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Effect of Hypoxia on Speech Recognition in Noise

by

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Naval Medical Research and Development Command
Research Project 61152N MR000101 5103

Released by:

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SUMMARY PAGE

PROBLEM

To determine whether breathing a low-oxygen (12%) mixture affects recognition of speech in background noise.

FINDINGS

No difference was found in speech-to-babble ratios required to recognize 50% of words presented under conditions of 12%- and 21%-oxygen concentrations.

APPLICATION

This study determined that breathing 12% oxygen does not change the capacity to hear and recognize speech. As 12% oxygen is considerably lower than would be recommended for submarine atmospheres, the reduction of ambient oxygen concentrations aboard submarines to reduce the fire hazard should not be detrimental to speech recognition.

ADMINISTRATIVE INFORMATION

This research was carried out under Naval Medical Research and Development Command Work Unit 61152N MR00001 MR0000101 5103, "Visual function during inhalation of 155, 130, and 95 Torr oxygen." It was submitted for review on 3 Aug 1987, approved for release on 16 March 1987, and designated as NSMRL Report Number 1111.

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ABSTRACT

Speech-to-babble ratios for 50% word recognition were measured in four men, age 30 to 35, while breathing 12% and 21% oxygen. There were no differences between the two conditions. Learning effects, however, were seen for the task. As the 12%-oxygen level is considerably lower than would be used for routine reduction of fire hazards onboard submarines, reduced oxygen levels at the intermediate levels being considered should not affect speech recognition.

Submarine fires can be disastrous. A low concentration of oxygen in the submarine atmosphere will suppress them. However, if the oxygen concentration is too low, performance of the crew will be impaired. As part of an investigation of the effects of low oxygen on physical, mental, and sensory performance, the present study examined the effect of low levels of oxygen on audition.

Tonndorf (1953) found a 1-2 dB increase in auditory pure-tone thresholds while breathing 10% oxygen. After the hypoxic exposure, thresholds were briefly enhanced. Physiological measures on animals have shown that hypoxia affects cochlear (inner-ear) function under extremely hypoxic conditions (e.g., Evans, 1974; Fechter et al., 1987). For milder hypoxic conditions, such as those used in studies with human subjects, an elevation in cochlear blood flow apparently serves as a protective mechanism (Fechter et al., 1987), insuring that the cochlea has adequate oxygen to maintain its functioning. Tonndorf's behavioral data seem consistent with the physiological data; apparently the increase in cochlear blood flow is sufficient to maintain the sensitivity of the ear.

Speech recognition has been measured by Burkett and Perrin (1976) at cabin altitudes corresponding to 10%- and 12%-oxygen concentrations. They postulated that the decreased speech-recognition scores were due either to cochlear hypoxia or inattention secondary to central nervous system hypoxia. However, their results of depressed speech recognition at higher altitudes is questionable because of procedural problems. For example, the test words were spoken "live voice" instead of being recorded, the subjects responded verbally by parroting each word (which was subjectively judged by the tester for correctness), and no mention was made of using a double-blind procedure.

The purpose of the present study was to more accurately assess speech recognition during hypoxia. Many speech-recognition tests require a quiet environment, and most are time-consuming, particularly if a high degree of reliability is desired. Because of the other measurements being done in this study, neither requrement could be met. The speech-recognition test used was a speech-in-noise threshold measurement. In the version we used, the speech is presented at a constant level, and the noise is varied to find the speech-to-noise ratio required for 50% speech recognition (Dirks et al., 1982). This measure is quick and reliable (Dubno et al., 1984).

Moreover, speech-recognition thresholds in background noise provide a direct and realistic measurement of communication difficulties in noisy environments. For example, Plomp and Mimpen (1979) found that near the 50% speech-recognition threshold each 1 dB increase in speech-to-noise ratio results in a 20% higher sentence-intelligibility score. Using data from Pearsons et al. (1977) on the distribution of voice levels of talkers in noise, Plomp (1986) estimated that every dB decrement in speech-recognition threshold in noise reduces the *a priori* chance of being able to understand a speaker in critical conditions by about 8%. In noisy submarine compartments, or, in emergencies when the noise levels might be high, a hearing loss for speech in noise could clearly have serious consequences.

