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THE EFFECT OF FREQUENCY PASSBAND UPON THE INTELLIGIBILITY OF HELIUM-SPEECH IN NOISE

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SUBMARINE MEDICAL RESEARCH LABORATORY

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ABSTRACT

The alteration in the pitch of speech produced by breathing helium mixtures suggests the possibility of increased intelligibility of such speech by selective frequency filtering.

This study evaluated speech, spoken after breathing an 80% — 20% mixture which was combined with broadband noise and then passed through a selection of bandpass filters. Results indicate that while intelligibility did not suffer appreciably when frequencies of 300 cps and below were eliminated, the loss of frequencies below 600 cps caused a marked deterioration. Even with the severe filtering restrictions of a 600-1200 cps bandpass and a 1-db Speech/Noise ratio, 38% intelligibility was achieved. Apparently the intelligibility of speech in a helium mixture, as in air, is quite distortion-resistant. The estimated frequency at which high- and low-pass filtering would have equal effects on intelligibility was lower than 1000 cycles/seconds in contrasts to approximately 1600 c/s for speech in air. No condition of filtering increased intelligibility over the no-filter condition.

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INTRODUCTION

Voice changes upon breathing mixtures of helium and oxygen (in order to avoid the deleterious effects of nitrogen narcosis) are today well publicized. Many people have encountered alterations to speech during respiration of gas mixtures containing large quantities of helium. A series of investigations of prolonged existence underwater is being conducted by the U. S. Navy. The purpose of the present study was to observe changes in intelligibility caused by altering the frequency passband of speech spoken while breathing a mixture of 80% — 20% HeO_2. It seemed possible that a concentration on that passband most suited to the reception of helium-speech, and the elimination of much other masking background noise as well, might render helium-speech more intelligible than when both speech and noise were unfiltered.

PROCEDURE

Original Recording:

Four male voices were recorded using a high-quality tape recorder in an anechoic chamber while the men spoke words from the Fairbanks Rhyme Test[1]. The equipment is diagrammed in Fig 1a. Each talker inhaled a mixture of 80% helium — 20% oxygen for a minimum of five deep breaths prior to a recording segment. Then after removing the inhalation mask, several stimulus words were spoken in combination with, and at the same effort as, carrier phrases while the talker attempted to keep a VU-meter peaking near zero for the carrier phrases. This procedure was continued until 12 words from each of four lists of the Rhyme Test were recorded from each talker.

The orders of words in the original lists were randomized, and two words from each list were discarded in order to have each talker speak the same number of words. Talkers read the 16 sets of words as follows:

	Talker 1			Talker 2	
Set	List	Items*	Set	List	Items*
1	A	1-12	5	A	1-12
2	B	13-24	6	B	13-24
3	C	25-36	7	C	25-36
4	D	37-48	8	D	37-48

	Talker 3			Talker 4	
Set	List	Items*	Set	List	Items*
9	A	1-12	13	A	1-12
10	B	13-24	14	B	13-24
11	C	25-36	15	C	25-36
12	D	37-48	16	D	37-48

*Items re-numbered according to randomization.

Creating Stimulus Tapes:

The 16 sets of 12 words each were arranged by Latin square design into four orders so that within each successive group of four sets (48 words), each randomized list, as well as each of the four talkers, was represented. Four stimulus tapes were produced, one for each of the above-mentioned orders.

Figure 1b diagrams the method of combining portions of the original recordings to produce stimulus tapes. A calibration tone was recorded at the beginning of each tape, and then the helium-speech was rerecorded, first a portion from one of the original tapes, and then another portion, and so on. Once again a VU-meter was used to make adjustments toward a more homogeneous level for the carrier phrase and consequently a more homogeneous level of effort for the stimulus words.

