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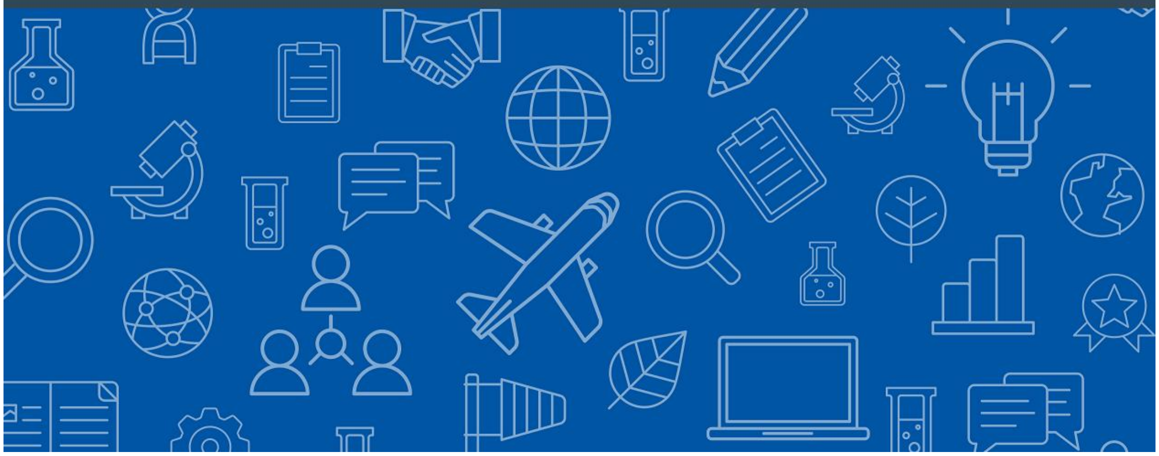

Ultralight Aviation and Hypoxia: Pilot Perspectives on Cerebral Oximetry Monitorization

Sara Zorro, Jorge Silva, Luís Patrão

Synopsis

The current study features collected information from a heterogeneous group of pilots regarding their prior experiences of hypoxia. The study focuses on whether the group of assembled pilots has received hypoxia training and on their perceptions of the trainings relevancy. Also analyzed is whether the installation of a physiological monitoring system would be considered by pilots as being relevant to improving flight safety. A monitoring system for brain oximetry was tested in light aviation pilots during real flight conditions

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ULTRALIGHT AVIATION AND HYPOXIA: PILOTS' PERSPECTIVE AND CEREBRAL OXIMETRY MONITORIZATION

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ABSTRACT

Aim/Purpose:	The general objective of this study is to analyze the relation between flight parameters and cerebral oximetry of the pilot during different flight situations.
Context:	Ultralight aviation pilots are exposed to different environmental situations due to the non-pressurized and non-acclimatized nature of the aircraft cabin. In a flying aircraft, any factor responsible for decreased mental function can result in errors that might threaten the life of the pilot, the passengers onboard and the people on the ground. Hypoxia can be one of those debilitating factors.
Method:	We used a developed survey to analyze specific questions about the hypoxia experiences of pilots and how a physiological monitoring system would be relevant to improving flight safety. Simultaneously, a portable and ergonomic monitoring system was built by the authors and tested on real flight environment. The statistic results show that hypoxia is a concerning situation.
Contribution:	Hypoxia is a serious condition for passengers flying in pressurized aircraft cabins and also for passengers who fly below 3,048 meters in unpressurized aircraft cabins. The results analysis proved that although most of the respondents reported no hypoxia symptoms, the majority of pilots found the physiological monitoring system useful and affirmed a willingness to use it. Providing education about early detection of hypoxia symptoms and how to react was considered crucial for most of the respondents, with only a few exceptions disagreeing on its importance. Comparing the altitude with the cerebral oximetry, we observed that a minimum mean value of regional cerebral oxygen saturation (rSO2) did not occur when the maximum altitude was reached as was expected; instead, it only occurred after a few seconds at a lower altitude.
Findings:	Generally, most of the participating pilots agreed that there is a need for hypoxia education and training for unpressurized aircraft because the existing level of training is not extensive enough. The analyzed experimental flight was a smooth flight. The minimum mean value of regional cerebral oxygen saturation did not occur when the maximum altitude was reached, as it was expected.
Recommendations:	Increase the sample group of pilots, especially the ultralight aviation pilot group. Hypobaric chamber and flight simulator tests should be realized to analyze the psycho-physiological behavior of the pilots when facing stressful situations. Additional flight tests must be done and more physiological parameters should be studied such as heart rate, temperature, sweat, fatigue and cognition.

