

A COMPARISON OF SPEECH DISCRIMINATION ABILITY FOR
SIMULATED AND REAL HEARING LOSS AT 3 AND 6 KHZ

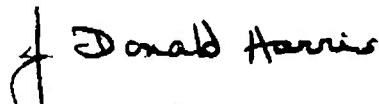
by

Russell L. Sergeant, Ph.D.
and
Thomas Murry, Ph.D.

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Transmitted by:



J. Donald Harris, Ph.D.
Head, Auditory Research Branch

Reviewed and Approved by:



Charles F. Gell, M.D., D.Sc. (Med)
Scientific Director
NavSubMedRschLab

Approved and Released by:



R. L. Sphar, CDR, MC, USN
Officer-in-charge
NavSubMedRschLab

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SUMMARY PAGE

THE PROBLEM

To evaluate the effects of high-frequency hearing losses (3-6 kiloHertz) on speech reception in quiet and in noise.

FINDINGS

Enlisted submariners with high-frequency hearing loss (average of 22, 45, and 60 decibels at 3, 4, and 6 kiloHertz, respectively) had poorer scores than a normal-hearing control group by 6.2 percentage points on rather easy tests of speech intelligibility, and by 5 percentage points on tests made more difficult by the addition of noise. This is a minor performance decrement. The performance of both groups, however, for the easier tests exceeded that of another normal-hearing control group in which the hearing loss was simulated by filtering. The hearing-loss subjects may by experience have compensated for their defect to some extent in the easier situations.

APPLICATION

For the use of communications engineers designing circuitry for speech transmission in noisy workspaces, and for medical personnel selecting individuals who must communicate in noisy situations.

ADMINISTRATIVE INFORMATION

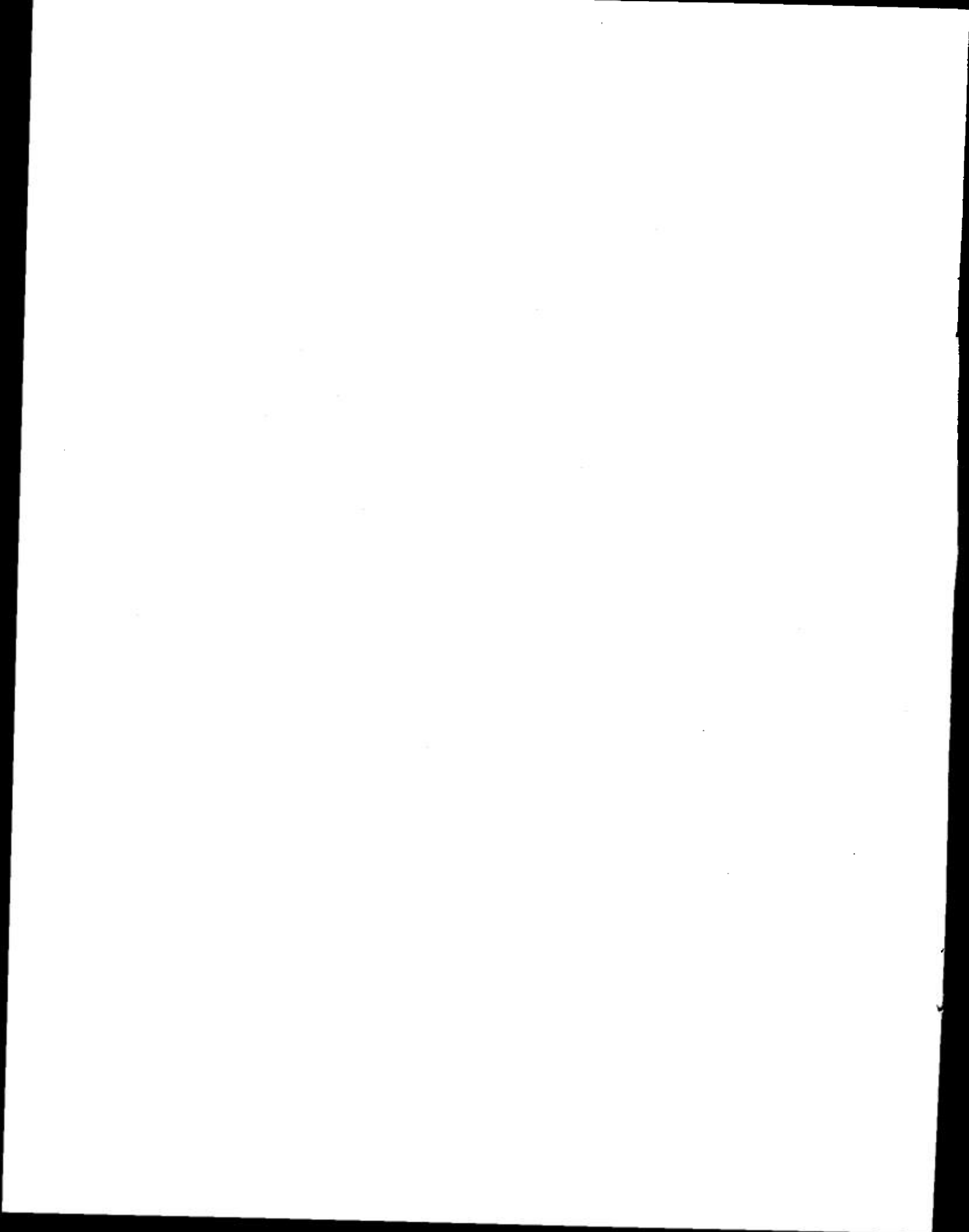
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ABSTRACT

