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## Conference Paper

# Light Aviation And Flight Safety: Monitoring System For Unpressurised Cabins. Physiological Parameters Monitorization

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# Light Aviation and Flight Safety: Monitoring System for Unpressurised Cabins. Physiological Parameters Monitorization

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**Abstract:** Light aviation pilots are exposed to many different environmental situations due to the non-pressurized and non-acclimatized aircraft cabin. Some of those variations can push the human body to some limits, which associated with psychological factors may culminate in incidents or even fatalities. Actually, a literature review on this theme suggests that a significant part of the incidents and fatalities within the light aviation that uses non-pressurized aircraft cabins are related to the human factor. This analysis might bring up a concealed but significant

and worrying phenomenon in terms of flight safety: changes of pilot performance in the amendment of psychological and physiological parameters concerning to different stress levels and to pressure variations during the various flight stages, respectively. Flying is a growing reality that, although being used mostly for passenger and cargo fast transportation, is sometimes also requested for leisure purposes by a very heterogeneous pool of pilots. This may be a concerning situation due to the disparity of human body reaction between different pilots to the same flight conditions. Nature, both in terms of environmental factors, as pressure and temperature, or in human physiological and psychological behavior during the different flight phases, is unpredictable. Therefore, it is very difficult to establish safety boundaries. This study general objective is to analyze the influence of flight environmental conditions and pilots psychophysiological parameters on task performance, during different flight situations, considering some of his everyday habits. To this end, a statistical analysis, regarding specific questions about the need for pilot's attention monitoring systems, was made, and in parallel, a portable and ergonomic monitoring system was built. This system equipment records cerebral oximetry, to study the phenomenon of hypoxia and its importance, electrocardiography (ECG), and electroencephalography (EEG), in order to establish a correlation between the influence of mental workload and other physiological parameters during different flight stages. The specific purpose of this study is to define physiological limits for each pilot, through simulation tests contemplating different flight scenarios, in order to create an on board alert system to prevent possible incidents. With this research is also intended to suggest that a potential restriction on pilots licensing legislation for light aviation, within physiological limits definitions, would be a positive contribution to a safer flight environment.

**Keywords:** Light Aviation, Non-Pressurized, Non-Acclimatized, Physiological Parameters, Psychological Parameters, Safety Boundaries, Flight Conditions, Monitoring System.

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**F**LYING is a growing reality that, although being used mostly for passenger and cargo fast transportation, is also increasingly requested for leisure purposes by a very heterogeneous pool of pilots. This may be a concerning situation due to the disparity of human body reaction between different pilots to the same flight conditions.

The light aviation and glider pilots are exposed to many different environmental situations due to the non-pressurized and non-acclimatized aircraft cabin. Some of those variations can push the human body to some limits, which associated with psychological factors may culminate in incidents or even fatalities. Nature, both in terms of environmental factors, as pressure, temperature and humidity, or in human physiological and psychological behavior during the different flight phases, is unpredictable. Therefore, it is very difficult to establish safety boundaries.

With increasing altitude, pressure decreases and, consequently, also reduces the oxygen partial pressure. The oxygen partial pressure decrease may cause the Hypoxia phenomenon, which can compromise the pilot's performance and, consequently, the flight safety. Once, each individual both in terms of physiological and psychological characteristics is unique, a standard safe altitude is difficult to establish, because what generally isn't considered a concerning altitude, may be lethal for a pilot who has some, minor but crucial in this situation, lung or heart problems. In low altitude flights, generally, hypoxia will not represent such a major factor to the well trained pilot but plays an important role in the sports or amateur pilot who is not as well trained in such conditions.

Flight safety is a crucial topic in aviation industry; it's a subject that constantly has something to improve, and that it will never be completely optimized, because there will always be, the unpredictable, human and nature factor. This study comes in sequence of a previous work, developed by Rocha [1], in 2011, related to the measurement of pilots' physiological parameters, as brain oximetry, in the study of the hypoxia phenomenon, during ultralight flights. This is a project that came with the challenge of optimize Leandro's work by extending the monitored physiological parameters to the ECG and EEG, and relate them with the pilots everyday habits and the flight environmental conditions, in order to understand how those factors may be relevant in the pilots' flight performance.

