HUMAN FATIGUE FACT SHEET

Human Fatigue as a Threat to Aviation Safety
**Introduction**

It can be stated that human fatigue – and especially pilot fatigue (i.e. airline, cargo, corporate and charter pilot fatigue) – is a real problem since the beginning of air travel\(^1\). Stressors for fatigue are for instance the long workdays, lengthy flights, time zone crossings and night flights. These factors are a threat to pilot performance and flight safety. This fact sheet explores different facets of human fatigue in the aviation industry within the context of human factors and safety; it discusses the impact, causes and countermeasures for fatigue. The information presented in this fact sheet is primarily based on a bachelor thesis on the effect of human fatigue on speech production\(^2\).

**Example 1: 6 July 2013**

A relatively recent accident in which fatigue was implicated is Asiana Airlines flight 214 with a Boeing 777-200ER that crashed during landing at San Francisco International Airport\(^5\). Three of the 291 passengers were fatally injured; 40 passengers received serious injuries. The Boeing was destroyed by a post-crash fire and impact forces. The NTSB evaluated a number of criteria regarding fatigue, including recent sleep and its quality, circadian factors as well as time awake and concluded that at the time of the accident all three pilots were experiencing some fatigue (e.g. a disruption of the circadian rhythm and having fragmented and/or less sleep than normal). This likely degraded the performance at the time of the accident.

**20 to 30% of transport accidents involve human fatigue**

The National Transportation Safety Board (NTSB) estimates that fatigue contributes to twenty to thirty percent of all accidents considering all transportation types\(^3\). Therefore fatigue is a serious threat to aviation safety (**Example 1**). A scientific study concluded that 20 to 25 hours of sustained wakefulness resulted in performance decrements that are equivalent to those of a blood alcohol concentration (BAC) of 0.10%\(^4\). This indicates that being fatigued is just as dangerous as being drunk.

**What is human fatigue?**

Fatigue is a human phenomenon that is easily recognizable in the observation of others, but difficult to define\(^6\). It can be a physical or a psychological (mental) type. Physical fatigue occurs when the muscles become fatigued and they are not capable to maintain optimum physical performance (e.g. performing intense physical exercises). Psychological fatigue is a decrease in cognitive performance; it lessens the ability to perform a task in a safe and effective manner. Fatigue can be a temporary condition due to a lack of sleep, but it can also result in chronic psychological and physical disability. Fatigue is often confused with tiredness or sleepiness. While there is a relation between fatigue and sleepiness, they are not identical. Sleepiness is
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defined as having the feeling to close the eyes and go to sleep. This is not necessarily the case when a person is fatigued.

According to the International Civil Aviation Organization (ICAO) fatigue is “a physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member’s alertness and ability to safely operate an aircraft or perform safety related duties.” (ICAO, 2013). 7

What is the impact of human fatigue?

An obvious threat of fatigue is that an individual loses the fight to stay awake while performing a certain task. This is extremely dangerous when for instance a person is operating equipment or driving a vehicle. A person who is experiencing fatigue may also experience a microsleep: a short (2 to 30 seconds) period of time in which the person enters the first stage of sleep. During this microsleep the person may continue to perform a relatively simple task before regaining consciousness, could possibly have the eyes still open and is typically unaware of the situation. Beside the possibility of microsleeps, fatigue has an effect on (1) attention level, (2) memory, (3) mood and (4) reaction time.

Attention level

The attention level of a fatigued person is significantly reduced. This can result in leaving out different steps while performing a task or focusing on just one part of it. A lower attention level can also lead to tunnel vision in which a person is less likely to notice unexpected situations. The performance level of the person can be influenced negatively, because he or she is not aware of a certain situation. Concentration may also be affected, because it requires more effort for the person to stay concentrated under normal circumstances.

Memory

The memory of a fatigued person is diminished. This can result in a poor memory while executing a task. Someone who is fatigued is more likely to forget routine procedures.

Mood

The mood of a fatigued person can be described as withdrawn. This can result in an attitude in which a person is more irritable, more easily frustrated by minor difficulties and is more likely to perform shortcut tasks instead of heavy ones. Communication can also be affected, because someone who is fatigued is less likely to interact with others.

Reaction time

Reaction time is also affected when a person is fatigued. It takes more time to notice problems and it takes more effort to control equipment or vehicles smoothly. Reaction time can also be related to the attention level, because a slower reaction time can be the result of inattention or poor concentration while performing a certain task.
**What are the causes for human fatigue?**

Fatigue can be stated as “a non-pathologic state resulting in a decreased ability to maintain function or workload due to mental or physical stress.”