This study evaluates speech discrimination ability, as determined by a standard test of speech reception in noise, for one type hearing defect commonly found in military personnel, namely, noise-induced high-frequency hearing loss.

Enlisted submariners with high-frequency hearing loss (average of 22, 45 and 60 decibels at 3, 4 and 6 kiloHertz, respectively) had poorer scores than a normal-hearing control group by 6.2 percentage points on rather difficult tests containing speech in background noise. The performance of the hearing-loss group, however, for the easier tests exceeded by 12.7 points that of another normal-hearing control group in which the hearing loss was simulated by filtering. The hearing-loss subjects may by experience have compensated for their defect to some extent in the easier situations. This was not true for the more difficult situations.



A COMPARISON OF SPEECH DISCRIMINATION ABILITY FOR SIMULATED AND REAL HEARING LOSS AT 3 AND 6 KHZ

INTRODUCTION

Naval personnel working in noisy areas are often unduly exposed to intense continuous noise which can cause a permanent hearing loss that affects primarily the frequencies of 3-6 kilohertz (kHz).^{1,2} However, in the American Academy of Ophthalmology and Otolaryngology standards³ which recommend that audiometric thresholds at .5, 1 and 2 kHz be used to predict hearing threshold for speech, there is the implication that a hearing loss above 2 kHz is relatively unimportant in assessing one's ability to understand speech and that audiometric loss at 3+ kHz is unimportant for this purpose.

It has been argued that tests which measure Speech Reception Threshold (SRT) in quiet do not necessarily predict speech reception at suprathreshold levels in background noise,⁴ a situation which indeed usually exists in the military. Consequently, while there may be justification for using three frequencies to predict the SRT in quiet, neither the SRT nor the pure-tone audiogram may be sufficient to evaluate speech discrimination in noise for persons with hearing losses restricted to the higher frequencies. Obviously speech discrimination tests with unfavorable speech-to-noise ratios (S/N) would have higher face validity for predicting on-the-job reception for speech embedded in noise. While such tests depend upon a host of variables, i.e., S/N, bandwidth of the noise, spectral characteristics of the noise, level of

presentation, etc., the results may be used to determine more efficiently the characteristics of voice communication in noise and to explore differences related to an individual and/or his listening environment.⁵

The purpose of this experiment was to determine whether one type of hearing defect commonly found in military personnel, namely, noise-induced high-frequency hearing loss, results in decreased performance on a standardized test of speech reception in noise, and if so, what criterion loss should be used to exclude men from situations in which they must communicate in a noisy environment.