Human factors, as awareness of flight physiology, have an essential role in flight safety [2]. However, the international legislations are negligent relatively to training requirements in altitude physiology. The International Civil Aviation Organization (ICAO) and the European Aviation Safety Agency (EASA) do not require any type of ground training in flight physiology. However, Title 14 of the U.S Code of Federal Regulations (CFR), Parts 61.31, states, for pilots, flight instructors and ground instructors, "Additional training required for operating pressurized aircraft capable of operating at high altitudes", with certain exception applied [3]. None of the current international legislations require altitude chamber training (ACT).

As a consequence of Helios Airways Boeing 737-31S accident, at Grammatiko in 2005, the investigation report recommended to EASA and to the Joint Aviation Authorities (JAA), the requirement of practical hypoxia training as a mandatory part of flight crew and cabin crew training [4].

Providing supervised ground training and education, as ACT, would allow the individuals to better recognize their own symptoms. A prior experience in ACT would also increase the recognition of hypoxia and critical reaction time.

The objective of the current study was to collect information from a heterogeneous group of pilots regarding their hypoxia experiences, their hypoxia training backgrounds and their perceptions about its relevancy; and the definition of physiological limits for each pilot, through simulation tests contemplating different flight scenarios, in order to create an on board alert system to prevent possible incidents.

### ***Flight Physiology***

The main constraint of high altitude, lies the fact that, although the percentage of oxygen remains constant up to the stratosphere, the hypoxia phenomenon occurs during the fall of atmospheric pressure and the resulting decrease in partial pressure of oxygen in ambient air and alveolar air, due to the reduction of gas exchange.

The appearance and intensity of the symptoms of hypoxia depend on factors like the speed of ascent, the absolute altitude flight, the duration of exposure to low atmospheric pressure, temperature and individual characteristics such as disease, everyday habits, physical fitness, acclimatization and emotion. Symptoms such as fatigue, drowsiness, dizziness, headache, and euphoria can occur, as also as, when exposed to this phenomenon, vision and hearing become impaired, the reasoning is faulty and may result in loss of memory and slow and uncoordinated reactions, [5] and [6].

To identify the phenomenon, the most widely used procedure consists in monitoring the pulse oximetry, which in turn can be peripheral or cerebral, the latter being addressed in this work.

Fatigue is a very common symptom and frequently associated with pilot error. Some of the effects of fatigue include degradation of attention and concentration, impaired coordination, and decreased ability to communicate. These factors seriously influence the susceptibility to hypoxia and the ability to make effective decisions. Factors such as stress and prolonged performance of cognitive work result in mental fatigue [7].

The high burden of brain activity that may be subject to a pilot during a flight, is a factor that can interfere with heart and respiratory rate, in particular, the appearance of spontaneous fluctuations, derived from reactions caused by various mechanisms / psychophysiological factors,

such as emotions, concentration, decision making, level of responsibility, performing tasks and physical capacity during the entire flight, emphasizing phases as takeoff and landing [8], [9].

