Effect of simulated heliox saturation diving on diver's perception ability

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Abstract

This study explored the changes in perception of divers under 2.0MPa simulated heliox saturation. Through the method of own experimental control, we selected 8 male divers who were physically and mentally healthy. Every participant was requested to join in test of auditory, olfactory and taste sense, self-assessment of physical and mental condition, orientation perception, depth perception, spatial perception and hand-eye coordination speed perception on of different pressure(0.0MPa (before pressurization), 2.0MPa (complete exposure) and 0.0MPa (after decompression)). All the data we collected were analyzed by repeated measure ANOVA. Results indicated that divers' perception, assessment of one's physical and mental state, the ability of orientation perception, depth perception and hand-eye coordination were all affected to varying degrees. Therefore, it was particularly important to strengthen the training of divers' perception ability.

Keywords: simulated heliox saturation diving, divers, perception ability,

1. Introduction

As we all know, divers was a special professional group. Long-term underwater work is a great physical and psychological challenge, especially for deep saturated diving. It required divers to have good physical and psychological qualities, of which perception ability is an important factor for divers to operate underwater safely, and is the key to successfully accomplish underwater exploration, inspection, salvage, rescue and other tasks.It is also an important indicator to measure the underwater operation and judgment ability of divers.

Then, what is divers' perception ability? And how does perception have an impact on divers' underwater work? It is the level of cognition of sensory stimulation and perceptual stimulation, and the sensitivity of the sense to the stimulus, as well as experience and decision judgment on stimulating(Dai et al.2016).For example, the diver makes judgments on the brightness and location of the underwater environment, that is a reflection of the perception ability. The level of perception is related to factors such as the diver's sensory sensitivity and underwater work experience. The worse the sensitivity, the longer the feeling, then the bigger the possibility of mistakes. The less experience, the more likely it is to be caught unprepared situation. Therefore, perceptual ability is one of the important factors affecting the safety of divers' underwater operations.

Saturated diving is a type of diving in which the diver stays in a high altitude or a high pressure environment equivalent to the depth of water, causing the inert gas in the breathing gas to be fully saturated in various tissues of the body(Jiang, 2012). Heliox saturation diving is an important mean for long-term operation in large-depth high-pressure underwater environment. Some researchers reviewed the effects of saturated diving on divers' psychological and physiological functions (Miaoet al.2015). It showed that large-depth saturated diving could reduce divers' sensitivity to perception and psychological stability, and also reduce their ability to use underwater skills and to deal with emergencies.

In this study, the diver's auditory, olfactory and taste sense, physical and mental condition, orientation perception, depth perception, spatial perception and hand-eye coordination were used as experimental indicators to explore the effect of simulated 2.0MPa heliox -saturated diving on the perception ability of divers. This study systematically explored the changes in the perception of divers under 2.0 MPaheliox exposure, and provided an empirical basis for studying how to improve the efficiency of large depth saturated diving operations.

2.Subjects and Methods

2.1 Subjects

Eight male professional saturated divers participated in the experiment, the average age was28.25±6.94years. All the divers got plenty of rest before the experiment began, and after a thorough physical examination and psychological tests, they were physically and mentally healthy and were right-handed.

2.2 Methods

2.2.1 Experimental design

The experiment design was a single factor repeated measurement design. The treatment factors were different environment pressures, which were 0.0 MPa (before pressurization), 2.0 MPa (complete exposure)and 0.0 MPa (after decompression). And every subject was asked to complete the tests of auditory, olfactory and taste sense, self-evaluation of physical and mental condition, orientation perception, depth perception, spatial perception and hand-eye coordination

2.2.2Instruments and methods

Self-edited sensory state questionnaire: Used to self-assess the diver's current state of auditory, olfactory and taste. Among them, auditory sense was based on the current condition of the subject, with 1 being normal, 2 being slightly worse, 3 being poor, 4 being very poor, and 5 being lost. Ol factory and taste sense were to let the subject judge the acidity and the sweetness of the liquid from 1 to 10respectively.

Self-edited state of physical and mental questionnaire: Used to self-assess the physical and mental state of the individual, including physical, emotional, fatigue and sleep conditions, with 1 being good, 2 being general, 3being poor.

Orientation Perception Tester: Produced by East China Normal University Science and Technology Instrument Factory (type: EP207), which was used to test hand orientation perception. Subjects put on the eye mask and practiced the three directions of 30°, 70°, and 90° with the help of the hand. Then, three tests were performed on each orientation by memory, and the error was recorded to calculate the average.