METHOD

Tests and Apparatus. A test was devised by a working group of the Committee on Hearing, Bioacoustics, and Biomechanics to aid in evaluation of speech discrimination in noise, the Proposed Clinical Test of Speech Discrimination (PCTSD).⁶ The test, to be presented at suprathreshold levels and at various S/N ratios, uses the Modified Rhyme Test word lists⁷ and a shaped noise resembling the United States of America Standards Institute noise (commonly referred to as USASI Noise).⁸ The test tapes were designed for use with speech audiometers and tape recorders meeting USASI specifications. This test consists of six different lists of 50 monosyllabic words constructed for a closed response set.

with six choices for each test word. The test lists spoken by two males and one female were produced with background noise adjusted to obtain three levels of proficiency with normal hearing individuals: 96% (P96), 83% (P83), and 75% (P75). The noise was flat between 500 and 800 Hz with a 6 decibel (dB) per octave rolloff from 500 to 100 and a 3 dB per octave rolloff from 800 to 6000 Hz. The entire signal and noise was band-passed through a 100 to 6000 Hz band-pass filter in order to stabilize results for various clinics and laboratories. The final recordings were organized into a series of six tapes, two for each speaker. The order of the four lists on each tape is P96, P83, P75 and P96. These tapes were kindly furnished us by Dr. James Kreul, Stanford Research Institute. In this study the test battery consisted of List B (P96), List F (P83), List D (P75) and List E (P96) spoken by one male talker. The lists were presented over an Ampex 601-2 tape recorder; an attenuator was used to set the calibration tone 40 dB above SRT. All testing was done in a sound-treated room; subjects (Ss) wore a headset containing a TDH-39 earphone with an MX-41/AR cushion on the test ear. The non-test ear was fitted with a dummy earphone with an MX-41/AR cushion.

Subjects: Three groups of Ss were selected, each composed of 19 young enlisted submariners. Those in Groups 1 and 2 had normal hearing between 1 and 6 kHz, i.e., no loss at 1, 2, 3, 4 and 6 kHz greater than 20 dB (ISO). In addition, each subject's average loss at 1 and 2 kHz was within 5 dB of his average loss at the upper three frequencies.

Group 3 had normal hearing at 1 and 2 kHz (no loss greater than 20 dB, ISO), but each S's average loss for 3, 4 and 6 kHz was at least 15 dB (in one case 57 dB) greater than his average of the lower two frequencies.

Table I shows hearing loss averaged for each group. The resultant mean difference between the average of 1 and 2 kHz and the average of 3, 4 and 6 kHz was 37.2 dB for the hearing loss group. For the two normal groups the same mean difference between averaged lower and upper frequencies was less than 2 dB.

All subjects were initially given pure-tone audiometry and SRT tests using recordings by Central Institute for the Deaf of Spondee words (CID W-1 records).⁹ The final selection of 19 Ss per group was accomplished by matching the three groups for SRT score: mean scores of -3.04, -2.02 and -2.03 dB for Groups 1, 2 and 3, respectively. The PCTSD was then administered to each S according to the procedures outlined by Kreul et al.⁶

RESULTS

Table II shows some differences and similarities among groups. For all groups, the lists with the greater S/N ratio (The speech signal was 30 dB above the noise for Lists B and E) of course produced higher mean scores than the other lists, in which the noise was much louder.

There was little difference for any group between scores on the P83 list (F) and the P75 list (D) even though they

Table I. Average Hearing Loss in Decibels re International Standards Organization for Each Group of Subjects. N = 19/group.

Group	Frequency in kiloHertz				
	1	2	3	4	6
1 - Normal Hearing	6.20	5.95	5.45	7.00	9.85
2 - Simulated Hearing Loss	3.75	2.75	2.75	4.75	7.25
3 - Impaired Hearing Group	4.50	6.50	22.25	45.50	60.45

Table II. Mean Per Cent Correct and Standard Deviations of Scores by List and Group on the Proposed Clinical Test of Speech Discrimination.