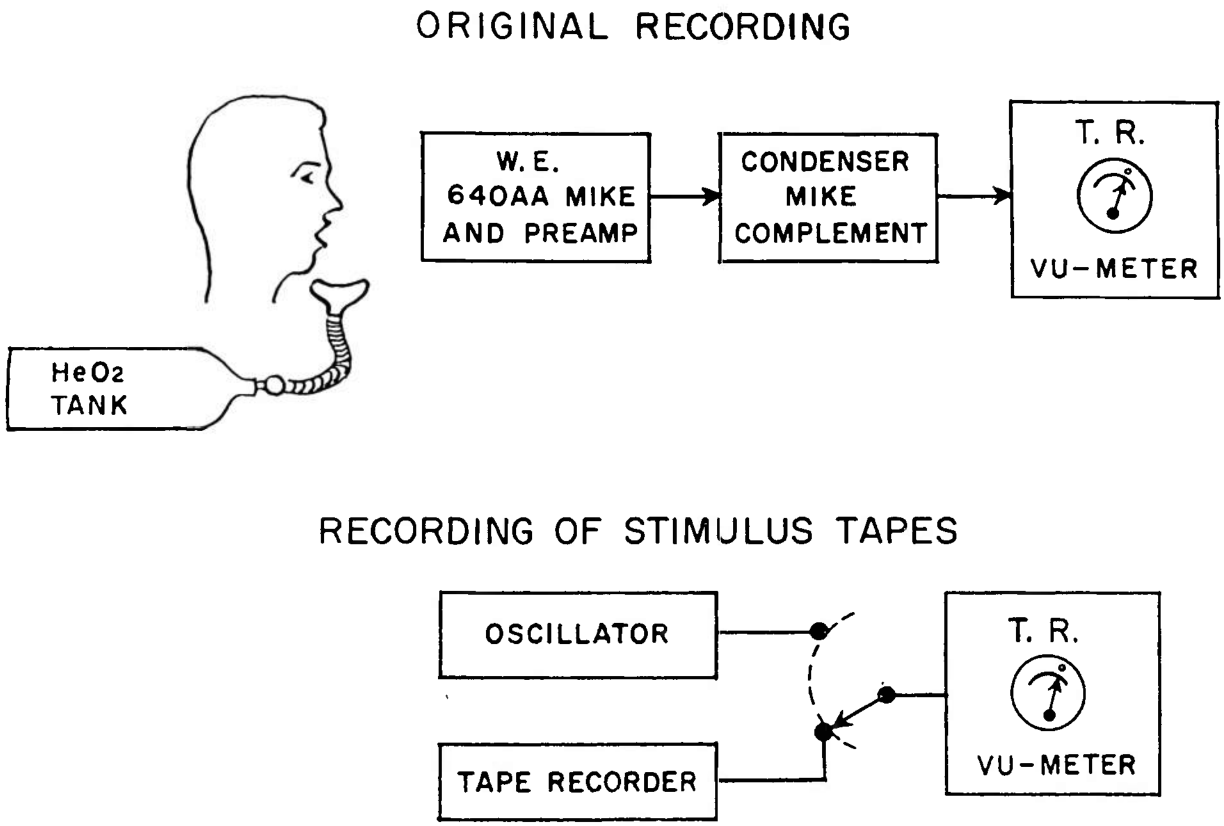

Figure 1-a.—Block Diagram of Original Recording and 1-b.—Recording of Stimulus Tapes.

Randomizing Filter Conditions:

The filtering conditions were all 16 possible combinations of low-pass settings at 1200, 2400, 4800 and infinity, with high-pass settings at "off," 150, 300, and 600 cs. The combination of high-pass "off" and low-pass "infinity" represented the unfiltered condition which is restricted only by the frequency-response limits of the phones.

Within each stimulus tape, the 16 sets were given the 16 filter conditions in semi-random fashion. Stimulus Tape No. 1 was given in its entirety to four separate groups. Each group received a different ordering of the 16 filter conditions. The next four groups, who listened to Stimulus Tape No. 2, received the same four orderings of filter conditions, and so on for the last two stimulus tapes which were presented to the last eight groups.

The semi-random orderings of filter conditions along with the organization of the sets of words for each of the stimulus tapes minimize errors primarily associated with: talkers, lists, and their interactions; difficulty of filter conditions; and fatigue and learning effects. The overall design provides data appropriate for generalizing to the case of the average male talker, and listener, with regard to the effect of frequency passband upon intelligibility of helium-speech in noise.

Presenting Stimulus Tapes to Listening Panels:

Figure 2 diagrams the apparatus used to present stimulus tapes to listeners. The mixing transformer combined the playback of helium-speech and white noise prior to filtering (this procedure differs from that used in most other studies of filtering speech-in-noise