## **SURVEY**

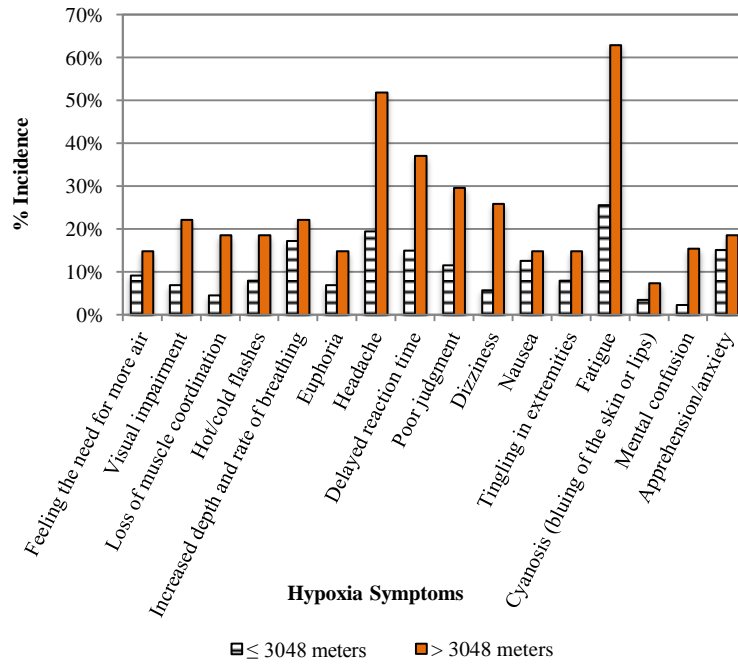
Based on a previously developed survey [1], a statistical analysis, regarding specific questions about the need for pilot's attention monitoring systems, was made. Permission was obtained from the corresponding authors to use the obtained data from April until November of 2011.

### ***Results***

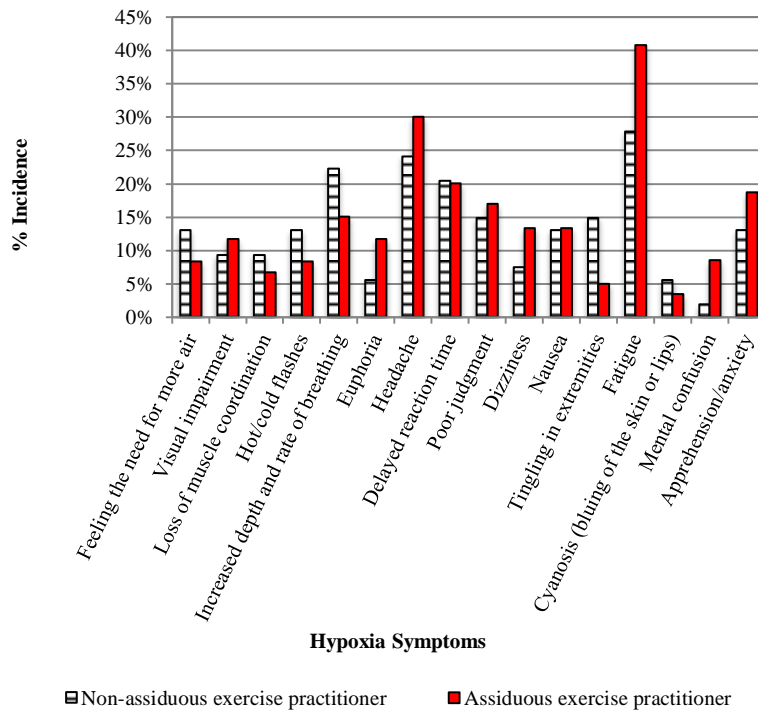
117 pilots, 2 of which were female, completed the survey. Mean age was 42.1 years (min=20yr, max=68yr, SD=13.0). Most respondents were nonsmokers (83%) and exercised assiduously (54%).

Further, 62 (53%) pilots reported having training in hypoxia fundamentals, where 38 (32%) had light aviation license, and 39 (33%) usually flew under 3.048 meters. About 61% took a basic introductory course on hypoxia, without ACT; 26% took an initial ACT, where only one pilot frequently had hypobaric chamber training; and 13% took a recurrent course on hypoxia without ACT. Additionally, of the pilots who had attended hypoxia training, 92% agreed and strongly agreed that the course was informative and addressed topics such as the effects, symptoms of hypoxia and other possible high-altitude sickness. 54 (45%) pilots considered formation/training in the hypoxia useful.

