USAARL Report No. 2009-17

Subtle Cognitive Effects of Moderate Hypoxia

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August 2009

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U.S. Army
Aeromedical Research
Laboratory

Human use

Human subjects participated in these studies after giving their free and informed voluntary consent. Investigators adhered to AR 70-25 and USAMRMC Reg 70-25 on Use of Volunteers in Research.

REPORT DOCUMENTATION PAGE	*Form Approved* *OMB No. 0704-0188*

1. REPORT DATE *(DD-MM-YYYY)*: 13-08-2009

2. REPORT TYPE: Final

3. DATES COVERED *(From - To)*:

4. TITLE AND SUBTITLE: Subtle Cognitive Effects of Moderate Hypoxia

5a. CONTRACT NUMBER:

5b. GRANT NUMBER:

5c. PROGRAM ELEMENT NUMBER:

5d. PROJECT NUMBER:

5e. TASK NUMBER:

5f. WORK UNIT NUMBER:

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P.O. Box 620577
Fort Rucker, AL 36362

8. PERFORMING ORGANIZATION REPORT NUMBER: USAARL 2009-17

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U. S. Army Medical Research and Materiel Command
504 Scott Street
Fort Detrick, MD 21702

10. SPONSOR/MONITOR'S ACRONYM(S): USAMRMC

11. SPONSOR/MONITOR'S REPORT NUMBER(S):

12. DISTRIBUTION/AVAILABILITY STATEMENT
Approved for public released; distribution unlimited.

13. SUPPLEMENTARY NOTES

14. ABSTRACT
Increasing worldwide concern over the effects of moderate altitude exposure on aircrew performance in unpressurized aircraft recently prompted efforts to formulate international standards for the use of supplementary oxygen. The purpose of this study was to assess the impact of low to moderate levels of hypoxic hypoxia on the performance of aircrew personnel. Fifty subjects were exposed in a randomized controlled fashion to 45-min exposures at each altitude (sea level, 8000, 10,000, 12,000 and 14,000 ft) simulated by the ROBD. During the latter part of the exposure the subjects completed the CogScreen®-HE to measure their cognitive performance. Saturation of Peripheral Oxygen (SpO2) analysis showed that although the subjects did become hypoxic (p<001), there was not statistically significant change in reaction time (p=.781), accuracy (p=.152), or throughout (p=.967) with increasing altitude. The results indicate that healthy individuals aged 19 to 45 years do not experience significant cognitive deficit, as measured by the CogScreen®-HE, when exposed to moderate levels of hypoxia for exposure times of 45 min at various altitudes.

15. SUBJECT TERMS
hypoxia, cognitive deficit, ROBD, CogScreen®-HE

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
UNCLAS	UNCLAS	UNCLAS	SAR	27	Loraine Parish St. Onge, Ph.D.

19b. TELEPHONE NUMBER *(Include area code)*: 334-255-6906

Reset

Acknowledgements

The authors would like to express their sincere gratitude to the following people for their contributions to this project. This was a complex effort requiring much coordination and teamwork all done to a challenging schedule. Without the participation of the following people this project would not have succeeded.

- COL Robert Noback, Dean of the United States School of Aviation Medicine (USASAM).
- MAJ Mike Mendenhall, Chief of USASAM Physiology Section for his help in providing facilities.
- SSG Thomas J. Rath, Atmospherics NCO, USASAM for his technical expertise in both the ROBD and the effects of hypoxia.
- SPC Navdeep Saini for unstinting effort in completing the project on time.
- Mr. Bradley Erickson for advice and technical acquisition.
- Dr. Loraine St. Onge for her editorial assistance and expertise.
- Dr. John Crowley and Dr. Art Estrada for their editorial guidance.

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Introduction and military significance

Due to recent rotary-wing accidents in the current theatre of military operations, there is increasing worldwide concern over the effects of moderate altitude exposure in unpressurized aircraft. To address this issue, efforts have recently been made to formulate international standards for the use of supplementary oxygen (Air and Space Interoperability Council, n.d.). Hypoxic hypoxia occurs when an individual is exposed to high altitudes and the body is deprived of an adequate supply of oxygen, and the partial pressure of oxygen (PO_2) of the arterial blood is reduced. Research findings led to a common assumption that aircrew could function perfectly well at altitudes up to 12,000 ft and even higher for limited periods (Bahrke and Shukitt-Hale, 1993; Reed, Youngs, and Kandid, 1994). Ernsting et al. maintain that ascent to 10,000 feet (ft) produces no hypoxia symptoms in resting individuals (1978). However, there is growing concern that hypoxia at moderate altitudes may cause cognitive deficits.

