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Does the Moderate Altitude Environment Impair the Words of our Memory?

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Authors' contributions

This study was carried out in collaboration with both authors involved. Author RR organised the study and wrote the manuscript. Author NC performed the statistical analyses, revised and corrected the manuscript. Both authors read and approved the final manuscript.

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ABSTRACT

Introduction: It is known that hypoxia affects human physiology and consequently impairs cognitive functions. In particular, low memory performances are common in a hypoxic extreme altitude environment.
Aims: The aim of our study was to evaluate the effects of moderate hypoxia on the specific words of memory and the persisting effects after hypoxia exposure.
Place and Duration of Study: The study was carried out in the Neurophysiology Laboratory in the Department of Neuroscience Imaging and Clinical Science (University of Chieti) in two distinct times: before and after the departure for the Ararat mountain expedition.
Methods: Seven (7) volunteers climbed to a moderate altitude and underwent a cognitive assessment before and after the expedition, by using the 15-Rey Words test. Descriptive statistics (mean and standard deviation) and two tailed t-tests were used. Data were analyzed with STATISTICA-Soft 8.0.
Results: Our results suggested a relevant impairment of words and verbal memory as well as a false recognition of words after the expedition. No significant results were found in the recognition

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of words memorised.
Conclusion: The moderate altitude hypoxia affects the memory of words for one week. In accordance with previous investigations, we could deduct that altitude-hypoxia is an important experimental model to study human cognitive impairment.

Keywords: Verbal memory; word memory; moderate hypoxia; altitude environment.

ABBREVIATIONS

Pre-expedition : before hypoxia, at sea-level.
Post-expedition : after hypoxia exposure, at sea-level.
STVM : short-term verbal memory.
STVM 1° : short-term verbal memory 1st repetition.
STVM 4° : short-term verbal memory 4th repetition.
LTVM : long-term verbal memory.
RMoW : recognition memory of words.
FRoW : false recognitions of words.
SpO_2 : saturation of peripheral oxygen.

1. INTRODUCTION

Altitude is a natural model of hypoxia characterized by a lower oxygen concentration. This condition causes a reduction of oxygenation of the blood and relevant derangement on human physiology [1,2,3] with consequent impairment of the brain function [4]. Frequently, in hypoxic conditions, several climbers reported mood changes [5,6], hallucinatory experiences [7] and cognitive impairment [6,8]. Previous studies highlighted the effects of hypoxia on reaction times and vigilance [9,10] whereas, others showed that altitude-hypoxia affects the visuo-spatial working memory [11], the associative memory [12] as well as verbal fluency [13]. In most cases memory deficits are reversible after return to sea level, when the climber do not reached extreme altitude (8000 m). However, other studies carried out in an extreme environment, showed how memory impairment persists for several days [14,12]. West and Townes observed persistent memory deficit during the course of one year in the participants that took part in the expedition to Mount Everest [15,8]. However, inadequate studies investigated the sub-acute hypoxia effects on word memory, especially at a moderate altitude environment. However, the period of time needed to recover memory functions after a moderate altitude exposure is still unclear. For this reasons we decided to deepen the studies of memory performance at a moderate altitude.

The aim of this study was to investigate the effects of moderate hypoxia on the word memory performance, especially persisting after returning from the expedition.

2. MATERIALS AND METHODS

2.1 Subjects

Seven (7) healthy volunteers (aged 56.86±9.19 years old) climbed to Mount Ararat (5165 m a.s.l. Eastern Turkey) and were selected with an appropriate cognitive assessment, for three days. The criteria which was excluded was: An inappropriate cognitive level and personal history of neuropsychiatric disorders. All seven (7) volunteers were considered eligible to participate in the study. All volunteers were not professional climbers and lived continuously at 250 m a.s.l. Each volunteer was free to interrupt the testing sessions at any time. Each volunteer also read and signed an informed consent form prior to assessment. In this study the small sample of volunteers reflects the peculiar dimensions of the mountain expeditions. All scientific procedures are in accordance with the ethical principles of the Helsinki Declaration 2008.

2.2 Procedures and Instruments

Volunteers underwent cognitive assessment in two distinct times: before hypoxia, at sea-level (pre-expedition, normoxia) and after one week of hypoxia exposure, at sea-level (post-expedition, normoxia) using the 15-Rey Words test [16]. Fifteen (15) words were presented to each volunteer with five repetitions. Volunteers were asked to repeat all the words they remembered (short-term verbal memory, STVM). After fifteen minutes, the volunteers were asked to repeat all the words possible (long-term verbal memory, LTVM) and to recognize all the words which were previously presented (recognition memory of words, RMoW). The number of the false recognition of words (FRoW) was also measured. The raw scores obtained were corrected according to gender, age and education, with the use of the Italian version of the standardized correction tables [16]. The

assessment was carried out in a quiet room, in ideal temperature conditions (20°C). For statistical analysis, two tailed t-tests were used. Data were analyzed by STATISTICA-Soft 8.0. and expressed as mean ± SD. The 'p' level was set at 0.05.

3. RESULTS

After exposure to moderate altitude hypoxia, a significant decrease was found for the STVM mean at post-expedition (34.35±15.18) compared to pre-expedition (40.07±15.80), $t(6) = 2.69$, ($p < 0.05$, unc.), (Fig. 1). In particular, a significant decrease was found for the STVM 1° repetition at post-expedition (2.87±3.19) compared to pre-expedition (4.87±3.39), $t(6) = 4.58$, ($p < 0.05$, Bonferroni's corrected), and for the STVM 4° repetition at post-expedition (8.01±3.86) compared to pre-expedition (9.72±3.21), $t(6) = 2.66$, ($p < 0.05$, unc.), (Fig. 2). A significant decrease was found for the LTVM at post-expedition (8.44±2.08) compared to pre-expedition (10.70±2.17), $t(6) = 2.60$, ($p < 0.05$, unc.), (Fig. 3). Finally, a significant increase was found for the number of FRoW at post-expedition (1.00±1.15) compared to pre-expedition (0.28±0.75), $t(6) = -2.50$. ($p < 0.05$, unc.), (Fig. 4). No significant results were obtained for the RMoW.

