

## VISUAL ACUITY AT HYPERBARIC AIR PRESSURE

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*Summary.*—The visual acuity of five divers in a dry pressure chamber was measured with a Landolt C test. Only one of them showed a significant reduction at 7.0 atm. These results contrast sharply with open sea experiments, which show a considerable reduction at much lower pressures (Baddeley, 1968). It is suggested that besides stresses, luminance differences, also turbidity, as a function of depth may account for the discrepancy.

It is well known that divers have a reduced sensitivity to various types of sensory stimuli. Physiological as well as psychological factors are generally thought to be responsible for this reduction. With air breathing scuba divers the role of N<sub>2</sub> gas narcosis symptoms (and O<sub>2</sub> intoxication) increases progressively with depth. Already at depths of 30 to 60 meters the behaviour of the diver can be influenced strongly, due to the high partial N<sub>2</sub> pressure. The influence of pressure on the visual performance of air breathing subjects has not been investigated sufficiently, despite the fact that for human beings the visual system is even more important under water than in air.

Some years ago Baddeley (1968) measured a reduction in visual line acuity of a factor two when the depths of open sea scuba dives were increased from 10 to 30 meters, but it is not clear whether this reduction was due solely to N<sub>2</sub> narcosis symptoms or whether psychological factors such as anxiety also contributed. Since the latter factors are likely to play a much smaller role in a diving tank, in the present study visual acuity was determined as a function of pressure measured up to 7 atm (equivalent to a depth of 60 m). Moreover, experimental conditions such as luminance and temperature can more easily be controlled.

### METHOD

Five moderately to well experienced amateur male divers were presented binocular Landolt C test figures at pressures of 1.6 and 7.0 atm ( $0.16 \times 10^6$  and  $0.70 \times 10^6$  N/m<sup>2</sup>) at room temperature. They had emmetropic vision without astigmatism, amblyopia, or strabismus. In the period prior to the experiment, each subject made several simulated dives in the pressure tank.

The Landolt C chart was read from a distance of 2 m through a glass window of a single person pressure tank. The chart was surrounded by a white field that subtended 25° of visual angle and had a luminance of 53 cd/m<sup>2</sup>. The contrast of the Cs was prac-

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tically 100% and the angles subtended by the gaps were 0.40, 0.50, 0.67, 0.80, 1.00 and 1.25'. The chart contained 100 each of the four smallest Cs and 80 each of the two largest ones.

Four preliminary experiments with two of the subjects suggested that below 4 atm the influence of pressure was either very small or absent (measurements at 1.0, 1.3, 1.6 and 4.0 atm). Also, symptoms of  $N_2$  narcosis were never observed in a group of 18 amateur divers at pressures between 3 and 4 atm in the dry pressure chamber. At higher pressures (6.0—7.5 atm) there seemed to be a tendency for a small reduction of acuity. However, this could not be confirmed due to the limited number of presentations of the test patterns. Therefore, in the present experiments the number of presentations was increased to 100 (80 for the 1.00 and 1.25' C). The 62½% level of correct choice in respect to the position of the C (right, left, upwards, downwards) was taken as criterion. Due to the restricted measurement time at 7.0 atm generally those two Cs were presented which result in a percentage correct answers just above and below 62½%. To prevent fatigue every series of 200 Cs was presented as two sets of 100, separated by a pause of 3 min. The chart was read at a rate determined by the subject. At both pressures the test was generally completed within 15 min. The sequence of Cs of various size alternated during the reading procedure. Before and after application of 7 atm a test was done at 1.6 atm. In the second test at 1.6 atm all six sizes of Cs were presented.

#### RESULTS AND DISCUSSION

The results of two of the subjects obtained at 1.6, 7.0 and again at 1.6 atm are presented in Fig. 1a. As can be seen for the used sizes of the Landolt C the score at 7.0 atm is slightly smaller than the scores at 1.6 atm. The data indicate that these subjects have a reduced acuity at the high pressure. By applying a *t* test to the difference in acuity between the high and the low pressure it can be determined whether or not the decrease in acuity at 7 atm is significant. Table 1 shows the results of these calculations for the five subjects. All show a reduced acuity at 7.0 atm. However, for two subjects significance could not

