When a subject with a unilateral conductive hearing loss or with a unilateral pathology in the neural pathway of the reflex arc is being tested, the response measurements in a given ear depend greatly upon whether the reflex-arousal sound is presented to that ear or to the opposite ear.)

employs an instrument which is sensitive to the dynamic displacement of the eardrum (tympanomanometer). This method is restricted to contralateral measurements because the ear canal into which the differential pressure probe is inserted must be tightly sealed.

PROCEDURE

Both ears of each test subject were examined by an otologist before acoustic impedance measurements were taken. This was done so that possible infections or perforations of the eardrums, which might interfere with or prohibit the test procedure, would be detected. Also, any otological history, or history of childhood diseases which may have affected the middle ears, was recorded wherever applicable. Then the ear canal into which the acoustic bridge was to be fitted was thoroughly cleaned.

The actual measurement session for each subject consisted of two parts. First, the acoustic impedance of the eardrum of the near ear* was measured at 250, 500, and 1000 cps in the conventional manner.[17] The test tones were generated by a Zenith (Model ZA 100T) portable audiometer and monitored through the stethoscope supplied with the bridge. For the second part, the stethoscope was replaced by a microphone whose output was amplified and band-pass-filtered so that a test tone could be graphically recorded. The impedance was measured at 750 cps and the test tone was now monitored through a pair of headphones. Then a steady reflex-arousal sound (100 dB SPL of white noise) was presented to the

---

* The near ear is defined as the left ear for right-handed firers (who place the butt of their weapon against their right shoulder) and as the right ear for left-handed firers.

opposite ear through an earphone fitted to a hearing-aid mold, and the impedance measurement was repeated. Finally, the bridge was adjusted again to the values obtained without the reflex and the test tone was graphically recorded while a particular pattern of reflex-arousal noise was being generated automatically.

A schematic diagram of the instrumentation used to measure and record the impedance changes produced by the acoustic reflex is shown in Fig. 1. The 750 cps test tone generated by the audiometer and supplied to the bridge was not permitted to exceed 75 dB (audiometer attenuator setting) so that it could not elicit the reflex. The idea of replacing the stethoscope with a microphone is not new; both Zwislocki and Lilly[9] have undertaken exploratory studies with an electrical output from this particular bridge.* From this figure it can be seen how the noise pattern is automatically generated by means of a special rotary switch that is coupled mechanically to the Brüel + Kjaer (Type 2305) level recorder.

The intensities of the 750 cps test tone and the reflex-arousal noise, and all amplifier gain settings, were kept constant throughout the experiment. Some difficulty was experienced during the recording of the output from the bridge. A few soldiers could not be properly fitted with any of the available hearing-aid molds,

---

* In the present study a single frequency (750 cps) is monitored with the electrical system. A variety of problems are encountered when an attempt is made to monitor several frequencies electrically. The dimensions of the coupling between the acoustic bridge and the microphone are such that the electrical frequency response of the composite system varies over a 40 dB range from 125 to 1500 cps. It is extremely difficult, if not impossible, to balance the bridge at frequencies below 500 cps.

so that some reflex-arousal noise from the opposite ear radiated to the microphone at the near ear. Noise picked up in the 450-1800 cps passband was consequently amplified and more or less obscured the recorded bridge output. In these cases, in order to determine how much of the recorded signal is contributed by the test tone and how much by the noise, a portion of the recording was made with the audiometer disconnected (no bridge excitation).

RESULTS

Acoustic Reflex

Impedance measurements have been obtained for the near ear of each subject at 250, 500, 750, and 1000 cps. Since impedance is a complex quantity, a given measurement produces two numbers which express the compliance (related to springiness) and the resistance (related to damping) of the eardrum. On the acoustic bridge the compliance scale is calibrated directly in cm^3 of equivalent air volume, but the resistance scale is in arbitrary units which may be converted to acoustic ohms by means of a calibration chart. In addition to quiescent impedance measurements, the reductions in compliance and resistance at 750 cps produced by the sustained contraction of the middle-ear muscles were obtained for each subject. The reductions in compliance and resistance may be expressed respectively in terms of a compliance ratio (C.R.) and a resistance ratio (R.R.). Ratios of unity would indicate that no change was recorded and that the acoustic reflex was not present.

Zwislocki has developed tentative criteria for middle-ear normalcy[17,18] which are given in Table 1. If several compliance

CRITERIA	FREQUENCY (CPS)			
	250	500	750	1000
COMPLIANCE RANGE	0.35 ↓ 2.3	0.35 ↓ 3.5	0.50 ↓ 5.0	0.60 ↓ >5.0
RESISTANCE RANGE	60 ↓ 1500	120 ↓ 850	120 ↓ 1200	120 ↓ 600

Table 1. Criteria for middle-ear normalcy. Compliance expressed in cm^3 of equivalent air volume, resistance in acoustic ohms. Values outside of these ranges suggest possible middle-ear pathology.

values have been obtained which exceed the lower limits of the compliance range,[18] and the associated resistance values exceed the upper limits of the resistance range,[17] otosclerosis should be suspected. Similarly, if several compliance values exceed the upper limits of the compliance range[17] and the resistance values exceed the lower limits of the resistance range,[17] ossicular discontinuity (rare) should be suspected. Examination of the impedance measurements suggested that six soldiers had a possible middle-ear pathology.

The remaining 34 soldiers with apparently normal middle ears (near ears) were then classified into three subject categories according to the degree of reflex activity that could be measured in their near ears. The somewhat arbitrary criteria that have been used for this classification procedure are given in Table 2.

Typical reflex recordings which have been obtained for 3 subjects who represent the three normal subject categories are presented in Fig. 2. The upward deflections, indicating impedance changes produced by the contraction of the middle-ear muscles, are seen to be maximal for the subject representing Category I and minimal for the subject representing Category III. The time periods during which the reflex-arousal noise is turned on are indicated in the figure by the gray areas (noise pattern). A long (1.65 sec) burst of noise is followed by a 750 msec silent period and then by three 300 msec bursts of noise separated by 100 msec of silence. After 1.30 sec the noise pattern is repeated.

