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HUMAN PERFORMANCE AND LIMITATIONS

CHAPTER 18 – FATIGUE AND CICADIAN RHYTHMS

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FATIGUE AND CIRCADIAN RHYTHMS

18.1 Fatigue

Fatigue can be simply described as a very deep tiredness that requires the body to rest. It does not necessarily imply the need for sleep, although sleep deprivation and fatigue often go hand-in-hand. The body resources requiring rest may be physical or mental, or both.

Fatigue affects every part our performance. It degrades attention and concentration, which results in missed cues or missed information and a reduced ability to make sound decisions; it has a negative impact on coordination and makes us less able to deal with other people, particularly in situations of conflict.

The person suffering from fatigue is usually unaware of their degraded performance.

There are two types of fatigue that affect a pilot:

18.1.1 Acute Fatigue (Short - Term)

This is often caused by intense mental or physical activity over a relatively short time frame and requires a relatively short recovery time. Examples of this are heavy physical work, having to work extremely hard on an important problem while under pressure, or flying in instrument conditions in turbulence for several hours. Anytime a task requires heavy physical activity or undivided attention for a prolonged period, acute fatigue is likely to result. Acute fatigue can usually be cured by having a good night's sleep.

18.1.2 Chronic Fatigue (Long - Term)

This is the result of prolonged stress or excessive workload, often over many weeks, or months, and requires prolonged recovery. It may also arise from a protracted illness.

Airlines and aviation regulatory authorities attempt to reduce fatigue in pilots by setting out rules on flight and duty time limitations.

Curing chronic fatigue is much more of a problem. We may need more than just two or three nights sleep, or a holiday to affect a cure. Chronic fatigue will usually require more time to cure and will often need professional medical intervention.

18.1.3 Causes of Fatigue

Any stress-causing factor mentioned earlier may result in fatigue.

18.1.4 Signs of Fatigue

These can be physiological, psychological or behavioural:

- Lack of awareness—missed radio calls, missing checklist items.
- Judgement and decision-making errors; slow reactions, a larger number of mistakes.
- Short-term memory problems, e.g. unable to remember a clearance.
- Channelled concentration—we are unable to think of more than one task.
- Obviousness tiredness—drooping eyes or head.
- Poor sleeping/eating habits.
- Aggressiveness or other abnormal moods.
- Diminished vision—an inability to focus, or the need to blink the eyes.
- ‘Sloppy’ flying and accepting lower standards.

18.1.5 Precautions against Fatigue

- Adequate sleep, balanced diet and exercise
- Moderate caffeine intake
- Avoid cigarettes
- Minimise alcohol intake
- Exercise while flying (legs, arms, shoulders)
- Drink sufficient water

- Maintain sugar levels.

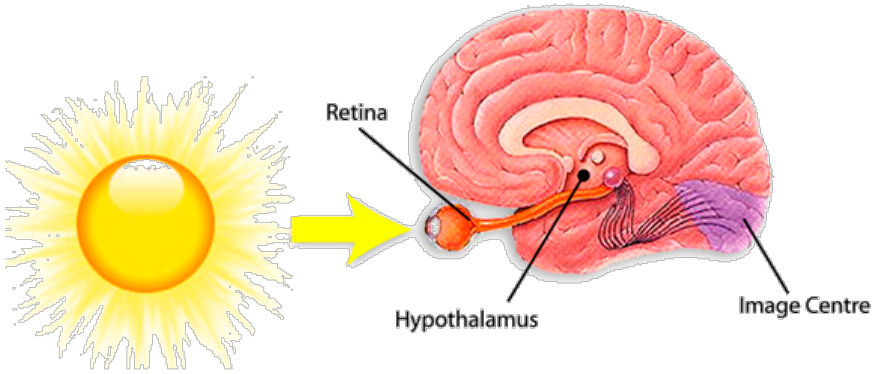
Symptoms of Acute Fatigue caused by excessive physical/mental activity, easy to overcome with sleep.

Symptoms	Signs
Sleepiness	Tired, bored, slow frequent yawning or sighing.
Lowered standard	Increased rates of errors, sloppiness, careless.
Increased reaction time	Slow to respond, missing radio calls, and rough on the controls.
Physical exhaustion	Slow movement, increased effort to carry out work, complains of cramps or stiff muscles.
Irritability	Faultfinding, impatience, temper flare-ups, grouchy.
Unable to concentrate	Instrument scan breaking down, indecisive, slow in solving simple problems.