4. DISCUSSION

Our study suggested that at a moderate altitude, there was a significant decrement of verbal memory performance. Furthermore, previous studies analysed the close relationship between altitude hypoxia and long-term memory. At a high altitude condition, Virués-Ortega emphasized the difficulty in new information being processed (short-term memory), but not in remembering past events (long-term memory) [17]. Differently, our study evidenced an important reduction of verbal long-term memory after the exposition to altitude hypoxia. These findings appeared to be confirmed by the results of the FRoW performance. Furthermore, a few studies, showed a reduction in the performance of words remembered at altitude level and also for short-term memory [13,18].

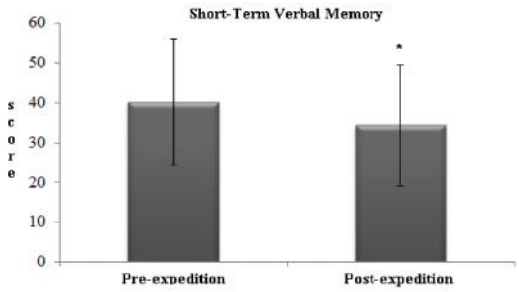

Fig. 1. The histogram shows how the hypoxic moderate altitude environment induces a significant modification on short-term verbal memory after ascendance ($p < 0.05$)

In general, this memory deficit is due to the reduced air oxygen inhaled, following hypoxia exposure, such as the saturation of peripheral oxygen (SpO_2) values previously submitted [11]. Furthermore, several investigations highlighted relevant cognitive impairment related to the reduction of SpO_2 [9,4]. Thus, the present study demonstrates that short and long-term word memory were impaired at a moderate altitude environment. Furthermore, an increase of the number of FRoW was registered.

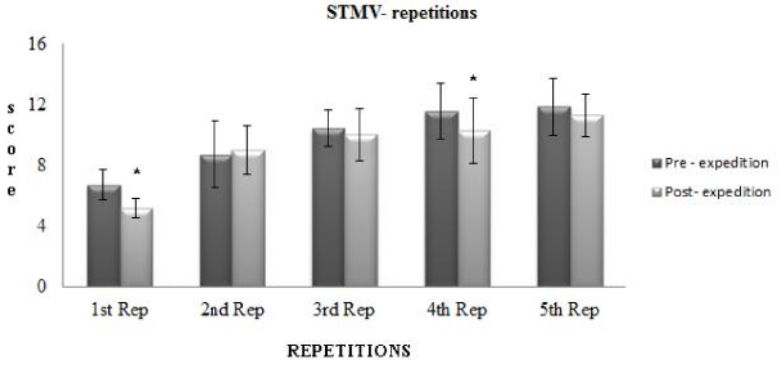

Fig. 2. The histogram shows how the 1° and the 4° repetitions were affected after exposure to an hypoxic moderate altitude environment ($p < 0.05$)

The great interest for the studies on human cognitive performance in a mountain environment, is due to the frequent number of accidents which occur during expeditions, primarily dependent on the irrationality of decision-making of the climbers. In this way, the Air Force paid attention to the new approaches and knowledge concerning the cognitive functioning that was modified by the hypoxic environments, especially to make the subjects ready for risky situations. Furthermore, other fields of study concerning hypoxia are represented by psycho-physic and biomedical research [19,20]. In conclusion, the limitation of the present study is the small number of participants. Usually, mountain expeditions are suitable for teams of just a few climbers given that extreme altitude-environment requires a physical and medical preparations. However, our sample is in line with those used in previous studies. Moreover, the effects of moderate altitude hypoxia on memory function persists after one week exposure. Hypoxia could be considered as an important experimental model to clarify the causes of impairment of several cognitive functions such as memory.

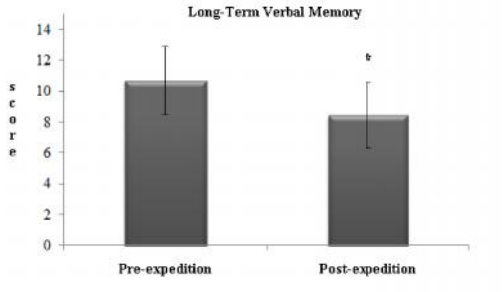

Fig. 3. The histogram shows how the hypoxic moderate altitude environment induces a significant modification on long-term verbal memory after ascendance ($p < 0.05$)

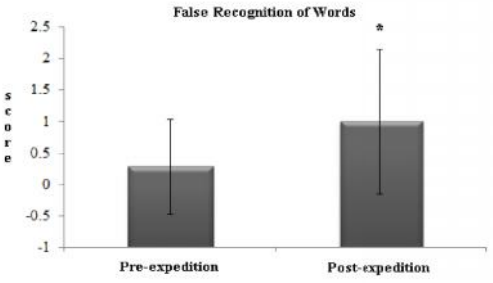

Fig. 4. The histogram shows how the hypoxic moderate altitude environment induces a significant increase of the false recognition of words after ascendance ($p < 0.05$)

5. CONCLUSION

The study represents a new contribution regarding the relationship between hypoxia and cognitive functions, such as, memory functions. Further research is necessary to evaluate the selective role of environmental hypoxia on the cognitive functions.

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COMPETING INTERESTS

The authors declare that the research was conducted in the absence of any commercial or financial relationship that could be construed as potential conflict of interest.

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