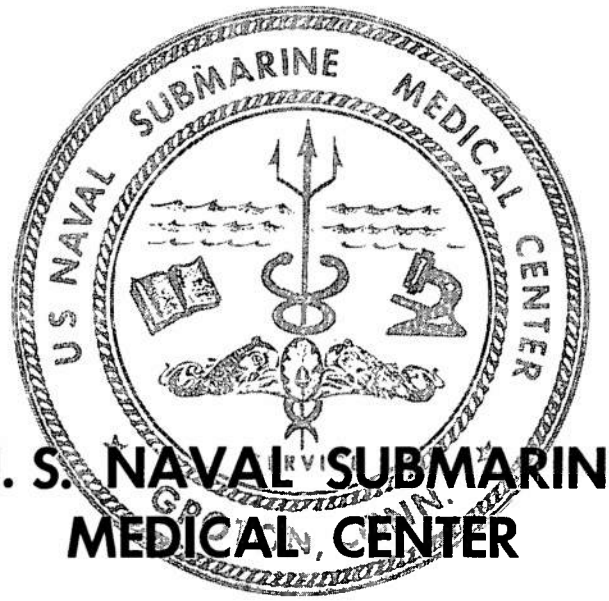

U. S. NAVAL SUBMARINE MEDICAL CENTER

Submarine Base, Groton, Conn.

REPORT NUMBER 602

AN EVALUATION OF THREE METHODS FOR UNSCRAMBLING HELIUM SPEECH PRODUCED AT DEPTHS OF 800 AND 1000 FEET

Joseph S. Russotti

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Bureau of Medicine and Surgery, Navy Department

Research Work Unit MF4306.03-2020D.01

Approved and Released by:

James E. Stark, CAPT MC USN
COMMANDING OFFICER
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Submitted by:

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

Reviewed and Approved by:

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

Reviewed and Approved by:

Joseph D. Bloom, CDR, MC, USN
Director
SubMedResLab

Approved and Released by:

J. E. Stark, CAPT MC USN
COMMANDING OFFICER
Naval Submarine Medical Center

SUMMARY PAGE — REPORT NO. 602

THE PROBLEM

To evaluate three systems for "unscrambling" helium speech produced at the more severe depths of 800 and 1000 feet and compare these to unaltered helium speech and helium speech played back at one-half normal speed.

FINDINGS

The increase in speech intelligibility imparted by the three commercial systems was limited at these depths although two of the units showed a significant improvement over the unaltered helium speech. Half-speed playback of unaltered helium speech was found superior to all other methods of presentation. Methods for improving the operation of these units are suggested.

APPLICATION

Information contained in this report is useful to the design of systems for improved reception of helium speech by divers during deep-submergence.

ADMINISTRATION INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Work Unit MF4306.03-2020D—Sensory Aids for Verbal Communication Under Water by Divers and Swimmers. The present Report is No. 1 on this Work Unit. It was approved for publication on 30 October 1969 and designated as Submarine Medical Research Laboratory Report No. 602.

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ABSTRACT

Three systems for "unscrambling" helium speech produced at simulated depths of 800 and 1000 feet were evaluated. Recordings of the Modified Rhyme test read by an experienced male diver in a pressurized helium atmosphere were processed through three commerical frequency-shifting devices. The intelligibility of words passed through these systems was compared to scores obtained when the same helium recording was presented directly without alteration and when presented at one-half playback speed to groups of listeners. A within-subjects' design was employed with suitable counterbalancing so that no word was heard twice by the same listener. Half speed playback (58.5% intelligibility) was significantly superior to all other conditions. The Kay Electric Company "Varivox" (43.2% intelligibility) was significantly inferior to the other two commercial systems. The Industrial Electronics Corp. and the Gotham Audio Corp. units were equal in performance (50.7% and 51.0% intelligibility respectively) and superior in intelligibility to unaltered helium speech (45.7%). The increase in the degree of intelligibility imparted by the three commercial systems is limited at the depths under study. Methods for adapting these units for improved operation at greater depths are suggested.

AN EVALUATION OF THREE METHODS FOR UNSCRAMBLING HELIUM SPEECH PRODUCED AT DEPTHS OF 800 AND 1000 FEET

INTRODUCTION

Efforts to "unscramble" helium-speech have led to the development of commercially available systems which lower the frequencies of helium speech to a more natural range. At present, these mechanical, electronic or electromechanical systems have a limited range through which frequencies can be translated. Since with increased depth the introduction of helium breathing mixtures causes a very considerable elevation in the frequency components of speech, the working capability of these units may well be exceeded. The present study evaluated three such systems for unscrambling helium speech, on the basis of the intelligibility of the speech at depths of 800 and 1000 ft. For comparison, a half-speed tape playback and an unaltered version of helium speech at these depths were included. The units studied were the Kay Electric Company "Varivox," the Eltro Company Rate-Changer (sold in the U.S.A. by Gotham Audio Corp. as the "Tempophon"), and the Integrated Electronics Corp. Model 701 Helium Voice Unscrambler.