Symptoms of Chronic Fatigue caused by prolonged exposure to stress (weeks/months). Requires extended recovery period.

Symptoms	Signs
Forgetfulness	Forgetfulness, unusual preoccupation.
Increases reliance on caffeine, alcohol etc	Chain-smoking, hangovers, coffee addiction.
Insomnia	Change of sleeping habits, nightmares.
Loss of appetite	Not eating well, loss of weight.
Depression	Withdrawal, anxiety, fearfulness, confusion, sense of failure.
Tenseness	Unable to relax, restless.
Psychosomatic illnesses	Headaches, heartburn, constipation, diarrhoea, vague chest pains, shortness of breath.

18.2 Circadian Rhythms

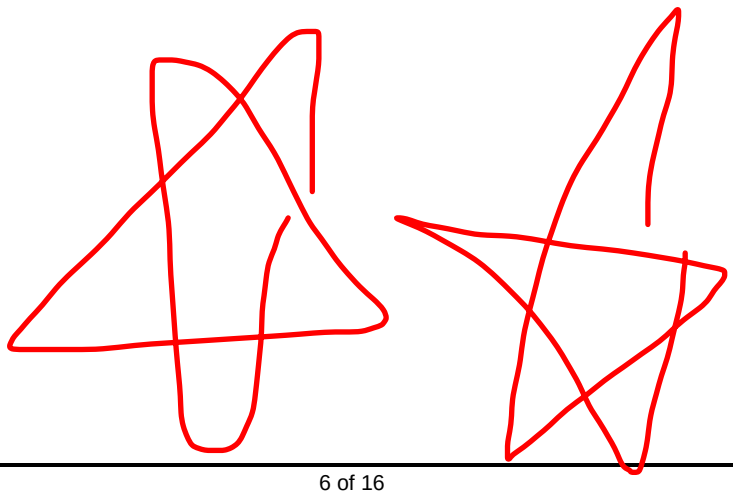


The word 'circadian' comes from two Latin words, *circa* meaning 'approximately' and *dies* meaning 'day'. Circadian rhythms are regular changes in our physiological and psychological states during the course of a day and are controlled by the body's internal biological 'clock'. This clock is a tiny cluster of cells situated in a portion of the brain called the hypothalamus.

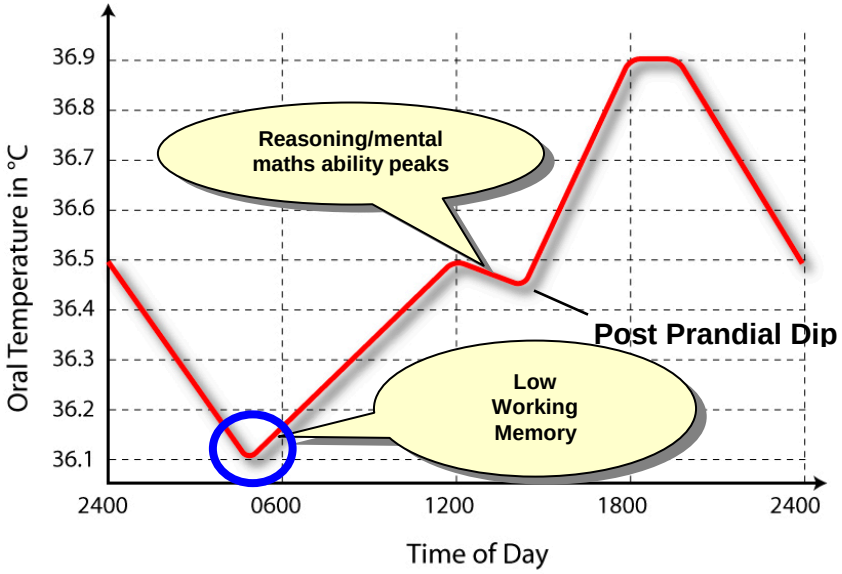
Light reaching the retina sends signals to this part of the brain as well as to the image centre of the brain, so light is the main activator of the body clock's 'on/off' switch. These rhythmic changes, regulated primarily by light levels, will persist in the absence of light, but in a haphazard, free run or irregular pattern running over 25 hours rather than 24 hours. Blind people often experience problems with their circadian rhythms.