List	GROUP					
	1-Normal Hearing		2-Simulated Hearing Loss		3-Impaired Hearing Group	
	Mn	SD	Mn	SD	Mn	SD
B (P96)	94.1	2.9	76.0	7.5	87.5	7.3
F (P83)	74.3	5.8	66.4	5.7	68.8	7.4
D (P75)	72.1	5.1	65.8	4.9	68.4	9.1
E (P96)	95.2	3.2	75.5	8.5	89.3	6.2

were stated to differ in S/N ratio by about 3 dB. One would predict a drop of about 7% intelligibility on the MRT test for a 3 dB decrease in S/N ratio. Since the similarity in mean response

occurred for all three groups in the present study, it must not be related to hearing loss; it may relate to test word difficulty, i.e., non-equivalent lists based upon the acoustics of the tapes.

For all four lists the normal-hearing Ss scored highest, the simulated hearing-loss group lowest. The simulated-loss group scored essentially the same as the hearing-loss group for the more difficult lists (P83, P75), but their unexpectedly lower scores for the easier lists indicate that interference with the fidelity of a speech signal alone can produce a noticeable drop in intelligibility. It appears that the normal-hearing Ss do use acoustic information contained within the 3 to 6 kHz region to interpret speech, inasmuch as artificial elimination of frequency information at 3+ kHz reduced intelligibility by 18.9 percentage points for easier tests and by 7.9 and 6.3 points for the more difficult. The reduction for the hearing-loss group was only 6.2 percentage points less than that of the normal-hearing group for the easier lists, and 4.6 points for the more difficult.

An analysis of variance was performed on the data. The obtained F-ratio for the effects due to Groups was 107 ($P_{.001} = 8.25$ for $df_{2,54}$), for the effects due to Word Lists, 104 ($P_{.001} = 23.70$ for $df_{3,6}$), and for the interaction of the main effects 4.36 ($P_{.001} = 4.04$ for $df_{6,162}$). The significant interaction is attributable to the fact that scores for the simulated-loss group were significantly lower than for the hearing-loss group on the easier tests.

DISCUSSION

This study shows that Ss with noise-induced high-frequency hearing losses but with normal SRT's perform slightly but significantly worse on speech discrimination tests than do normal-hear-

ing subjects, by 4.6 percentage points for speech in noise and by 6.2 percentage points for speech in relative quiet.

The impaired Ss exceeded the simulated-impaired Ss by only 2.5 percentage points for the two difficult S/N ratios, but by 12.6 points for the easy S/N ratios. These results imply that when a simulated hearing loss is imposed upon normal-hearing subjects (as may occur in many intense military environments), the ability to discriminate speech deteriorates even more than for Ss with high-frequency hearing loss. The dramatic reduction of approximately 19 percentage points intelligibility for the easy lists in those persons with simulated hearing loss, and even of 6.2 points for patients with a similar degree of actual hearing loss, emphasizes the fact that a reduction in fidelity of the stimulus at 3+ kHz either at the ear, or within the ear itself, reduces one's ability to discriminate speech.

Situations which produce combined distortions in signal fidelity do exist in the military; e.g., wearing of helmets and ear-protection devices may alter or distort the received speech signal.

This study provides insight into a person's ability to function within an already familiar environment. Ss with permanent hearing loss did slightly poorer than normals, but Ss with artificially simulated hearing loss, not conditioned to the low-pass listening situation, did even worse. Their scores reflect a non-familiarity component. These differences in group

performance were more noticeable for the easy than for the more difficult tests.

According to Acton,¹¹ conditioning the auditory mechanism to speech discrimination tasks in noise may take as long as two to four weeks. In this study, there was no difference between scores of the first vs fourth test for any group. Perhaps our simulated-loss group would have reached the performance of the hearing-loss group, or even of the normal group after further practice.

Acton¹¹ suggests that neither pure-tone nor speech audiometry may well predict speech reception in noise. This study agrees, in that real differences appeared among groups on the PCTSD even though all were carefully matched for pure-tone thresholds through 2 kHz and for SRT in quiet. Correlational studies should later bear on this point.

Figure 1 is a scattergram of mean Discrimination Score (DS) for the two easier tests versus mean hearing loss at 3, 4 and 6 kHz for individuals in Group 3. Figure 2 is the same but for the two more difficult tests. Figures 3 and 4 are the same but for the hearing loss at 3 kHz only. It is seen that on the basis of the audiogram alone it would be possible to reject those whose DS is two standard deviations or more below the mean, only at the cost of rejecting a very substantial fraction of those whose DS is well within normal limits, obviously an untenable procedure. There is, therefore, no justification for using the audiogram at 3 kHz and above to select or reject individuals

for their ability to discriminate speech in noise.