There were two items assessed to the occurrence of hypoxia. Most pilots (95%) stated that had never experienced it and 59% believed that at the environmental and altitude conditions, they usually flew, there are scarce chances of hypoxia. When questioned about hypoxia related symptoms, 38% of pilots (80% usually flew below 3.048 meters), reported having experienced at least one of the asked symptoms (Fig. 1 and Fig. 2).



**Fig. 1.** Percentage of pilots who have felt each one of the various hypoxia symptoms. The pilots sample was divided in those who usually flew under 3.048 meters and those who flew above it.



**Fig. 2.** Percentage of pilots who have felt each one of the various hypoxia symptoms. The pilots sample was divided in those who usually exercise and those who don't.

Furthermore, 48% of the sample population agreed or strongly agreed that all pilots should make recurrent hypoxia training without ACT.

The last two items of the survey aimed to probe the respondents in order to see how far they found relevant the use of a monitoring system, in real time, and whether they would be receptive to its use if it is proven to contribute to flight safety. Hereupon, 75% of the pilots found it useful and 92% affirmed they would use it. Among light aviation pilots these percentages were even more expressive, being 83% and 94%, respectively.

## **MONITORING SYSTEM**

As mentioned above, the current work comes in sequence of Leandro's [1] study where a monitoring system for brain oximetry was tested in ultralight pilots, during real flight conditions.

The adopted equipment, for cerebral oximetry, was the Nonin Medical Inc. Model 7600 Regional Oximetry System, with the two-channel configuration.

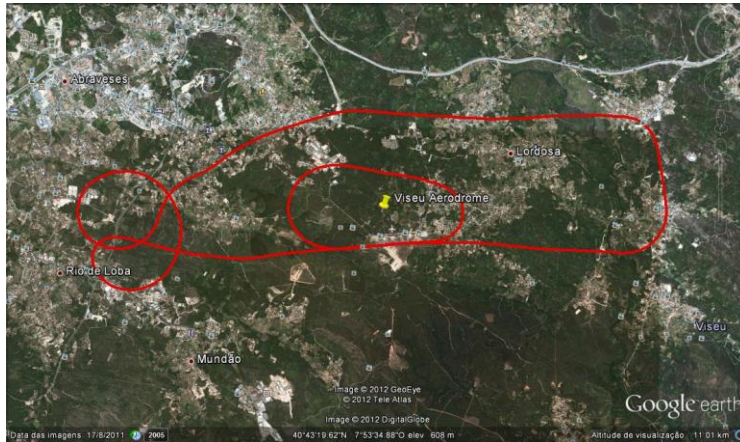
In the current work, in parallel with the brain oximeter, was also assembled a flight data recorder, to record the flight parameters, as trajectory, altitude and G loads. Both equipments were synchronized in the same time scale, to allow the comparison between physiological and flight data.

This system is meant to record cerebral oximetry, to study the phenomenon of hypoxia and its importance, electrocardiography (ECG), and electroencephalography (EEG), in order to establish a correlation between the influence of mental workload and other physiological parameters during different flight stages.

## ***Results***

The experimental flight took place in Viseu, Portugal, on June 13<sup>th</sup> of 2012, in a CZW Sport Cruiser, performed by a 25-year-old male pilot, with 150 hours of flight experience. It had the duration of, approximately, 15 minutes and a maximum altitude of 1.520 meters above sea level (Fig. 3).