Operational necessity intensifies the effects of hypoxia at moderate altitudes because military personnel are routinely required to transition quickly to, and operate in, a wide range of altitudes. With air transport, personnel can be moved from sea level to over 10,000 ft in a few minutes, a far shorter time than required for acclimatization. In a recent survey of Australian helicopter aircrew, approximately 75% of physically active helicopter aircrew who returned surveys reported experiencing at least one hypoxic symptom during flight between 8,000 and 10,000 ft (Smith, 2005). The surveys also showed non-pilot aircrew reported a significantly higher number of hypoxia symptoms than pilots. A follow-up study demonstrated that hypoxia experienced at about 10,000 ft may be exacerbated greatly by physical exertion typical of the duties of aircrew personnel (Smith, 2006). These studies found hypoxia effects at altitudes previously thought to be too low for significant concern.

Table 1.
Symptoms of hypoxia from U.S. Army Aeromedical Training Manual (Department of the Army, 2000).

Altitude (thousands feet)	0 - 10	10 - 15	15 - 20	20 - 25
Estimated Arterial Oxygen Saturation	99 – 90%	89 – 80%	79 – 70%	69 – 60%
Symptoms	Decrease in night vision.	Drowsiness. Poor judgment. Impaired – coordination, Efficiency.	Impaired - flight control, handwriting, speech, vision, judgment. Decreased – Coordination, memory, sensation to pain.	Circulatory failure. CNS failure. Convulsions. Cardiovascular collapse. Death.

The crews of U.S. Army rotary wing aircraft on operations around the world are exposed to repeated incidences of moderate altitude (up to 18,000 ft). The current flight regulations (Headquarters, Department of the Army, 2008) list the following requirements for flight at altitude:

"Approved oxygen systems will be used as follows:

Unpressurized aircraft

Oxygen will be used by aircraft crews and occupants for flights as shown below:

Aircraft crews.
(1) On flights above 10,000 feet pressure altitude for more than one hour.
(2) On flights above 12,000 feet pressure altitude for more than 30 minutes.
b. Aircraft crews and all other occupants.
(1) On flights above 14,000 feet pressure altitude for any period of time.
(2) For flights above 18,000 feet pressure altitude, oxygen pre-breathing will be accomplished by aircrew members. Pre-breathing may utilize either 100 percent gaseous aviator's oxygen from a high pressure source, or an onboard oxygen generating system (OBOGS) that supplies at least 90 percent oxygen in the inspired gas. Pre-breathing will be for not less than 30 minutes at ground level and will continue while en route to altitude. In those extraordinary cases where mission requirements dictate rapid ascent, commanders may authorize shorter pre-breathing times on a case-by-case basis, with the realization that such practice increases the risk for developing altitude decompression illness. Return to normal oxygen (pressure demand regulator, gaseous oxygen-equipped aircraft) is authorized on descent below 18,000 feet pressure altitude, provided continued flight will not exceed this altitude."

A recent study demonstrated slight but statistically significant decrements in the cognitive performance of resting individuals for 20-minute (min) exposures at 12,000 ft (Balldin, Hickey, Sundstrom, Pilmanis, and Doan, 2006). To date, most of the literature has assessed gross cognitive change after multiple hours of exposure (Shukitt, Burse, Banderet, Knight, and Cymerman, 1988; Balldin, Tutt, and Dart, 2007) whereas a majority of the current studies focus on subtle changes in cognition. This research tested the hypothesis that hypoxia at moderate altitudes degrades cognitive performance as measured by the CogScreen®-Hypoxia Edition (Rice, Moore, Moore, and Kay, 2003; Rice, Moore, Jernigan, Moore, Clemons, Rife, and Kay, 2005; Rice, Moore, and Vacchiano, in press). A concern was the possibility that the CogScreen®-Hypoxia Edition (CogScreen®-HE) might not be sufficiently sensitive to the subtle effects reported at lower altitudes (<15,000 ft) as in the studies by Rice et al. (2003), Rice et al. (in press), and Rice et al. (2005).

A major aim of this study was to expose subjects to moderate levels of hypoxia in smaller increments than previous studies in an attempt to assess whether there is a gradual change in cognitive functions with increasing altitude. This information may more accurately inform policy and countermeasure strategies. The overall purpose of this study was to assess the impact of low to moderate levels of hypoxic hypoxia on the cognitive performance of aircrew personnel.