It is true that Elkins¹² found her Ss with hearing losses did poorly on the PCTSD, but there were other features of her group in addition to their high-frequency loss which undoubtedly contributed: e.g., some were veterans in the upper decades of life, there were substantial losses at 2 kHz and below, and some may have had phonemic regression such that all speech, not only in noise, was received poorly. In our population of hearing loss subjects, demonstrated to be normal according to their SRT scores in quiet, the addition of noise degraded the DS from that of the normal hearing group to only a minor degree. We conclude that hearing loss in the 3-6 kHz region, actual or simulated, is a more serious factor for speech discrimination in quiet than in noise.

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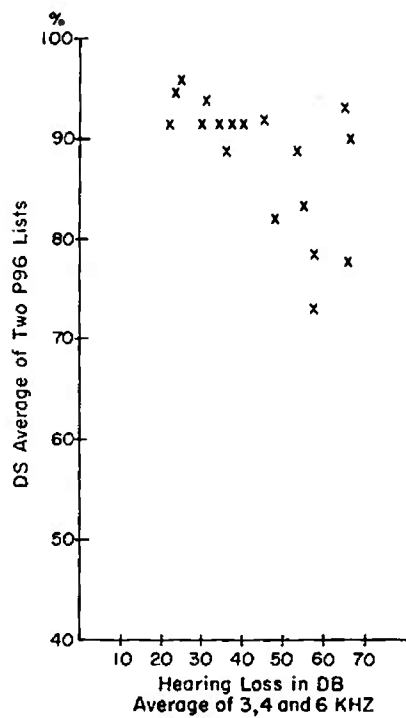


