Perception of Speech in a Hyperbaric Helium-Oxygen Atmosphere

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This report presents results from an investigation of the relations between some linguistic factors and the intelligibility of speech produced in an atmosphere consisting of a mixture of helium and oxygen. The mixture in question is the one appropriate for saturation diving between 100 and 500 msw.

We have measured the intelligibility of unprocessed speech in helium-oxygen, using 20 respondents in multiple choice tests. The test design makes a strict distinction between initial and final ambiguity or confusion position, and the consonant phonemes have mainly been treated as either initial or final consonants. The findings are based on 24 000 individual judgments. The work is still in progress, and this report must therefore be considered as a preliminary one.

Intelligibility, as expressed by the mean percentage of correct identifications, can be broken down as a function of various test parameters. Table I gives the intelligibility as a function of depth.

Intelligibility has been broken down by consonant phonemes, as shown in table II. The ranking was done before rounding off.

The Spearman's Rank Order Correlation (r(s)) between the hierarchies for initial and final intelligibility is 0.83. Consequently, I consider the combined ranking in Table II as a general intelligibility hierarchy, derived from initial and final positions from depths between 100 and 500 msw.

The relations between the hierarchies for initial and final positions can be studied at individual depths.

Table I. Intelligibility as a function of depth

Depth (msw)	Intelligibility	S.D.	N (words)
0	97.5	9.2	300
100	67.3	28.0	150
200	62.4	29.0	150
300	59.7	27.8	350
400	56.4	27.0	200
500	60.0	22.5	50

Table II. Intelligibility and ranking for consonants initially, finally and combined. Depths from 100 to 500 msw pooled

	Initially		Finally		Both positions	
	Int.	Rank	Int.	Rank	Int.	Rank
/p/	81	3	63	6	69	5
/b/	52	11	38	12	49	9
/m/	50	12	33	13	42	12
/f/	67	8	72	4	69	6
/v/	75	6	63	5	69	4
/t/	68	7	61	7	64	7
/d/	49	13	39	11	45	11
/n/	65	9	57	8	59	8
/l/	83	2	74	2	78	2
/r/	83	1	75	1	78	1
/s/	63	10	74	3	70	3
/kj/	75	5	–	–	–	–
/j/	48	14	–	–	–	–
/k/	45	15	46	9	45	10
/g/	44	16	28	14	40	13
/ng/	–	–	41	10	–	–
/h/	76	4	–	–	–	–

Table III. Correlations (r(s)) between intelligibility hierarchies for initial and final ambiguity positions for 5 depths

Depth	r(s)	N (cons.)	p-level (dir.)	Sign.
100	0.49	13	$p < 0.05$	*
200	0.72	13	$p < 0.005$	***
300	0.76	13	$p < 0.005$	***
400	0.76	12	$p < 0.005$	***
500	0.30	8	$p < 0.05$	n.s.

At 500 msw the intelligibility hierarchies for initial and final position seem to be different from each other. At the other depths the hierarchies do not differ more than what may be expected by chance.

The intelligibility hierarchies for initial position have been studied in pairs of depths.

Correspondingly for final ambiguity position (Table V).

We see from Tables IV and V that the consistency of the intelligibility hierarchies does not depend on depths, but rather on the differences between depths.

Intelligibility can be related to structure type, to place of articulation or to phonation.

One of the purposes of this study is to provide adequate background knowledge for developing improved technical equipment for unscrambling

Table IV. Correlations (r(s)) for 10 pairs of depths with respect to intelligibility hierarchies for consonants in initial ambiguity position

Depths in comparison	Diff.	r(s)	p-level (dir.)	N (cons.)	Sign.
100 vs 200	100	0.64	$p < 0.005$	16	***
200 vs 300	100	0.85	$p < 0.005$	16	***
300 vs 400	100	0.90	$p < 0.005$	16	***
400 vs 500	100	0.69	$p < 0.005$	14	***
100 vs 300	200	0.54	$p < 0.025$	16	**
200 vs 400	200	0.76	$p < 0.005$	16	***
300 vs 500	200	0.75	$p < 0.005$	14	***
100 vs 400	300	0.48	$p < 0.05$	16	*
200 vs 500	300	0.41	$p > 0.05$	14	n.s.
100 vs 500	400	0.20	$p > 0.05$	14	n.s.

Table V. Correlations (r(s)) for 10 pairs of depths with respect to intelligibility hierarchies for consonants in final ambiguity position

Depths in comparison	Diff.	r(s)	p-level (dir.)	N (cons.)	Sign.
100 vs 200	100	0.98	$p < 0.005$	14	***
200 vs 300	100	0.91	$p < 0.005$	14	***
300 vs 400	100	0.69	$p < 0.025$	13	**
400 vs 500	100	0.90	$p < 0.005$	11	***
100 vs 300	200	0.86	$p < 0.005$	14	***
200 vs 400	200	0.48	$p > 0.05$	13	n.s.
300 vs 500	200	0.73	$p < 0.025$	11	**
100 vs 400	300	0.40	$p > 0.05$	13	n.s.
200 vs 500	300	0.61	$p < 0.05$	11	*
100 vs 500	400	0.53	$p > 0.05$	11	n.s.

Table VI. Intelligibility by depth by structure type. (a: Only finally. x: Reduced reliability – less than 100 judgments.)

	Depth (msw)				
	100	200	300	400	500
Plosive	62	54	54	51	60
Nasal	54	51	50	44	43
Lateral	85	81	77	70	67
Vibr./Tap.	64	82	83	79ax	75ax
Fricative	78	73	65	63ax	71ax

Table VII. Intelligibility by depth by place of articulation. (b: Only initially. x: Reduced reliability – less than 100 judgments.)

	Depth (msw)				
	100	200	300	400	500
Labial	61	53	61	60	63
Dent./Alv.	74	71	60	56	59
Palatal	78b	70b	53b	52b	58bx
Velar	47	42	42	45	45x
'/h/'	84b	76b	72b	73b	80bx

Table VIII. Intelligibility by depth by phonation

	Depth (msw)				
	100	200	300	400	500
Unvoiced	74	69	63	60	67
Voiced	62	57	57	53	53

speech distorted by helium. An experimental unscrambler is at present being developed in Bergen, with the Norwegian Underwater Technology Center (NUTEC) as main coordinator.

It is further believed that this will be useful knowledge for standardizing terminology and procedures in saturation diving.

Acknowledgement

This paper was supported by a grant from the Norwegian Underwater Technology Center - NUTECH.