When discussing the response of the middle-ear muscles it is necessary to differentiate between the time period from the onset

CATEGORY	NO. OF SUBJECTS	CRITERIA
I PRONOUNCED REFLEX	7	$\mathrm{C.R.} \leq 0.55$ or $0.55 < \mathrm{C.R.} \leq 0.65$ $\mathrm{R.R.} < 0.80$
II SOME REFLEX	10	$0.55 < \mathrm{C.R.} \leq 0.65$ $\mathrm{R.R.} > 0.80$ or $0.65 < \mathrm{C.R.} \leq 0.80$
III NO REFLEX	17	$0.80 < \mathrm{C.R.} \leq 1.00$
IV ABNORMAL	6	SUSPECTED PATHOLOGY IN NEAR MIDDLE-EAR

Table 2. Criteria for subject categories. The compliance ratio (C.R.) and resistance ratio (R.R.) of each subject in a given category fall within the ranges indicated.

of the stimulus (noise) to the start of muscle contraction (defined as latency) and the time period from the onset of the stimulus to the point of full muscle contraction (defined as contraction time).[7] Although different experimenters report different results, the contraction times for the stapedius muscle and for the tensor tympani have been estimated to be respectively 20 msec and 200 msec.[7] The respective latencies are considerably shorter than these contraction times. Since the acoustic impedance method of measuring muscle activity cannot resolve between the contributions of the two individual muscles, which tend to displace the eardrum in opposite directions, the "resultant contraction time" will tend to fall between the values given above.

The subject representing Category I in Fig. 2, for example, shows a resultant contraction time of approximately 200 msec, which implies that his reflex cannot effectively protect his inner ear from intense sounds having a duration of less than perhaps 100 msec. But adequate protection appears to be provided for the last two of the three 300 msec bursts of noise. After the second long (1.65 sec) burst of noise the audiometer was disconnected, and the remainder of the recording for this subject shows the amount of noise leakage from the opposite ear as picked up by the microphone attached to the bridge.

A resultant contraction time of perhaps 100 msec has been recorded for the subject representing Category II, but his acoustic reflex is seen to be weaker than that of the subject from Category I. The subject representing Category III displays a similar resultant contraction time (100 msec) on those occasions when a very weak reflex could be elicited. The three recordings shown in this figure were obtained from subjects who could be provided with tight-fitting hearing-aid molds for their opposite ears, and consequently the reflex-arousal noise did not obscure the traces of the 750 cps test tone for these subjects.

Audiometric Data

The audiometric data for the near and opposite ears of the 40 soldiers are presented in Figs. 3 and 4. (The near ear is the left ear and the opposite ear the right ear for right-handed firers.) For each ear of each subject the temporary threshold shifts measured at 3 and 4 Kcps were converted to values that would have been obtained 2 minutes after exposure to the weapon noise (TTS_2) and then averaged. This average TTS_2 is plotted as a function of the pre-exposure hearing level (HL), which was also averaged at 3 and 4 Kcps. In these figures the entries are coded according to subject category in order to illustrate the wide spread of the results for subjects in a given category.

Before the audiometric data were processed further, a convention was established and imposed with respect to small and negative values of TTS_2. All values between plus 4 and minus 4 dB were arbitrarily called zero. Values below minus 4 dB were also called zero; it was suspected that for these subjects head noises (tinitus), produced by the exposure, had interfered with the audiometry. All values of TTS_2 above plus 4 dB were left unaltered. For reference purposes this convention is noted in the right-hand margin of Figs. 3 and 4.

It is unfortunate for this experiment that all subjects were not exposed to the same weapon noise. Two different types of weapons and various firing schedules were assigned to these soldiers when they participated in the earlier weapon-evaluation program.[8] For this reason the TTS_2 values obtained for different subjects cannot be directly compared in an attempt to show differences in susceptibility to auditory fatigue.

To partially overcome this shortcoming, the TTS_2 averages for the four subject categories were corrected for equivalent exposure to all categories by means of the following procedure. First, the TTS_2 values obtained in the weapon-evaluation program for each group of soldiers using a particular weapon and firing schedule were averaged and adjusted to take into account group differences in pre-exposure HL. These data represent, then, average TTS_2 values that can be predicted from exposure to various combinations of weapon and firing schedule. Second, the appropriate predicted TTS_2 value was recorded for each of the 40 test subjects and averages were obtained for the four subject categories. These predicted averages and TTS_2 correction factors derived from them are shown in Table 3.

With reference to Table 3, one would expect -- other things being equal, such as pre-exposure HL, middle-ear impedance and acoustic reflex -- that the TTS_2 average for Category II will be about 4 dB lower than the TTS_2 average for Category I, because the soldiers in Category II happen to have been exposed to firing conditions which produce, on the average, less TTS_2 than the firing conditions to which the soldiers in Category I were exposed.

Figure 5 shows the averaged TTS_2 and pre-exposure HL for each subject category, including the TTS_2 correction factors listed in Table 3. Data for near ears and opposite ears are shown separately. Five tentative observations can be made from this figure which are presented below as statements; the first four of these statements will be discussed in the next section of this report.

	SUBJECT CATEGORY				
	I	II	III	IV	ALL
PREDICTED TTS_2 in dB	16	12	18	16	16
CORRECTION dB	0	+4	-2	0	0

Table 3. Predicted TTS_2 for each subject category and for all subjects, based on audiometric data (averaged at 3 and 4 Kcps) obtained from a larger population of soldiers using the same types of weapons and firing schedules as the test subjects.[8] TTS_2 correction factors for under- or over-exposure relative to the average for all categories are also indicated.

1. Ears having a high pre-exposure HL tend to be less susceptible to TTS than ears having a lower pre-exposure HL. The relation between TTS_2 and pre-exposure HL is nearly linear and has an approximate slope of -8 dB TTS_2/20 dB pre-exposure HL.

2. Subjects (Category III) whose near ears give normal impedance measurements (no appreciable conductive hearing impairment) but who possess a weak acoustic reflex (as measured at the near ear and elicited at the opposite ear) tend to have a low pre-exposure HL and a high TTS_2. Conversely, subjects (Categories I and II) with a stronger reflex tend to have a high pre-exposure HL and a low TTS_2.