There are many areas of the body that experience rhythmic fluctuations. Some that interest us as pilots include the sleep/wake cycle, digestive activity, vigilance, body temperature, blood pressure (lowest in the morning), sensory acuity and brain function. Other areas include heart rate and adrenal gland output, hand-eye coordination, reaction time, spatial awareness and mental arithmetic ability.

Body temperature is usually considered the standard by which circadian rhythms are measured, probably because it is one of the easiest to observe and record.



Below is a graph showing the normal daily changes in body temperature:



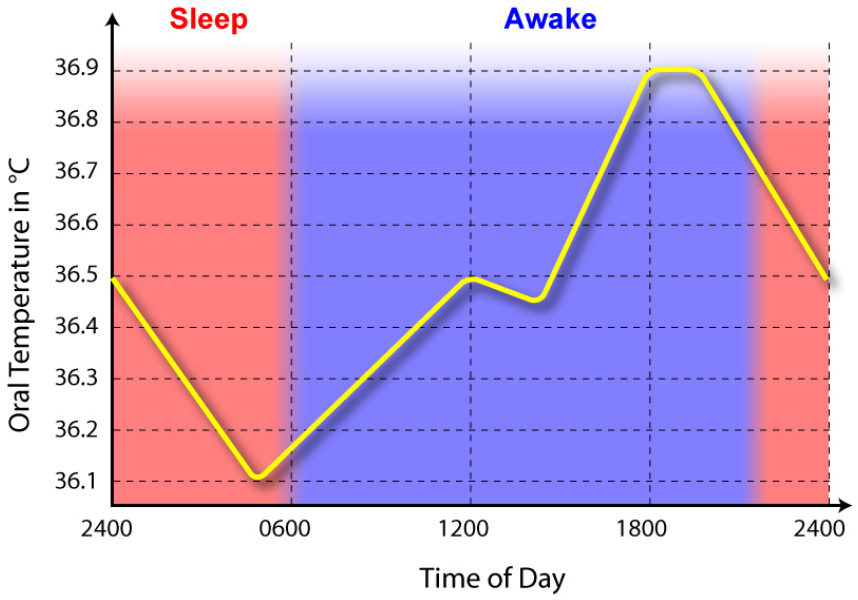
THE CIRCADIAN RHYTHM OF BODY TEMPERATURE (oral)

The following body characteristics follow body temperature:

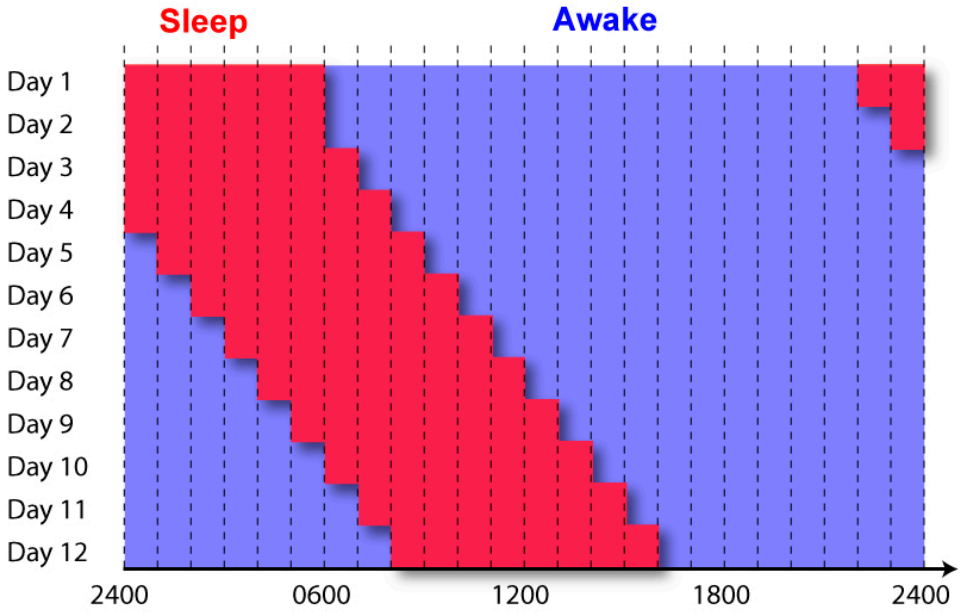
- Low working memory loads (vigilance, dexterity) follow low body temperature.
- Short- term memory tasks decline throughout the day.
- Reasoning/mental maths ability peaks at midday, although this differs with individuals.
- It is more difficult to fall asleep when body temperature is high, and to stay awake when it is low.