It can be induced by sleep deprivation or a disruption of the circadian rhythm.

**Sleep deprivation**

Sleep is – as well as for instance food and water – one of the basic needs for survival. When an individual experiences sleep loss it results in sleepiness. This can be defined as a signal in the brain that indicates that sleep is needed. Sleep loss means that a person has obtained less sleep (i.e. the person is sleep deprived) than needed for maximal waking alertness and performance. Sleep loss over several consecutive days results in a sleep debt. A study concluded that even relatively moderate sleep deprivation seriously impairs waking neurobehavioral functions in healthy adults. It also impairs physical health and the functioning of individuals (Figure 1).

- Irritability
- Cognitive impairment
- Memory lapses or loss
- Impaired moral judgement
- Severe yawning
- Hallucinations
- Symptoms similar to ADHD
- Impaired immune system
- Risk of diabetes Type 2
- Increased heart rate variability
- Risk of heart disease
- Decreased accuracy
- Tremors
- Aches

**Example 2: 12 February 2009**

An accident in which sleep loss was implicated is Colgan Air, Inc., flight 3407 with a Bombardier DHC-8-400. The aircraft crashed during the approach phase while it was heading to Buffalo-Niagara International Airport, Buffalo, New York. Two pilots, two flight attendants and 45 passengers aboard were killed and one person on the ground was killed. The aircraft was totally destroyed by a post-crash fire and impact forces.

According to the captain’s wife, he would normally sleep between eight and ten hours. However, in the days before the accident he had significantly earlier awakening times as well as being away from home often. This would have produced some sleep loss. In the 24 hours before the accident the first officer slept her normal needs, but the quality of the sleep may have been diminished due to the manner in which it was obtained (aboard the aircraft and in the crew room). Furthermore at the time of the accident she was already awake for at least 15 hours.

The NTSB concluded in the accident report that the captain experienced some chronic sleep loss and both pilots obtained poor-quality sleep in the 24 hours before the accident.

Sleep debt can be the result of work commitments (e.g. shift work), family situations (e.g. young children) but can also be affected by medical conditions, the use of alcohol or the intake of other drugs.
Disruption of the circadian rhythm

The human body is constantly experiencing biochemical, physiological and behavioural rhythms. The brain is programmed to sleep during the night by a biological body clock, which is known as the circadian rhythm (Figure 2). The circadian rhythm is affected by light exposure. This enables the body clock to keep pace with the day/night cycle. When people have to sleep out of step with this circadian day/night cycle, problems may occur.

Circadian rhythm and the aviation industry

Some of the people working in the aviation industry have to deal with shift work or time zone crossings (Example 3). In case of shift work a person has to be awake when he or she would normally be asleep considering the circadian body clock cycle. Due to shift work it is more difficult to get adequate sleep and the chance of sleep deprivation increases.

Crossing time zones also influences the circadian body clock. The human body has to adapt itself to a new time zone when these are crossed, which will take some time. The rate of adaption depends on many factors. For instance the number of time zones that are crossed and the direction of travel affect the rate of adaption.

Example 3: 14 January 2011

When Air Canada, flight ACA878 from Toronto, Ontario, to Zurich, Switzerland was halfway across the Atlantic, the aircraft (a Boeing 767) experienced a 46-second pitch excursion during the hours of darkness. The aircraft deviated 400 feet above and below the assigned altitude of 35,000 feet. Fourteen passengers and two flight attendants were injured from contacting armrests and cabin fixtures.

The Transportation Safety Board of Canada (TSB) concluded that one of the contributing factors to the incident was the circadian phase of the pilots. Due to the time of the incident (in the middle of the night) the pilots were experiencing a circadian low (i.e. periods of high fatigue and poor performance).

There is a correlation between the circadian body clock and sleep. The circadian body clock determines when hormones related to sleep and attention (e.g. melatonin and cortisol) are released. Circadian disruption may result in difficulty to fall asleep or stay alert. ‘Jet lag’ is a well know example of the effect of circadian disruption.

What are countermeasures against human fatigue?

A problem with fatigue is that it cannot be reduced by typical prevention measures such as training. However, there are still a few lifestyle recommendations that should be taken into account to minimize the risk of becoming fatigued.
Lifestyle recommendations: don’t do this...
- Consume alcohol or caffeine in the three to four hours before going to bed.
- Exercise in the two to three hours before going to bed. Although exercising leads to a healthier lifestyle it should not be done very close to bedtime.
- Eat a heavy meal before going to bed.
- Take work-related aspects to bed.
- Take sleeping pills.