3. Because the test subjects fired their weapons only once every 5 seconds (presumably the middle-ear muscles were relaxed at the onset of each impulse), the present experiment did not bear on the question of whether the acoustic reflex tends to protect against high TTS. However, the results suggest that the reflex did not adequately protect the hearing of these soldiers during their Army careers.

4. Subjects (Category IV) whose near ears are categorized as abnormal on the basis of impedance measurements (conductive hearing impairment suspected) tend to have the highest pre-exposure HL in both ears and tend to possess no acoustic reflex.

5. Although the data for near and opposite ears differ somewhat for Categories I and II, the pre-exposure HL and TTS_2 averages for the two ears are highly correlated.

DISCUSSION

The relation between TTS_2 and pre-exposure HL is the subject of the first observation. This relation, with approximately the same slope, is also encountered in studies of TTS induced by steady-state industrial noise and has been reported previously.[5] Also, the same relation and slope can be demonstrated for this study by grouping the 40 subjects according to pre-exposure HL (instead of reflex category). This was done, but the results are repetitious and therefore not included in this report.

The subject matter of the second observation is more controversial. Those subjects who have a high pre-exposure HL but no appreciable conductive hearing impairment are suffering from the noise-induced (sensory-neural) loss that is typically associated with career infantrymen. However, the lowest intensity of the reflex-arousal sound which will first elicit the acoustic reflex in these subjects (reflex threshold) is known to be, on the average, the same as in subjects with normal hearing (70-90 SPL).[11] This fact is attributed to the complete recruitment of loudness at these levels that is characteristic of most sensory-neural losses.[1,6] It may be assumed, therefore, that the reflex-arousal noise was perceived equally loud by nearly all subjects in Categories I, II, and III.

In order to examine whether the observed association of high pre-exposure HL with strong acoustic reflex might not be an artifact introduced, perhaps, by the particular criteria used for establishing the subject categories, all 40 subjects were grouped according to their pre-exposure HL. The average acoustic reflex was calculated for four ranges of pre-exposure HL, separately for both ears. The results, which are shown in Table 4, are in agreement with and thus serve to confirm the observation.

Pre-X HL Range	Near Ears			Opposite Ears		
	No. Ears	C.R.	R.R.	No. Ears	C.R.	R.R.
≤ 0 dB	10	0.84	0.84	9	0.87	0.83
1 - 19 dB	13	0.88	0.90	15	0.85	0.93
20 - 39 dB	8	0.79	0.92	7	0.74	0.82
≥ 40 dB	9	0.75	0.81	9	0.78	0.84

Table 4. Average acoustic reflex of near and opposite ears, expressed in terms of compliance ratio (C.R.) and resistance ratio (R.R.), for four ranges of pre-exposure HL (averaged at 3 and 4 Kcps).

If a significant number of the subjects with a high pre-exposure HL had over-recruitment of loudness, then the 100 dB SPL reflex-arousal noise would have been perceived louder by these subjects than by subjects with a lower pre-exposure HL (and less recruitment). This increased loudness, in turn, would have elicited a stronger reflex. But it appears that over-recruitment is not encountered in acoustic trauma cases, although it is common with Ménière's disease.[6,11] It should be noted, however, that the degree of recruitment is determined with the aid of specific clinical tests (developed by Fowler and by Reger) which do not, and were not intended to, explore all aspects of the intensity-loudness relation.

Even if it can be assumed that both normal-hearing subjects and subjects with a sensory-neural loss have the same intensity-loudness relation above the reflex threshold, the relation between loudness and degree of reflex response may still be quite different for the two populations. Well above the intensity corresponding to reflex threshold, then, it might be possible to elicit a stronger reflex from subjects with large sensory-neural losses than from subjects with smaller losses. Perhaps the stronger acoustic reflex is able to reduce pain which may be produced by the stimulus in subjects with large losses. Not enough is known at present about the relation between loudness and degree of reflex response for different hearing disorders, and the need for more research is indicated.

There are reasons, however, to question the assumption that the intensity-loudness relation above reflex threshold is indeed the same for all degrees of sensory-neural loss. In the clinical recruitment tests a 4 Kcps tone is usually employed, and it is known that different recruitment charts can be obtained when loudness balances are made at different frequencies or with wide-band or narrow-band noise. Therefore, the absence of clinical over-recruitment (at 4 Kcps) in subjects with noise-induced hearing loss does not necessarily mean that these subjects perceive a reflex-arousal sound which is not a 4 Kcps tone with the same loudness as subjects having normal hearing.

Also, the general failure of clinical tests to demonstrate over-recruitment can perhaps be explained as follows. Noise-induced hearing loss is usually bilateral and the monaural version of the recruitment test must therefore be employed. In the monaural test a high-frequency tone is matched in loudness to an alternately presented low-frequency reference tone for which the loss is smaller. Since a high-frequency tone is known to be effective in eliciting the acoustic reflex and the attenuation provided by the reflex is greater for low than for high frequencies, the loudness of the low-frequency reference tone is handicapped whenever this tone is switched on. (Presumably the reference tone is not presented long enough for the middle-ear muscles to relax.) Consequently, subjects with a strong reflex may actually have over-recruitment* but their recruitment charts will show the same intensity-loudness relation above the reflex threshold as charts obtained from normal-hearing subjects with a weaker reflex. Again, more research is indicated in this area.

---

* Perhaps over-recruitment can be demonstrated in these cases if the acoustic reflex is elicited by non-acoustic means during the entire test.

Terkildsen reported a study which is somewhat related to the subject under discussion.[14] He compared measurements of the acoustic reflex obtained from 18 workers exposed for years to intense industrial noise (at 4 Kcps the average HL was 42 dB) with measurements obtained from 50 subjects having normal hearing. Both groups exhibited the same average reflex threshold (75 dB SPL) and the same average "resultant contraction time," but the average degree of reflex response was slightly <u>less</u> for the workers group. While this finding is at variance with the present results, the two studies differ in several important respects. In the first place, Terkildsen used different instrumentation. Also, he employed a 1 Kcps reflex-arousal tone rather than broad-band noise. And finally, there was a considerable difference between the average ages of the workers group (48 years) and the group with normal hearing (28 years). The average age of the infantrymen who participated in the present study was about 24 years.

