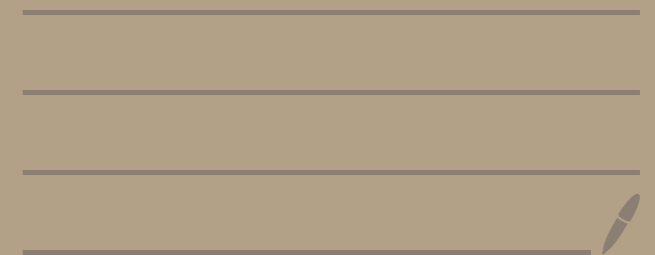


Human Performance and Limitation



01 Human Factors: Basic concepts

Human factors in aviation

• initially: competent but low confidence

• Competence:

- Knowledge
- Skill
- **Altitude**
- **Situational Awareness**
- Communication
- leadership and teamwork
- application of procedures

Flight Safety Concepts

• **TEM model**

- Undesired Aircraft State (UAS)
 - reduction in margin
 - **Fuel shortage**
 - high/approach speed than cleared by ATC
- Organizational threats (in aviation structures)
 - expired charts
- Environmental threats
 - contaminated runway
- Latent threat
 - Cockpit design error
 - not obvious
- Errors:
 - Handling
 - Procedural
 - Communication

• Hard countermeasure → **ACAS**

• GPWS and SOPs are **Systematic based**
Hardware-based countermeasures

• **SHELL concept**

- Software (checklist)
- Hardware
- Environment
- Liveware
- Liveware at the center



Safety Culture

• Safety Management System (SMS)

- Safety **policy** (and objectives)
- " risk management
- " assurance
- " promotion

• Safety culture is **a subset** of national culture

• Closed culture
→ Captain yells

• Reporting culture

• Informed culture → safety risk management more effective

• Good safety culture:

- Responsibility = individuals
- Accountability = Management

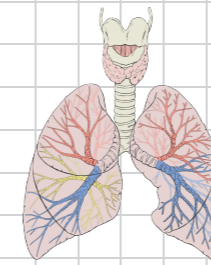
02 Basics of Aviation Psychology and Health Maintenance

Basics of flight physiology

The Atmosphere

78% Nitrogen, 21% O₂, 0.03% CO₂, 0.92% Rare gas

8000 ft	3/4 of sea level pressure
18000 ft	1/2 of sea level pressure
27000 ft	1/3 of sea level pressure
36000 ft	1/4 of sea level pressure



Respiratory and Circulatory System

• **External respiration**

- Tidal volume of lungs is not usable
- Average volume is 5-6 liters
- Gas exchange through passive diffusion (**alveoli**)
- Normal: 10-16 cycles per minute

- Tidal volume = **0.5ℓ**
- Residual volume = **1.2ℓ**

• **Internal respiration**

- Gradient of diffusion affects diffusion of O₂ between blood and body cells
- **Pulmonary artery**: high in CO₂, low in O₂ (low saturation)
- **Fick's law** oxygen absorption in blood
- Cardiac output: **stroke volume × heart rate** ~ 5ℓ/min

• **The circulatory system**

- Anaemia → not enough haemoglobin

• **Blood pressure**

- Normal: **120/80 mmHg**
- Measured at same height as the heart

- **Hypertension** starts at **140/90**
 - increased pressure on the artery walls
 - increase risk of heart attack and stroke

- **Hypotension**
 - caused by clinical shock
 - medication against hypertension

• **Systolic pressure**: force of heart

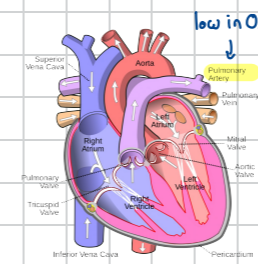
• **Diastolic pressure**: static pressure

• Blocked coronary artery: **heart infarction**

• Stroke: blood supply to brain is cut off

• Myocardial infarction or heart stroke → total blockage of coronary artery / death part of a muscle

• Plasma: blood without cells



Hypoxia

- Explained by **Dalton's law**
- **Anemic hypoxia** → smoking
- **Hypoxic hypoxia** → reduced partial oxygen pressure

Stages of hypoxia

Indifferent stage		0 to 6000 ft	
Compensatory stage / Reaction	Night vision reduced	6000 to 15000 ft	7000ft
Disturbance stage		15000 to 20000 ft	10'000 12'000 → short-term memory impairment
Critical stage		20000 to 23000 ft	22'000

Time of useful Consciousness (TUC)

