GLIDING HIGH: PLEASURE OR PAIN

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Introduction

Gliding has become an increasingly popular recreational and competitive pastime, with some 1100 glider pilots registered in New Zealand, and 91 competitors at the 24th World Gliding Championships in New Zealand in 1995. Most scientific activity concerned with the sport of gliding has centered on aerodynamic designs, more sophisticated meteorology, and so on; research whose aim is primarily to enhance the interactive performance of man and machine.

But, the glider pilot faces another, somewhat insidious, hazard – namely, hypoxia (or, lack of oxygen). Humans are very susceptible to an oxygen deficiency and unprotected exposure to altitude (such as that experienced by aviators, mountaineers, etc) is one of its principal causes.

Current New Zealand Civil Aviation Regulations permit crews of unpressurized aircraft, such as gliders, to fly below 10,000ft (3,048m), and to fly between 10,000 and 13,000ft (3,048 and 3,960m) for up to 30 minutes, without supplementary oxygen. The effect of breathing air at these altitudes causes hypoxic hypoxia, a reduction in the oxygen tension in the arterial blood and hence in the tissues.

Effects of hypoxic hypoxia

Figure 1 shows the relation between percentage arterial oxyhaemoglobin saturation (SaO_2) and altitude.

A person exposed to hypoxic hypoxia at about 10,000ft (3,048m) experiences a reduction in percentage SaO_2 from about 98% at sea level to approximately 90%. Above 10,000ft (3,048m), SaO_2 levels decrease rapidly such that at 18,000ft (5,490m) SaO_2 levels can be as low as 70%. In response to this hypoxic insult, respiration and cardiac rates increase, and times of useful consciousness decrease.

The physiological effects of hypoxia in aviation are well understood and Table 1 documents some of the various visual, physiological, and neuromuscular deficits that often occur. (See also Ernsting & King, 1988 for an excellent summary.) As altitude increases, the severity of these symptoms increases and the time required for their onset decreases. Other variables, such as physical activity, temperature, illness, and the ingestion of certain drugs including alcohol and tobacco, are also known to accentuate the various symptoms.

Despite this, of the 48 papers presented at the XXIII Ostiv Congress in 1993, only one was concerned with such "altitude sickness". Weien & Harmer (1993) studied

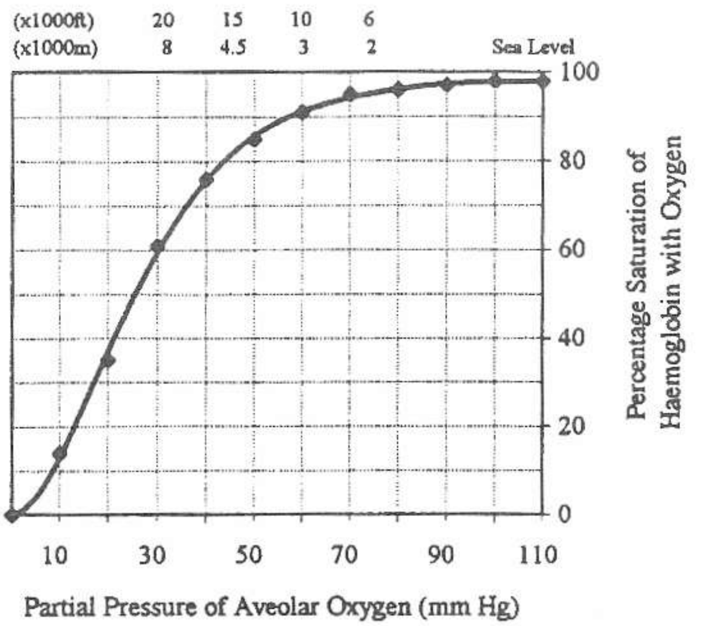

FIGURE 1. Carriage of oxygen in the blood by haemoglobin. This shows that oxygen saturation falls rapidly above 10,000ft (3,048m).

decompression sickness (DCS) which occurs as a result of a reduction in ambient barometric pressure. While Weien and Harmer reported that *"we are not aware of any reported cases of DCS in glider operations, despite flight profiles which are clearly provocative: the altitudes reached, the lack of denitrogenation, and failure to use 100% oxygen routinely all suggest that DCS should be occurring"*, they also stated that *"a possible explanation for this apparent low incidence is underreporting: the symptoms are not recognized for what they are, and are attributed to some other cause"*. So it is with hypoxic hypoxia; often the aviator is subjectively unaware of the occurrence of symptoms, although objective physiological indicators clearly point to an hypoxic state.

The psychological effects, by contrast, are less well understood and contradictions regarding the effects of hypoxic hypoxia on cognitive performance abound. As a result, there has been much debate in the literature concerning the minimum altitude at which aviators may safely breathe air. Some psychological research has reported impaired cognitive performance (such as reaction time, memory, and attention) between 5,000ft and 8,000ft (1,524m and 2,440m). Other experimenters, however, have failed to show consistent and reliable performance deficits below 12,000ft (3,660m).