Depth Perception Ability Tester: Produced by East China Normal University Science and Technology Instrument Factory (type: EP503A),which was used to test the ability to estimate the distance. The subject should use a remote controller to move the middle vertical bar to the same plane as the two standard side bars. The subject was asked to test 8 times, then we measured the deviation of distance (in centimeter), recorded the error and calculated the average.

Spatial Perception Ability Tester: Produced by East China Normal University Science and Education Instrument Factory(type:EP507), which was used to determine the spatial perception characteristics and grouping ability. The subject was asked to perform 8 times, we recorded the correct response of the subjects to different graphs, and then calculated the average reaction time(in second).

Hand-eye coordination test: Produced in Austria(type: Laffette), which was used to measure the coordination of fine movements of the handin visual cooperation of individuals. The subject took the dice and picked up the small metal nails in the plate ,who could practice for ten seconds, then tested for one minute, we counted the numbers that the subject was picked up within one minute to measure the hand-eye coordination.

2.2.3 Experimental environment

The experiment was carried out in the living quarters of the simulated 2.0MPa saturated diving system in our laboratory. The living space is 2240mm high and the volume is 15.2 m3. The bulkhead has 4 observation windows and the light transmission size is Ø150mm. During the experiment, the pressure range was 0-2.0MPa, the cabin temperature was (30±1) °C, the relative humidity was 64-68.5%, the normal running noise was not higher than 60 dB, and the illuminance was 50-100 lx.

2.2.4 Experiment process

The experiment is divided into three stages: 0.0MPa before pressurization, fully high pressure exposure(2.0MPa) and 0.0MPa after decompression. Before the pressurization, participants needed to be familiar with the operation of all instrumentsto eliminate the effects of the exercise effect, and then test all indicators.

The high pressure exposure stage was selected to pressurize to 2.0MPa, stabilized for 3 hours, the second experiment is carried out during this stay period. After the pressure was reduced to 0.0MPa, the third experiment was carried out. The test sequence for each experiment was not fixed to eliminate the effects of sequential effects.

2.2.5Data statistics method

The data were analyzed by SPSS16.0 statistical software. The statistical data were expressed by X±S. The variance analysis method of single factor repeated measurement data was used. The difference was statistically significant at $p<0.05$.

3. Results

3.1 The variation of divers' sensory state on condition of different pressure

Table 1 Describe statistics of sensory state on condition of different pressure.

Measurements	Values(Mean ± Std deviation)		
	1	2	3
auditory	1.00±0.00	1.75±0.50	1.25±0.50
olfactory	8.75±1.89	8.22±1.48	8.75±0.50
taste sense	9.50±0.57	9.00±0.82	9.25±0.95

N=8,the numbers of pressure ranging from 1 to 3 represented0.0 MPa (before pressurization), 2.0MPa (complete exposure) and 0.0 MPa (after decompression) respectively

As shown in table 1, on the basis of descriptive statistics, repeated measure ANOVA was used to analyze the difference. The results wererespectively$F(2,14)_{auditory}=4.200, p=0.072>0.05, F(2,14)_{olfactory}=2.600, p=0.154>0.05, F(2,14)_{sense}=1.800, p=0.244>0.05$. Although no significant difference among the three sets of data was observed, we can see from the descriptive statistics that with the increase of pressure, the diver's sensory experience would decrease, and it would be recovered after decompression.

3.2 The variation of divers' state of physical and mentalon condition of different pressure

Table 2 Describe statistics of state of physical and mental on condition of different pressure.

Measurements	Values(Mean ± Std deviation)		
	1	2	3
physical	1.50±0.57	1.75±0.50	1.50±0.57

emotional	1.00±0.00	1.50±0.57	1.50±0.57
fatigue	1.50±0.57	1.80±0.40	1.25±0.50
sleep	1.50±1.00	1.75±0.50	2.00±0.00

N=8,the numbers of pressure ranging from 1 to 3 represented0.0 MPa (before pressurization), 2.0MPa (complete exposure) and 0.0 MPa (after decompression) respectively

As shown in table 2, on the basis of descriptive statistics, repeated measure ANOVA was used to analyze the difference of divers' state of physical and mental on condition of different pressure. There was no significant change indivers' self-assessment on physical, emotional, fatigue or sleep status. The results were respectively $F(1,7)_{physical}=1.000, p=0.422>0.05$, $F(1.26,7.73)_{emotional}=1.050, p=0.391>0.05$, $F(2,14)_{fatigue}=2.416, p=0.170>0.05$, $F(2,14)_{sleep}=0.692, p=0.5360>0.05$.