Altitude ft	TUC
20'000	30 min
25'000	2-3 min
30'000	1-2 min
35'000	30-90 sec
40'000	15-20 sec

Altitude ft	Equivalent altitude with 100% O2
34000	Sea level
38000	8000
40000	10000
45000	20000

Altitude ft	Oxygen
Sea-level - 10'000	Outside air
10'000 - 34'000	Mixture
34'000 - 40'000	Pure O2
➤ 40'000	Pure O2 with positive pressure

Hyperventilation

- Symptoms: dizzy, tingling hands, rapid heart rate
- Measure: breath in plastic bag or speak slowly
- Can cause a lack of carbon dioxide in the body
- blood circulation to the brain is slowed down
- Caused by shortage of CO₂ in blood
- Acidity of the blood is reduced (**more alkaline**)

High Altitude

• **Decompression sickness**

- Nitrogen bubbles released causing gas embolism; bends and chokes
- over-saturated nitrogen gas molecules in body tissue

① • **Bends**: nitrogen bubbles in joints that cause pain
↳ **Henry's law**

- **Chokes**: gas bubbles in lungs
- **Creeps**: gas bubbles under skin

- Need to wait **12h**
24h after diving

• **Acceleration**

- high radial acceleration → **Grey-out**

• **Carbon Monoxide (CO) poisoning**

- CO binds 200 times greater to red cells than oxygen
- Symptoms like flu, without high temperature
- Several days needed to recuperate

• **Radiation**

- GCR → steady and predictable
- High altitude: Basic solar radiation and solar storm
- Annual radiation with adverse effect ~ **100 mSv**
- Same as background radiation

Humidity

- lowest humidity: cold outside aircraft
warm inside

Ozone → should be below defined limits
(ozone remover)

People and the environment: the sensory system

Senses

- Proprioceptors: sense joint position

Central, peripheral and autonomic nervous system

Vision

Functional Anatomy

- Pupil controls amount of light to retina
- Cornea: clear portion of the eye where light passes through
- Retina: contains photoreceptors for vision
 - acquisition of visual signal and coding of physiological data
- Rod, periphery, night, moving object
 - Rhodopsin (visual purple) for night vision
 - Needs Vitamin A
 - Scotopic vision
- Cones
 - 2-3° of fovea, decreases rapidly
 - photopic vision

Accommodation

- Change of shape of lens
- Controlled by ciliary muscles

Hearing

- At oval window, vibrating chain of ossicles induce pressure waves in endolymph
- Sound: fluid-filled portion of the cochlea

- Presbycusis: hearing loss of high tones through aging

Equilibrium

- Vestibular apparatus
 - 3 semi-circular canals: rotation and angular acceleration
 - Otolith organ (utricle and saccule): gravity and linear acceleration

- Motion sickness
 - Hyperventilation, Euphoria

Illusions

- Most critical: Visual (blind spot), kinaesthetic (leans) and auditory (missed radio call) illusion
- Black hole effect
 - illusion that aircraft is too high
 - flying above water
 - leads to low approach
- Haze: objects seem further away than in reality

Vestibular illusion

- Somatogyral

- Somatogravic: linear acceleration, otoliths
 - Acceleration: head up illusion

Fovea and peripheral vision

Night Vision

Binocular and Monocular vision

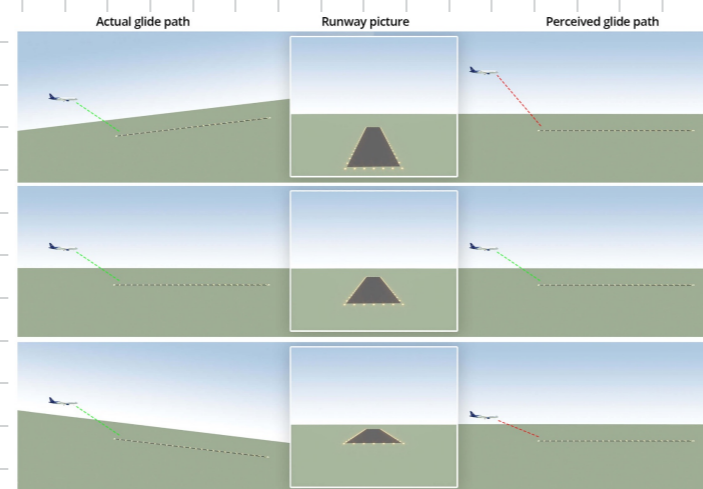
- Monocular depth cue: linear perspective
 - Obscuration, texture, atmospheric perspective