The third observation made in the previous section of this report deals with the protective function of the acoustic reflex. The data shown in Fig. 5 do not demonstrate that the reflex tends to protect against high TTS_2 because of the effect of different pre-exposure HL. If the TTS_2 averages shown for the subject categories are adjusted to correspond to some common pre-exposure HL, using the -8 dB $\text{TTS}_2/20$ dB pre-exposure HL slope, all values of TTS_2 will converge. In this particular study the absence of protection is not surprising, however, because the firing schedules were purposely designed to exclude the acoustic reflex as an experimental variable. (Each soldier pulled the trigger of his weapon once every 5 seconds for the duration of the exposure.)

Fletcher and Riopelle have clearly demonstrated the protective function of the reflex for controlled exposures to weapon noise in terms of reduced TTS when the weapon is fired during contraction of the middle-ear muscles.[3] But the limitations of reflex protection against the type of weapon noise ordinarily encountered by infantrymen have also been reported.[10,16]

Because of the relatively long contraction time of the muscles, no attenuation is provided for acoustic impulses having a short rise time if they are separated by at least 1 second (present study). Some protection is provided for all but the first impulse if the impulses are spaced closer in time. But since the reflex action attenuates low frequencies much better than high frequencies, and Fourier Analysis of these impulses reveals the presence of strong high-frequency components, this protection is relatively inefficient. If the impulses occur in rapid succession, as in the case of sustained machinegun fire, a gradual adaptation of the reflex takes place and the cochlea is again offered little protection.

It is reasonable, therefore, to expect that the acoustic reflex may not be effective in preventing career infantrymen from developing a permanent hearing impairment. The results of the present study certainly support this expectation. They also suggest the possibility that the level of an individual's reflex response gradually increases as he continues to be exposed to noise and eventually acquires a noise-induced hearing loss.

The fourth observation made earlier concerns those subjects who have a suspected conductive hearing impairment (Category IV). The proximity of the plots for the near and opposite ears of these subjects in Fig. 5 suggests that the conductive impairment was mainly bilateral. No appreciable acoustic reflex could be measured in the near ears because of the abnormally enhanced reflex threshold that is characteristic of cases with conductive impairment (absence of loudness recruitment).[1]

ACKNOWLEDGMENTS

The authors would like to thank Dr. Jozef Zwislocki, Syracuse University, Syracuse, New York, for his helpful instructions on the correct technique for measuring the acoustic impedance of the middle ear. Thanks are also due Dr. Allan Goodman, Children's Hospital Medical Center, Boston, Massachusetts, for the loan of the acoustic bridge. Finally, the assistance of Mr. Georges Garinther, U.S. Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland, in arranging for the test subjects is very much appreciated.

REFERENCES

1. Davis, H., and S. R. Silverman, Hearing and Deafness. Holt, Rinehart and Winston, Inc., New York (1960).
2. Feldman, A. S., Impedance measurements at the eardrum as an aid to diagnosos. J. Speech Hearing Res. 6, 315-327 (1963).
3. Fletcher, J. L. and A. J. Riopelle, Protective effect of the acoustic reflex for impulsive noises. J. Acoust. Soc. Am. 32, 401-404 (1960).
4. Galambos, R. and A. Rupert, Action of the middle ear muscles in normal cats. J. Acoust. Soc. Am. 31, 349-355 (1959).
5. Glorig, A., W. D. Ward and J. Nixon, Damage risk criteria and noise-induced hearing loss. Paper E-2, The Control of Noise, Symposium No. 12, National Physical Laboratory, Her Majesty's Stationary Office, London (1962).
6. Hood, J. D., A comparative study of loudness recruitment in cases of deafness due to Ménière's disease, head injury and acoustic trauma. Acta Oto-Rhino-Laryng. (Belg.) 14, 224-233 (1960).
7. Kobrak, H. G., The human ear. University of Chicago Press, Chicago, Illinois (1959).
8. Kryter, K. D. and G. R. Garinther, Auditory and acoustical evaluation of SPIW. (Preliminary Report.) U.S. Army Human Engineering Laboratories, Aberdeen Proving Ground, Maryland (1964).
9. Lilly, D. J., Acoustic-reflex measurements with the Zwislocki acoustic bridge. Per. Prog. Rept. No. 7, Research Dept., Central Institute for the Deaf, St. Louis, Missouri, p. 26 (1964).

10. Loeb, M., Psychophysical correlates of intratympanic reflex action. Middle ear function seminar, Rept. No. 576, U.S. Army Medical Research Laboratory, Ft. Knox, Kentucky, 152-170 (1963).

11. Metz, O., Threshold of reflex contraction of muscles of the middle ear and recruitment of loudness. Arch. Oto-Laryng. 55, 536 - (1952).

12. Møller, A., Acoustic reflex in man. J. Acoust. Soc. Am. 34, 1524-1534 (1962).

13. Simmons, F. B., Middle ear muscle protection from the acoustic trauma of loud continuous sound. An electrophysiological study in cats. Ann. Otol. 69, 1063-1071 (1960).

14. Terkildsen, K., The intra-aural muscle reflexes in normal persons and in workers exposed to intense industrial noise. Acta Oto-Laryng. (Stockh.) 52, 384-396 (1960).

15. Thomsen, K. A., The Metz recruitment test. Acta Oto-Laryng. (Stockh.) 45, 544-552 (1955).

16. Ward, W. D., Studies on the aural reflex. II. Reduction of temporary threshold shift from intermittent noise by reflex activity; Implications for damage-risk criteria. J. Acoust. Soc. Am. 34, 234-241 (1962).

17. Zwislocki, J., An acoustic method for clinical examination of the ear. J. Speech Hearing Res. 6, 303-314 (1963).

18. Zwislocki, J. and A. S. Feldman, Post-mortem acoustic impedance of human ears. J. Acoust. Soc. Am. 35, 104-107 (1963).

