Australian Government
Civil Aviation Safety Authority

# Safety behaviours: human factors for pilots 2nd edition

## Resource booklet 9 Human information processing



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Whether you are a single pilot flying VFR or flying a multi-crew, multi-engine jet under IFR, operating at a busy metro airport or at a bush landing strip, your performance is influenced by factors such as age, health, stress, experience, distractions, the environment and individual information processing limitations.

You need to be aware of how your ability to process information affects your performance and situational awareness, and how this varies from day to day, place to place and task to task.

# Contents



*Understanding how thoughts work, how connections are made, how the memory works, how we process information, how information is stored—it's all fascinating.*

*Lisa Randall, theoretical physicist*

# Introduction

To make decisions and take action, we gather, assess and prioritise information from our five senses—vision, hearing, touch, taste and smell. The vestibular system, largely responsible for our sense of balance and spatial orientation, is also very important.

But we can also be tricked by our senses. As pilots, it is vital that we recognise illusions and deal with them before they get us into trouble. Let's look at the example on the page opposite, where disorientation had fatal consequences.

There are many safety lessons from the Lake Eyre accident, a key one being that experience alone is not enough. The diversity of rotary wing operating profiles can produce mismatches of experience to task. This accident clearly shows that experience is no substitute for targeted currency training or appropriate recency.

The tragedy at Lake Eyre also reminds us just how quickly we can become disoriented when our senses are fooled, and that our performance will suffer when we are distracted, fatigued, stressed, or pressured.

We need to practise and be prepared for these situations.

Let's have an overview of how our information processing system works before we look at some of the things that might have been going on in the pilot's head with limited outside visual reference on a pitch-black night.

Figure 1 shows the four main stages in human information processing: *sensing, perceiving, deciding, and acting*. Supporting these stages are various elements of memory, and our 'attention directing' mechanism.

We continuously sense and assess changes resulting from our actions and make any necessary adjustments, such as to attitude on take-off and climb out, or to maintain a constant aim point on approach. However, sometimes things aren't what they seem! We will look at specific information processing misperceptions later in this section.

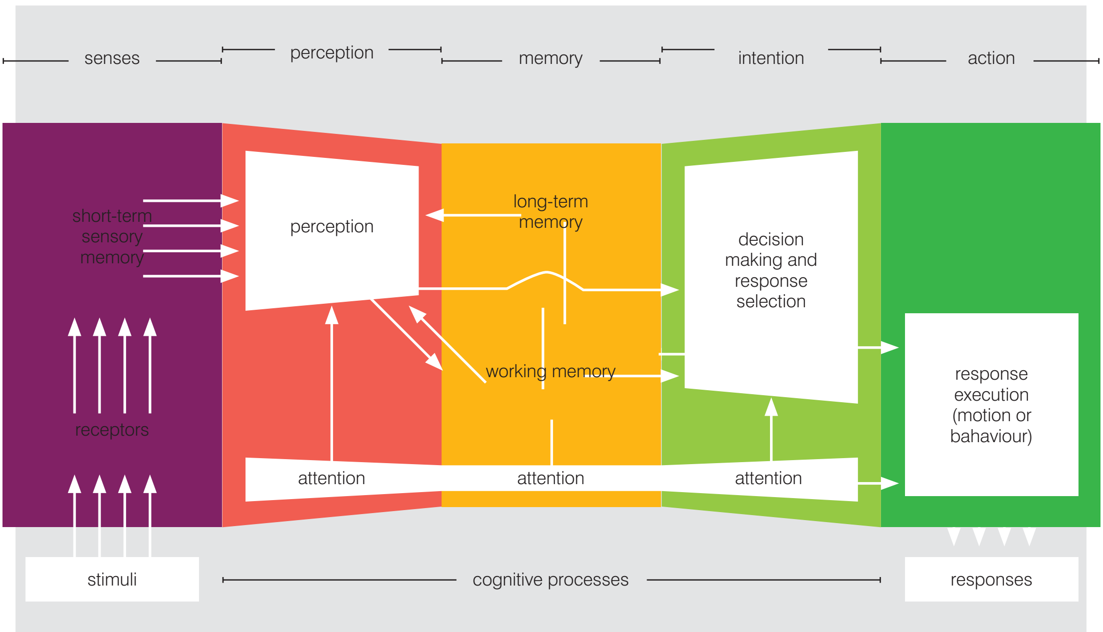



**Figure 1 Basic human information processing**

## Lake Eyre

On 18 August 2011, an Aerospatiale Twin Squirrel helicopter took off under VFR in dark night conditions near Lake Eyre, South Australia. Shortly after it entered a gentle right turn, the descent rate rapidly increased until the helicopter impacted terrain 38 seconds later at high speed with a bank angle of about 90 degrees. The pilot and the two passengers were fatally injured.