Keywords: *Ultralight Aviation, Hypoxia, Physiological Parameters, Monitoring System.*

INTRODUCTION

The ultralight aviation pilots are exposed to different environmental situations due to their exposure to non-pressurized and non-acclimatized aircraft cabins. Moreover, when inside a flying aircraft, any factor responsible for decreased mental function can result in errors that might threaten the pilots' lives, passengers, and people on the ground. Nature, both in terms of environmental factors such 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 to occur, which can compromise the pilot's performance and consequently the flight safety. Every pilot in terms of physiological and psychological characteristics is unique. Therefore, an altitude that is generally not considered dangerous may be lethal for a pilot who has lung or heart problems. In low altitude flights, hypoxia generally is not a problem to the well-trained pilots. However, it plays an important role in the performance of the ultralight pilots who are not as well trained. Flight safety is a crucial topic in aviation; there is always something to improve due to the unpredictable human and nature factor. This study comes in sequence of a previous work by (Rocha, 2011) related to the measurement of physiological parameters, as brain oximetry, in the study of the hypoxia phenomenon, during ultralight flights. Human factors and awareness of flight physiology have an essential role in flight safety (Reinhart,1999). However, international legislation is negligent relative 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. While Title 14 of the US Code of Federal Regulations (CFR)Part 61.31, states that pilots, flight instructors and ground instructors "Additional training required for operating pressurized aircraft capable of operating at high altitudes", with certain exceptions applied **Invalid source specified.**. None of the current international legislations require for altitude chamber training (ACT).

As a consequence of the Helios Airways Boeing 737-31S accident that took place in Grammatiko in 2005, the investigation report recommended to EASA and to the Joint Aviation Authorities (JAA), a requirement of practical hypoxia training as a mandatory part of flight crew and cabin crew training (Hellenic Republic Ministry of Transport and Communication, 2012). Providing supervised ground training and education such as ACT, would allow individuals to better recognize their own symptoms. ACT training would also increase the recognition of hypoxia and improve critical reaction time. The objective of the current study was to collect information from a heterogeneous group of pilots regarding their hypoxia experiences and to inquire about their hypoxia training backgrounds and perceptions about its relevancy. In this project, we also intended to analyze how a physiological monitoring system would be considered relevant, from pilot's perspective, to improving flight safety.

FLIGHT PHYSIOLOGY

Hypoxia is defined as a diminished amount of oxygen in organ tissues, regardless of whether it is symptomatic. It is an important concept in aviation because, as altitude increases, absolute atmospheric pressure drops, leading to less oxygen being available to breathe. One can then easily conclude that if there is less oxygen available, less oxygen will be transferred from the lungs to blood. Hypoxia can affect pilots' performance directly due to lack of cerebral oxygen and indirectly because of the signs and symptoms that are associated with it. The appearance and intensity of the symptoms of hypoxia depend on factors like the speed of ascent, absolute altitude flight, duration of exposure to low atmospheric pressure, temperature and pilot's individual factors such as disease, everyday habits, physical fitness and stress. Symptoms such as fatigue, drowsiness, dizziness, headache, and euphoria can also occur when exposed to low pressures. The reasoning is faulty and may result in loss of memory sluggishness and uncoordinated reactions (Alves, 2008) and (Thomas, 2002). To identify hypoxia, the most widely used procedure involves monitoring the pulse oximetry, which in turn can be peripheral or cerebral; the latter is addressed in this article.

Fatigue is a very common symptom that is frequently associated with pilot error. Some of the effects of fatigue include the degradation of attention, concentration, coordination, and a decreased ability to communicate. These factors seriously influence pilot susceptibility to hypoxia and the ability to make effective decisions. Factors such as stress and prolonged performance of cognitive work will result in mental fatigue (US Department of Transportation, Federal Aviation and Administration, 2009). The high burden of brain activity that a pilot is subjected to during a flight is a factor that can interfere with heart and respiratory rate particularly in 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 (Roscoe, 1992) and (Sayers,1971).

