
162
EAA
NASHVILLE

Understanding Hypoxia and its impact on pilot performance

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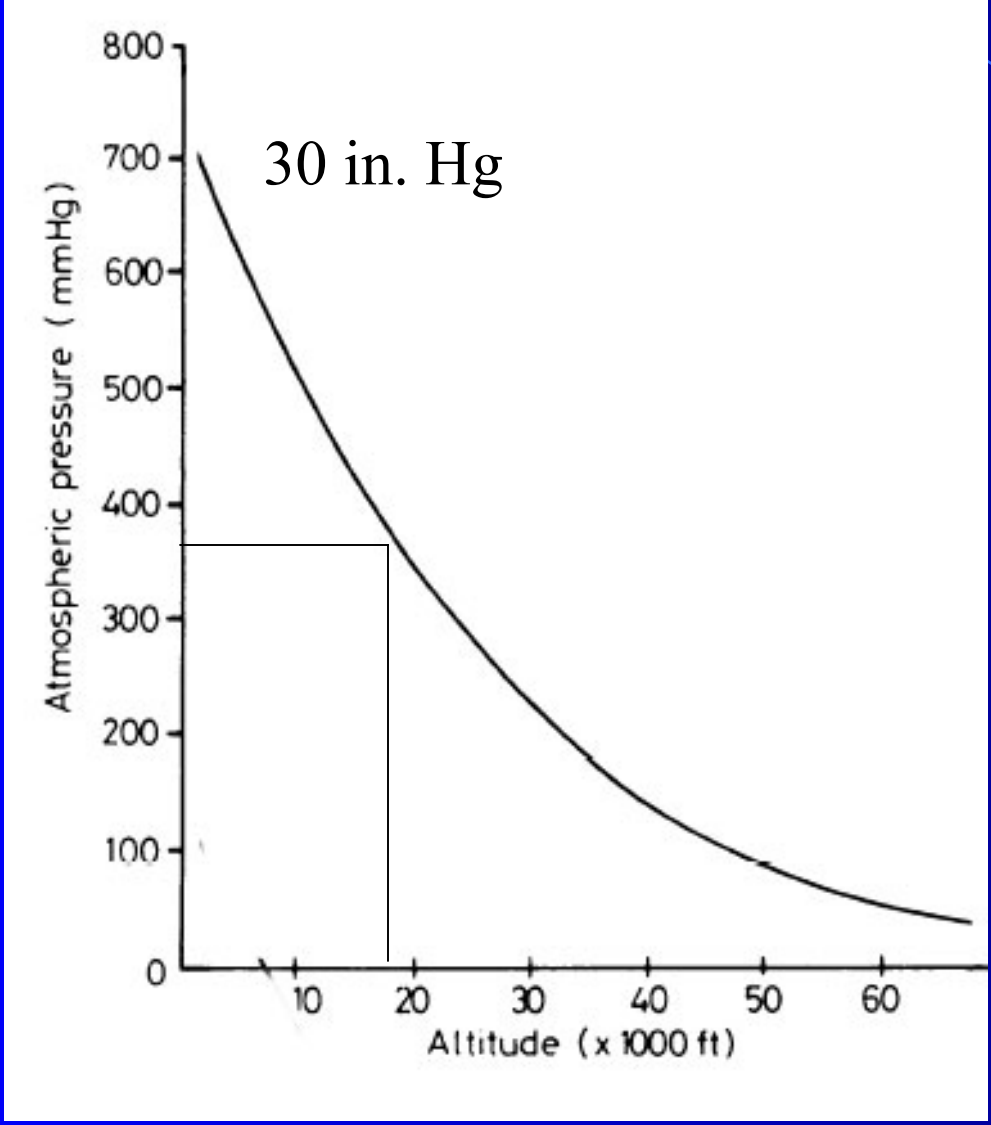
EAA Chapter 162