Methods

The study was a within-subjects repeated measures design and was conducted by the U.S. Army Aeromedical Research Laboratory (USAARL) personnel with logistical and technical assistance from the U.S. Army School of Aviation Medicine (USASAM). Fifty subjects were evaluated during the study and each subject was exposed to each of five simulated altitudes; sea level, 8,000, 10,000, 12,000 and 14,000 ft, at rest, whilst conducting a cognitive test battery. The research intervention or independent variable that the research volunteers experienced was a condition of hypoxic hypoxia that simulates the amount of oxygen in the atmosphere at defined altitudes. These hypoxic conditions were generated with a Reduced Oxygen Breathing Device (ROBD) described in appendix A. The ROBD is a portable, computerized, gas-blending instrument that produces hypoxia without changes in atmospheric pressure. It uses thermal mass flow controllers (MFC) to mix breathable air and medical nitrogen to produce the equivalent atmospheric oxygen partial pressures for altitudes up to 34,000 ft. The MFCs are calibrated on a primary flow standard traceable to the National Institutes of Standards and Technology.

The ROBD was developed by the Naval Aerospace Medical Research Laboratory (NAMRL) and is now marketed commercially by Environics for aviation training and for research purposes. The ROBD enables individuals to be safely made hypoxic, without risk of barotrauma and decompression illness under controlled conditions in such a way that these individuals can engage in the performance-based testing procedures described below that are the dependent measures for this study. The ROBD is now routinely used by the Army and the Navy for refresher altitude training for aircrew personnel.

The ROBD provides:

- Simulation of 0 to 34,000 ft elevation,
- 21% to 4.4% oxygen,
- An integrated pulse oximeter,
- An integrated oxygen analyzer, and
- An emergency oxygen dump switch for essentially instantaneous delivery of 100% oxygen.

Inclusion and exclusion criteria

The volunteers were drawn from the pool of Army aviators, student aviators, or individuals waiting to begin Army flight training. The participants were aged 19 to 45 years. Pregnant individuals were excluded from the present study due to the remote possibility of unforeseen complications that might adversely affect the fetus. To limit the effect of any confounding variables, participants were disqualified if they had a history of drug abuse or addiction and if they drank more than ten beers per week or eight glasses wine or eight mixed drinks per week.

Sample size

Power is defined as 1-p, and represents the probability of rejecting the null hypothesis when that hypothesis is false. The generally accepted benchmark for power in experimental research is

0.80 (i.e., an 80% chance of rejecting a false null hypothesis). Assuming our dependent measures were sensitive to hypoxia, which is tantamount to saying that hypoxia will have an effect, we estimated that 50 volunteers would be sufficient to test the hypotheses over four levels of hypoxia with a power of .80, and a 0.05 level of significance (Keppel, and Wickens, 2004). Each subject experienced all altitudes, and altitudes were counterbalanced with randomized presentations to eliminate any possible order effects.

Experimental design

The study was a within-subjects repeated measures design in which 50 Soldiers were exposed to each of five simulated altitudes (i.e., sea level, 8000, 10,000, 12,000, and 14,000 ft) while wearing a pulse oximeter to measure saturation of peripheral oxygen (SpO_2). Any possible order effect was prevented by blinding of the subject to the simulated altitude to which they were exposed. These altitudes were assigned to the subjects in a semi-random fashion to ensure that the final totals of each altitude in each order were the same.

The purpose of recording SpO_2 was to ensure acclimation occurred at each altitude before cognitive testing started. The independent variable was altitude, as generated by the ROBD, and the dependent variable was performance on the CogScreen®-HE.

Cognitive tests

CogScreen®-Aeromedical Edition (CogScreen®-AE) was designed for the Federal Aviation Administration (FAA) to detect subtle changes in cognitive functioning by, "rapidly assessing deficits or changes in attention, immediate- and short-term memory, visual-perceptual functions, sequencing functions, logical problem solving, calculation skills, reaction time, simultaneous information processing abilities, and executive functions" (Kay, 1995).

The CogScreen®-HE is a shortened version of the CogScreen®-AE specifically designed for detecting changes in cognitive functioning due to hypoxia. The CogScreen®-HE's touch-pen technology delivers rapid, non-invasive, validated, and sensitive cognitive tests that are appropriate for repeated measures testing. The CogScreen®-HE presents four subtests, visual sequence comparison, divided attention test, pathfinder combined, and matching to sample, which takes ten minutes. The program administers the subtests three times resulting in a thirty min testing session. Following test completion, the CogScreen®-HE provides several performance scores derived from the four subtests. For the purpose of this study, only reaction time, accuracy and throughput (number of correct responses per minutes) were used.

Procedure

Data were collected on a single day for each volunteer. Upon arrival to USASAM, participants read and signed informed consent forms and were given the opportunity to ask the researchers questions. Participants then spent approximately 1 hour training and practicing the CogScreen®-HE. The practice session did not involve exposures to any altitude other than ambient room air (roughly 350 ft above sea level). Practice sessions ensured that test performance was asymptotic and that the measurements were made with maximum efficiency.