Figure 1

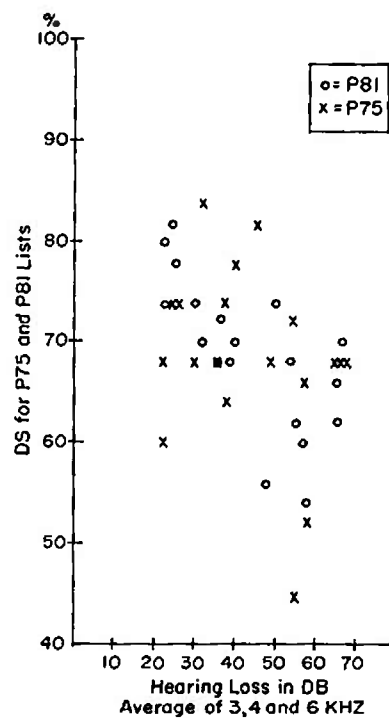


Figure 2

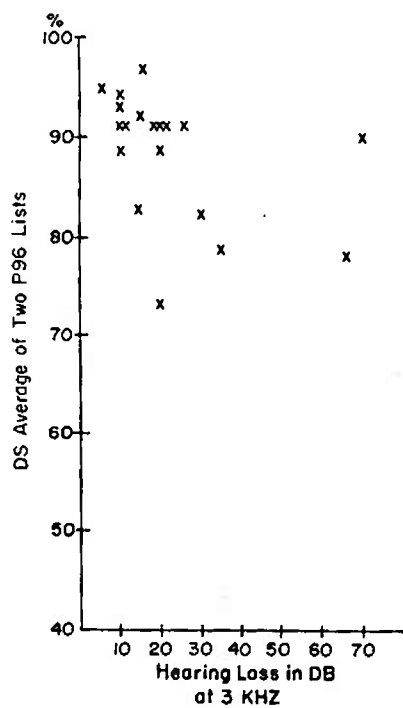


Figure 3

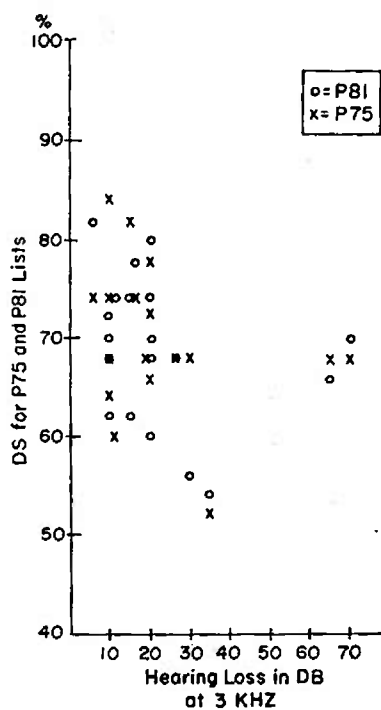
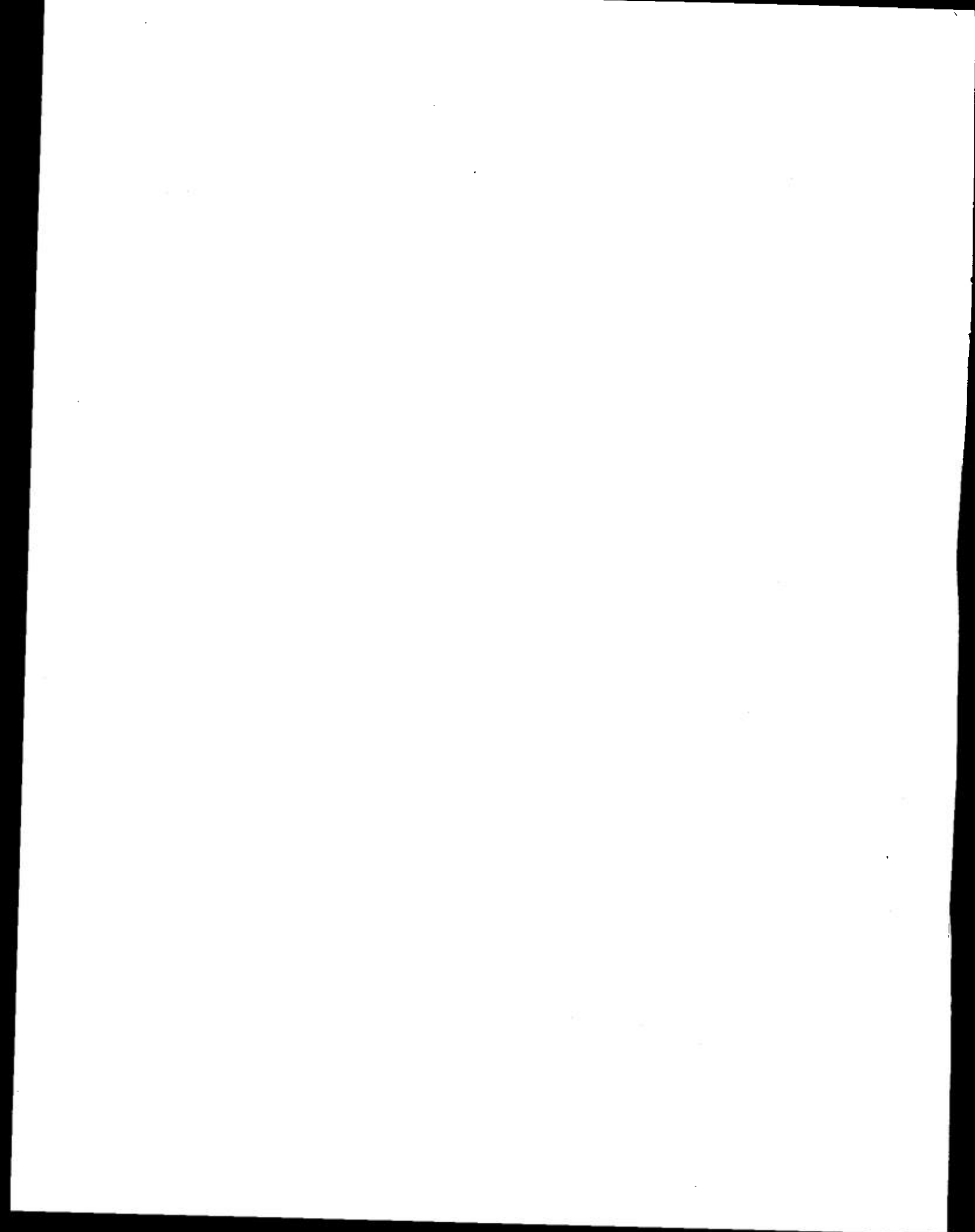