Topics

- How the atmosphere changes with altitude
- Oxygen transport in the body
- Hypoxia
  - What it is
  - Types of Hypoxia
- Effects of hypoxia
  - General
  - Pilot performance-specific
- Nature's gotcha – why hypoxia can kill
- Components for supplemental oxygen in your plane
- Monitoring oxygen effectiveness

Oxygen in the Atmosphere



- Atmospheric pressure is 50% of sea level at 18,000 ft. "Half as many air molecules per unit volume"
- Oxygen content approx. 21% of atmosphere. Relative content (pressure) of atmospheric gases decreases in proportion to total atmospheric pressure

Oxygen Transport in the Body

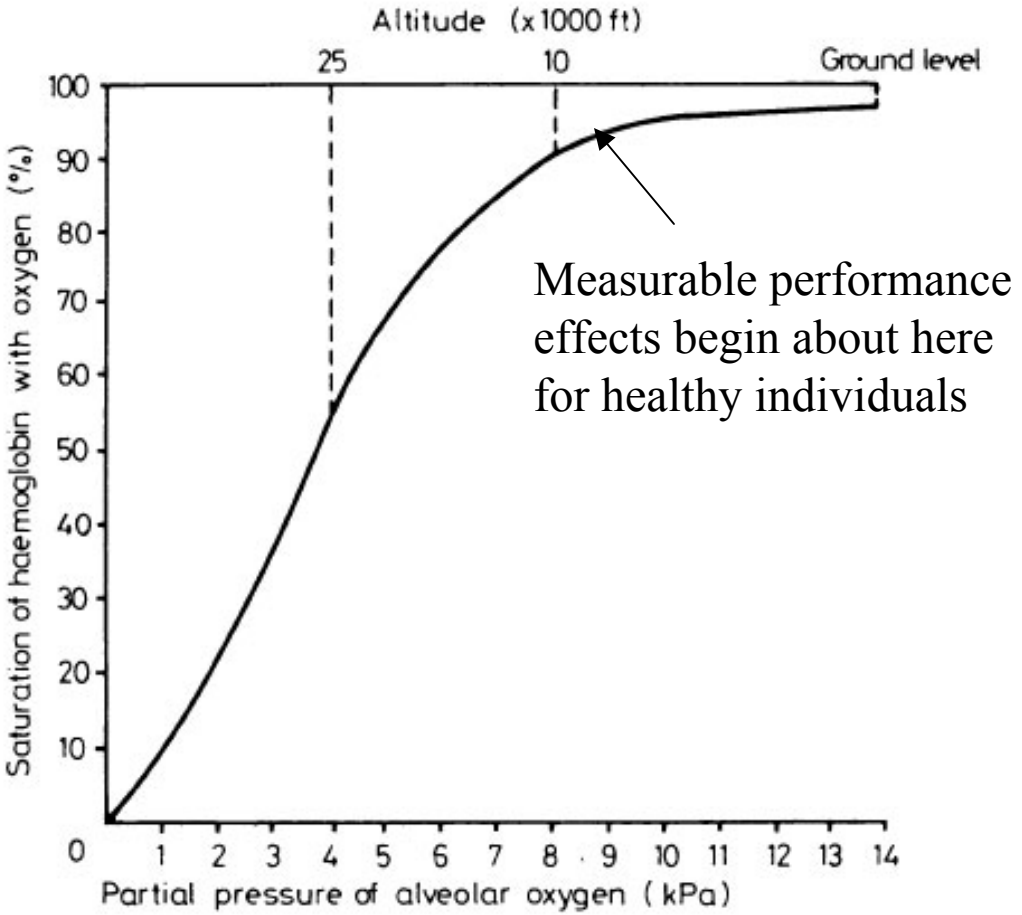


FIG 2—Relation between partial pressure of alveolar oxygen, percentage saturation of haemoglobin with oxygen, and altitude. *Conversion: SI to traditional units*—partial pressure of alveolar oxygen: 1 kPa ≈ 8 mm Hg. (Altitude: 5000 ft ≈ 1500 m.)