Following training, individuals were exposed to the five hypoxic conditions. The exposures were presented in pseudo-randomized, blinded order and consisted of: sea level, 8000, 10,000, 12,000 and 14,000 ft mean sea level (MSL). The exposures simulated flight at altitude and lasted for 45 minutes total. The 45 min was broken down into 15 min at rest to equilibrate to the altitude and 30 min for completing the CogScreen®-HE. After each exposure to altitude, volunteers rested for 15 min, breathing ambient room air (350 ft MSL), before starting the next altitude condition. Table 2 describes participants' schedules during their participation in the experiment.

Table 2.
Testing itinerary.

Time	**Activity**
08:00	In-Processing and Informed Consent
08:30	CogScreen®-HE Practice
09:00	Hypoxia Condition 1* and Cognitive Testing
10:00	Hypoxia Condition 2* and Cognitive Testing
11:00	Lunch
12:00	Hypoxia Condition 3* and Cognitive Testing
01:00	Hypoxia Condition 4* and Cognitive Testing
02:00	Hypoxia Condition 5*and Cognitive Testing
03:00	Out-Processing and Release

*Note: The hypoxia conditions (i.e., sea level, 8,000, 10,000, 12,000, and 14,000 ft) were randomly presented to each participant.

Because the U.S. Army and FAA guidance places no limitation on the duration of altitude exposures to non-required aircrew for altitudes less than 14,000 ft MSL, we placed no duration limit for testing at the specified altitudes. In the event that a volunteer's peripheral arterial oxygen saturation fell below 70%, oxygen would be increased to the equivalent of 13,000 ft to safeguard the health of the participant. This procedure was not required as all participants maintained their oxygen saturation above 70%.

Results

All statistical analyses were performed using SPSS® 13.0 with significance set at an alpha level of .05 for all statistical tests. A repeated measures analysis of variance (ANOVA) was conducted to evaluate the impact of altitude on SpO_2. Saturation of peripheral oxygen declined with increasing simulated altitude, $F(2.220, 108.77) = 155.675$, $p < .001$, with the Greenhouse-

Geisser correction. These findings confirm the efficacy of the ROBD system and that participants were, indeed, hypoxic. Follow-up results that emerged using paired samples *t*-tests confirmed significance ($p < .001$) at all levels of altitude.

Repeated measures ANOVA were conducted to evaluate the impact of altitude on cognitive performance, as measured by the CogScreen®-HE. The dependent variables were reaction time, accuracy, and throughput as measured by the CogScreen®-HE. No significant effect was found between altitude and reaction time, $F(4,192) = .437$, $p = .781$ (figure 1). Likewise, a non-significant effect emerged for altitude and accuracy, with a Greenhouse-Geisser correction, $F(2.193, 105.245) = 1.889$, $p = .152$ (figure 2). No significant effect was found between altitude and throughput, $F(4,192) = .140$, $p = .967$ (figure 3).

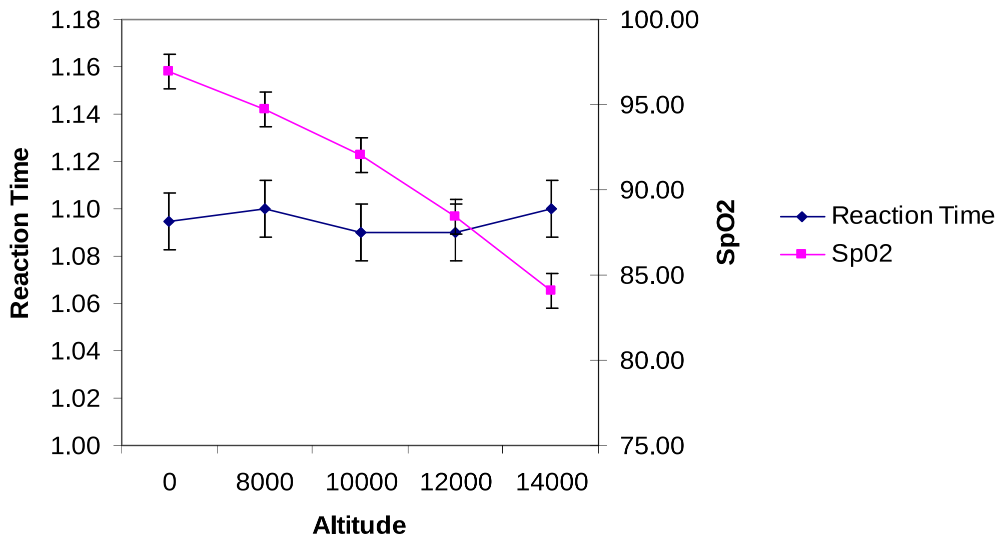

Figure 1. Graphical representation of the relationship between reaction time, SpO_2 and altitude. Standard error bars for each mean are also shown.