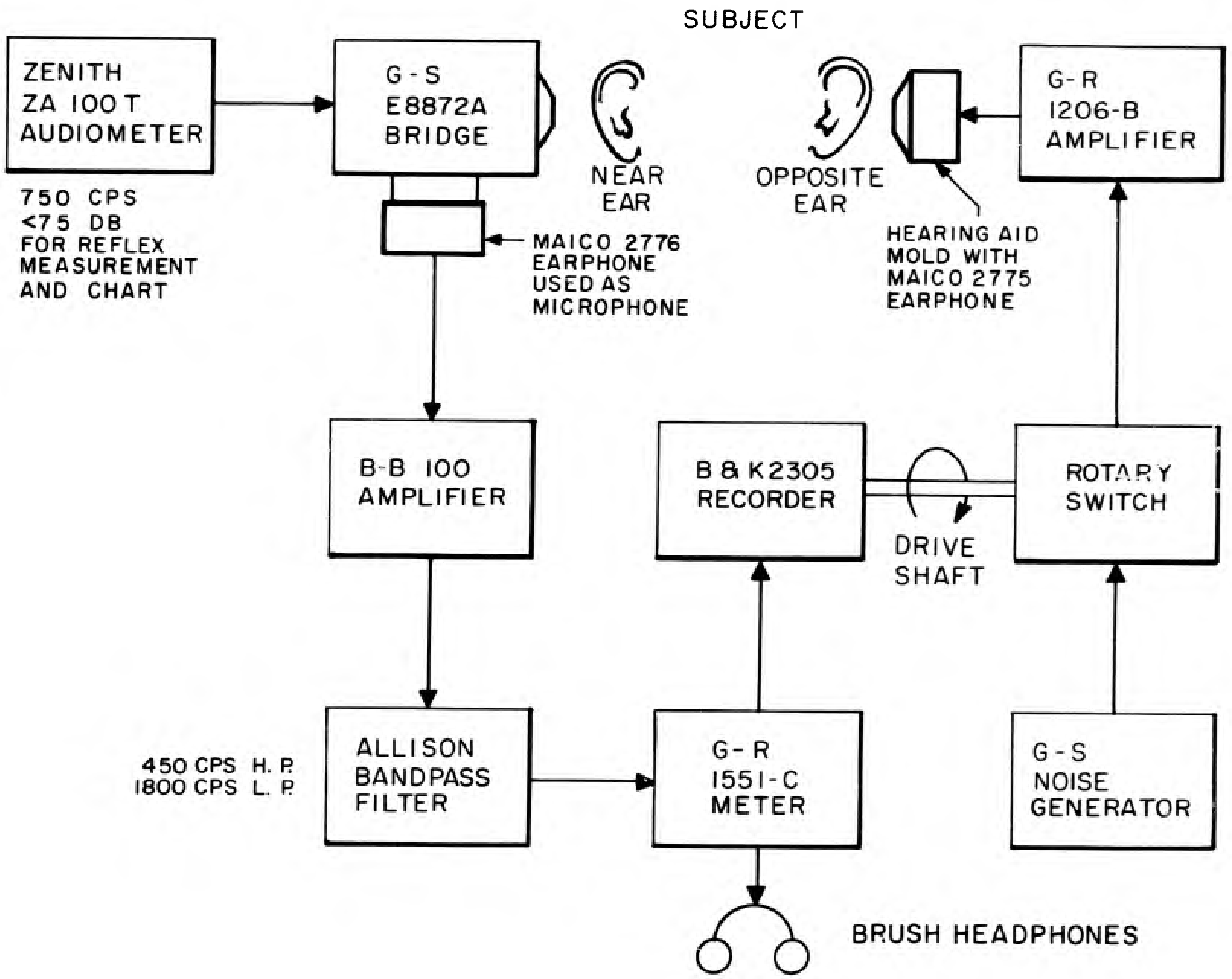

FIG. 1 SCHEMATIC DIAGRAM OF INSTRUMENTATION USED TO MEASURE AND CHART MUSCLE REFLEX AT 750 CPS

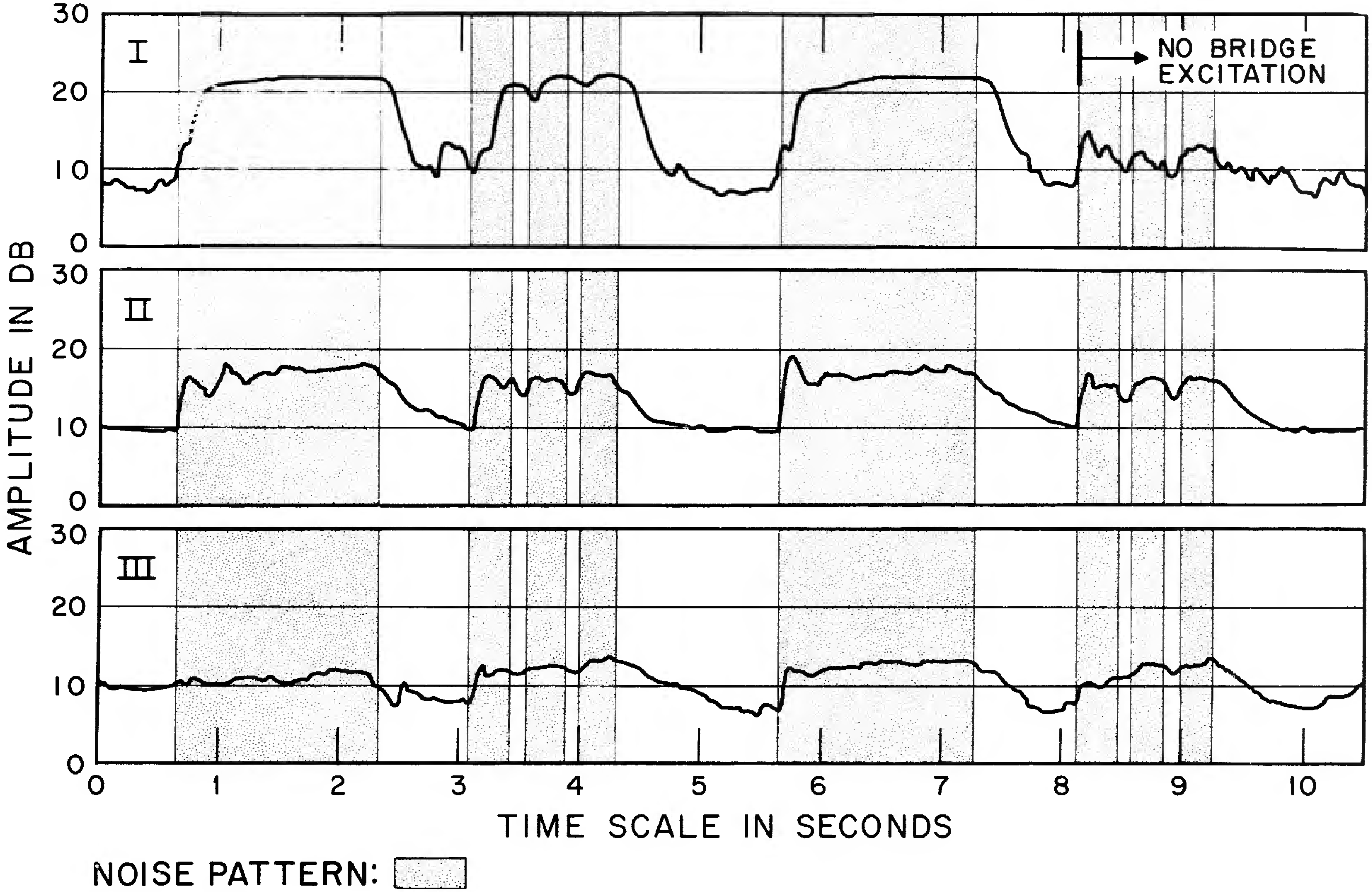

FIG. 2 REFLEX CHARTS FOR 3 SUBJECTS REPRESENTATIVE OF CATEGORIES I, II, AND III. UPWARD DEFLECTIONS RESULT