Performance on the Manikin Task; a test of perceptual-motor performance routinely used to assess the effects of mild hypoxia, illustrates the inconsistencies in experimental results. The task requires the recognition of the orientation of a Manikin figure (front, back, upright, inverted), and a subsequent motor response to indicate the hand in which the Manikin is holding a symbol which matches a stimulus shape surrounding the Manikin..

Results from experiments using the Manikin indicate that the threshold altitude for reaction time decrements appears to be anywhere between 5,000 and 10,000ft (1,524 and 3,048m). Examples of these results are summarized in Table 2.

Another example of contradictory results comes from Ledwith (1970) with a reported result of slower reaction times on the Manikin task at 7,000ft (2,135m) relative to sea level, but with reaction times at 12,000ft (3,660m) faster than those at 7,000ft (2,135m).

However, none of these studies measured how accu-

Table 1
Effects of exposure to hypoxic hypoxia

Visual	General	Neuro-muscular
Decrease in colour perception	Euphoria	Clumsiness
Decrease in peripheral awareness	Task fixation	Fine tremor
Decrease in acuity	Personality changes	Slurring of speech
Dimming	Fuzziness (not dizziness)	Slow movements
	Amnesia	Hypoxic 'flap'
	Lethargy	
	Mental confusion	
	Sensitivity to cold or heat	
	Cyanosis	
	Loss of self criticism, judgement	

Table 2
Threshold altitude for reaction time decrements

Authors	Year	Threshold altitude	
Denison, Ledwith and Poulton	1966	5,000ft	1,524m
Farmer, Lupa, Dunlop and McGowan	1993	8,000ft	2,440m
Fowler, Elcome, Kelso and Porlier	1987	9,750ft	2,972m
Tune	1964	10,000ft	3,048m
Crow and Kelman	1973	>12,000ft	>3,660m
Green and Morgan	1985	>12,000ft	>3,660m

rate the subjects were in performing the task. So, in Ledwith's (1970) study, for example, subjects may well have performed faster at 12,000ft (3,660m) than at sea level or 7,000ft (2,135m), but at the same time they may have been less accurate.

Explanations for the empirical contradictions

Explanations commonly given for the differing results include:

1. Workload: In the Denison et al. (1966), study, for example, subjects had to pedal a bicycle ergometer while breathing oxygen-deficient gas mixtures at sea level. The effect of this exercise is to lower SaO_2 levels even further. So, effective altitude may well have been lower than the oxygen deficient gas mixtures actually suggested. However, in this, and indeed in most, studies objective individual-subject blood oxygen saturation levels were not measured. We will refer to this important point again.

2. Task Novelty: About the only agreed upon effect of hypoxia in the 5,000 to 10,000ft (1,524 to 3,048m) range appears to be that it affects an individual's ability to make new decisions in response to a novel situation (or task). So, the positive results obtained at less than 10,000ft (3,048m) have often been ascribed to task novelty.

But, the controversy rages on. For example, Paul and Fraser (1994) were unable to confirm the finding of Denison et al (1966) that subjects who had one Manikin session at sea level prior to their altitude exposure performed much better at 8,000ft (2,440m) than subjects who had their first session at 8,000ft (2,440m). But, by contrast, Lupa reported that Manikin Task learning by humans was impaired when they were exposed to a simulated altitude of 8,000ft (2,440m) Furthermore, if task learning had occurred under hypoxic conditions, subjects continued to perform more poorly even when returned to normoxic conditions (H.T. Lupa, personal communication, October 13,1994).

Such contradictions also exist when performance is examined on tasks other than the Manikin. For example, it is commonly stated that short-term memory is impaired by hypoxia, but some (e.g., Fowler, Prlic and Brabant, 1994) suggest that the sensitivity of short-term memory to hypoxia is not as clear-cut as is commonly held.

McCarthy, Corban, Legg and Faris (1995) suggested that the failure to find consistent effects of hypoxia at operational altitudes may be due to four important factors:

The physiological responses of individuals to the hypoxic insult vary markedly. Hence, the critical independent variable should be the effective altitude of the subject (as measured by the percentage of oxygen being carried in the arterial blood) rather than their nominal altitude (as measured by an altimeter).

- The use of naive subjects with no previous exposure to hypoxia, which produces subject apprehension concerning the testing environment (e.g., the altitude chamber).
- Variations in the duration of exposure to the hypoxic insult.
- The use of tasks with little relevance to those performed in the aviation environment.

In an attempt to address empirically some of these issues, McCarthy et al (1995) used a perceptual-motor task designed to simulate the quadrant-by-quadrant visual search patterns by P3K Orion aircrew conducting maritime surveillance. They found significant individual variation in the responses of subjects to mild hypoxia induced by reducing the partial pressure of oxygen in the inspired air in an altitude chamber.

