Asleep at the Controls

Pilots and other shift workers, unaware of the effects of sleep inertia and microsleeps, may be putting lives at risk.

*This article by Joanne De Landre, Christine Boag and Adam Fletcher featured in the September/October 2002 edition of **Flight Safety Australia**. Minor modifications have been made for our New Zealand audience.*

Ever had one of those mornings when you wake up, stumble to the kitchen, and the most arduous task you can perform is to make a coffee?

And, if some chirpy little morning person dares talk to you during this time, they are threatened with menacing glares and grimaces?

Do your family and friends tease you about the dangers of talking to you before you've had your first coffee? Do you think that it just takes you a bit longer than most people to wake up, communicate in words rather than grunts, and regain your senses?

> ***"If you are awoken suddenly, the effects of sleep inertia can last up to 30 minutes or more."***

You could be experiencing a very real phenomenon known as 'sleep inertia'.

While on the domestic front this condition might cause a general lack of civility in the morning, in hi-tech transport systems it can be a killer.

Sleep inertia occurs in the period just after waking, and results in a measurable decrease in alertness. Ever nodded off at a performance or lecture? It might be a very highly rated film, and your friend might be really enjoying it, but you just can't stay alert.

After a while, the feeling of tiredness just swallows you up. As your head falls towards your chest, you bounce awake, only to nod off again soon after. What we know as 'nodding off' researchers call microsleeps, and it too is a killer in a complex technical environment.

Sleep inertia and microsleeps are two areas of research that have recently gained prominence after decades of study of fatigue and levels of alertness.

Sleep Inertia

Sleep inertia is a recognised state of transition from sleep to wakefulness.

New research into sleep inertia has revealed a range of effects, including:

- Impairment of performance and reaction time on tasks ranging from arithmetic to simple motor tasks such as grip strength and finger tapping.
- Reduction in memory ability.
- Impairment of the ability to make decisions.

Decision making is a cognitively complex process that involves recognition of the need to make a decision, generation of decision alternatives, and selection of a decision alternative.

Within the first three minutes of waking, decision-making performance can be as low as 51 percent of the person's best decision-making ability before sleep. Decision-making performance may still be 20 percent below optimum performance 30 minutes after waking.

When woken, most people experience some degree of sleep inertia. The degree of impairment that sleep inertia has on performance is influenced by a number of variables, including:

- The abruptness of awakening. When awakening from sleep normally, the effects of sleep inertia are believed to last for less than five minutes; however, if you are awoken suddenly, these effects can last up to 30 minutes or more.
- The stage of sleep that has been interrupted. If you are woken from deep or slow wave sleep, the effects of sleep inertia are more pronounced. Slow wave sleep is more likely to occur during the early stages of sleep. In a well rested person, slow wave sleep usually occurs within 45-60 minutes, whereas for shift workers or those people already sleep deprived, slow wave sleep may be reached in as little as 20-30 minutes.
- Sleep deprivation, which will increase the effect of sleep inertia.
- The type of task performance – the effects of sleep inertia vary among different types of tasks. For example, performance accuracy is more impaired by sleep inertia than reaction time.
- The time between awakening and time of performance – sleep inertia will cause less impairment as the time between awakening and task performance increases.

Some variables have been shown not to have an impact upon the effects of sleep inertia on task performance.

These include:

- The time of day – the effects of sleep inertia are most apparent when the individual is abruptly woken from sleep, regardless of whether the sleep occurs as a daytime nap or occurs during the night. The exception to this is naps that end during the low point in the alertness cycle. Sleep inertia will generally last longer following naps ending between 0300 and 0700 hours.

- Sleepiness – no evidence of any relationship between sleepiness and sleep inertia has been found.

If you have sleep inertia, you might demonstrate all the outward physical signs of being awake but are not cognitively awake.

It can occur regardless of the duration of sleep – disorientation is experienced after a few seconds of sleep (microsleeps), a nap or a long episode of sleep.

NASA Naps

Dr Mark Rosekind, a scientist who worked for the National Aeronautics and Space Administration (NASA) fatigue counter-measures programme, has studied pilots on trans-Pacific routes where no napping was allowed. He found a consistent decline in performance measures such as vigilance and reaction time.

However, when Rosekind repeated the experiment over the same route allowing a 40-minute nap, the results showed a marked difference, with performance improving by 34 percent and physiological alertness by 100 percent.

Rosekind believes there are many arguments against napping due to the possible effects of sleep inertia upon waking. However, there are several stages of sleep and the body cycles through each in turn.

An effective nap in operational settings according to Rosekind should be limited to 45 minutes to ensure the nap does not go beyond the second stage of sleep.