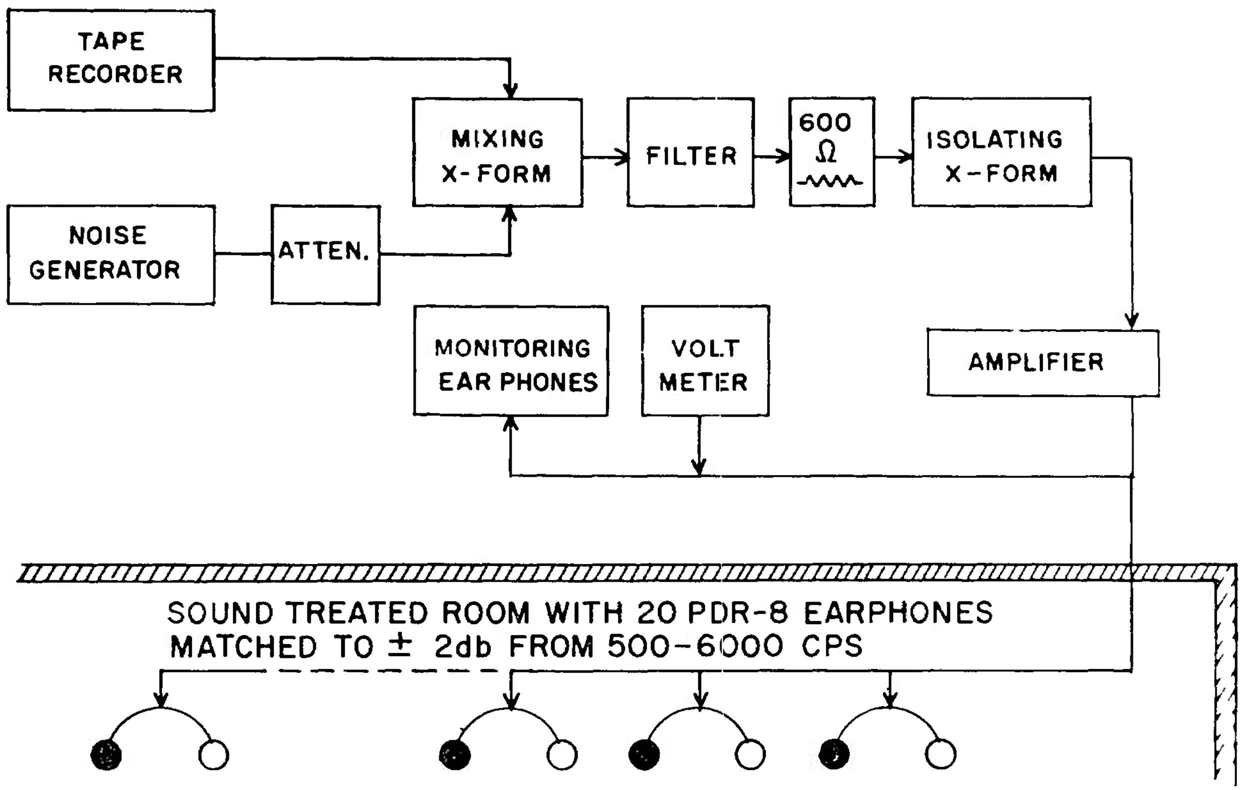

Figure 2.—Schematic Diagram of Presenting Tapes to Subjects.

in that here **both** speech and noise were passed through the same filter). Passband settings were made just before presenting each set of 12 words. A 600-ohm resistance was placed at the output of the stacked filters to obtain good filter response characteristics, (72 db/octave) and the signal was passed through another isolating transformer, amplified, and presented monaurally to a panel of 20 Ss. Each group listened in a sound-treated room provided with 20 earphones matched within 2 db out to 6000 cs.

Test material was introduced to the filters so that in the unfiltered condition the peak-level for speech was 87 db re .0002 microbar in the phones with a 1-db speech/noise ratio. No further alterations in level were made to the input intensity-level of the stimulus.

RESULTS AND DISCUSSION

Figure 3 presents the results. The ordinate is per cent intelligibility, the abscissa high-pass cutoff; parameter is low-pass cutoff. For all low-pass conditions the major drop in intelligibility occurred when the high-pass cutoff was increased from 300 to 600 cs. Indeed, for all low-pass settings, the drop in intelligibility was negligible (4%) with high-pass cutoffs up to 300 cs.

Miller and Nicely[3] reported a mean intelligibility of 71.5% for speech with SN=0 and bandpass of 200-6500 cs. That condition approximates the conditions of the present study with bandpasses of 150-4800 and 300-∞ for which the intelligibilities were 57.3% and 55.7%. Our lower scores may partially be due to the simpler test material used by

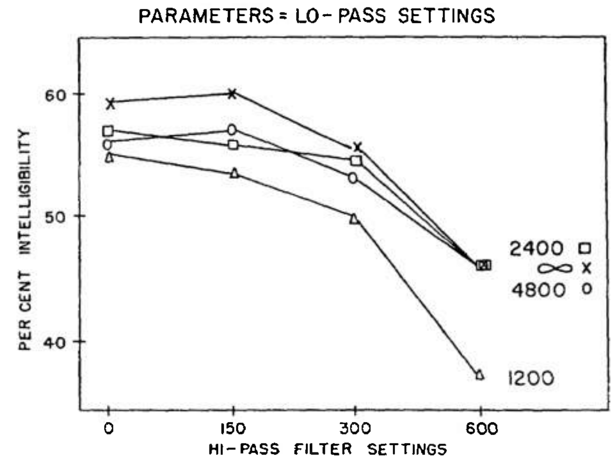

Figure 3.—Speech Intelligibility in Helium as a Function of High-Pass Filter Settings for Constant Low-Pass Filter Settings.