- Hemoglobin transports oxygen from lungs to body tissues
- Amount of O2 carried by hemoglobin varies with 'partial pressure' of O2 in atmosphere.
- A 'sigmoid curve' that favors altitudes below 10,000 ft

Hypoxia

= Insufficient Oxygen Is Supplied To Body Tissues

A few historical tidbits…

- Joseph Priestly discovered elemental Oxygen in 1774, showed life sustaining effects using animals
- Balloonists became aware of and wrote about breathing issues in 1793 (19 years after Priestly and 110 years before the Wright Brothers).
- First documented balloon hypoxia injuries in 1804 (15,000 ft) and first fatalities associated with 1874 balloon flight to 28,000 ft.
- Some German biplanes in WWI had liquid oxygen systems(!). Some English aircrews considered shooting down an enemy while 'hiding behind a mask' unsportsmanlike and rejected use of O2.
- England, US and Russia lagged behind Germany, but made rapid technology advances during WWII.

Types of Hypoxia

- Anemic
- Histotoxic
- Stagnant
- Hypoxic

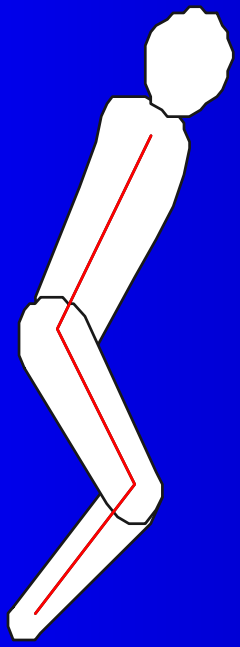
Anemic Hypoxia

- Reduced oxygen carrying capacity of the blood…
  - Trauma with blood loss
  - Blood donation
  - Chronic inflammatory illness with anemia e.g., kidney disease, arthritis
  - Carbon Monoxide
    - Binds hemoglobin 200x more efficiently than oxygen and displaces oxygen
    - Most common source: smoking
    - Other sources: exhaust leak

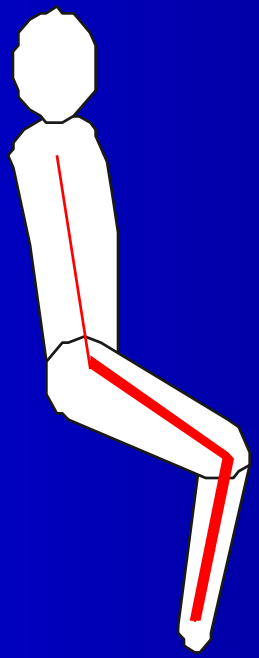
Histotoxic Hypoxia

- Reduction in the ability of tissues to utilize oxygen...
  - Alcohol
  - Cyanide
  - Drugs
    - Sulfa drugs (Septra)
    - Antihistamines
    - Narcotic pain relievers

Stagnant Hypoxia (g-forces, prolonged sitting)