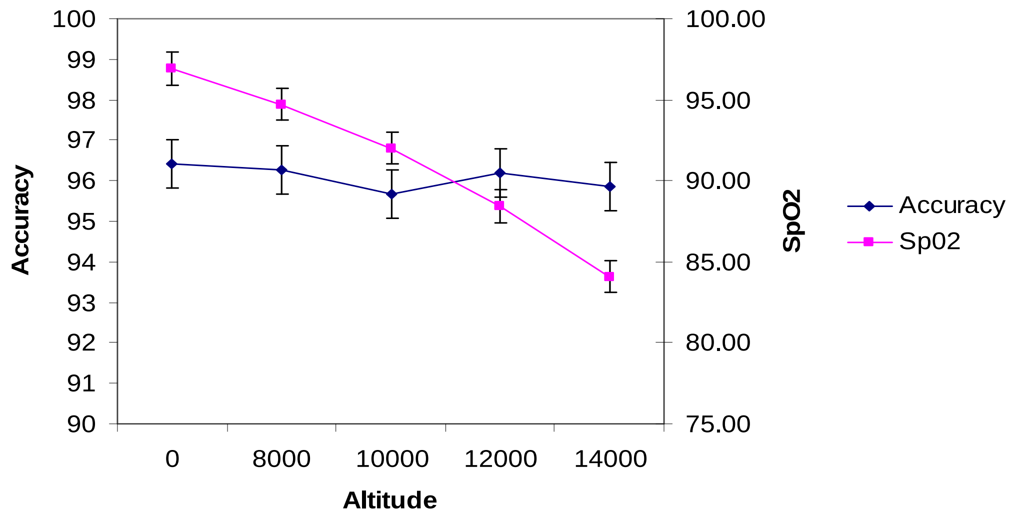

Figure 2. Graphical representation of the relationship between accuracy, SpO_2 and altitude. Standard error bars for each mean are also shown.

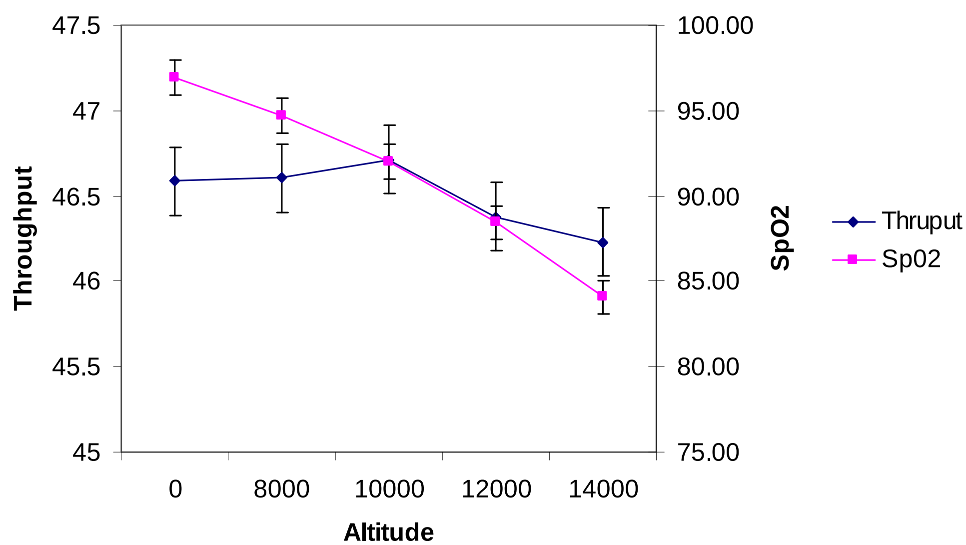

Figure 3. Graphical representation of the relationship between throughput, SpO_2 and altitude. Standard error bars for each mean are also shown.

Discussion

Results from this study did not support the original hypothesis that moderate hypoxia (8,000 to 14,000 ft) would significantly decrease cognitive performance as measured by the CogScreen®-HE. These findings may be due to this specific cognitive test battery not being sensitive enough to detect extremely subtle changes in performance due to low altitude hypoxia, although the battery has been validated in other studies (Rice, Moore, Moore, and Kay, 2003, and Rice, Moore, and Vacchiano, in press). Rice et al. (in press) found the CogScreen®-HE sensitive enough to detect cognitive changes due to hypoxia at 15,000 ft; however, these changes were only detected in certain 8 min segments of the Sequence Comparison and Vigilance subtests. In a separate study, Rice et al. (2005) used the CogScreen®-HE to estimate the altitude at which cognition degradation occurs. Sixty resting aviators' scores at 10,000 ft, 12,000 ft, and 15,000 ft were compared to their baseline scores. The only significant finding was in accuracy during the Vigilance subtest for 15,000 ft and the baseline scores ($p = 0.012$). Analysis of reaction time and accuracy indicated no significant differences. The combination of the current study's findings and the other studies' that utilized the CogScreen®-HE suggest the test may not be sensitive to cognitive changes at lower altitudes (< 15,000 ft). Further research is needed to determine at what specific altitudes the CogScreen®-HE is able to detect cognitive degradation.