METHODOLOGY

SURVEY

Based on a previously developed survey by (Rocha, 2011), a statistical analysis regarding specific questions on the need for pilot attention monitoring systems was conducted. Permission was obtained from the corresponding authors to use the obtained data from April until November of 2011. For analysis purposes, ultralight, microlight and glider pilots were considered as ultralight aviation pilots.

RESULTS

One hundred and seventeen pilots, two of whom were female completed the survey. Mean age was 42.1 years (min=20yr, max=68yr, SD=13.0). Most respondents were non-smokers (83%) and exercised assiduously (54%). Piloting license distribution was the following: ultralight aviation (70%), commercial (27%), airline (21%), and flight instructor (13%).

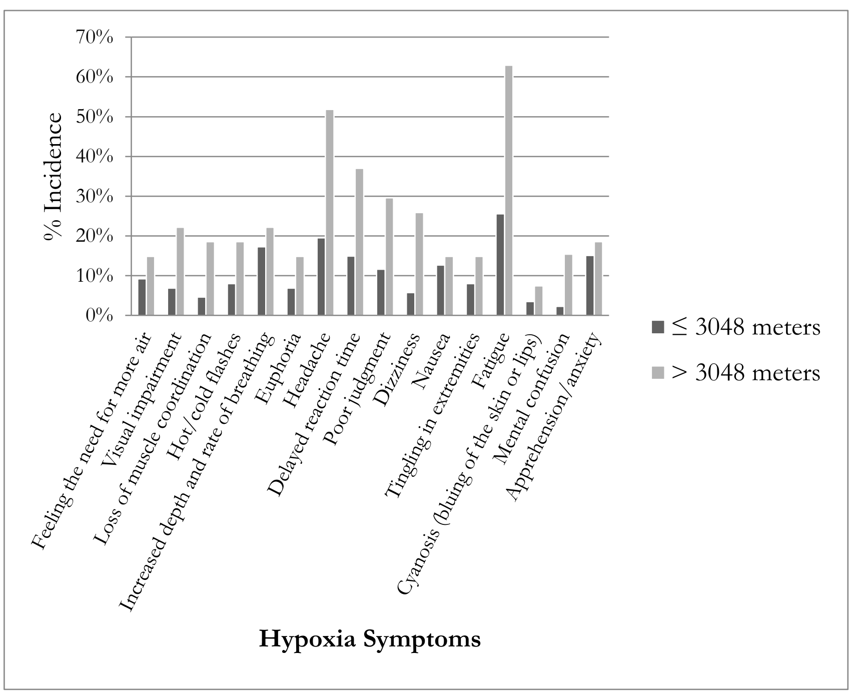

Figure 1.
Percentage of Pilots who have Experienced each of the various hypoxia symptoms "The pilots are divided into those who usually fly below 3,048 m and those who fly above it"

Furthermore, 62 (53%) pilots reported having undergone training in hypoxia fundamentals, 38 pilots (32%) held an ultralight aviation license and 39 (33%) often flew under 3,048 meters. Approximately 61% took a basic introductory course on hypoxia without ACT, 26% took an initial ACT course where only one pilot frequently had hypobaric chamber training and 13% took a recurrent course on hypoxia without ACT. Of the pilots who attended hypoxia training, 92% agreed and strongly agreed that the course was informative and addressed topics such as the effects and symptoms of hypoxia and other possible high-altitude sickness. 54 (45%) pilots considered hypoxia formation and training useful. There were two items regarding the occurrence of hypoxia. Most pilots (95%) stated they had never experienced it and 59% believed that at the environmental and altitude conditions in which the fly render the occurrence of hypoxia rare. When questioned about hypoxia-related symptoms, 38% of pilots (80% usually flew below 3,048 meters) reported experiencing at least one of the symptoms (Figure 1 and Figure 2).