During prolonged flights blood may begin to pool in the extremities



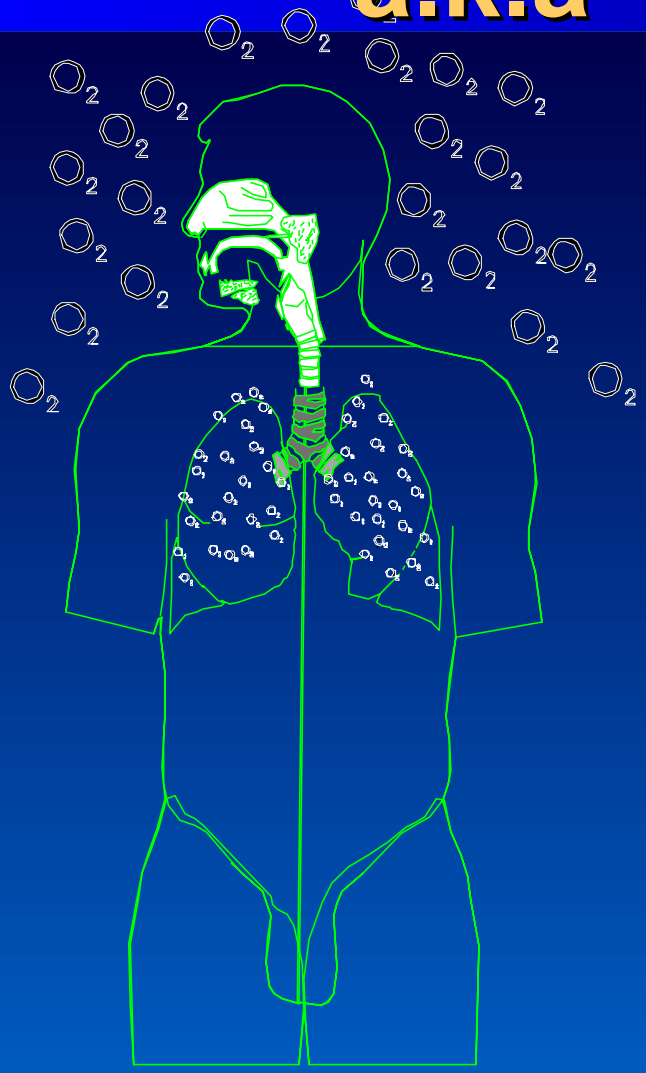
Pooling increases, vision begins to fade(gray-out).

Blackout occurs due to a lack of blood to the brain.

Stagnant Hypoxia

- Medical conditions associated with increased risk of stagnant hypoxia:
  - Heart failure
  - Shock
  - Arterial spasm
  - Occlusion of blood vessels from tissue edema
  - Thrombus (blood clot inside vein)
  - Embolus (clot traveling through vessels)
  - Plaques (narrowing of arteries, esp. coronary arteries)

Hypoxic Hypoxia
a.k.a "altitude hypoxia"