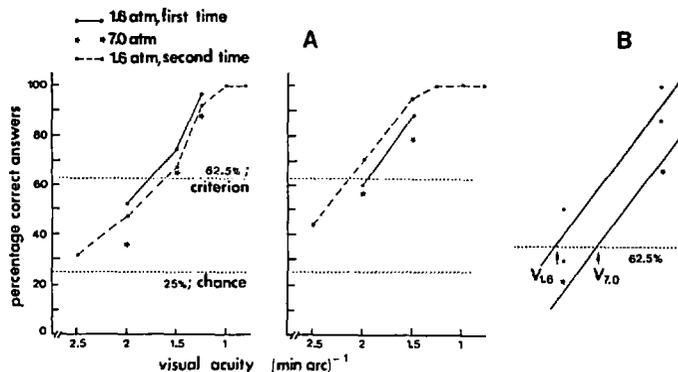


FIG. 1a. Psychometric data of two subjects. FIG. 1b. Visual acuity of one subject at 1.6 atm ( $V_{1.6}$ ) and at 7.0 atm ( $V_{7.0}$ ), estimated from the central position of the psychometric function.

TABLE 1  
STATISTICS OF VISUAL ACUITY OF FIVE DIVERS AT 1.6 AND 7.0 ATM  
IN DRY PRESSURE TANK

Subject	Visual acuity (V)		$\Delta V$ (%)	$t$	$p$	$\Delta T$ (%)	Experience at pressure > 5 atm		N <sub>2</sub> narcosis symptoms
	1.6 atm	7.0 atm					water	dry	
HvG	1.69	1.47	-13.3	2.45	<0.1	11	4	5	-
NS	1.48	1.44	- 2.4	0.12		30	0	3	+
AN	2.74	2.07	-24.5	4.86	<0.025	-3	26	0	+
HD	2.05	1.84	- 9.5	2.40	<0.1	41	1	0	-
JW	2.41	2.36	- 2.2	0.60		15	9	0	-

Note.— $\Delta V = (V_{7.0} - V_{1.6})/0.01 V_{1.6}$ ;  $T_{7.0}$  is the duration of the test at 7.0 atm and  $\Delta T = (T_{7.0} - T_{1.6})/0.01 T_{1.6}$ . N<sub>2</sub> narcosis symptoms refer to subjects' own reports.

be proven, in contrast to another who shows a significant effect. It is worth noting that the only subject for whom a strong effect was found was the only one who completed the test more rapidly at 7.0 atm than at 1.6 atm. The remaining two have a weakly significant effect. As can be seen from the table, the size of the effect does not seem to be correlated with experience with pressures above 5 atm in open water or the dry pressure chamber. The subjects were asked if they noticed N<sub>2</sub> narcosis symptoms during the 7.0-atm period. (They were instructed to disregard their speech distortion when making this judgment.) The opinion of the subjects about their state does not seem to be related to the change in acuity. Yet the experimenter observed a reduced alertness in all subjects. At both pressures there was no correlation between acuity and the time required to complete the test, although there is generally an increase of decision time at 7.0 atm. A part of this increase is, however, due to speech distortion, resulting in less effective communication with the experimenter. The question why visual acuity of the various divers is affected so differently cannot be answered, since the strength of N<sub>2</sub> narcosis cannot be quantified easily and the experience of the subjects is difficult to compare.

In the present experiments, pressures of up to 7 atm had little or no effect on acuity. This raises the question why Baddeley (1968) found a nearly ten times larger effect in open sea experiments. Acuity is dependent on luminance: at 1 cd/m<sup>2</sup> it is about 64% and at 10 cd/m<sup>2</sup> ca. 86% of its maximum value that is reached at 100 cd/m<sup>2</sup> (Pirenne & Denton, 1952). Baddeley does not give any information about the luminance of his test patterns. If he used daylight, it cannot be ruled out that luminance differences between 10 and 30 m could have influenced his reported results since at 30 m the luminance is presumably much less than 100 cd/m<sup>2</sup>. In rather clear sea water brightness is halved with every 4- to 10-m increase in depth. By controlling the luminance in open water experiments a comparison could be made with the results of the dry pressure chamber. In this way the influence of environmental conditions

(like cold) and psychological stresses (like fright) can be isolated from the physiological N<sub>2</sub> effect.

## REFERENCES

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