3.3 The variation of divers' orientation perception on condition of different pressure

Table 3 Describe statistics of orientation perception on condition of different pressure.

orientation perception	Values(Mean ± Std deviation)		
	1	2	3
30°	2.71±1.17	4.01±1.08	3.31±0.73
70°	3.40±1.79	7.31±1.90	4.04±1.85
90°	4.81±2.41	6.10±4.35	3.69±1.54

N=8,the numbers of pressure ranging from 1 to 3 represented0.0 MPa (before pressurization), 2.0MPa (complete exposure) and 0.0 MPa (after decompression) respectively

The absolute value of diver's orientation perception error was described and counted. And on this basis, we used repeated measure ANOVA to analyze the difference. Furthermore, the indicators which had significant differences were post-tested.

Table 4 The difference analysis of orientation perception ability test on condition of different pressure

Measurements	df	MS	F	Post-test results
30	2	3.429	6.531*	1<2**
70	2	35.190	23.25**	1<2**, 3<2**
90	2	11.699	1.861	

* Significance level < 0.05, ** Significance level < 0.001, the numbers of pressure ranging from 1 to 3 represented0.0 MPa (before pressurization), 2.0MPa (complete exposure) and 0.0 MPa (after decompression) respectively.

Orientation perception was significantly influenced by pressure, especially when pressure reached 2.0MPa, the divers' orientation perception error increased significantly, and when pressure recovery to 0.0MPa, the error also significantly reduced, but failure to recover to pre-pressure performance. It is worth noting that, fine or moderate orientation variations are more susceptible to high pressures.

3.4 The variation of divers' orientation perceptual abilityon condition of different pressure

Table 5 Describe statistics of perceptual abilityon condition of differentpressure

Measurements	Values(Mean ± Std deviation)		
	1	2	3
depth perception(cm)	0.84±0.27	2.00±1.30	1.46±1.31
spatial perception(s)	1.28±0.50	1.39±0.59	1.18±0.57
hand-eye coordination (n/min)	19.25±3.50	16.50±1.29	21.5±3.00

N=8,the numbers of pressure ranging from 1 to 3 represented0.0 MPa (before pressurization), 2.0MPa (complete exposure) and 0.0 MPa (after decompression) respectively

In the experiment, there were three variables of perceptual ability, including depth perception, spatial perception and hand-eye coordination. On the basis of descriptive statistics in table 5, repeated measure ANOVA was performed on the three variables (depth perception response error, correct response time in spatial perception and the number of folds in hand-eye coordination in one minute).

Table 6 The difference analysis of perceptual ability on condition of different pressure

Measurements	df	MS	F	Post-test results
depth perception	2	2.564	3.547*	1<2*
spatial perception	2	18.583	3.780	
hand-eye coordination	2	25.083	10.379*	2<3*

* Significance level < 0.05, ** Significance level < 0.001, the numbers of pressure ranging from 1 to 3 represented0.0 MPa (before pressurization), 2.0MPa (complete exposure) and 0.0 MPa (after decompression) respectively.

As shown in table 6, we found that when pressure was 2.0MPa, depth perception response error increased significantly, and the number of folds in hand-eye coordination in one minute reduced obviously. Although the difference of spatial perception is not statistically significant, it can be seen a more obvious trend from descriptive statistics, namely divers' spatial perception could be effected by high pressure.

4. Discussion

In this study, eight divers participated in the simulated heliox saturation diving experiment when the pressure achieved predetermined value. From the results, we could inference that the large-depth saturated diving had a great influence on divers' perception ability.

Feeling was the initial process of an individual's understanding of external things. Did the diver's sensory state change with the change of environmental pressure? The answer was of course yes (Vaernes et al, 1982), although the effects of saturated diving on divers' auditory, olfactory and taste sense were not significant in this study. We can see from the descriptive statistics that with the increase of pressure, the diver's sensory experience would decrease, through the analysis of the specific results of each diver, we also found that the auditory ability of the divers under high pressure decreased slightly, and the decrease of only one diver's olfactory ability was more obvious. And during decompression, the sensory state partial recovered, but it did not return to the initial level after decompression to 0.0 MPa.

Assessment of self-state of mind and body is an important manifestation of divers' perception ability. In our study, high pressure did not cause significant changes in divers' physical and mental state. But the results suggested that high pressure may cause changes in divers' physical and mental state to some extent. Actually, under saturated diving conditions, the total sleep time of divers decreased, sleep latency prolonged and sleep quality decreased, especially during high-pressure exposure and decompression. The main reason was the long-term closed-loop environment and the influence of decompression process on sleep, so it was inferred that sleep disturbance was one of the reasons for the general fatigue of divers after decompression (Lewisa et al,1981;Nagashima et al,2002).It could be inferred from this that bad sleep conditions would react to divers' physical, emotional and fatigue states. The results of this study also showed that divers'self-assessment ability was weakened in high pressure environment.