Crews allowed to proceed into a deeper sleep stage, will feel the effects of sleep inertia and may perform worse than they did before the scheduled nap.

Preventing Sleep Inertia

Napping to avoid sleep deprivation can significantly improve alertness, communication and performance. However, it is important that the potential effects of sleep inertia following a nap be acknowledged and actions are taken to mitigate effects.

Anecdotal evidence suggests that the use of 'alerting factors' upon awakening, such as washing your face in cold water, bright lights, loud noise and physical exercise may help to minimise the effects of sleep inertia. The effectiveness of these alerting factors, however, has not been empirically validated by research.

There are a range of options that should be considered by operators to guard against the effects of sleep inertia.

You should ensure that anyone likely to suffer from sleep inertia is aware that their performance may be affected for up to 30 minutes or more after waking. For some operators it might be useful to consider using automated facilities, such as auto flight planning and auto fuel calculations.

Involving all crew members in flight planning and decision making can minimise the likelihood of errors going unnoticed.

Operators should consider factoring additional time into the response times to accommodate the effects of sleep inertia. Many emergency medical service operators quote a six-minute response time which would not allow pilots who were deeply asleep to recover from sleep inertia before becoming airborne.

The impact of sleep deprivation on sleep inertia has implications for shift workers who are required to make important decisions shortly after waking, such as crews who are woken to conduct unscheduled emergency flights for medical evacuations, search and rescue, or police work.

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Stages of Sleep

Sleep patterns vary from person to person, however, a well-rested person generally moves through progressive sleep stages, including Rapid Eye Movement (REM) sleep and non-REM sleep.

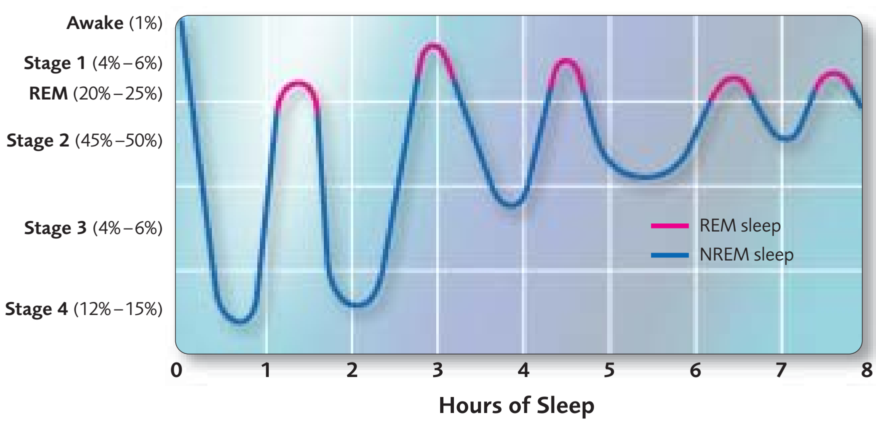
Stage 1 sleep is a transition phase between wakefulness and sleep. Brain waves become smaller and slower. In this stage, a person is still easily awakened and might even deny having slept.

Stage 2 sleep is a deeper, intermediate stage of sleep and occupies about 50 percent of an adult's sleep pattern. In this stage, blood pressure, metabolism and cardiac activity decrease. Brain waves are larger with occasional bursts of activity. A person will not see anything even if the eyes are opened, but can easily be awakened by sound.

Stage 3 sleep is the beginning of deep sleep and is characterised by delta waves – slow brain waves which are about five times the size of brain wave patterns in Stage 2 sleep. A person will be far more difficult to awaken during this stage.

Stage 4 sleep is when the deepest sleep occurs and is characterised by larger delta brain waves. If the person is a sleepwalker or a bed wetter, these activities will begin in this phase.

Waking someone from Stages 3 and 4 sleep is quite difficult. A person awakened from these deep sleep stages will probably be groggy, disorientated and confused and experience sleep inertia.



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These workers are often abruptly woken from deep sleep episodes and need to dress, travel to an aerodrome, and perform flight planning and pre-flight checks before departing within a very short time.

Professor Drew Dawson and Dr Adam Fletcher, two of Australia's leading experts on fatigue and sleep, recommend that emergency service workers should not engage in any critical decision-making or performance tasks, like driving, for a minimum of 20 minutes after waking, to allow any effects of sleep inertia to dissipate.

Several aircraft accidents over the past few years have highlighted performance problems that result when pilots are woken from a deep sleep.

In one recent fatal aircraft accident, the pilot had been woken abruptly to transport medical staff to a patient. Less than 15 minutes elapsed between the time of the pilot waking and the aircraft departing, during which all pre-flight preparation had to be done.