Another possible explanation for the lack of significance is that participants were given a practice session. Hypoxia is known to affect the learning process, and because participants were given a practice session before testing began, the CogScreen HE® tasks were no longer novel. Denison, Ledwith, and Poulton (1966) attributed increased reaction time in exercising subjects, at 8,000 ft, to task novelty. Denison found participants who had a practice session at sea level on the Manikin test performed better at 8,000 ft than those participants who did not have a practice session. Similarly, Kelman and Crow found that impairment of mental performance, as measured by a vigilance task, occurred at 8,000 ft (1969). However, subsequent studies by Fowler et al., using the same study design as Denison, failed to demonstrate learning difficulties up to 12,000 ft (1985). Figarola and Billings (1966) found no impairment on practiced tracking and vigilance tasks at 8,000 ft; however, they did find performance decrements at 17,000 ft. In a study on both resting and exercising participants, Paul and Fraser (1994) found that the ability to learn new tasks is not impaired by mild hypoxia at altitudes up to 12,000 ft.

In addition, perhaps the critical altitude which causes marked performance decrements was not reached in this study. According to Nelson (1982), the decisive altitude for changes in higher cognitive functioning lies between 4000 and 5000 meters (13,123 ft and 16,404 ft, respectively). Even at 4500 meters (14,764 ft), Pavlicek et. al. (2005) found no significant difference in word fluency, word association, or lateralized lexical decision performances. In addition, Schlaepfer, Bartsch, and Fisch (1992), found that mild hypoxia improved visual perception in healthy individuals. If a testing session at 15,000 ft, for example, had been added to the experiment and significance was found at that altitude, the experimenters would not only know that the CogScreen®-HE was sensitive enough to detect changes in performance due to hypoxia, but it would show that, on certain tasks, performance was not negatively impacted by moderate hypoxia (8,000ft to 14,000 ft).

Many studies on moderate altitude hypoxia merely record cognitive performance, and not subjective symptoms experienced at altitude. Some of the participants reported experiencing symptoms of hypoxia, particularly at 14,000 ft MSL (e.g., slight light-headedness and minor headaches). Although participants experienced hypoxic symptoms, their cognitive performance on the CogScreen®-HE was not significantly compromised. These reported symptoms came up in conversation between test sessions and were not recorded for later analysis. It is conceivable that, similar to Smith's subjective survey study (2005), levels of hypoxia assessed in the present study may solely impact the psychological perception of hypoxia and not the measurable, objective consequences. Further research is needed to compare both the perception of hypoxic symptoms to objective decrements in cognitive performance.

Crewmembers in the cabin of the aircraft are rarely stationary and the cognitive effects of moderate altitude may be exacerbated by increased heart rate due to physical movement often required of flight medics and crew chiefs. Physical exertion accelerates the onset of hypoxia and lowers the altitude at which symptoms occur. Paul and Fraser (1994) found exercising subjects' reaction time to be slower on the Manikin task than resting subjects. Smith (2005) surveyed Australian Army helicopter pilots and found 60% of non-pilot aircrew reported experiencing four or more hypoxic symptoms, compared to only 17% of pilots. The most common symptoms experienced were light-headedness (37.7%), calculation (45.3%), and reaction time (37.7%). Further research is needed to examine the how physical exertion affects cognitive performance at moderate altitudes.

Conclusion

These results suggest that current Army standards regulating supplemental oxygen use sufficiently protect against hypoxia in the helicopter cockpit. Recall that AR 95-1 (Headquarters, Department of the Army, 2008) requires aircraft crews at 10,000 ft during flights longer than 1 hr to use oxygen; flights above 12,000 ft longer than 30 min to use oxygen, and during flights above 14,000 ft for any period of time to use oxygen. In conclusion, healthy individuals aged 19 to 45 years did not experience any significant cognitive deficits as measured by the CogScreen®-HE when exposed to moderate levels of hypoxia for up to 1 hour.

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Appendix A.

ROBD-2 Description.

Product Data
Series 6202
Reduced Oxygen Breathing Device

Licensed from U.S. Navy under U.S. Patent Application No. 10/959.764

DESCRIPTION

The Environics® Series 6202 Reduced Oxygen Breathing Device 2 (ROBD 2), is a portable computerized gas-blending instrument used to produce hypoxia without changes in atmospheric pressure. This simulated altitude exposure can be utilized for both research and training purposes. The U. S. Navy currently uses the ROBD 2 to train aircrew to recognize the signs and symptoms of hypoxia and to perform the appropriate emergency procedures and additionally, conducts hypoxia research.