Miller and Nicely, but they also may reflect a difference between normal speech and helium-speech when both type utterances are subjected to masking by noise.

The data are replotted in Fig. 4 with intelligibility as a function of low-pass cutoff. Note that the high-pass cutoff has a negligible effect through 300 cs.

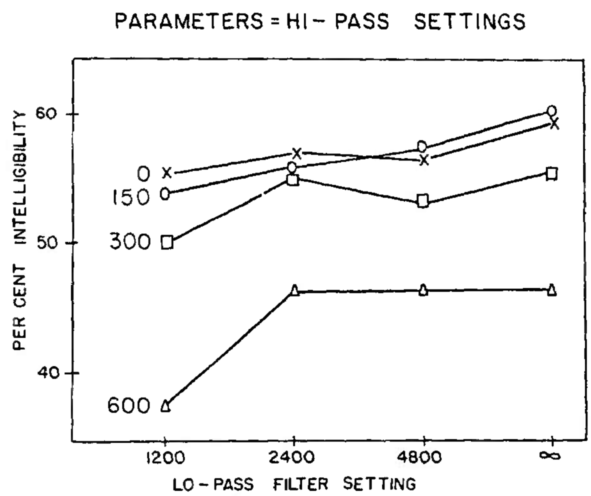

Figure 4.—Speech Intelligibility in Helium as a Function of Low-Pass Filter Settings for Constant High-Pass Filter Settings.

The most restrictive filter condition used in the present study was the 600-1200 cs octave, which produced a mean intelligibility of 38%. For S/N=1 prior to filtering, this is quite high. These data support the impression that speech intelligibility even in helium atmospheres is quite distortion-resistant and relatively stable.

Note also in Fig. 4 that the best scores were obtained for the unfiltered condition: no combination of filtering was found which would increase the intelligibility of helium-speech.

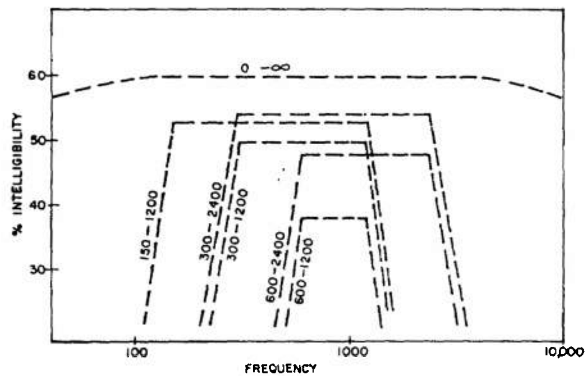

Figure 5.—Speech Intelligibility in Helium as a Function of Passband.

Fig. 5 compares the intelligibility of a variety of passbands. It is clear that a passband of only one octave (600-1200) is insufficient, but that two octaves (either 300-1200 or 600-2400cs) will yield about as good intelligibility as three octaves (either 150-1200 or 300-2400 cs), and that removing all filters will raise intelligibility by only another 6-8%.

Finally, note that intelligibility has just begun to deteriorate at the lowest low-pass condition. Using this information in conjunction with the trend shown in Fig. 3 one may estimate that the cross-over point in high-pass and low-pass filtering will be 1000 cs or lower. This is surprising when one realizes, first, that the commonly-observed cross-over frequency in studies of normal speech is close to 1600 cs (French and Steinberg[2]), and second, that a major difference between helium speech and speech in air is that helium causes the frequency spectrum to shift upward (Sergeant[4]). Indeed, it seems that one would more logically expect the crossover frequency for helium to be higher than for air. We have no ready explanation as yet for this discrepancy.

SUMMARY AND CONCLUSIONS

Speech spoken after breathing an 80%-20% HeO_2 mixture was combined with white noise and then passed through a variety of bandpass filters. Intelligibility was determined on 16 different groups of 20 listeners each. While intelligibility does not suffer appreciably when frequencies of 300 cs and below are eliminated, the loss of frequencies below 600 cs causes a marked deterioration. Even with the severe filtering restrictions of a 600-1200 cs bandpass and a 1-db Speech/Noise ratio, 38% intelligibility was achieved. This indicates that the intelligibility of speech in a helium mixture, as in air, is quite distortion-resistant. The frequency at which high- and low-pass filtering will have equal effects on intelligibility appears to be lower than 1000, in contrast to approximately 1600 cs for speech in air. Reasons for this downward shift are not known. No condition of filtering helium-speech in noise increased its intelligibility.

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