Both the Varivox and Eltro units use a segmented rotating head which electromechanically splices tape so as to lower the frequency positions of recorded signals by reducing the relative speed of short sections of tape which contact energized segments of the playback head. Except for the short delay in speech reception caused by the distance between record and playback heads, real time is preserved. The all-electronic IEC System, on the other hand, achieves real time by using heterodyning techniques which lower frequency. The signal is divided into two separate frequency bands, heterodyned and finally reconstituted for real-time reception.

*Normal speech produced by loudspeaker and picked up by this microphone at pressures equivalent to 1000 ft submergence was easily understood and instantly recognized as a reproduction of normal speech without distortions due to depth or helium.

PROCEDURE

The voice of an experienced male diver was recorded from inside a pressurized test chamber containing the gas mixtures shown in Table I, at pressures equivalent to those found at 800 and 1000 ft of water. Recordings were made of the diver's voice when he read the same 50-word list from the Modified Rhyme Test (MRT) twice at both depths, once with the microphone connected directly to a General Radio Data Recorder located outside the chamber, and then again with the IEC unit between the microphone output and the recorder. The microphone was especially constructed by IEC for use with their unscrambler under conditions of high ambient pressure.*

For each of the two depths a working master tape was produced, which consisted of three identical re-recordings of the originally recorded unaltered helium-speech transmission and one re-recording of the originally recorded IEC alteration. An additional re-recording of the unaltered helium transmission, played back at half original speed, was also included on each tape.

Ten stimulus tapes for presentation to groups of listeners were finally prepared, each consisting of the same word list presented at either of two depths, under one of five test conditions: (1) unaltered helium speech, (2) half-speed playback, (3) Eltro alteration, (4) Varivox alteration, and (5) IEC alteration.

Field operation of the IEC system in this study was by IEC technicians. The Varivox and Eltro units were adjusted for optimum performance and operated in this laboratory by the authors.

The intelligibility scores reported here are by no means representative of the performance of any of the three systems at the much shallower depths for which they were designed.

Since all ten conditions (five at each depth)

TABLE I

Contents of Breathing Mixtures.

800 ft.	1000 ft.
96.50% Helium	97.46% Helium
1.22% Nitrogen	1.46% Nitrogen
.17% Carbon Dioxide	.10% Carbon Dioxide
2.02% Oxygen	1.04% Oxygen
Temp. Approx. 80°	
Rel. Humidity 40-50%	

were comprised of the same 50 words, separate listening groups were necessary. To reduce the number of such groups to less than 10, the high split-half reliability of the MRT word list allowed constructing the tapes using only 25-word lists, with items 1-25 always taken from the 800-ft and items 26-50 always from the 1000-ft tape. In an effort to cancel group differences and minimize order effects, the resultant five 50-word tapes, which now contained samples from both depths, were systematically spliced in groups of five words so that items 1-25 contained all five conditions at 800 ft, and items 26-50 contained all five conditions at 1000 ft. The order of presentation of these two sets of five conditions was arranged according to two 5 x 5 Latin Squares derived from a Greco-Latin square. Thus, the design for presentation of the data made use of a sample of listeners determined from the responses of five groups of actual listeners.

An advantage to this unusually complex design for presentation of words was that a specific set of five words for a particular treatment at either depth was never heard more than once within or between groups, but each of the 25 words was heard 28 times for a particular treatment. In other words, a sampling of 28 listeners theoretically at random heard 25 different words for each of five treatment conditions, at two different depths, although the equivalency inherent in using the same 25 words for all treatments at a particular depth was retained.

Each of five groups of 28 listeners, all with normal hearing, heard a different one of the five 50-word lists monaurally in a room equipped with 49 matched Telephonics TDH-39 earphones mounted in Otocups. The mean level of the speech signals on a stimulus tape were set at 75 db Sound Pressure Level (SPL). Responses were made on a machine-scoring answer sheet especially constructed for the MRT test (See Appendix I).