The ROBD 2 uses Thermal Mass Flow Controllers (MFC) to mix breathing air and nitrogen to produce the sea level equivalent atmospheric oxygen contents for altitudes up to 34,000 feet. The MFC’s are calibrated on a primary flow standard traceable to the National Institute of Standards and Technology (NIST). The ROBD 2 introduces pressure changes and gas expansion as a function of altitude. Several safety features are built into the device: prevention of over pressurization of the subject’s mask, prevention of reduced oxygen contents below those being requested for a particular altitude and an emergency dump switch that will supply 100% O2 to subjects. The software is menu driven.

The main operators menu consists of three selections, simplifying the use of the system for the field operator. Built-in self-tests verify all system component functionality before the operation of the system can begin. If any self-test fails the system will not operate. The system is designed to work with both bottled gases and gases produced by a Nitrogen/Air Generator (available separately).

FEATURES

- 0-34,000 feet elevation
- 21% oxygen to 4.4% oxygen
- Integrated pulse oximeter
- Integrated oxygen analyzer
- Emergency Oxygen dump switch for delivery of 100% oxygen

OPTIONS

- Shipping case with wheels
- Dual stage regulators with braided hoses
- Additional pulse oximeter probes, sensors
- Nitrogen/Air Generator

ROBD APPLICATIONS

- Aircrew training and research

    Application Document: US Navy – Mask-On Hypoxia Training for Tactical Jet Aviators (PDF)

- High altitude training and research
- Medical stress testing
- Hypoxia Simulator

SPECIFICATIONS
Power Input: 110 to 240 VAC
EMI / RFI protected

Gas inputs:

Standard: ¼” FNPT

Pressure: Nitrogen and air: 40 psig
Oxygen: 20 psig

Optional: Rear panel quick disconnect fittings with SS braided hoses and regulators

Regulator fittings Gas input color codes
Nitrogen: CGA 580 (BLACK)
Air: CGA 346 (YELLOW)
Oxygen: CGA 540 (GREEN)

Communications: RS232

Capacity: One Subject Under Test (SUT) at a time.

Oxygen Dump: 100% oxygen dump switch to be activated by the operator.

Pulse oximeter:
Built in displays for both pulse and SpO2
User selectable alarm settings
Finger tip probe or Y sensor with ear clips

SpO2 (Oxygen Saturation)
Range: 0-100%
Accuracy: (for 1 standard deviation or 68% of sample distribution)
+/- 2% SpO2 (for 80-100% SpO2)
Unspecified for 0-79%
Display Resolution: 1%

Pulse Rate
Range: 30-250 beats per minute (bpm)
Accuracy: +/- 1% of full scale (for 1 standard deviation or 68% of sample distribution)
Display Resolution: 1 bpm

Oxygen sensor:
Range: 1 – 100% oxygen
Accuracy: Less than +/- 1.0% oxygen at constant temperature and pressure
(when calibrated in air and 100% oxygen)
Resolution: 0.1% oxygen

Output range: User programmable for altitude / oxygen concentration and duration at each step

Altitude range: 0 ft (21% oxygen) to 34,000 ft (4.4% oxygen)
Incremental adjustment of altitude: 1 foot
Maximum ascent/descent rate: 60,000 feet per minute

Minimum ascent/descent rate: 1 foot per minute

Breathing mask connector: MS 22058-2

Dimensions:
Height: 12.0” (30.48 cm)
Width: 17.5” (44.45 cm)
Length: 23.5” (59.69 cm)

Weight: 55 lbs (20.4 kg)

Electrical Requirements:
Voltage: 110-240 VAC (+/- 10%), 50/60 HZ
Power consumption: 55 watts

Performance Temperatures:
15° C to 35° C

Storage Temperature Range
-10° C to 50° C

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Appendix B.

Subtest tables.