Lifestyle recommendations: do this!
- Get a sleeping pattern of eight hours of sleep per night.
- Take naps during the day if possible.
- Try to get a bedtime routine to fall asleep quicker.
- Create (or select when traveling) a comfortable sleeping environment (i.e. free from any noise and light, good temperature, comfortable mattress, etcetera).
- If falling asleep is difficult within the first 30 minutes, get out of bed and try an activity that induces sleep (e.g. reading, listening to relaxing music, etcetera).

How to cope with circadian rhythm disruption while on duty?
Flying across time zones leads to a disruption of the circadian rhythm. The following countermeasures may help to cope with it:
- Make sure to sleep well at home before the flight.
- Try to get the same amount of sleep per 24 hours as normally.
- Try to get some sleep when feeling sleepy. It is better to take a nap whenever possible instead of not sleeping at all.
- Avoid adaption to a local circadian rhythm in case of short layovers. It is better to maintain the circadian rhythm from the place of origin.
- Use caffeine in a strategic way throughout the flight.
- Have a conversation with others, stretch your legs and take regular breaks while on duty.

Minimizing fatigue issues with the FRMS
ICAO, the International Air Transport Association (IATA) and the International Federation of Airline Pilots’ Associations (IFALPA) developed a guide for the implementation of a Fatigue Risk Management System (FRMS). This publication adds a new safety dimension to fatigue related issues in the aviation industry and should for instance increase pilot safety.

According to ICAO an FRMS is defined as “a data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness.” (ICAO, 2013).
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The FRMS guide presents the common approach of operators, regulators and pilots to the complex human factor fatigue. It is based on scientific principles of fatigue and provides a possible alternative to the traditional and strict flight rules and duty times. The guide includes a methodology and framework to implement an effective fatigue risk management system. The implementation principle is based on four different phases, which consist of (1) planning, (2) implementing reactive FRM processes, (3) implementing proactive and predictive FRM processes and (4) implementing FRMS safety assurance processes.

How to go further?

Although FRMS tries to minimize fatigue and countermeasures can be very helpful against this phenomenon, fatigue still remains a problem. Since it poses a threat to aviation safety it should be taken seriously, which is why the aviation industry is still searching for ways to decrease the risks that are associated with human fatigue.

Scientific research at the Amsterdam University of Applied Sciences (AUAS) is aimed at better understanding fatigue and the effects of fatigue on the performance of aviation professionals, effective ways for the management of fatigue and developing ways to measure fatigue in a fast, easy and non-invasive manner.
Above mean sea level (AMSL): The elevation or altitude of an object that is relative to the average sea level datum.

Amsterdam University of Applied Sciences (AUAS): Higher professional education institute in the Netherlands, which offers educational and research programmes. Dutch name: Hogeschool van Amsterdam (HvA).

Blood alcohol concentration (BAC): The amount of alcohol in the bloodstream or on someone’s breath. It can be measured by breath, blood or urine tests.

Crewmember*: A person assigned by an operator to duty on an aircraft during a flight duty period.

Circadian rhythm: The brain is programmed to sleep during the night by a biological body clock. It is affected by the light exposure, which means that the sensitivity to light enables the body clock to keep pace with the day/night cycle.

Duty*: Any task that flight or cabin crew members are required by the operator to perform, including, for example, flight duty, administrative work, training, positioning and standby when it is likely to induce fatigue.

Evening wake maintenance zone: A period of several hours in the circadian rhythm, which is just before usual bedtime, in which it is difficult to fall asleep.

Fatigue*: A physiological state of reduced mental or physical performance capability resulting from sleep loss or extended wakefulness, circadian phase, or workload (mental and/or physical activity) that can impair a crew member’s alertness and ability to safely operate an aircraft or perform safety-related duties.

Fatigue Risk Management System (FRMS)*: A data-driven means of continuously monitoring and managing fatigue-related safety risks, based upon scientific principles and knowledge as well as operational experience that aims to ensure relevant personnel are performing at adequate levels of alertness.

Internal alarm clock: A time in the circadian rhythm in which there is a strong drive to wake up; it is very difficult to fall asleep or stay asleep.

International Air Transport Association (IATA): A trade association of the world’s airlines.

International Civil Aviation Organization (ICAO): A specialized agency of the United Nations, which works with global aviation organizations and the Convention’s 191 Member States to develop international Standards and Recommended Practices (SARPs).