18.2.1 Sleep wake cycle

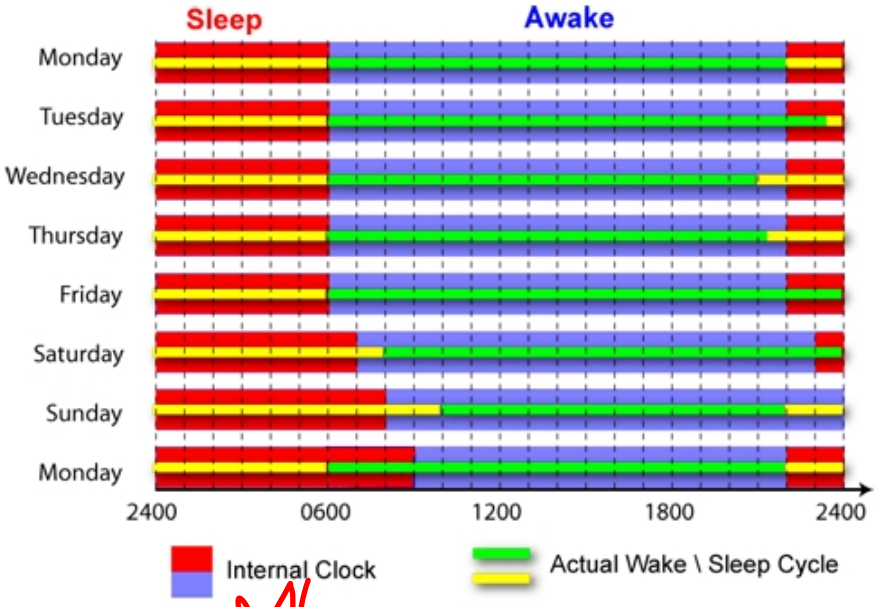
Normally the sleep/wake cycle follows a 24 hour rhythm with approximately one third of the day being asleep. The sleep/wake cycle and the body temperature rhythm tend to run together so that the lowest point of the temperature cycle coincides with the lowest point of the sleep/wake cycle – that is, when we want to be asleep rather than awake and active. This occurs around 0500 when the body temperature is at its lowest and it is usually quite difficult to stay awake at this time.



A common circadian feature is that in the absence of time cues (sunrise, alarm clock, bird calls), such as in sleep study isolation suites or as experienced by astronauts, the sleep/wake cycle will naturally want to stretch to between 25 - 28 hours.



The second common circadian disorder has been termed the "Monday morning blues". An individual who sleeps late on Saturday morning misses the normal early morning zeitgeber signal and as a consequence the 25-hour internal clock drifts approximately one hour later. The process is repeated on Sunday morning so that when the alarm clock rings at 6 a.m. on Monday morning, the body's clock is 2 hours behind and one has to struggle to get out of bed because it is 4 a.m. according to the body's internal clock.



18.2.2 Zeitgebers

Zeitgebers (German for 'time givers') synchronise our rhythms to 24 hours. These can be external such as light and dark, or internal such as hunger.

Other zeitgebers are clocks and watches, bird and traffic noises, mealtimes and social influences.

In the absence of Zietgebers the body clock will extend to a 25-hour day.

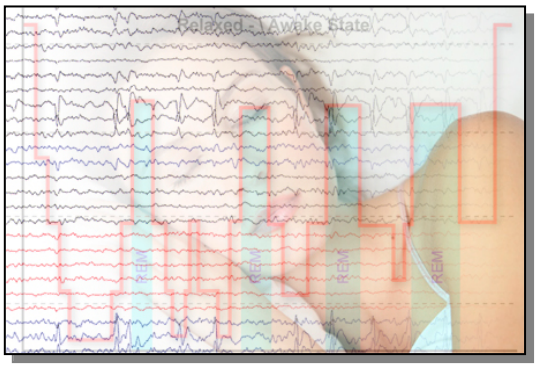
18.2.3 Credit-Debit System

Sleep deprivation and the likelihood of sleep can be predicted using this concept:

- We add 2 pts for every hour of sleep
- We deduct 1 pt for every hour we are awake.
- However long the sleep; we cannot exceed 16 points, as we cannot 'store' sleep.