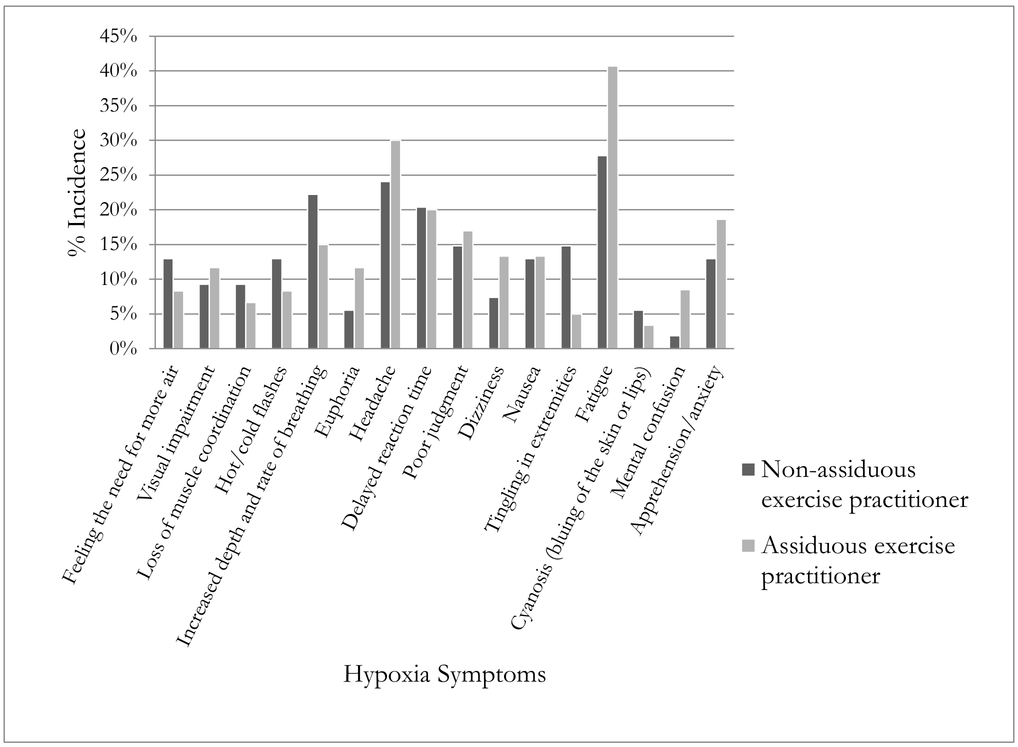

Figure 2.

Percentage of pilots who have experienced each of the various hypoxia symptoms "The pilots are divided into those who usually exercise and those who do not"

Furthermore, 48% of the sampled participants agreed or strongly agreed that all pilots should undergo recurrent hypoxia training without ACT. The last two questions of the survey aimed to discover whether respondents found the use of a pilot monitoring system relevant in real time and whether they would be receptive to its use if it was proven to contribute to flight safety. Of the sampled pilots, 75% found it useful and 92% affirmed they would use it. Among the ultralight aviation pilots these percentages were even more expressive, being 83% and 94% respectively.

MONITORING SYSTEM

As mentioned, this study comes in sequence of Rocha's (Rocha, 2011) work where a monitoring system for brain oximetry was tested on ultralight pilots during real flight conditions. The adopted equipment used to measure cerebral oximetry was the Nonin Medical Inc. Model 7600 Regional Oximetry System with a two-channel configuration. In the current work, in parallel with the brain oximeter, a flight data recorder was installed to record the flight parameters of trajectory, altitude and G loads. Both pieces of equipment were synchronized in the same time scale to allow the comparison between physiological and flight data. This system is meant to record cerebral oximetry and to study the phenomenon of hypoxia and its importance, electrocardiography (ECG), and electroencephalography (EEG) to establish a correlation between the influence of mental workload and other physiological parameters during different flight stages. However, in this work only the brain oximetry was used.

Findings

The experimental flight took place in Viseu, Portugal on June 13th 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 (Figure 3).