In the present study, speech-recognition thresholds in noise were measured for men breathing oxygen-nitrogen mixtures of 20.94% oxygen (normal) or 11.8% oxygen (low). The 20.94% value is equivalent to sea-level breathing of 21% oxygen with a total pressure of 1 ATA (760 torr). The 11.8% concentration has a partial pressure of oxygen equivalent to that at an elevation of 15,000 ft. where the total pressure is 428 torr (of which 21% is still oxygen). The 12% oxygen level is lower than that being considered for submarines, but was chosen in an attempt to find a level where performance begins to degrade. If differences were seen between 12% and 21% oxygen, additional measurements would be necessary to find the highest levels where hearing for speech in noise was affected. Otherwise, it would be concluded that intermediate levels of oxygen would not impair speech recognition.

METHOD

Subjects

The subjects were four male Navy enlisted volunteers, age 30-35. Their audiograms are shown in Table I. Two of them had hearing within normal limits (i.e., thresholds of 15 dB HL or less; dB HL is a measure used to quantify hearing levels in decibels). The other two had slight-to-mild high-frequency hearing losses.

Speech Materials and Instrumentation

Magnetic tape recordings of 11 spondaic words were used as speech stimuli (Dubno et al., 1984). (Spondaic words are two-syllable words with equal stress on each syllable; e.g., railroad, northwest.) Multi-talker speech babble from the Speech Perception in Noise (SPIN) test (Kalikow et al., 1977) was used for the background noise (masker). The speech was dubbed onto one track and the speech babble onto a second track.

Output from each channel of the tape recorder (TEAC A7030U) went to an attenuator (Hewlett-Packard 350D) and to a speech audiometer (modified Grason-Stadler 162) for mixing and attenuation. Stimuli were delivered to one of a pair of earphones (Telephonics TDH-39) mounted in supra-aural cushions (MX-41/AR).

Signal and babble levels were specified by the sound pressure of a 1000-Hz calibration tone at the beginning of each tape. Calibration of the sound pressures at the earphone was performed prior to each test session.

Noise levels in the test room when all the physiological monitoring equipment used in the experiment was turned on were measured in 1/3-octave bands. Assuming that the spectrum of the male talker used in the Dubno recordings was similar to that of a published spectrum of the SPIN talker (Kalikow et al., 1977), the room noise was only around 10 dB below the level of the speech at 125 and 250 Hz. If the attenuation provided by the headset at those frequencies was 5 dB (ANSI S3.1, 1977), the room noise probably did not interfere with the test. At higher frequencies, the room noise was much lower, and headset attenuation is greater.

Procedure

Speech-recognition thresholds were measured after the subject had been breathing the oxygen mixture for around 12-15 minutes. Oxygen levels in the blood generally reach equilibrium in less than eight minutes (range of 5-10 minutes). Neither subject nor experimenter was informed of the percent oxygen for that day. For two subjects, practice runs were made prior to the experimental conditions. For the other two, there were no practice runs. Data were collected on two days, one for 21% and the other for 12% oxygen. The order of presentation for the subjects was randomized. Three received the 21%-oxygen concentration first. (Note: additional subjects were used in other aspects of the study, and half of them received 21% first. Due to equipment difficulties and scheduling problems, only four of the subjects were included in this auditory experiment.)

An up-down adaptive procedure (Levitt, 1971) was used to determine the signal-to-babble (S/B) ratios required for 50% word recognition. The speech was fixed at a level of 72 dB SPL. Familiarization with the test materials took place at a high S/B ratio (+30 dB). All of the spondees were presented at least once at this level. The initial starting level of the noise was determined by adjusting the noise in 10-dB steps using a simple up-down procedure (i.e., after each correct response, the level of the noise increased; after an incorrect response, it was decreased.) After determining the starting level, the noise was adjusted in 2-dB steps until ten reversals were obtained. The first two reversals were eliminated, and the levels of the final eight reversals were averaged to obtain the S/B ratio. This was done three times for each of the experimental conditions.

The subjects were tested while seated on an exercise cycle. They breathed through a mouthpiece connected to the breathing apparatus and wore a nose-clip. The 11 spondaic words were displayed on a card at eye level. The stimuli were presented through earphones. After each stimulus presentation, the subject tried to identify which of the 11 words had been presented. He responded using a keypad mounted just in front of the handlebars of the exercycle. Each button was labelled with a number, which corresponded to one of the stimulus words. There was no feedback.