The aircraft subsequently departed from the patient's home with insufficient fuel for the return flight to its base and lost power while attempting to land.

All five people on board died. It is possible that the pilot may have been affected by sleep inertia during pre-departure and the early stages of flight, although the extent to which the pilot actually experienced sleep inertia, if at all, could not be determined (Australian Transport Safety Bureau).

Fatigue Factors

Humans need adequate rest, and if we don't get it our performance suffers markedly. We have a hard-wired, genetically determined biological need for sleep, and a circadian pacemaker that programmes us to sleep at night and be awake during the day.

Nowadays, 24-hour operations challenge these basic physiological principles. Shiftwork, altered and changing work schedules, crossing time zones, long hours of continuous wakefulness, and sleep loss can create disruptions to sleep and circadian rhythms that seriously degrade the waking function.

When someone is deprived of sleep, the physiological response is sleepiness, which is the brain's signal to prompt an individual to obtain sleep. Eventually, when sufficiently deprived of sleep, the human brain can spontaneously shift from wakefulness to sleep in order to meet its physiological need.

The sleepier the person, the more rapid and frequent the intrusions of sleep into wakefulness – these spontaneous sleep episodes can be very short (microsleeps) or last for extended periods of time.

Fatigue has frequently been found to be a major contributing factor in aviation, marine, rail and road accidents with catastrophic consequences.

In 1985, fatigue was cited as a factor in one of the worst aviation disasters in Canadian history when a charter plane carrying US military personnel crashed

A Blink of an Eye

During a microsleep, the brain "shuts off" for just a moment even though the eyes may remain open.

Microsleeps are a very short period of sleep lasting from a fraction of a second to approximately 10 seconds.

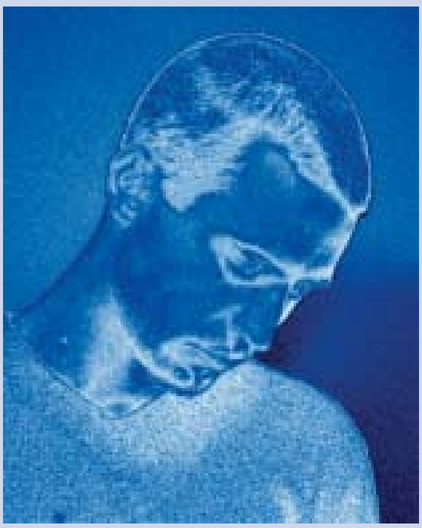
Microsleeps may be associated with a blank stare, 'head snapping', momentary dozing or prolonged eye closure that occurs when a person is fatigued but tries to remain awake to perform a task.

Although the existence of microsleeps can be confirmed by electro-encephalography (EEG) recordings, people are generally not aware of them, which makes the phenomenon especially dangerous.

Due to the fact that microsleeps are involuntary and no warning is given, they can result in fatal accidents, particularly while driving, due to the speed of the vehicle and the distance travelled while out of control of the driver.

If a person driving at a speed of 100 kilometres per hour has a microsleep lasting just four seconds, the vehicle will travel for 111 metres while completely out of the control of the driver.

During a microsleep people are unable



to respond to external stimuli such as other traffic, curves in the road, warning lights or other visual signals.

Microsleeps are uncontrollable by the individual and the perceptual isolation accompanying them can lead to disorientation after the sleep episode and an initial decrease in performance.

According to the NASA fatigue counter-measures group, when microsleeps occur the potential for sleep inertia exists. Pilots could have performance lapses and difficulty in maintaining alertness.

Neurocognitive functioning, such as vigilance, the ability to maintain focus on a specific task, memory lapses and decreased social interactions, can be affected.

In 1994, researchers from NASA travelled with pilots over several trans-Pacific routes and logged their sleep, rest and duty times. The pilots were connected to devices that measured biomedical evidence of microsleeps.

The observations revealed 154 occurrences of microsleeps; of these, almost half lasted 10 seconds or longer.

A worrying finding was that a quarter of the microsleeps were recorded during the critical phases of descent and landing. The findings clearly demonstrated the potential for fatigue and sleep loss to result in unplanned and involuntary occurrences of sleep, particularly in long-haul operations.

and burned in Gander, Newfoundland killing all 256 on board.

More recently, crew fatigue was found to be a contributing factor in the crash of American Airlines Flight 1420 at Little Rock, Arkansas in 1999 (see *Flight Safety Australia*, June-July 2002).

The captain and 10 passengers died when the MD-82 landed in a violent storm and the plane overran the runway, went down an embankment, and slammed into approach light structures.