The fewer points we have, the more likely it is that we will want to sleep. A gradual reduction of credit will build up into what is called "Cumulative Sleep Debit".

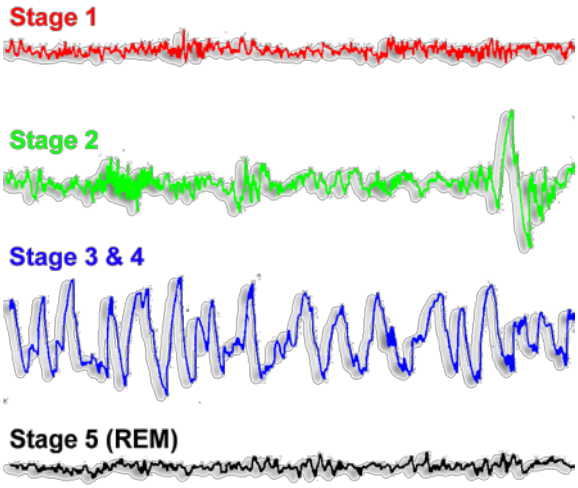
18.2.4 Stages of Sleep



Sleep is an altered state of consciousness. Researchers have studied sleep by means of the EEG (electroencephalograph, which graphs the electrical activity of the brain), the EOG (electrooculogram, which graphs the movement of the eyes) and the EMG electromyogram (which graphs muscle tension).

The brain's normal, alert and aroused state will show a characteristic pattern on the EEG graph. This pattern is known as the 'Beta activity'. When we are resting quietly, with the eyes closed and just before we drop off to sleep, the EEG graph will show a different pattern. This is known as 'Alpha activity'.

After we drop into sleep, we will typically experience five different depths of sleep. These different stages of sleep can be determined from the EEG, EOG and EMG graphs.



Example of an EEG

Stage 1

This is the transition between sleeping and waking. Rapid eye movements are not present, but there is slow rolling eye movement. The EMG shows only moderate activity.

18.2.4.1 Stage 2

A deeper sleep stage. EOG shows little movement and EMG trace is similar to that of Stage 1.

18.2.4.2 Stage 3

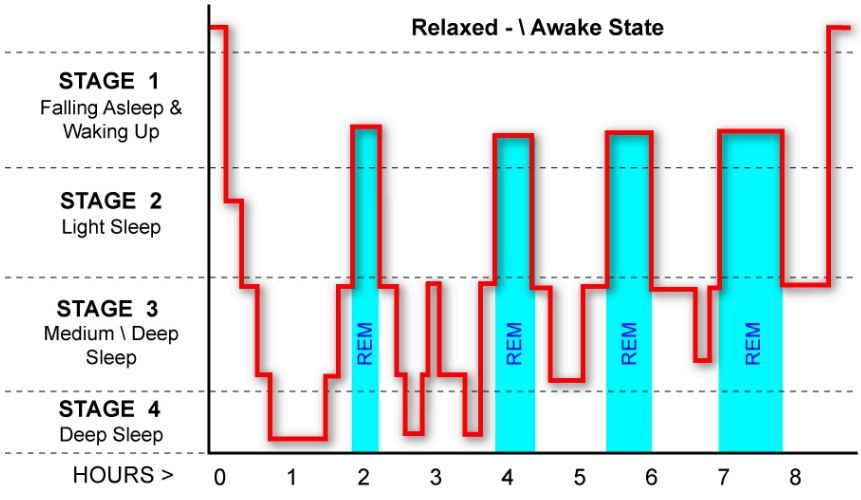
EEG; EOG and EMG remain much the same as the previous two stages.

18.2.4.3 Stage 4:

EEG show predominantly Delta waves (a Delta wave is a large, slow brain wave and is usually associated with deep sleep), but little change to EOG and EMG patterns.

18.2.4.4 Rapid Eye Movement (or REM) Sleep: `Remember Dream`

This is the 5th stage also called **paradoxical** (a puzzle) sleep because the EEG is similar to that of the individual when they are awake. The EOG shows periods of rapid eye movement, EMG shows occasional small muscle twitches, but apart from that the skeletal muscles are more-or-less paralysed in the REM phase.



Slow wave sleep (Stages 1 to 4) restores the body. REM sleep strengthens or organises the memory. REM sleep is a very important stage of sleep and any disruption to this form of sleep can have fatiguing affects on the body the next day.