FROM BRIDGE UNBALANCE CAUSED BY IMPEDANCE CHANGE IN NEAR EAR WHEN NOISE IS PRESENTED TO OPPOSITE EAR. BRIDGE EXCITATION: 750 CPS

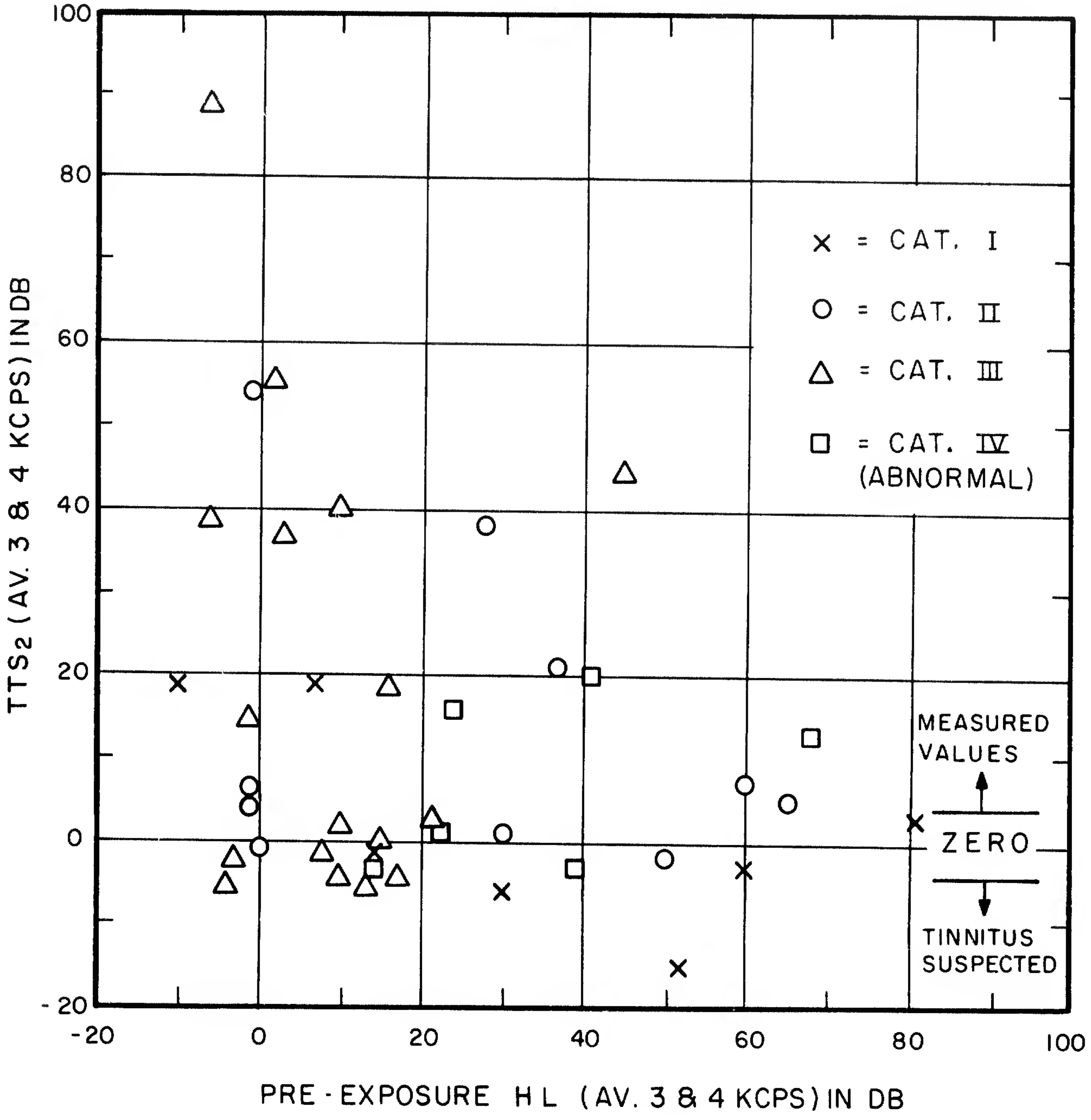

FIG. 3 TTS_2 AS A FUNCTION OF PRE-EXPOSURE HL FOR 40 NEAR EARS. DATA OBTAINED FROM PRE- AND POST-EXPOSURE AUDIOGRAMS.

