Aviation hypoxia, cognition and human performance

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I have no financial relationships to disclose

I will not discuss off-label use and/or investigational use in my presentation
“Anoxaemia not only stops the machine, it wrecks the machinery”

- J.S. Haldane
Does aviation hypoxia impair cognition and performance?
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Could aviation hypoxia negatively impact CRM?
Does aviation hypoxia impair cognition and performance?

Could aviation hypoxia negatively impact CRM?

We don’t know
## Time of useful consciousness

<table>
<thead>
<tr>
<th>Altitude (ft)</th>
<th>Time (seconds/minutes)</th>
</tr>
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<tbody>
<tr>
<td>20,000</td>
<td>30+ minutes</td>
</tr>
<tr>
<td>25,000</td>
<td>3-5 minutes</td>
</tr>
<tr>
<td>30,000</td>
<td>1-2 minutes</td>
</tr>
<tr>
<td>35,000</td>
<td>30-60 seconds</td>
</tr>
<tr>
<td>40,000</td>
<td>15-20 seconds</td>
</tr>
<tr>
<td>45,000</td>
<td>10 seconds</td>
</tr>
</tbody>
</table>
Commercial airline cabin

5,000 – 8,000 ft
Commercial airline cabin

5,000 – 8,000 ft

Denver
Commercial airline cabin

5,000 – 8,000 ft

Denver

Mexico City
Physiological effects of aviation hypoxia

↑ ventilation (ventilatory acclimatisation to hypoxia)

↑ erythropoietin secretion

↑ pulmonary artery pressure (hypoxic pulmonary vasoconstriction)
  Smith TG et al. *Aviat Space Environ Med* 2012
How hypoxic are commercial aircrew?
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38 pilots on 21 flights

Peak cabin altitude range 6,000-8,550 ft

Cottrell JJ. *Aviat Space Environ Med* 1995
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Half desaturated below $\text{SpO}_2$ 90%

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What about cerebral oxygenation?
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volunteers ascending to altitude

Sea level: 69%

2,400 m: 68%

What about cerebral oxygenation?

17 paediatric helicopter transport patients

Sea level: 69%

> 5,000 ft: 66%

Stroud MH et al. *Pediatr Emerg Care* 2012
What about cerebral blood flow and autoregulation?

13 volunteers breathing 15% oxygen for 5 hours

Nishimura N et al. *J Appl Physiol* 2010
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Fall in cerebral blood flow velocity (accompanying the ↓ CO₂)

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Impaired dynamic cerebral autoregulation

Nishimura N et al. J Appl Physiol 2010
Does aviation hypoxia impair neuro-cognitive performance?
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Several studies have examined psychomotor and cognitive tasks at 5,000-8,000 ft.
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Early work in the 1960s established that the ability to respond to novel tasks is affected by mild hypoxia.

Denison DM et al. *Aerosp Med* 1966
Does aviation hypoxia impair neuro-cognitive performance?

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   Denison DM et al. *Aerosp Med* 1966

Some subsequent studies have replicated these findings, others have not

   Paul MA et al. *Aviat Space Environ Med* 1994
One suggested hierarchy of hypoxic thresholds:

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| 10,000 ft | Complex hand-eye co-ordination  
Performance on previously learnt coding and conceptual reasoning tasks |
| 12,000 ft | Performance on pursuit motor tasks  
Choice reaction time on well learned tasks |
| 15,000 ft | Fine hand tremor reduces ability to make precise adjustments |
| 16,000 ft | Simple reaction time increased |
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But the literature is conflicting for altitudes up to 10,000 ft
A good review of the subject covering 8,000-15,000 ft:

Petrassi FA, Hodkinson PD, Walters PL, Gaydos SJ.
Hypoxic hypoxia at moderate altitudes: review of the state of the science. *Aviat Space Environ Med* 2012; 83(10): 975-84.
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“Undoubtedly, most readers are familiar with Reason’s Swiss cheese model of human error, and it is with ease that one can imagine hypoxic hypoxia opening new holes (or enlarging existing ones) with respect to HFACS accident preconditions.”
Hypoxia symptoms ≤ 8,000 ft in helicopter aircrew

53 aircrew surveys

Smith A. Aviat Space Environ Med 2005
Hypoxia symptoms ≤ 8,000 ft in helicopter aircrew

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76% had experienced symptoms of hypoxia
    - difficulty with calculations
    - light-headedness
    - delayed reaction time
    - mental confusion

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Symptoms as low as 6,500 ft

Smith A. *Aviat Space Environ Med* 2005
Abridged narratives from aircrew

A loadmaster took 35 min to complete the takeoff and landing data (TOLD) card at an altitude of ~ 7,500 ft (2,286 m).

(Note: a TOLD card would normally take ~ 5 min to complete.)
Abridged narratives from aircrew

During an approach to a confined landing zone at 8,000 ft (2,438 m), an experienced loadmaster instructor stopped calling ground clearance distances. He did not respond appropriately to prompting from the other loadmaster and was unable to participate in the landing procedure.

Smith A. Aviat Space Environ Med 2005
Abridged narratives from aircrew

When approaching a landing zone at 8,000 ft (2,438 m), a loadmaster was unable to complete the TOLD card and became "unable to complete [his] flying duties," requiring the aircraft to complete the mission with a single effective loadmaster.
Abridged narratives from aircrew

While cruising at 8,000 ft (2438 m), the co-pilot had to take control of the aircraft when he noticed the handling pilot had become "euphoric" and wanted to keep climbing. The affected pilot recovered when the aircraft descended to a lower altitude.
Conclusions
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This applies to aeromedical crew too!