Figure 4

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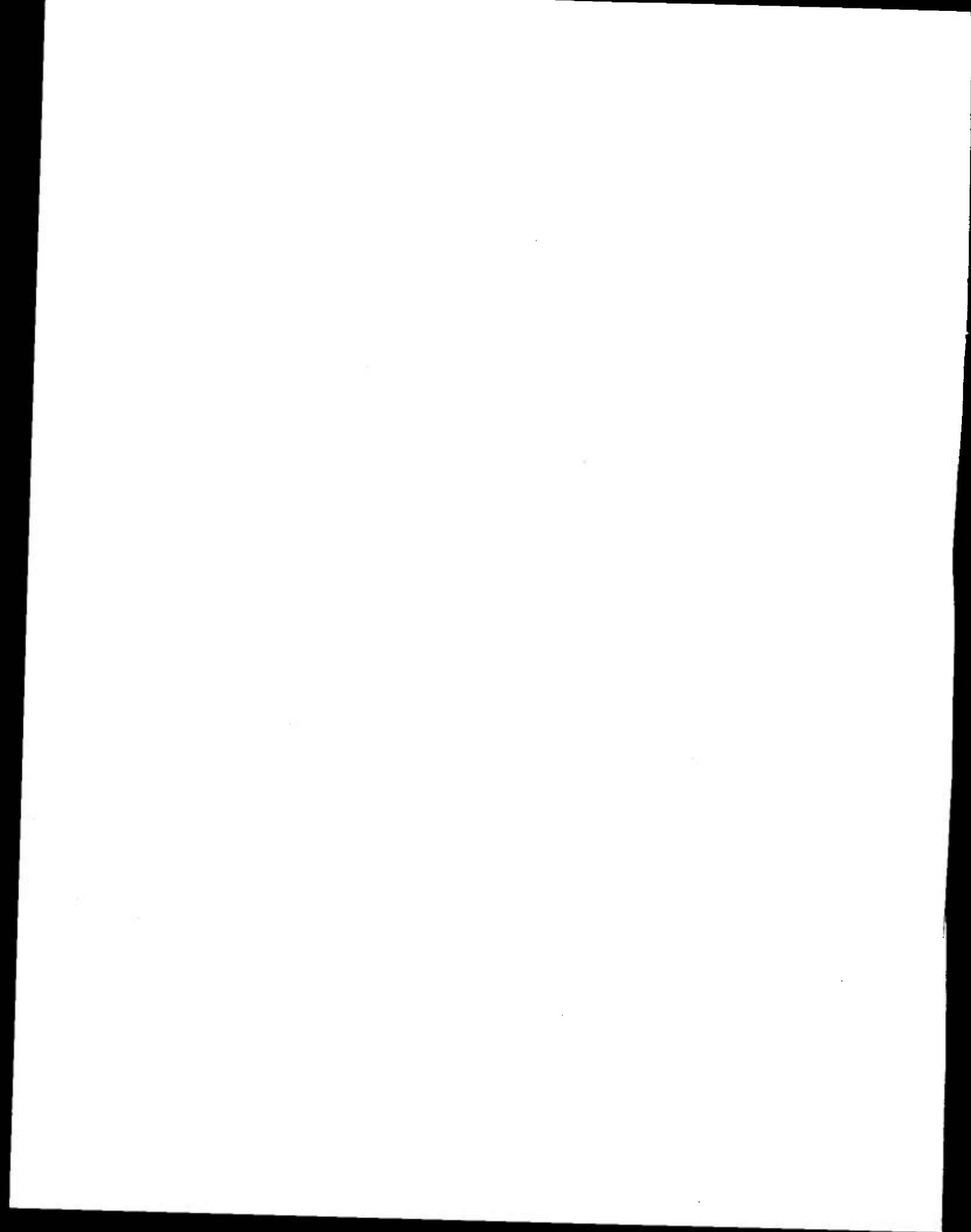
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