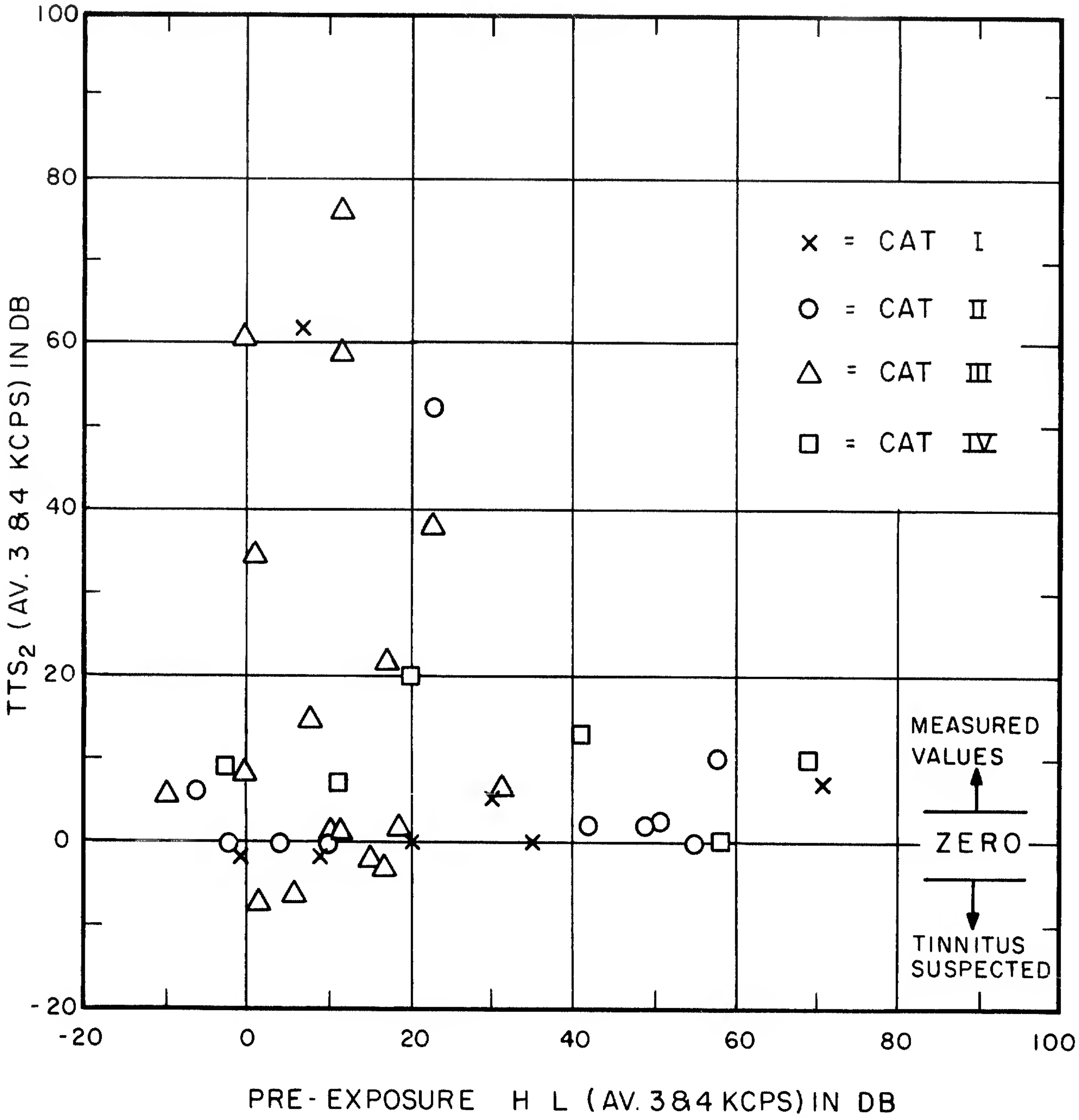

FIG. 4 TTS$_2$ AS A FUNCTION OF PRE-EXPOSURE HL FOR 40 OPPOSITE EARS. DATA OBTAINED FROM PRE- AND POST-EXPOSURE AUDIOGRAMS.