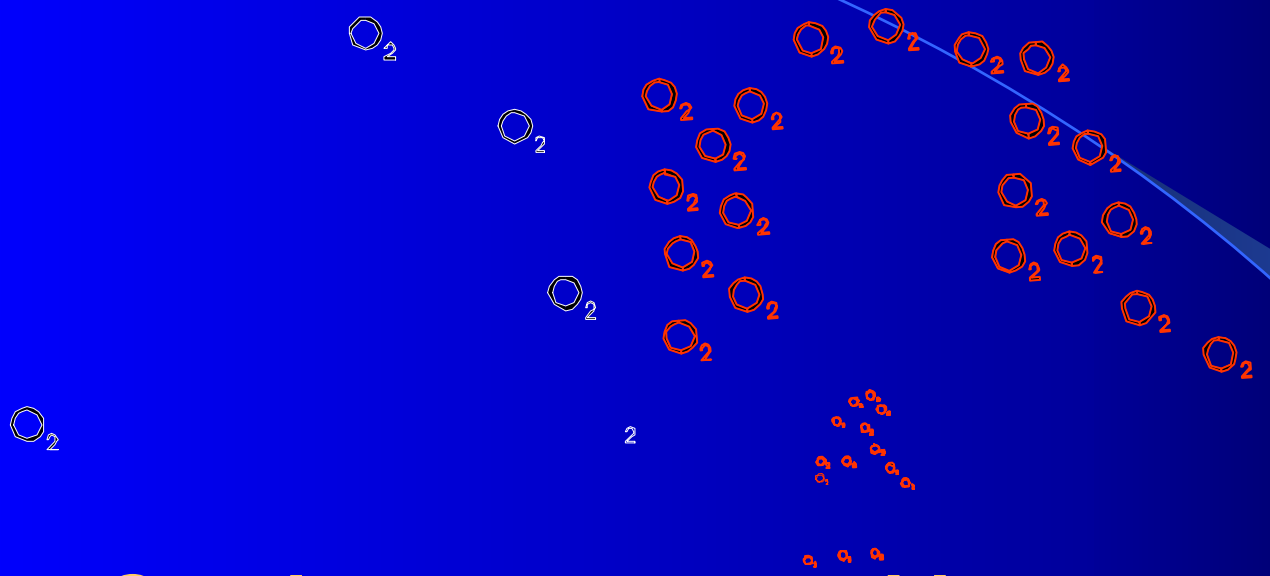


Sea Level

A reduced amount of oxygen in inhaled air, most commonly due to altitude

18,000 ft

Hypoxic Hypoxia



- Can be accentuated by concurrent medical conditions:
  - Laryngospasm
  - Asthma, severe bronchitis
  - Hypoventilation (decreased breath rate)
  - Congenital heart defects
  - Fluid in lungs (pulmonary edema, pneumonia)

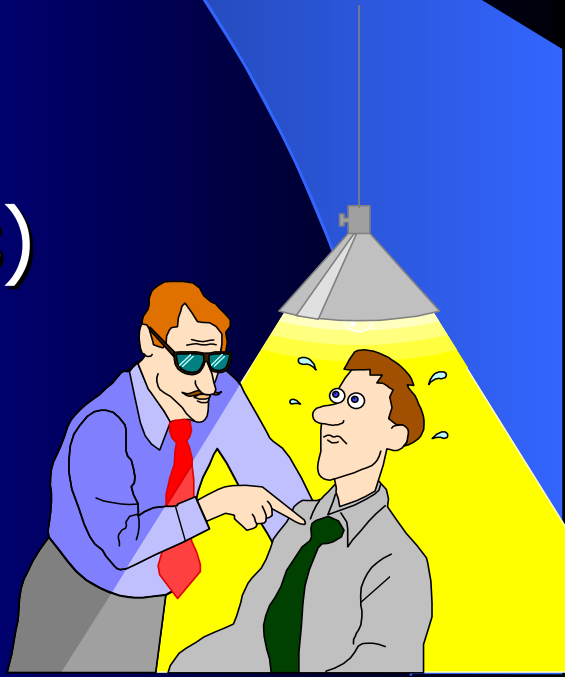
Effects of Hypoxia: Subjective Symptoms

- Tingling sensation
- Dizziness
- Fatigue
- Air hunger
- Euphoria
- Dimmed or tunnel vision
- Hyperventilation
- Nausea
- Headache
- Nothing

However, sequence of appearance and predominant symptom is different for each person. Only way to know for certain is to do high altitude chamber training.

Effects of Hypoxia: Objective Signs

- Increased breathing rate
- Slow reaction time and speech
- Inattentiveness, 'target fixation'
- Decreased visual acuity
- Personality change
- Cyanosis (blue lips and nailbeds)
- Confusion
- Loss of muscular coordination
- Unconsciousness



FAA rules relevant to hypoxia

- FAR 91.211
  - (a) *General*. No person may operate a civil aircraft of US registry – (1) at cabin pressure altitudes above 12,500 feet MSL up to and including 14,000 feet MSL unless the required minimum flight crew is provided with and uses supplemental oxygen for that part of the flight at those altitudes that is of more than 30 minutes duration…

Hypoxia effects on pilots

DOT/FAA/AM-97/9

Office of Aviation Medicine
Washington, D.C. 20591

Effects of Mild Hypoxia on Pilot Performances at General Aviation Altitudes

Thomas E. Nesthus
Ladonna L. Rush
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Civil Aeromedical Institute
Federal Aviation Administration
Oklahoma City, Oklahoma 73125

April 1997

Final Report

U.S. Department of Transportation
Federal Aviation Administration

Hypoxia effects on general aviation pilots: FAA study

- Randomized 20 relatively low time pilots to two groups of 10
- Cross country task (3 simulated flights with ATC flight following between Arizona and Colorado) in high fidelity simulator of Beech Sundowner
- Flight segments at 8K, 10K, and 12.5K
- Half breathed oxygen mixtures representing flight altitudes, half breathed sea level air
- Both groups had physiologic monitoring and observation of performance