The last decade has seen extensive research on the risks associated with fatigue. A confidential reporting system administered by NASA found that of the 2,900 aircraft incident reports received per month, approximately 21 percent of pilot errors reported were fatigue related, with most of the errors occurring during critical descent and landing phases.

This year the US National Transportation Safety Board (NTSB) cited crew fatigue as one of the paramount safety issues facing all modes of transportation. The nuclear power plant industry has also recognised the need to manage the effects of fatigue after the events at Three Mile Island and Chernobyl.

Under pressure to travel long distances in monotonous conditions, workers admit they struggle. While the image of a freight train engineer falling asleep somehow seems less threatening than thoughts of pilots dozing in the cockpit or truckers falling asleep at the wheel, the risk of a catastrophic accident remains, as the accompanying case studies reveal.

Case Study 1

In 1994, a Bell 206B helicopter collided with a high tension power line with the pilot sustaining fatal injuries. The profile of the flight path, indicated by breaks in the trees, showed a gradual descent with a steep pull-up at the last group of trees before the power line.

The pilot was very experienced and the autopsy revealed no physical anomalies or impairments that could have contributed to the accident. Examination and disassembly of the helicopter and components by aircraft accident investigators and representatives of Bell Helicopter found no evidence of malfunction.

The investigation found that the pilot's flight duty time during the preceding week was excessive. The investigation report concluded that the flight path was consistent with the pilot falling asleep or having a microsleep episode, and the helicopter beginning a gradual descent into the tree tops.

On impact with the trees, it's likely that the pilot woke suddenly suffering from disorientation due to sleep inertia. Despite his immediate efforts to pull up the helicopter, he misjudged the situation, and did not clear the hydro lines just ahead (Transportation Safety Board of Canada).

Case Study 2

On 26 October 1990, a heavy vehicle truck transporting eight cars entered a highway work zone and struck the rear of a utility trailer being towed. This car and trailer then struck the rear of another vehicle, and the truck and the two automobiles travelled into the closed right lane and collided with three road maintenance vehicles.

Fire ensued, and the eight occupants in the two cars died. All six vehicles involved in the accident were either destroyed or severely damaged. The truck driver and one fire fighter sustained minor injuries.

The investigation by the US National Transportation Board found that the probable cause of this accident was the inattention of the driver of the heavy vehicle truck after a microsleep due to fatigue, exacerbated by an inadequate and unbalanced diet the day of the accident. The investigation also criticised the truck company's failure to ensure that its drivers were qualified and received adequate rest (National Transportation Safety board, USA).

Case Study 3

In December 2000, a northbound express freight train passed through a stop signal and collided head-on with a departing southbound express freight train. The driver told investigators that he "sort of woke up ... to see the headlight of another freight train coming straight at him". He braked and braced himself against a console as the trains hit at a combined speed of 58 kilometres an hour

Three locomotive crew members received minor injuries. The locomotive on each train and a number of wagons were extensively damaged. Safety issues revealed in the subsequent investigation included the control of locomotive engineers' hours of duty, fatigue management, the locomotive engineer losing situational awareness during a microsleep, and the inability of the locomotive vigilance system to overcome short-term attention deficits in time to prevent this type of collision (Transport Accident Investigation Commission, NZ).

Long-range Operations

Fatigue and related issues such as napping, crew alertness and sleep inertia is currently the subject of research co-ordinated by the international safety group, the Flight Safety Foundation.

A team of international specialists including representatives from international airlines, pilots, flight attendants, scientists, civil aviation authorities and manufacturers are working together to recommend regulatory and operational guidelines for ultra-long range (ULR) flights. ULR flights can involve flight-duty periods of 18 to 22 hours.

Around 85 safety specialists from 14 countries recently attended the second workshop in France conducted by the ULR crew alertness steering committee, co-chaired by Flight Safety Foundation and Boeing, and hosted by Airbus Industries.

The aim of the committee and workshops is to develop operational guidelines and strategies for ULR flights, to ensure that crew fatigue is minimised and crew alertness is optimised.

Conclusion

Managing fatigue in transport operations is a complex task that provokes many opinions and lively discussions from a range of personnel including companies, regulatory and investigation agencies, workers and unions.

Education, information dissemination and learning from accidents are a few of the strategies in use to decrease the risks and hazards associated with microsleeps and sleep inertia.

The next time you're woken for work urgently or find yourself tired during a shift, take some time to protect yourself and others from the potentially dangerous effects of sleep inertia and microsleeps.

Individuals and organisations need to become familiar with the high risk precursors to sleep inertia and microsleeps and have a mitigation plan in place. ■

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