International Federation of Airline Pilots’ Associations (IFALPA): Non-political and non-profit organization that represents over 100,000 pilots and engineers around the world. It promotes the highest level of aviation safety.

Jet lag: Desynchronization between the day/night cycle and the circadian body clock, which is experienced as a sudden shift in the day/night cycle. Symptoms include degraded cognitive and physical performance, mood changes, digestion problems and wanting to sleep and eat at times that are out of step. It is resolved when sufficient time is spent in the new time zone.

Microsleep: A short period of time in which a person enters the first stage of sleep, which takes approximately between two and thirty seconds.

Nap: A short period of sleep, typically described as less than a half of full night-time sleep duration.

National Transportation Safety Board (NTSB): An independent U.S. government investigative agency that is responsible for civil transportation accident investigation.

Non-invasive: Not puncturing the skin or penetrating body tissue.

Shift work: A work pattern in which a person has to be awake when he or she would normally be asleep considering the circadian body clock cycle.

Sleep: A natural and periodic state of rest for the mind and body in which there is a decrease in physical activity and responsiveness. The brain experiences a cycle with brain-wave activity that consists of intervals of dreaming.

Sleep debt: Obtaining less sleep than needed for maximal waking alertness and performance over several consecutive days.
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- **Sleep need**: The amount of sleep that is needed to maintain maximal alertness and performance.
- **Sleep quality**: The sleep capacity to reinstate waking function.
- **Transportation Safety Board of Canada (TSB)**: An independent Canadian government investigative agency that is responsible for civil transportation accident investigation.

* Represents an ICAO definition.

References


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18 International Air Transport Association (IATA), International Civil Aviation Organization (ICAO) and International Federation of Air Line Pilots’ Associations (IFALPA). (2011). Fatigue Risk Management System (FRMS) - Implementation guide for operators. Chapter 2.3: Introduction to Circadian Rhythms. (First ed.).


21 International Air Transport Association (IATA), International Civil Aviation Organization (ICAO) and International Federation of Air Line Pilots’ Associations (IFALPA). (2011). Fatigue Risk Management System (FRMS) - Implementation guide for operators. (First ed.).


Image references (top to bottom, left to right)


3 Wordcloud: http://www.wordle.net
Vermoeidheid is een groot probleem als het gaat om luchtvaartveiligheid. Volgens de National Transportation Safety Board (NTSB), een agentschap van de Amerikaanse overheid dat onderzoek doet naar transport ongevallen, speelt vermoeidheid een rol in twintig tot dertig procent van alle ongevallen in de transportsector. Vermoeidheid onder pilooten, luchtverkeersleiders en vliegtuigonderhoudsmonteurs vormt een ernstige bedreiging voor de luchtvaartveiligheid.

Vermoeidheid kan het functioneren ernstig belemmeren. Het heeft zowel effect op (1) oplettendheid, (2) geheugen, (3) stemming en (4) reactietijd. Een vermindering hiervan kan negatieve gevolgen hebben zodra iemand een verantwoordelijke functie uitoefent en bijvoorbeeld een voertuig moet besturen of een machine moet bedienen. Het kan ontstaan doordat iemand lijdt aan een slaaptekort of doordat er een verstoring plaatsvindt in het biologisch (circadiaan) ritme. Een probleem is dat het niet voorkomen kan worden door bijvoorbeeld training. Echter zijn er wel diverse tegenmaatregelen te bedenken en is er specifiek voor de luchtvaartsector een Fatigue Risk Management System (FRMS) ontwikkeld. Het FRMS geeft een aanpak om vermoeidheidsrisico’s te verminderen in aanvulling op werk- en rusttijdenregelingen en is van toepassing voor zowel exploitanten, regelgevende agentschappen en pilooten. Het berust op wetenschappelijke informatie en beschrijft een implementatieplan als het gaat om risicobeheer voor vermoeidheid.

Ondanks al deze inspanningen blijft vermoeidheid een probleem in de luchtvaartsector. De luchtvaartindustrie is daarom voortdurend bezig om manieren te bedenken om het vermoeidheidsrisico te verkleinen.

Wetenschappelijk onderzoek bij de Hogeschool van Amsterdam (HvA) richt zich op het verkrijgen van beter inzicht in vermoeidheid, het effect hiervan op luchtvaartgebied, effectieve managementmethoden tegen vermoeidheid en methoden waarmee vermoeidheid op een snelle, gemakkelijke en een non-invasieve manier gemeten kan worden.