Hypoxia effects on general aviation pilots: results

- No difference in performance on low-workload enroute segments
- Significant increase in errors associated with approach and landing
- Some errors potentially very serious

FAA hypoxia study: results

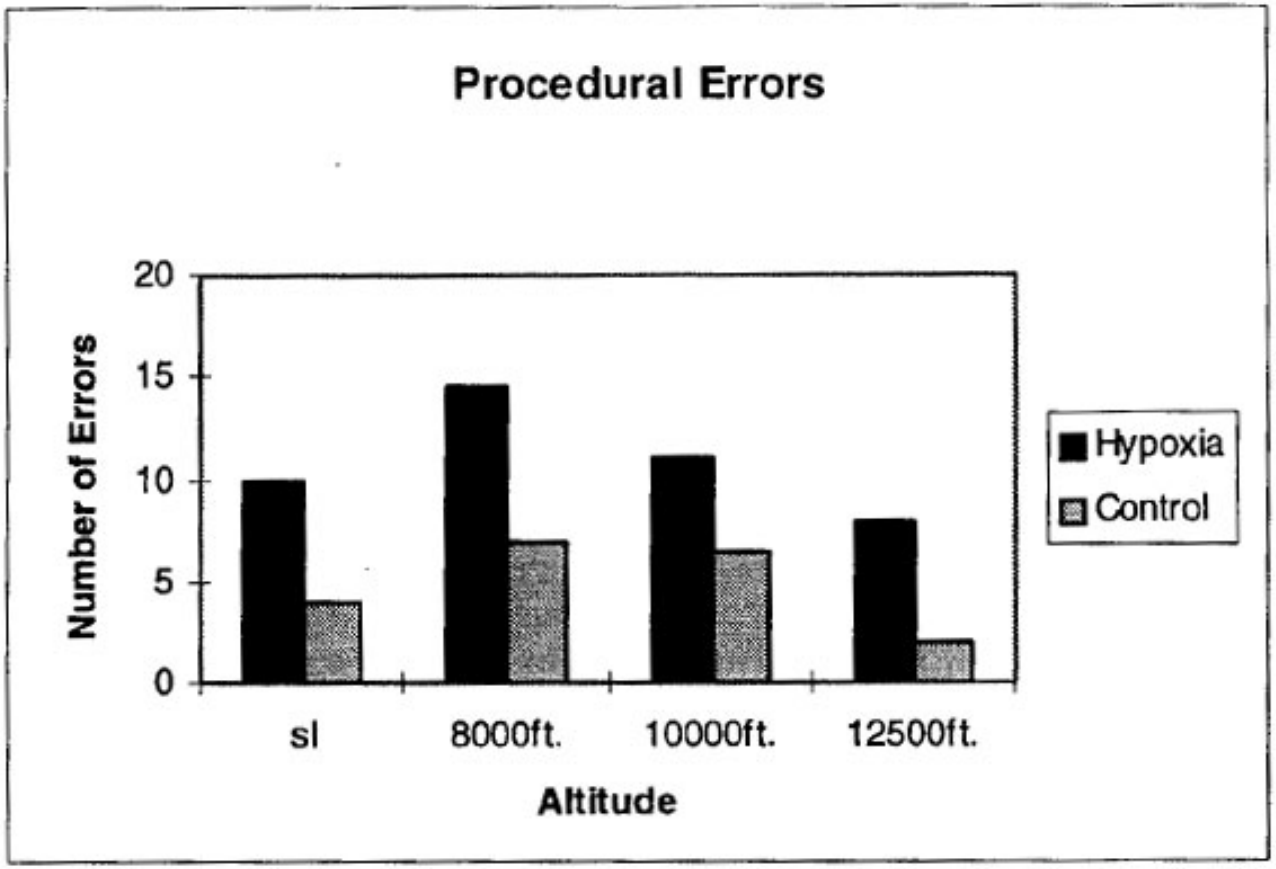
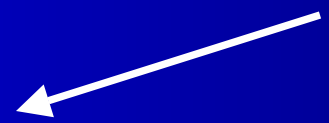


Figure 7: Number of procedural errors for each group and altitude condition.