A sleeping person passes through the 5 stages in approximately 90 minute cycles, each succeeding cycle contains more REM sleep, and less stage 4.

Notice that the slow wave sleep (stages 1 to 4) becomes shorter and shallower, while the REM events become longer as the sleep session progresses.

18.2.5 Additional Facts about Sleep

- Women sleep more than men do.
- Individuals differ, but generally require between 7-9 hours each night.
- Requirements change with age; REM sleep periods decline and staying asleep becomes more difficult in the elderly.
- Effect of sleep disruption varies with individuals, so too does the method of overcoming it.
- Old people require less sleep but are less flexible with timing.
- Helping the body to sleep:
- Avoid caffeine near bed time.
- Drink warm milk instead.
- Avoid exercise or emotional stress near bed time.
- Avoid napping during the day.
- Ensure the room is quiet, cool and comfortable.
- Read something light in bed.

19 degree good to sleep

18.2.6 Sleep Disorders and Idiosyncrasies

- **Narcolepsy:** The person is always sleepy. They may fall asleep any time irrespective of how much sleep achieved at night. This may happen during driving and flying, so is very dangerous.

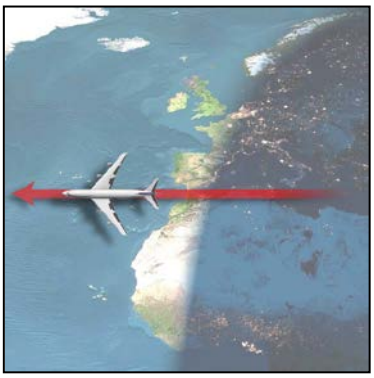
- **Sleep Apnoea:** Because of problems in the structure of the throat and throat muscles, the throat closes, resulting in cessation of breathing during sleep. The person wakes frequently and does not receive adequate sleep, which results in daytime sleepiness. Waking can occur up to 130 times per night for up to 30 seconds or more each time.

- **Sleepwalking:** Does not occur during REM sleep.

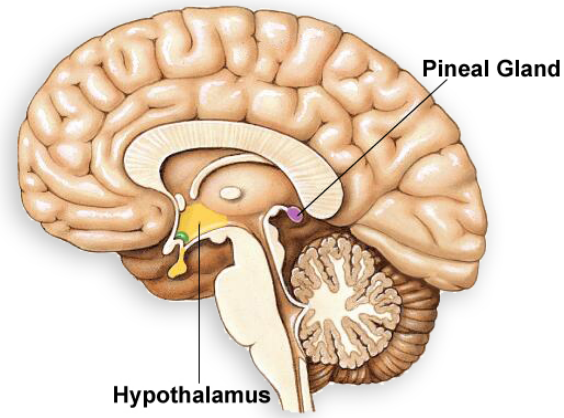
- **Sleeptalking:** Occurs in slow wave sleep (Stages 1 to 4) and sometimes during REM sleep.
- **Insomnia:**
  - **Clinical:** Inability to sleep under normal favourable conditions.
  - **Situational:** Due to disrupted work or rest conditions.
- **Naps:** Effect varies between individuals. Naps need to be greater than 10 minutes (to get any benefit) and less than 40 minutes. Longer than 40 minutes increases the chance of 'sleep inertia', i.e. feeling 'groggy' when you wake up.
- **Microsleeps:** Vary from fractions of a second to several seconds. Only detected by the EEG. Very dangerous, because the victim is unaware of them.
- **Dreams:** Will be remembered if woken from REM sleep. Nature and duration change over the sleep period.

18.3 Disturbance of Biological Rhythms

18.3.1 Circadian Disrhythmia, or 'Jet-Lag'



This is sometimes also called Circadian Desynchronosis or Transmeridian Dyschronism. When we travel by aircraft east or west, we are transported very quickly into a new time zone. But our circadian rhythms remain set at the time of our departure and the peaks and troughs of our body temperature (and therefore our activity cycles) will now occur at a different time of the day at our destination. When our bodies want to sleep, the sun may be rising and the day is beginning.



Our bodies produce melatonin, a natural, mild sedative. Melatonin is produced by the pineal gland, a gland about the size of a pea, which is located in the center of the brain. Production of melatonin by the pineal gland is controlled by the hypothalamus (located close to the centre of the brain), which receives information from the eyes about the daily pattern of light and darkness.