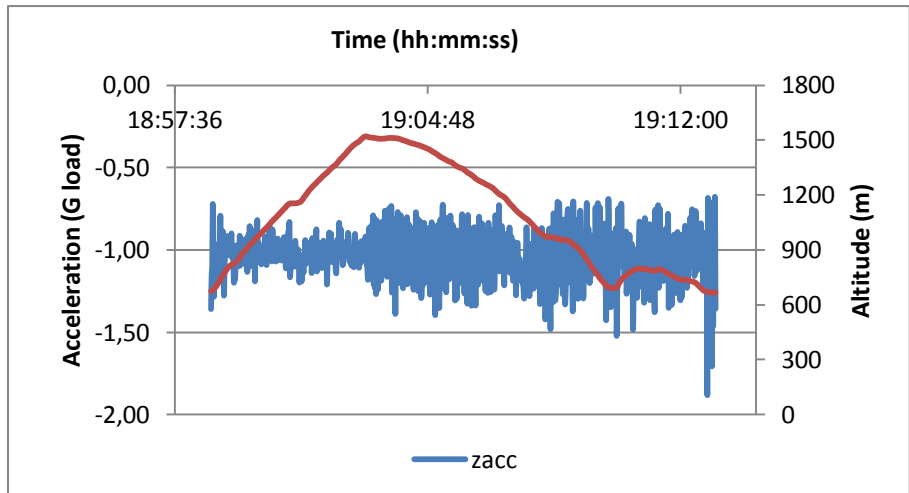
**Fig. 3.** Visu experimental flight route, GPS coordinates.

Each sensor of the Nonin Medical Inc. (Model 700) was placed on the frontal region of each cerebral lobe (Fig. 4).



**Fig. 4.** Nonin Medical Inc. (Model 700) equipment configuration.

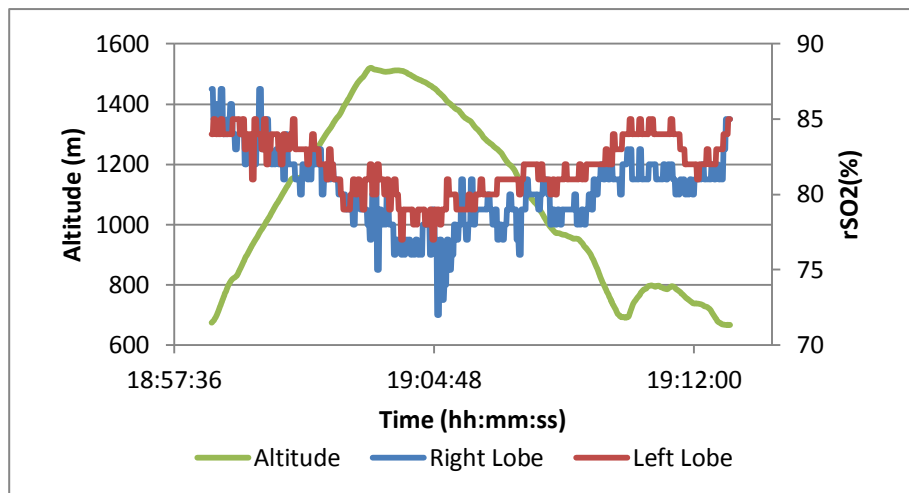
Both climb and descent rates were mild and didn't cause direct high G loads to the pilot. The flight phase where such load was higher occurred at the time of the low pass maneuver (19h09m45s), where the pilot felt about -1.5 G, and the landing stage, about -1.8 G. (Fig. 5)



**Fig. 5.** Altitude and yaw axis acceleration variation during the Viseu experimental flight.

At the beginning of the flight (18h58m38s) the rSO<sub>2</sub> mean value was 86%, which corresponded to the maximum absolute value recorded during the entire test. From that moment, the rSO<sub>2</sub> mean value decreased almost continuously until around 19h04m48s when it reached the absolute minimum of 77%, that, according to the flight data recorder was the approximate moment when the aircraft reaches the highest altitude, about 1.520 meters.

Then, the pilot kept descending until 700 meters where he performed a low pass maneuver. By then, the rSO<sub>2</sub> mean value was about 82%. After this maneuver, he raised the aircraft again, until the 800 meters, and the rSO<sub>2</sub> mean value reached the 84%. When he started the landing procedures (19h10m29s) the rSO<sub>2</sub> mean value decreased to the 81.5% and at 19h11m59s it increased until 85%, as at the beginning of the flight. (Fig. 6)



**Fig. 6.** Cerebral oximetry and altitude variation during the Viseu experimental flight.

## CONCLUSIONS

### *Survey*

Hypoxia is a concerning situation not only for those who fly in pressurized aircraft cabins but also for those who fly under 3.048 meters in unpressurized aircraft cabins. The sample population was constituted by a very heterogeneous pool of pilots, where most of it reported that the majority of the performed flights, in the six months preceding the survey, took place in unpressurized aircraft cabins at a maximum ceiling altitude of 3.048 meters. From this restrict range of pilots was possible to observe that half of them had felt, at least, one of the addressed hypoxia symptoms, but only 44% had received hypoxia training.