Reaction time subtests

	Mean	SD	Sig.
VSCRTC			.393
0 ft	1.6152	0.4337	
8000 ft	1.6236	0.4387	
10000 ft	1.5594	0.3917	
12000 ft	1.6042	0.3805	
14000 ft	1.6230	0.4111	
DATIRTC			.434
0 ft	0.3124	0.0585	
8000 ft	0.3212	0.0658	
10000 ft	0.3230	0.0666	
12000 ft	0.3226	0.0735	
14000 ft	0.3252	0.0778	
DATDRTC			.323
0 ft	0.4810	0.1771	
8000 ft	0.4632	0.1327	
10000 ft	0.4952	0.1623	
12000 ft	0.4746	0.1656	
14000 ft	0.4908	0.1574	
DASCRTC			.440
0 ft	1.7684	0.4477	
8000 ft	1.8074	0.4890	
10000 ft	1.7782	0.4748	
12000 ft	1.7506	0.3713	
14000 ft	1.8040	0.4669	

	Mean	SD	Sig.
SDCRTC			.836
0 ft	1.4410	0.2218	
8000 ft	1.4462	0.1698	
10000 ft	1.4296	0.2016	
12000 ft	1.4336	0.1925	
14000 ft	1.4466	0.1779	
PFCRTC			.773
0 ft	0.9538	0.1728	
8000 ft	0.9464	0.2180	
10000 ft	0.9714	0.2093	
12000 ft	0.9520	0.1760	
14000 ft	0.9440	0.1895	
MTSRTC			.088
0 ft	1.0872	0.2234	
8000 ft	1.0678	0.1878	
10000 ft	1.0396	0.1643	
12000 ft	1.0826	0.1898	
14000 ft	1.0792	0.1944	

N = 50; SD = Standard Deviation; Sig. = Significance
VSCRTC = Visual Sequence Comparison Speed; DATIRTC = Divided Attention Task Indicator Alone Speed; DATDRTC = Divided Attention Task Indicator Dual Speed; DASCRTC = Divided Attention Task Sequence Comparison Speed; SDCRTC = Symbol Digit Coding Speed; PFCRTC = Pathfinder Combined Speed; MTSRTC = Matching to Sample Speed

Accuracy subtests

	Mean	SD	Sig.
VSCACC			.396
0 ft	97.5996	2.4486	
8000 ft	97.8660	2.8776	
10000 ft	97.0662	2.7259	
12000 ft	97.6658	2.4097	
14000 ft	97.5324	2.6134	
DATSCACC			.256
0 ft	94.6068	3.3233	
8000 ft	94.6112	2.2319	
10000 ft	93.5880	5.0865	
12000 ft	94.2628	3.2538	
14000 ft	94.5422	3.2112	
SDCACC			.512
0 ft	98.8722	1.3506	
8000 ft	98.6368	2.5653	
10000 ft	98.2318	5.1267	
12000 ft	98.9428	1.6467	
14000 ft	98.6804	1.3105	

	Mean	SD	Sig.
PFCACC			.822
0 ft	97.5410	3.6457	
8000 ft	97.6792	2.4613	
10000 ft	97.3742	3.1094	
12000 ft	97.3876	2.6419	
14000 ft	97.1102	3.4576	
MTSACC			.186
0 ft	93.5166	5.5228	
8000 ft	92.4998	8.2884	
10000 ft	92.0998	7.3510	
12000 ft	92.6498	7.4399	
14000 ft	91.4667	6.5474	

N=50; SD = Standard Deviation; Sig. = Significance
VSCACC = Visual Sequence Comparison Accuracy; Divided Attention Task Sequence Comparison Accuracy; SDCACC = Symbol Digit Coding Accuracy; PFCACC = Pathfinder Combined Accuracy; MTSACC = Matching to Sample Accuracy;

Throughput subtests

	Mean	SD	Sig.
VSCPUT			.567
0 ft	38.8374	9.1125	
8000 ft	38.7406	9.0763	
10000 ft	39.7544	8.6791	
12000 ft	38.5812	8.7453	
14000 ft	38.5536	8.8270	
DASCPUT			.821
0 ft	34.0962	7.5187	
8000 ft	33.4536	7.2257	
10000 ft	33.8254	7.3649	
12000 ft	33.7466	6.2676	
14000 ft	33.5332	7.6622	
SDCPUT			.574
0 ft	42.1362	5.6937	
8000 ft	41.5884	5.0170	
10000 ft	42.1760	6.4073	
12000 ft	42.2426	5.3640	
14000 ft	41.6440	4.9942	

	Mean	SD	Sig.
PFCPUT			.620
0 ft	64.1094	12.2091	
8000 ft	65.4218	14.0373	
10000 ft	63.1166	12.0648	
12000 ft	63.9878	12.2419	
14000 ft	64.6028	12.2427	
MTSPUT			.446
0 ft	53.7510	10.8887	
8000 ft	53.8228	10.8425	
10000 ft	54.6904	9.3475	
12000 ft	53.3378	10.6067	
14000 ft	52.8042	9.8594	

N = 50; SD = Standard Deviation; Sig. = Significance
VSCPUT = Visual Sequence Comparison Thruput; DASCPUT = Divided Attention Task Sequence Comparison Thruput; SDCPUT = Symbol Digit Coding Thruput; PFCPUT = Pathfinder Combined Thruput; MTSPUT = Matching to Sample Thruput

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