The production of melatonin is inhibited by light and permitted by darkness. For this reason melatonin has been called "the hormone of darkness". The production of melatonin peaks in the middle of the night, and gradually falls during the second half of the night. Because melatonin promotes sleep, and melatonin is produced only during darkness, we naturally find it more difficult to sleep during the day.

The need for long-haul pilots to sleep during the day will result in a number of problems, including lack of good, deep sleep, headaches, poor mental performance, disturbed eating patterns, dizziness, possible constipation, and possible depression.

Our bodies will gradually adjust to the new time zone, but this will take about 1 day for each 1 to 1-1/2 hours of time zone change. For example, the 10 hour time zone change between London and the eastern states of Australia will require 7 to 10 days for the body to adjust.

Our body has a number of internal ‘clocks’. For them all to resynchronise totally, we may need longer than the 1 to 1-1/2 hours per day As with most human factors, we are all different and each of us will experience varying difficulty in adjusting completely. The decision for the long-haul pilot who will be making an onward flight in a couple of days will be whether to remain on ‘home’ time or to try to adapt to local time. This will be a personal decision, as there are no rigid rules.

West is best

18.3.1.1 Eastbound or Westbound – Easier or Harder?

The adjustment of our internal clocks is easier if we travel west. The sun travels westward across the earth, and as we fly westward, we experience a longer day, that is, a longer period of daylight. As we know, our bodies have a natural rhythm of 25 or more hours, not 24, and will have a natural tendency to more easily move to the new time zone.

The reverse happens if we fly to the east. The days are shortened and our body rhythms have to realign to less than 24 hours, which is against their natural tendency.

18.3.2 Aircrew and Their Sleep

Jet-lag is a problem for long-haul airline pilots. They will often need to sleep at unusual times during the day. Disturbed sleep is also inevitable when resting during the day, as the day does not favour sleep. There is more light, more noise and less melatonin. It is also warmer, and surrounding activity may disturb even the most tired sleeper.

The body's core temperature will be higher, making sleep more difficult. The individual may fall asleep quickly, but waken after only a few hours, so sleep is broken and will be of short duration.

Sleeping at unusual times is inherent in most air operations. Even the duty hours of short-haul routes may encroach on the normal nocturnal sleep period and some sleep periods may be shortened.

18.3.3 Sleep Management

Managing sleep during long-haul operations is a complex, and usually individual problem, with personal variations being the norm.

With, say, a 24-hour rest period after a long trans-meridian flight, a long sleep immediately after a flight could mean that the crew would not be in the most rested state prior to the next flight. To avoid undue sleepiness during duty after a 24-hour rest, crews often split their sleep into two parts. Restricting sleep immediately after the preceding flight creates the need for sleep immediately before duty (an anticipatory sleep). If, however, he has difficulty in sleeping during this second period, he will commence the flight with a significant sleep deficit.

Short periods of sleep are often taken to maintain effectiveness during schedules that require working at unusual times of the day. Some people find it easy to nap, and they will benefit from this approach. The non-nappers may have problems.

Again, it is a complex and personal decision for airline pilots.

18.3.4 Flight Time Limitations

The aim of such limitations is to ensure safety in aircraft operations—in both general aviation and regular public transport. Duty hours must be arranged to ensure that aircrew can achieve acceptable sleep.

Duty hours that can be effectively achieved by aircrews decrease as the number of days of the schedule increases. This is due to the cumulative effect of the irregularity of sleep. In this sense aircrew operating world-wide routes are able to cope with 50–55 hours in the first 7 days of a world-wide schedule, but they can only manage about 75 hours duty by the end of 14 days.

Airlines and regulatory authorities around the world have done a lot of work (and will continue to do so) on flight and duty time limitations.

18.3.5 Management of Aircrew Sleep Disturbance; Drugs and Sleep Management

Management of sleep is a matter of what suits the particular individual—there are no universal rules. What works for a particular individual might not be satisfactory for another. We will all need to determine what works for us as individuals.

Hypnotics (sleeping tablets) are not normally acceptable for use by aircrew. Because of the potential problems concerning the use of hypnotics by aircrew, only doctors very familiar with aircrew operations should recommend their use, and then only when non-drug options have been explored. Contact your aviation medical examiner for advice if necessary.

Alcohol is a Central Nervous System depressant. It induces sleep initially, but inhibits REM sleep. While it might feel that you drop off to sleep quickly after drinking alcohol, the quality of sleep is reduced.