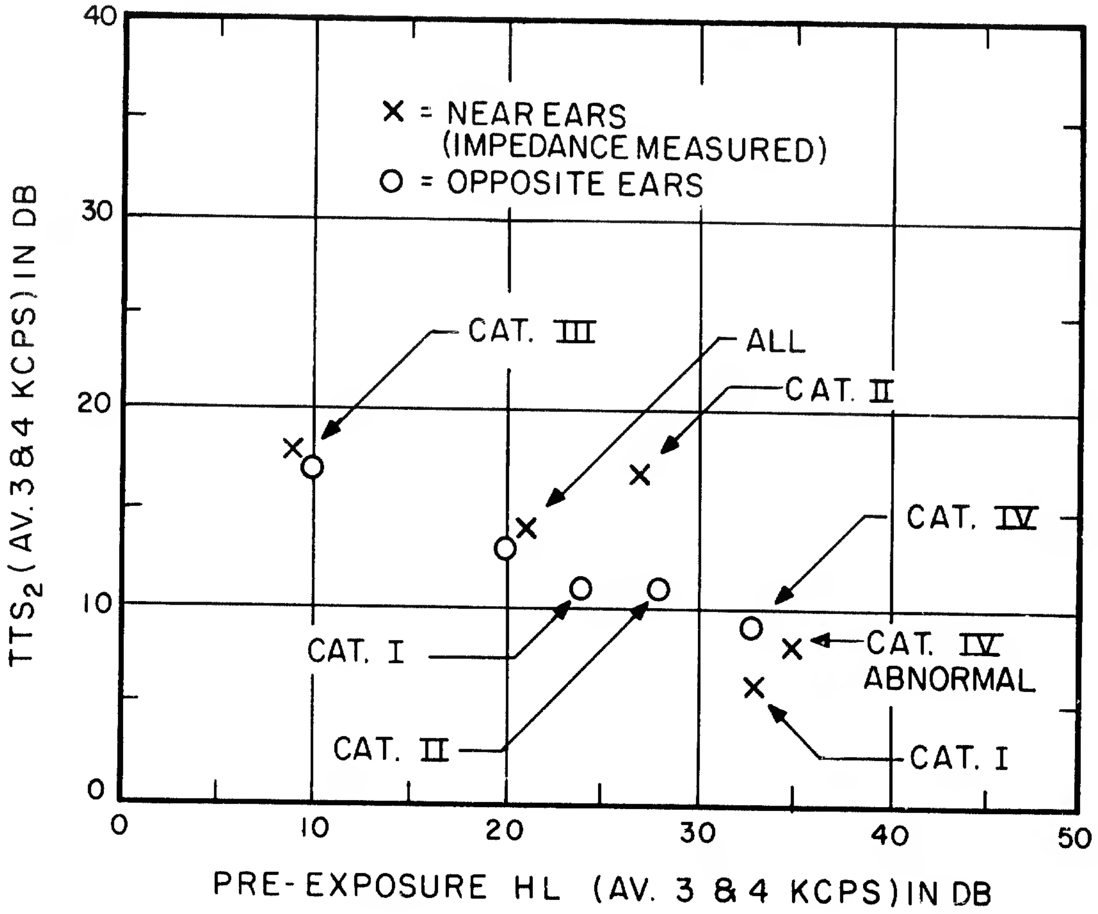

FIG. 5 TTS_2 AS A FUNCTION OF PRE-EXPOSURE HL, AVERAGED FOR EARS IN EACH SUBJECT CATEGORY AND FOR ALL CATEGORIES (40 EARS). CORRECTED FOR EQUAL EXPOSURE.

AD Accession No.

U.S. Army Medical Research and Development Command,
Office of the Surgeon General, Washington, D. C. 20315
A STUDY OF THE ACOUSTIC REFLEX IN INFANTRYMEN
M. H. L. Hecker and K. D. Kryter, Bolt Beranek and
Newman Inc., Cambridge, Mass.
Report No. 1159, 1 October 1964, 22p. 5 figs.
Contract DA-49-007-MD-985

Unclassified Report

The degree of reflex response to monaurally presented white noise (100 dB SPL) was measured and graphically recorded at the contralateral ear for 40 career infantrymen with an acoustic bridge. These soldiers had been exposed to controlled amounts of weapon noise, and pre- and post-exposure audiograms were obtained. The results show that subjects with a high-pre-exposure HL are less susceptible to TTS than subjects with normal hearing. The results further indicate that a strong acoustic reflex is associated with high rather than low pre-exposure HL for subjects having no appreciable conductive hearing impairment. Subjects with suspected middle-ear disorders exhibited no reflex response to the same stimulus.

UNCLASSIFIED

1. Acoustic reflex
2. Audition
3. Psychology

AD Accession No.

U.S. Army Medical Research and Development Command,
Office of the Surgeon General, Washington, D. C. 20315
A STUDY OF THE ACOUSTIC REFLEX IN INFANTRYMEN
M. H. L. Hecker and K. D. Kryter, Bolt Beranek and
Newman Inc., Cambridge, Mass.
Report No. 1159, 1 October 1964, 22p. 5 figs.
Contract DA-49-007-MD-985

Unclassified Report

The degree of reflex response to monaurally presented white noise (100 dB SPL) was measured and graphically recorded at the contralateral ear for 40 career infantrymen with an acoustic bridge. These soldiers had been exposed to controlled amounts of weapon noise, and pre- and post-exposure audiograms were obtained. The results show that subjects with a high-pre-exposure HL are less susceptible to TTS than subjects with normal hearing. The results further indicate that a strong acoustic reflex is associated with high rather than low pre-exposure HL for subjects having no appreciable conductive hearing impairment. Subjects with suspected middle-ear disorders exhibited no reflex response to the same stimulus.

UNCLASSIFIED

1. Acoustic reflex
2. Audition
3. Psychology

AD Accession No.

U.S. Army Medical Research and Development Command,
Office of the Surgeon General, Washington, D. C. 20315
A STUDY OF THE ACOUSTIC REFLEX IN INFANTRYMEN
M. H. L. Hecker and K. D. Kryter, Bolt Beranek and
Newman Inc., Cambridge, Mass.
Report No. 1159, 1 October 1964, 22p. 5 figs.
Contract DA-49-007-MD-985

Unclassified Report

The degree of reflex response to monaurally presented white noise (100 dB SPL) was measured and graphically recorded at the contralateral ear for 40 career infantrymen with an acoustic bridge. These soldiers had been exposed to controlled amounts of weapon noise, and pre- and post-exposure audiograms were obtained. The results show that subjects with a high-pre-exposure HL are less susceptible to TTS than subjects with normal hearing. The results further indicate that a strong acoustic reflex is associated with high rather than low pre-exposure HL for subjects having no appreciable conductive hearing impairment. Subjects with suspected middle-ear disorders exhibited no reflex response to the same stimulus.

UNCLASSIFIED

1. Acoustic reflex
2. Audition
3. Psychology

AD Accession No.

U.S. Army Medical Research and Development Command,
Office of the Surgeon General, Washington, D. C. 20315
A STUDY OF THE ACOUSTIC REFLEX IN INFANTRYMEN
M. H. L. Hecker and K. D. Kryter, Bolt Beranek and
Newman Inc., Cambridge, Mass.
Report No. 1159, 1 October 1964, 22p. 5 figs.
Contract DA-49-007-MD-985

Unclassified Report

The degree of reflex response to monaurally presented white noise (100 dB SPL) was measured and graphically recorded at the contralateral ear for 40 career infantrymen with an acoustic bridge. These soldiers had been exposed to controlled amounts of weapon noise, and pre- and post-exposure audiograms were obtained. The results show that subjects with a high-pre-exposure HL are less susceptible to TTS than subjects with normal hearing. The results further indicate that a strong acoustic reflex is associated with high rather than low pre-exposure HL for subjects having no appreciable conductive hearing impairment. Subjects with suspected middle-ear disorders exhibited no reflex response to the same stimulus.

UNCLASSIFIED

1. Acoustic reflex
2. Audition
3. Psychology