Defective vision

- Astigmatism: irregular misshapen cornea
- Presbyopia
 - loss of elasticity due to aging (common over 50)
 - Decrease of accommodation
- Astigmatism
 - Cornea not even shaped
- Glaucoma
 - increase in pressure of the eye liquid

Contact lenses

- Acceptable only if short-sighted (must see instruments)
- Damage to cornea due to low humidity and hypoxia



Health and hygiene

Body Rhythm and sleep

- Sleep Cycle
 - Each cycle ~ 90 min
 - Stage 3 and 4 → physical recovery
 - REM 90-120 min in 5 to 6 phases
 - ↑ Paradoxical sleep phases get longer
 - Credit/Debit
 - 2 points per 1h sleep
 - Free running circadian rhythm = 25h
- Intoxication
 - Tobacco and smoking
 - loss of 5-8% oxygen transportation
 - physiological altitude rise to 6000-8000ft
 - Caffeine: max 250 mg/day
 - Alcohol
 - Assimilation ~ 0.1-0.15/100 per hour
 - 0.6/100 = 4h
 - You can have 0.2/100 in your blood (orange juice)

Problem Areas for Pilots

- Barotrauma
 - When descending rapidly
- Barodontalgia
 - sensitive tissue close to the root of tooth
- Eustachian tube
 - equalize pressure btw middle ear and environment
- Obesity and diabetes
 - Type I (birth)
 - Type II (obesity) → unexplained weight loss
 - BMI > 30 = obesity
 - Sleep apnoea / Diabetes / Coronary disease
- Tropical climates
 - Disinsecting at least 30 min before landing

- Dengue fever / Cholera and dysentery
 - Can kill in a short time
- Nasal spray 7-12 µm

Basic of Aviation Psychology

Human error processing

Short term memory

- Information stored for 20 sec
- 7 bits

Long term memory

- episodic: influenced by suggestions (events)
- Semantic: meaning of words and general knowledge
- unlimited storage

Mental schemes

- Memorised procedures

- Modelling → learning a task by imitation

Error of a motor program

- Action slip (wrong checklist)
- Environmental capture (habituation)
 - skill executed in environment where frequently exercised
 - skill from old aircraft type used in new aircraft

Human error and reliability

- violation: not using the checklist
- Error rate:
 - Simple: 1-100
 - Complex: 1-1000

Decision making

- Detect
- Estimate
- Choose
- Identify
- Do
- Evaluate

Top-down

- In reduced visibility, objects are perceived as larger or smaller
- Compare brain data to new info
 - critically disguising inconsistent details

Anderson model of skill learning

- Cognitive Trainee
- Associative
- Automatic/Autonomous Captain / FO

Rasmussen model

Skill-based behaviour

- routine errors

Rule-based behaviour

- approach or divert decision
- checklist
- sound alert

Knowledge-based

Gestalt laws

- how objects are mentally organized and perceived

Avoiding and managing errors: cockpit management

Type of authority

- Autocratic → overloaded
- Laissez-faire
- Synergistic
- Paralanguage: tone of voice, break in sentence
- Metacommunication 80%.

Human behaviour

- Self-concept: complete set of attitude
 - New captain might be aggressive
- Invulnerability: "it will not happen to me"
- Anti-authority: "Don't tell me what to do"
- Resignation: hard taking difficult decision

Human overload and underload

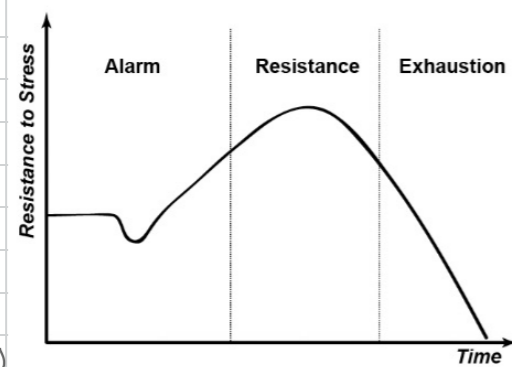
① Alarm reaction

② Resistance

- fat transformed in sugar
- psychosomatic disorder

③ Exhaustion

- Stress promotes physical capability (more than mental)
- Dry mouth
- Homeostatic mechanism
- Environmental stress
- Economical stress
- Social stress



- General Adaption Syndrome GAS
 - connected to the ANS Automatic Nervous System

Fatigue

- Acute (short term)
- Chronic (long term)

Advanced cockpit automation