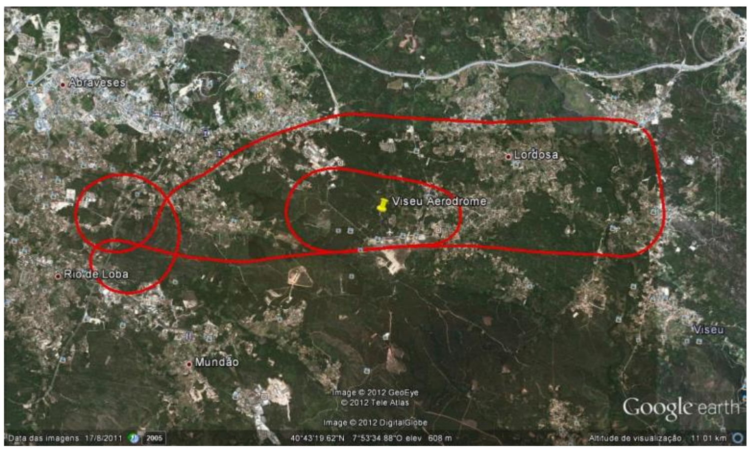

Figure 3.
Viseu experimental flight route, GPS coordinates

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

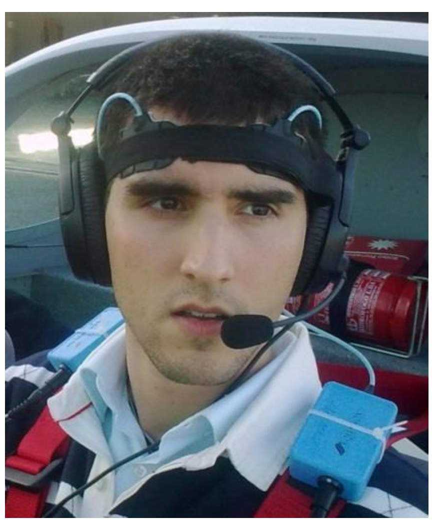

Figure 4.
Nonin Medical Inc. (Model 700) Equipment Configuration

Both climb and descent rates were mi*-ld and did not cause direct high G loads (zacc) to the pilot. The flight phase where such load was higher occurred at the time of the low pass maneuver (19h09m45s) at 697 meters, where the pilot felt about -1.5 G, and at the landing stage where the pilot felt about -1.8 G (Figure 5).

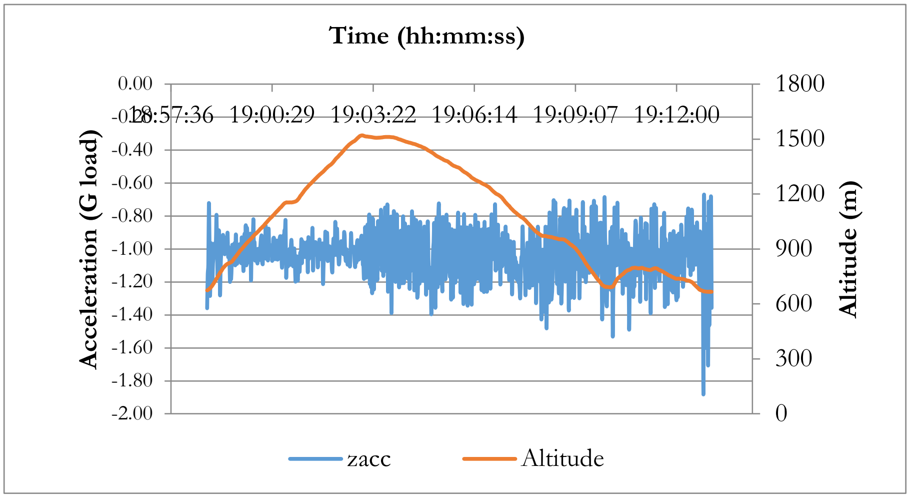

Figure 5.
Altitude and yaw axis acceleration variation during the Viseu experimental flight

At the beginning of the flight (18h58m38s) the regional cerebral oxygen saturation (rSO2) mean value was 86% which corresponded to the maximum absolute value recorded during the entire test. From that moment, the rSO2 mean value decreased continuously until around 19h04m48s when it reached the absolute minimum of 77% which, according to the flight data recorder was the approximate moment when the aircraft reached the highest altitude of about 1,520 meters. The pilot then kept descending until 700 meters where they performed a low pass maneuver. At that stage the rSO2 mean value was approximately 82%. After this maneuver, the pilot raised the aircraft again to 800 meters and the rSO2 mean value reached 84%. When the pilot started the landing procedures (19h10m29s) the rSO2 mean value decreased to 81.5% and at 19h11m59s it increased to 85% similar to what it was at the beginning of the flight (Figure 6).