The statistical analysis regarding the unpressurized aircraft pilots showed that this particular population is the one that the respondents considered less significant, regarding hypoxia education and training. Although, the lack of education, in the hypoxia subject, demanded for light aviation license combined with each individual values and responsibility shouldn't be neglected, especially in this type of aviation where the legislation is less restrictive and where the accidents/incidents are many.

Two of the key questions of the analyzed survey aimed to evaluate how relevant a physiological monitoring system would be considered important for pilot's flight safety. The results analysis proved that, besides the fact that most of the sample population reported that had never felt any hypoxia symptoms, almost all pilots found this system useful and affirmed to be willing to use it.

Providing education about hypoxia symptoms and how to react before them within a supervised ground location was considered crucial for most of the respondents, with only a few exceptions.

The analyzed survey examined a heterogeneous sample of pilots whose field experiences and perceptions were different, whereby the generalizability of these results should be considered. Once the studied individuals are a small segment and an unbalanced mixture of the entire pilots' population these findings may not generalize to pilots overall. The factors mentioned above could have affected the observations found in the current study.

## *Monitoring System*

From the obtained results, it was observed that, considering the analyzed flight as a mild flight, the direct G loads that the pilot was subject did not exceed the 1.8 G. Apparently, these were not reflected in the values of cerebral oximetry. However, as mentioned above, only one flight has been successfully completed, and it was very harmonious, i.e., without any risk or intense maneuvers.

From the cerebral oximetry analysis, can be seen that both channels (right lobe and left lobe) have slightly different values and that during the flight, some peaks can be observed. These discrepancies are there for even a healthy individual, once the human body is not fully symmetrical and perfect. However, it is believed that the sporadic peak values occur because the pilot isn't at rest and therefore, there is the susceptibility of poor contact by the cerebral oximetry sensors. Although, still, and in the near future these data have to be carefully analyzed by clinical experts in determination of the existence or not of significant changes that constrain the psychophysiological capacity and, consequently, compromise the flight safety.

Upon comparison of cerebral oximetry with the altitude variation, it was observed that the minimum mean value of rSO<sub>2</sub> did not occur when the maximum altitude was reached, as expected, but after a few seconds. Just as when the pilot makes the low pass maneuver, 700 meters of altitude, the mean value of rSO<sub>2</sub> is lower when compared with the value obtained for the 800 meters, a few seconds after the maneuver. Such inconsistencies do not have an apparent justification due to the scarce information available for this type of study. As such, and only as superfluous suggestions, these may be due to either differences of the equipment updating speed or at the physiological level, such as adrenaline or even the reaction time that human body takes to respond to the external environment.

Both equipment, the cerebral oximeter and the flight data recorder, were placed inside the aircraft and as far as possible from the instrument panel, to avoid the motor interference.

During this study there were three experimental flights, where only in the one analyzed in the current article was possible to extract the full data. Due to the uniqueness and innovation of this project part of the hardware and software used were made by us, so that the field work becomes quite time consuming. This was the main reason why wasn't possible to integrate the ECG and EEG equipment on board until the disclosure of this article.

Furthermore, intrinsic to this research are also the hypobaric chamber and the flight simulator tests, which purpose is to improve the physiological performance, when oxygen deprivation, the hypoxia phenomenon, and psychophysiological behavior of the pilot under situations of great responsibility, attention and concentration, respectively.

Flight physiology is a vast field of research, where are many unexplored situations, particularly related to the light aviation, that deserves our best concern, so in order to improve safety for everyone this research intends to answer to some of the international legislation flaws.

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