Key finding: increase in performance errors associated with as little as 45 minutes at 8,000 ft in some pilots

Types of Errors increased with hypoxia

- Misdialed frequency and transponder codes
- Failure to use reciprocal heading when setting OBS for inbound radial
- Failure to report as instructed by ATC
- Course deviation due to inattention or distraction
- Failed to follow ATC instruction
- Premature maneuver
- Mis-identified airport
- Missed approach/go-around
- Crashed on landing attempt



4 of 10 pilots reported having airport in sight in VFR conditions, then overflew it and required vectors back

FAA hypoxia study: results

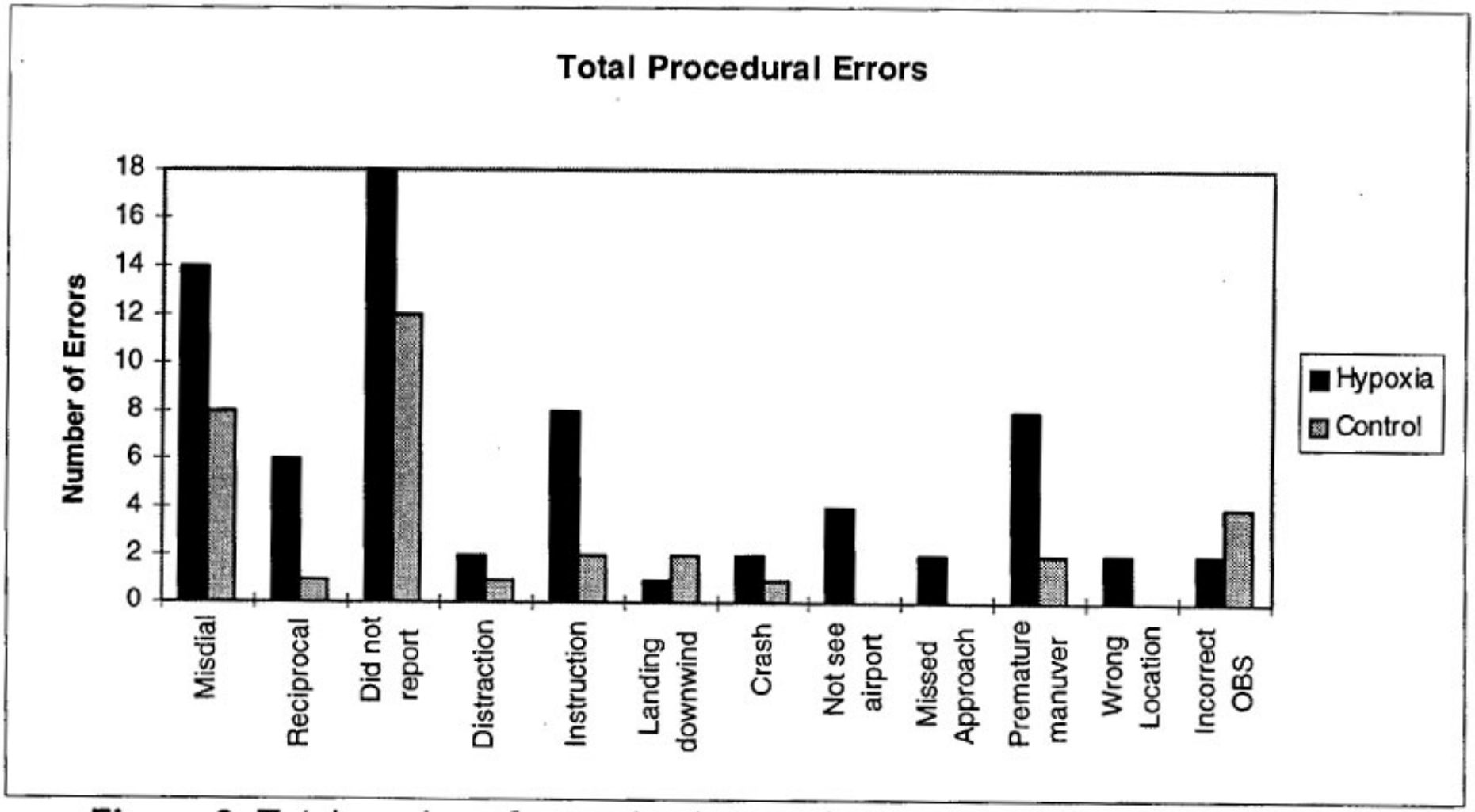


Figure 6: Total number of procedural errors for each group by error category.

FAA study: other results

- "Hurried and precipitous behavior" during descents observed only in hypoxia group
- After simulation, hypoxia group reported higher workload, higher anxiety, higher fatigue during flights
- Hypoxia group was aware of flight deviations, but *"only realized the importance of them after leaving the laboratory"*

Nature's gotcha – why hypoxia can kill

- At general aviation altitudes, hypoxia effects are insidious
  - Gradual onset
  - Nonspecific: something is different but you don't know what
- Loss of insight is nearly universal
  - Not necessarily euphoria but you lose the ability to be critical of your own performance
  - You know you are making some mistakes but underestimate how serious they are

A partial myth

- Breathing faster and deeper raises oxygen levels in blood and can compensate for low atmospheric oxygen levels
- True…, however
- Hyperventilation also drops carbon dioxide level in blood, causing pH shift that constricts blood vessels in the brain
- So, your brain doesn’t see much of the improvement in blood oxygen level

Good news:
the antidote to all of these GA hypoxia issues is to breath supplemental oxygen