RESULTS

Data from the five groups were combined to control order effects, and each experimental condition at both depths was analyzed by means of a treatments x treatments analysis of variance for repeated measures. Table II shows a significant difference (level of confidence better than 99%) for the conditions of altering the helium speech heard by each listener. No significant difference was found, however, between intelligibility for the two depths. Further, the interaction between depth and condition was not significant (95% level).

TABLE II

Analysis of Variance of Test Condition X Depth.

	df	MS	F
Between Ss	139	1.084	.969
Within Ss	1260	1.189	
Depth	1	.686	.613
Test Condition	4	23.990	21.457*
Depth X Test Cond.	4	.983	.879
Total Error	1251	1.118	
Total	1399	1.179	

*Significant at 99% level.

Based upon these results, data for the two depths were combined, and a revised summary table for a one-way analysis of variance using repeated measures was performed. Table III, a summary of this analysis, shows that the difference for condition is decreased, but still significant (99% level).

The mean correct responses to the various conditions are in Table IV. Comparison of conditions by a Cochran statistic showed that the assumption of homogeneity of variance is valid.

TABLE III

Summary of Revised Analysis of Variance.

	df	MS	F
Between Ss	139	2.168	
Within Ss	560	2.654	
Test Condition	4	47.980	16.717*
Residual Error	556	2.870	
Total	699	2.557	

*Significant at 99% level.

According to a Newman-Keuls comparison (see Table V) the half-speed condition was significantly better (99% level) than all other conditions. The Varivox was significantly inferior (99% level) to the Eltro, IEC, and half-speed conditions, and slightly worse than unaltered speech, though this trend was not formally significant (<95%). Finally, the Eltro and IEC units yielded similar data, both significantly better (95% level) than unaltered speech.

TABLE IV

Percent Correct Responses Based Upon 50 Words Under Each Condition for 28 Theoretical Listeners.*

Varivox	Unaltered HeO_2	IEC	Eltro	Half Speed
43.2%	45.7%	50.7%	51.0%	58.5%

*28 Ss each group x 5 groups = 140 actual listeners.

TABLE V

Summary Table of Newman-Keuls Comparison of Test Conditions Showing Level of Significant Difference Between Pairs of Means.

	Half Speed	Eltro	IEC	Unalt	Varivox
Half Speed		99%	99%	99%	99%
Eltro			*	95%	99%
IEC				95%	99%
Unaltered					*

*Not Significant.

DISCUSSION

Since speech intelligibility was best under half-speed playback and was, in fact, significantly better than any other condition, one may conclude that the splicing/heterodyning processes employed in maintaining real time while shifting frequency do so at the expense of intelligibility.

Considering together all the ways used here for treating helium speech, the intelligibility appears poorer than might have been expected. While this overall decrement is primarily due to the excessive distortions produced at these depths, the particular design employed may have contributed to some extent. In order that each listening group hear the five experimental conditions at both depths, five words from each condition were presented. Since after each group of five words a novel situation confronted the listener, learning and adaptation were kept to a minimum. Had listeners been able to "get used to" a particular type of speech at each condition, they might well have done better.

The operating ranges of the Eltro, Varivox, and IEC units had apparently been exceeded so that they were not quite able to lower the frequencies to the degree that would theoretically be needed. In effect, then, a certain amount of distortion to the speech was still present, and the resultant signal was not perfectly intelligible. Further, once the Eltro and Varivox units were operated in the upper ranges of frequency shift, far too many small sections of the speech were eliminated. Both of these systems sample small portions of the recorded signal and reduce frequency by reducing the relative playback speed of each small section sampled. The extent of the shift, then, determines the amount each section is expanded in playback time, and therefore since real time is maintained, fewer sections are sampled when the frequency shift is greater.

The Varivox condition was less intelligible to these listeners than the direct unaltered transmission; this is most probably attributable to the noise which this unit adds to signals during the splicing operation, combined with the appreciable loss in speech signal caused by the sampling techniques.

It should be noted that the altered speech produced by the Eltro unit at these depths is by no means representative of this unit in improving intelligibility at lesser depths. Advanced design of the switching mechanism employed in the rotating multiple-playback head assembly has lowered appreciably the splicing noise inherent in the system. In fact, we have found that helium speech produced at one ATA could be altered by the Eltro so as to recreate in part the particular speaker's normal voice and speech characteristics. The machine was also successful in rendering intelligible a sample of helium speech previously recorded at 400-ft depth, although voice quality could not be studied, since no tape of the speaker's voice under normal conditions was available. At the 800-ft depth, however, the frequencies could not be brought far enough down to reach a normal-sounding speech. At maximum settings the unit sampled too few sections of speech and was poor in intelligibility. A compromise was made by having three speech-researchers shift the playback frequencies to what they felt would produce maximum intelligibility; this met with some success.