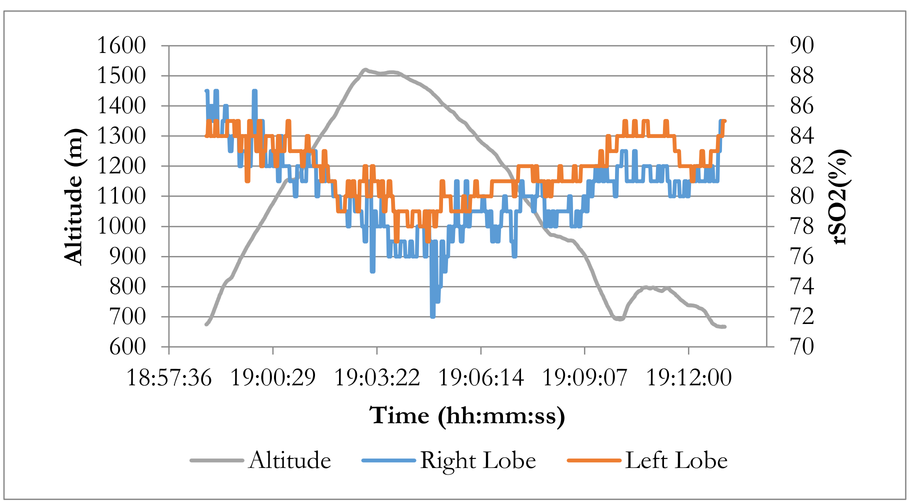

Figure 6.
Cerebral oximetry and altitude variation during the Viseu experimental flight

DISCUSSION

Hypoxia is a serious condition not only for those who fly in pressurized aircraft cabins, but also for those who fly below 3,048 meters within unpressurized aircraft cabins. The sample population was comprised of a heterogeneous pool of pilots most of whom reported that the majority of flights performed during the six preceding months. The survey took place in unpressurized aircraft cabins at a maximum altitude of 3,048 meters. From this restricted range of pilots, it was possible to observe that half of them experienced at least one of the listed hypoxia symptoms and only 44% had received hypoxia training. Statistical analysis showed that respondents felt hypoxia education and training was less necessary for pilots of unpressurized aircraft. However, the lack of training in hypoxia demanded for an ultralight aviation license combined with each pilot responsibility should not be neglected, especially in this type of aviation where the legislation is less restrictive and where accidents and incidents are more common. Two of the key questions of this survey are aimed to evaluate whether a physiological monitoring system would be considered important for pilot flight safety. The results analysis proved that most of the sample population reported no hypoxia symptoms; almost all pilots found this system useful and stated their willingness 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. Generalization of these results should be considered with caution. As the individuals in this study represent a small segment and an unbalanced mix of the entire pilot population, the study's findings should not be used to generalize the overall situation amongst pilots.

MONITORING SYSTEM

In the analyzed flight, the direct G loads that the pilot was subjected not to exceed the 1.8 G which apparently were not reflected in the values of cerebral oximetry. However, as mentioned above, only one flight was successfully completed and no risk or intense maneuvers were performed. For the cerebral oximetry analysis, both channels (right lobe and left lobe) had slightly different values and during the flight some peaks were observed. The discrepancies could happen for any healthy individual knowing that the human body is not fully symmetrical. The sporadic peak values can also occur due to pilot movements and the consequent poor contact of the cerebral oximetry sensors. Comparing the altitude with the cerebral oximetry, we observed that the minimum mean value of rSO2 did not occur when the maximum altitude was reached, but only after a few seconds. At the low pass maneuver at 700 meters of altitude, the mean value of rSO2 was lower than the rSO2 value obtained from 800 meters. Such inconsistencies do not have a scientific explanation due to the lack of studies in this field. We believe that it might be related with the equipment updating speeds and with psychophysiological factors such as adrenaline or pilot's reaction time. Both the cerebral oximeter and the flight data recorder were placed inside the aircraft and as far as possible from the instrument panel to avoid motor interference. Three experimental flights were performed however we could only get complete data in one flight. We developed part of the hardware and software and that is why the fieldwork was so time consuming, making impossible to integrate the ECG and EEG equipment in this article. All the factors mentioned above could have affected the observations found in the current study. Besides its limitations, this study provides interesting and useful information that can positively contribute to flight safety which is at the core of ICAO's strategic objectives. Although, ICAO has already been implementing practical and achievable measures to improve safety and efficiency in airline industry, adding requirement for flight psychology training might be necessary as common industry practice. This requirement could form the foundation for a new training and testing standard that would make a progress for formulating SARPs.

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Sara Zorro (MSc) has a graduation in Aeronautical Engineering from the University of Beira Interior (UBI), Covilhã, Portugal) since 2012, and currently she is a medical student at UBI. She is a research collaborator at the Institute for Research and Innovation in Civil Engineering for Sustainability (CERIS). The areas of scientific activity of Sara Zorro are Air Transport in general and Flight Safety and Accessibility in particular. She has published 3 articles in international journals with scientific referee, and more than 10 communications in proceedings of national and international conferences.

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