Portable oxygen system components

- Tank (aluminum, kevlar)
- Primary regulator – attaches to tank
- Individual regulator
- Delivery apparatus
  - Nasal prongs up to 16K
  - Full flow mask required over 18K
  - Pressure mask over 25K

Oxygen conserving devices

- Simple: 'oxymizer' cannula with accumulating reservoir
  - "mustache" cannula
  - "pendant" cannula
- Better but expensive
  - Digital on-demand regulator
  - Lighter cannula without reservoir
  - Includes mask

Monitoring oxygen effectiveness

- Fingertip pulse-oximeter runs on 2 AAA batteries
- Uses infrared reflectance to measure oxygen saturation
- Conservative goal: keep O2 sat at 90% or better (8K density altitude => 87%)

Refilling your own O2 cylinder

- All oxygen is now produced by electrochemical processes that generate pure O2.
- Difference between welder's, medical and aviation O2 is documentation only.
- A large (200 cu ft) cylinder of welders oxygen can refill avg. size aviation cylinder > 100 times, at cost of about $0.25 per refill.

Don’t let a version of this be your eulogy

- “They leap up and death seized them, without a struggle, without suffering, as a prey fallen to it on those icy regions where an eternal silence reigns. Yes, our unhappy friends have this strange privilege, this fatal honour of being the first to die in the heavens.”

  - Paul Bert, March 1874, at funeral service of balloonists Croce-Spinelli and Sivel

Keeping your performance in the safest range

- Use supplemental oxygen for cross country flights at or above 8000 ft density altitude during the day
- Use supplemental oxygen for all flights at or above 5000 ft density altitude at night
- Monitor your oxygen saturation to keep O2 saturation at or above 90% in flight
- If you feel tired or sleepy enroute at any altitude, add supplemental oxygen
- Now, take a deep breath and go fly. ☺

Thanks for coming. Have fun and Fly safely!