We would emphasize that while a decrease in the number of sections sampled does accompany an increase in frequency shift, the sampling system should not be discarded as incapable of successful operation at greater depths. Note that present sampling systems incorporate four pick-up segments in the rotating head array. With, for example, eight-part heads, smaller sections could be sampled and expanded with perhaps smaller loss in intelligibility.

Further refinements seem in order in both the Eltro and the IEC units, equal here in performance, to adapt them to greater depths. Factors in favor of the IEC all-electronic unit are its capability of microminiaturization, and elimination of moving parts more prone to breakdown. On the other hand, an advantage of the rotating-head system is that resulting speech does sound more nearly normal, miniaturization of the rotating-head principle is within present-day capabilities, should a demand exist.

SUMMARY

An experienced male diver read a 50-word list of the Modified Rhyme Test at depths of 800 and 1000 ft simulated submergence, while breathing helium. A faithful rendition of this speech was played to a group of listeners for intelligibility testing, together with the same tape played at half-speed, and as altered by three frequency shifting devices manufactured by the Industrial Electronics Corporation, the Kay Electric Co., and one of German make sold by the Gotham Audio Corp. Type of speech treatment and groups of listeners were suitably counterbalanced so that no word was heard twice by the same listener. Significantly superior to all other conditions was one of half-speed playback. The Kay "Varivox" was significantly inferior to the unaltered condition, though this trend was not significant. The IEC and the Gotham units were not different, and both were significantly superior to the unaltered condition. It was suggested that had these latter units been able to extend even further the frequency shifts of which they are now capable, intelligibility of helium speech at these depths might well have been further improved.

SCORES

1.
2.

NAME _____ (LAST) _____ (FIRST) FORM 3X _____ GROUP _____

RANK/RATE _____ DATE _____ TEST NO. _____

1	gold	hald	sold	11	pap	shop	hap	21	bill	fill	till	31	sofe	save	soke	41	came	cape	cane
	told	fald	cald		cop	tap	map		will	hill	kill		sale	sane	same		case	cave	cake
2	lame	lane	lace	12	tang	tab	tack	22	sap	sag	sad	32	map	mat	math	42	wig	rig	fig
	late	lake	lay		tam	tap	tan		sass	sack	sat		mad	mass	man		pig	big	dig
3	bust	just	rust	13	keel	feel	peel	23	gale	male	tale	33	gang	hang	fang	43	ban	back	bat
	dust	gust	must		reel	heel	eel		pale	sale	bale		bang	rang	sang		bad	bass	bath
4	did	din	dip	14	heal	heap	heath	24	peas	peal	peach	34	sip	rip	tip	44	test	nest	best
	dim	dig	dill		heave	hear	heat		peat	peak	peace		lip	hip	dip		west	rest	vest
5	sin	win	fin	15	paw	jaw	saw	25	rent	went	tent	35	beach	beam	beak	45	seen	seed	seek
	din	tin	pin		thaw	law	raw		bent	dent	sent		bead	beat	bean		seem	seethe	seep
6	sun	sud	sup	16	pub	pus	puck	26	sun	nun	gun	36	hen	ten	then	46	dun	dug	dub
	sub	sung	sum		pun	puff	pup		run	bun	fun		den	men	pen		duck	dud	dung
7	lot	not	hot	17	meat	feat	heat	27	bus	buff	bug	37	cuff	cuss	cub	47	led	shed	red
	got	pot	tat		neat	beat	seat		buck	but	bun		cup	cut	cud		wed	fed	bed
8	pill	pick	pip	18	kit	kick	kin	28	tick	wick	pick	38	park	mark	hark	48	tease	teak	tear
	pit	pin	pig		kid	kill	king		kick	lick	sick		dark	lark	bark		teal	teach	team
9	may	gay	pay	19	caak	baak	haak	29	sin	sill	sit	39	fizz	fill	fib	49	bit	sit	hit
	day	say	way		shaok	loak	toak		sip	sing	sick		fin	fit	fig		wit	fit	kit
10	pave	pale	pay	20	race	ray	rake	30	name	fame	tame	40	sail	toil	oil	50	pad	pass	path
	poge	pane	pace		rate	rave	raze		came	game	same		fail	cail	boil		pack	pan	pat

APPENDIX I

Machine-score version of Modified Rhyme Test answer sheet developed at Naval Submarine Medical Center.

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13. ABSTRACT

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