Orientation perception refers to individual's perception of the direction of themselves or an object in space. When a diver worked underwater, the dim light seriously affected his correct judgment of the orientation of the object or himself. In the research, the diver was asked to judge the direction of their arm. The results showed that under high pressure, the more obvious divers' errors in judging small or medium orientation changes were, this result suggested that the training of divers' orientation perception ability needed to be strengthened, especially in deep saturated diving. Studies have also shown that large depths of heliox -saturated diving can significantly reduce the perception and space operation capability of divers(Lewis et al,1981; Logie et al,1983), thereby greatly affecting the speed and accuracy of underwater operations.

Depth perception was the ability of human visual organs to perceive distant and close distances of objects in three-dimensional space (Guo, 1999).The judgment of the distance between underwater objects and themselves, and the judgment of the distance between different objects were very important to divers, therefore, the depth perception ability determined whether the diver could efficiently complete underwater operations. In addition, we found the diver's depth perception ability has been restored after decompression. Spatial perception refers to the perception of spatial characteristics such as distance, shape, size and orientation of objects. In our study, we measured divers' spatial perception ability by correctly and quickly judging figures shapes. Our results showed that the high pressure environment has no significant effect on the shape space perception ability of divers. The possible reason was the role of experience. Abundant underwater working experience enabled divers to quickly and accurately determine the spatial shape of objects. The measurement of hand-eye coordination ability in this study required divers to perform some fine movements for one minute, This was not only a test of divers' sustained attention, but also a measure of their sensory integration. High pressure environment of 0-2.5 MPa could reduce the hand-eye coordination ability of divers, which might be caused by caused by dysfunction of central nervous system of high pressure, thus affecting the performance of divers (Hou,2011;Baddeley et al,1985). And our research got a similar result.

5. Conclusion

The perception ability was an important factor for divers to complete deep underwater operations safely and efficiently. The research showed that with the increase of exposure pressure, divers' perception (auditory, olfactory and taste sense) would change. At the same time, assessment of one's physical and mental state was not accurate, and the ability of orientation perception, depth perception and hand-eye coordination were all produced significantly. Although these changes recovered after decompression, they did not immediately return to pre-pressure levels. The study reminded us of the importance of strengthening divers' perception training, so as to form a correct self-assessment, make more accurate judgment of small changes in orientation and distance, pay more attention and have better hand-eye coordination. This was also an important manifestation of the importance of medical support for divers (Fan, 2013).

References

Baddeley A, Idzikowski C.,1985, Anxiety, manual dexterity and diver performance.Ergonomics. 28(10):1475-1482

Dai,J,J., Wang,J,L., Jiang,Z,L., Liu,X,H.,2016, Mental Health and Maintenance of Professional Divers. China Communications Press Co., Ltd.:38.

Fan,Y,Q., Wang,M., Cen,B,H., 2013, Medical Support for Saturated Diving Machines (Part I).People's Military Medical Journal.56(11):1278-1298.

Guo,W,L., He,C,D., Ge,X,H.,1999, Research on depth perception of truck drivers. Ergonomics.5 (3): 10-13.

Hou,G,L., Zhao,N., Chen,R,Y.,2011, Effects of helium and oxygen exposure on maximum grip and hand-eye coordination of divers. Aerospace Medicine and Medical Engineering. 24(2):108-110.

Jiang,Z,L.,2012. NauticalMedicine. Science Publishing Pree, Beijing, China:66-367.

Lewis VJ, Baffeley AD. 1981, Cognitive performance, sleep quality and mood during oxyhelium diving. Ergonomics. 24(10):773-793.

Logie RH, Baddeley AD., 1982, Atrimix saturation dive to 660m studies of cognitive performance, mood and sleep quality. Ergonomics. 26(4):359-374.

Miao,L,Q., Wang,J,L., Dai,J,J.,2015, Rasearch overview and progress of effect of saturation diving on divers' physiological and psychological functions. Chinese Occupational Medicine. 42(6):1-5.

Nagashima H, Matsumoto K, Seo Y, et al.,2002, Sleep patterns during 30-m nitrox saturation dives and in a confined atmospheric environment. Psychiatry ClinNeurosci.

56(3):267-268.

Vaernes R, Bennett PB, Hammerborg D, et al.,1982,Central Nervoussystem reactions during heliox and trimix dives to 31ATA. Undersea Biomedical Research.9(1) : 1-14.