The variability in response to the hypoxic condition is illustrated in Figure 2. Further, by using signal-detection analyses (not discussed here), they were able to obtain measures of accuracy independent of any biases or predispositions they subjects might show. Interestingly, while accuracy levels were not affected until between 10,000 and 12,000ft (3,048 and 3,660m), reaction times were significantly slower at 7,000ft (2,135m) relative to sea level.

To extend the work of McCarthy et al., we have embarked on a program of research designed specifically to further address the contradictions in the literature. Two major experiments are in progress, and a third is planned for early 1995. The first two experiments are:

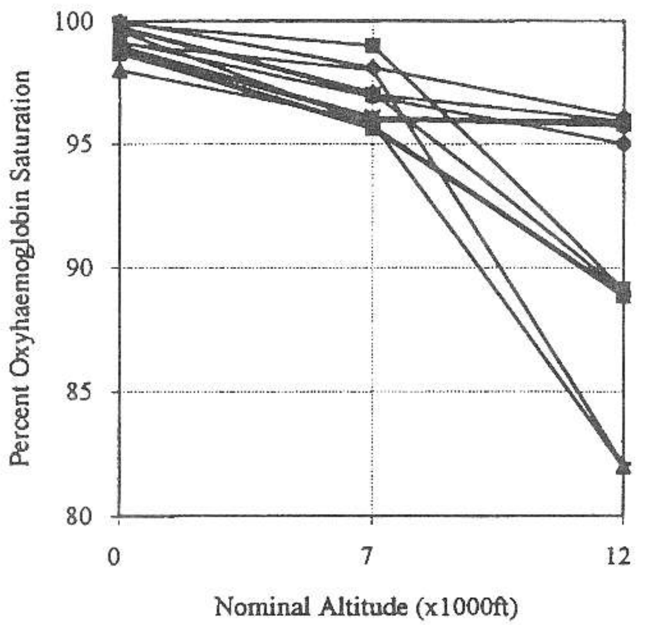

FIGURE 2. Percentage of SaO_2 for individual responses as a function of nominal altitude (from McCarthy, et al, 1995).

Experiment 1:

The first experiment is being conducted in the altitude chamber at the Aviation Medicine Unit (RNZAF Base, Auckland). Here, the performance of trained aircrew is being examined while they are exposed to controlled levels of hypoxia between sea level and 14,000ft (4,270m) for up to six hours. Specific performance measures include PC-based simulated flying tasks, and a variety of reaction time, memory, and attentional tasks.

Preliminary results suggest that:

1. Performance on well learned tasks is not significantly affected below 10,000ft (3,048m). However, there seems to be an accuracy/speed tradeoff occurring at altitudes of 10,000 and 14,000ft (3,048 and 4,270m) compared to sea level.
2. Marked variability in individual subject SaO_2 levels were apparent. These variations appeared to be related to the arousal level exhibited by the subject and the relative difficulty of the task.
3. Initial observations suggest that subjects exposed to 10,000ft (3,048m) exhibited an increased SaO_2 level, relative to that recorded during a non-oxygen-intervention trial at 10,000ft (3,048m), in response to an intervention of 100% oxygen provided for two minutes every 60 minutes.

Experiment 2:

The second experiment is being conducted with subjects who have had no prior exposure to hypoxia. This is taking place at sea level with subjects breathing oxygen-deficient gas mixtures. In this experiment, each exposure to the hypoxic condition is brief (less than 90 minutes), and subjects are performing a visual short-term memory task at altitude equivalents of 10,000 and 14,000ft (3,048 and 4,270m) in which they are required to choose which of two comparison stimuli matched a sample stimulus previously presented.

The primary focus here is on the subjects' ability to discriminate between different visual stimuli, and the way in which this ability decays over time.

Preliminary results suggest:

1. Again, significant variation in the subjects' response to the hypoxic insult.
2. A change in the rate at which memory for the visual stimuli decays over time. Specifically, rates of decay are faster at 10,000 and 14,000ft (3,048 and 4,270m) than at sea level.

Implications for gliding

Gliding, especially at a competitive level requires the pilot to make decisions constantly to maximize speed. The pilot is under stress from the effects of heat or cold, depending on the altitude, temperature and radiant heating from the sun. The pilot is also under stress from dehydration and fatigue. During an extended competition period the effects of these fatigue stressors could be cumulative.

When hypoxic hypoxia is also imposed as a stressor the pilot's well-learnt skills of manipulating the aircraft controls and making basic, habitual decisions about aircraft flight path management, are probably not affected. What we would expect to find, however, is that the pilot's decision-making processes and cognitive functioning are adversely affected. In other words, the pilot's ability to recognize a particular situation or respond to new information, is degraded.

At the international level the points gained by a top performer may amount to one every few seconds. Any interference with a top pilot's ability to quickly assimilate information and accurately deduce subsequent options will result in a loss of time and therefore a loss of points.

The variability of individuals' responses to the hypoxic insult suggest that the effects of hypoxia on cognitive functioning could occur at altitudes significantly lower than those at which it is legal to fly without supplementary oxygen. The availability and timely use of supplementary oxygen could, therefore, be a significant factor in the results achieved by elite glider pilots

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