RESULTS

The three S/B ratios for each condition were averaged to produce a mean S/B ratio for threshold. There was virtually no difference in average threshold between the 12- and 21%-oxygen conditions. The average thresholds were -10.8 dB for 12% oxygen and -10.5 dB for 21% (i.e., the speech was at 72 dB SPL, and the babble was 10.8 and 10.5 dB higher). The 12% oxygen condition required, if anything, more masking (background noise) than did the 21% condition. The reverse would have occurred if hearing levels for speech in noise had been negatively affected by the low oxygen levels. Individual data are presented in Table II. None of the subjects was discernably affected by the 12% oxygen mixture.

DISCUSSION

The S/B ratios found in this study were lower (more masking required for 50% intelligibility) than those found by Dubno et al. (1984), who reported S/B ratios of around -5.5 dB for young, normal-hearing listeners. The reason for the difference is not apparent, especially since the conditions for this study were very similar to theirs. The values reported here are in better agreement with an earlier study using spondee thresholds in babble (Dirks et al., 1982), in which S/Bs of around -9.0 were found.

Another difference between the current study and the one by Dubno et al. is learning effects. Dubno et al. found none, but consistent learning effects were seen in the present study. The mean S/B ratios for the subjects across both days for runs 1, 2, and 3 (omitting

Subject 3, Day 2), were -10.2, -10.7 and -10.8 respectively. Practice effects were also seen for average thresholds. For the four subjects the first average threshold (omitting the practice sessions) was -10.1 dB and the second was -10.5 dB. For two of the subjects, one set of practice thresholds was completed prior to the test conditions, so three averaged thresholds were available. Their average thresholds were -10.2, -10.4, and -11.4 dB.

The presence of a learning effect in the current study perhaps is explainable by the environment of the test. Dubno et al. tested their subjects in a typical research setting. The subjects were presumably seated comfortably in a sound-treated booth with no distractions. They responded by parroting the words on the tape. In the present study, the subjects were perched on an exercise cycle, wearing a noseclip, and breathing through a mouthpiece connected to their breathing apparatus, which was supported on a tray in front of them, and they coordinated their breathing with the spondee presentation. In order to respond, they had to find the word on the keypad, which was also placed on the tray. Other people and equipment were in the room, which may have been distracting even though no one was talking or moving during the test. The combination of all these less than ideal conditions could have resulted in practice effects.

CONCLUSIONS

Breathing 12% oxygen did not change the capacity to recognize speech in a noisy background for the four subjects tested. Although the N was small, it is unlikely that increasing the number of subjects would give different results, particularly given the very small pure-tone threshold shifts at a lower oxygen level (Tonndorf,

1953) and the lack of changes in physiological measures of cochlear function until high levels of anoxia are reached (Fechter et al., 1987). As the 12%-oxygen level used in the present study is considerably lower than would be used for routine reduction of fire hazards onboard submarines, reduced oxygen levels that more closely approximate the normal concentration of oxygen should not affect speech recognition.

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Table I. Pure-tone audibility thresholds in dB HL. An ascending audiological technique with a 5-dB step size was used for these measurements.

	Frequency in kHz								
Subject	0.25	0.50	1.0	1.5	2.0	3.0	4.0	6.0	8.0
1	-5	0	-5	-	0	-	0	-	-5
2	15	10	5	10	15	15	15	30	35
3	0	5	5	-	10	-	5	-	5
4	0	5	0	-5	0	0	15	20	20

Table II. Signal-to-babble (S/B) ratios for 50% spondee recognition.

Subject	Day		Runs		Mean Threshold
1	1 (Practice)	-8.0	-9.8	-9.8	-9.2
	2 (21%)	-8.2	-9.2	-10.5	-9.3
	3 (12%)	-10.2	-9.8	-11.0	-10.3
2	1 (21%)	-8.8	-9.8	-9.2	-9.2
	2 (12%)	-10.2	-11.0	-11.2	-10.8
3	1 (21%)	-11.8	-9.8	-11.0	-10.8
	2 (12%)	[*-2.8]	-11.2	-9.8	*-10.5
4	1 (Practice)	-9.8	-12.2	-12.0	-11.3
	1 (12%)	-12.5	-11.8	-10.2	-11.5
	2 (21%)	-12.5	-13.0	-12.0	-12.5

* The subject was uncomfortable due to poorly placed equipment on the first trial. It is omitted in the threshold average (i.e., threshold was the average of trials 2 and 3).

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Speech-to-babble ratios for 50% word recognition were measured in four men, age 30 to 35, while breathing 12% and 21% oxygen. There were no differences between the two conditions. Learning effects, however, were seen for the task. As the 12%-oxygen level is considerably lower than would be used for the reduction of fire hazards onboard submarines, hearing need not be a consideration in setting these levels.

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