The report found that the pilot most probably became spatially disoriented. Contributing factors included the dark night conditions, high pilot workload establishing cruise flight while probably being distracted attempting to reprogram the GPS, the pilot's limited recent night flying and instrument flying experience, and the lack of an autopilot.

The very experienced pilot's daylight command hours were of little benefit in a pitch-black sky and an empty landscape. Without moonlight or useful ground lights, no matter how experienced you are as a pilot, visually, it can be very difficult to tell the difference in direction between down and up. In these conditions, our vestibular system or 'balance organs', are also easily fooled, and only by referring to instruments can we prevent disorientation and potential disaster.

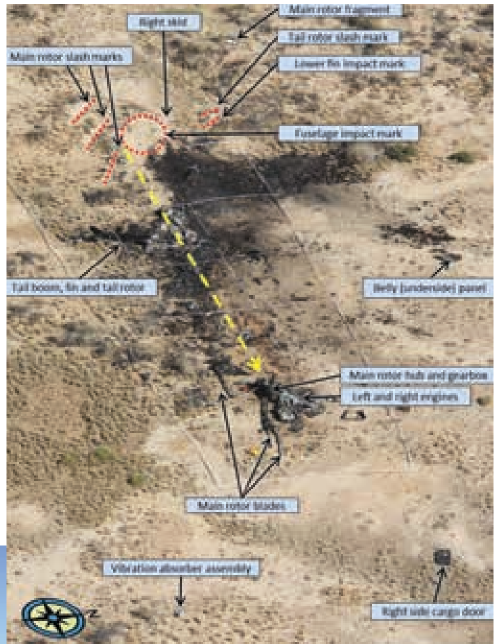



image: Ground and aerial views of the crash scene at Lake Eyre, August 2011 | Australian Transport Safety Bureau

# Sensing: sight, hearing and balance

Our brain interprets and integrates information from our visual, auditory and vestibular systems to determine the body's condition and its interaction with the environment. Let's look at each of these systems and how unwanted side effects, such as sensory illusions and disorientation, can come about.

## Sight

Our eyes are the brain's primary information source when we fly—whether under VFR and looking out, or IFR on instruments and looking in. Vision is a complicated process, with some processing in the eye before the optic nerve transmits information and images to the brain for further interpretation. Figure 2 shows the structure of the eye.

The way in which we see objects can be distorted by physical attributes of the eye and by the way the brain processes information. It's also possible to look without 'seeing'. We need awareness of how easily our eyes can deceive us so that we can compensate for these limitations and fly safely.

What does this mean when, for example, we are looking for traffic? Low light conditions from dusk till dawn impair our ability to see other aircraft. Our central vision can be reduced to the extent that looking directly at an object can make it disappear. In such conditions, rather than looking directly at an object as we would in good light, we need to purposely look about 10 to 15 degrees to the side of the object to see it in our peripheral vision.

It takes around 30 minutes for the eyes to adapt to full night vision. We should take care at night to keep lights low; sudden brightness can cause temporary flash blindness and cause the adaptation cycle to start again. We will look at some typical night visual illusions later in this section.

Table 1 show some of the factors which can affect vision, particularly at night.

**Table 1 Aviation-related vision issues**

| Factor | Effect on vision |
|---|---|
| **Low light** | Reduces central and colour vision |
| **Bright light** | Damages night vision |
| **Empty field myopia** | Objects appear further than they are; need to focus regularly on distant objects |
| **Inadequate scanning** | Objects may not be seen; scan regularly to ensure detection |
| **Dirty windshield** | Interferes with focus and scanning |

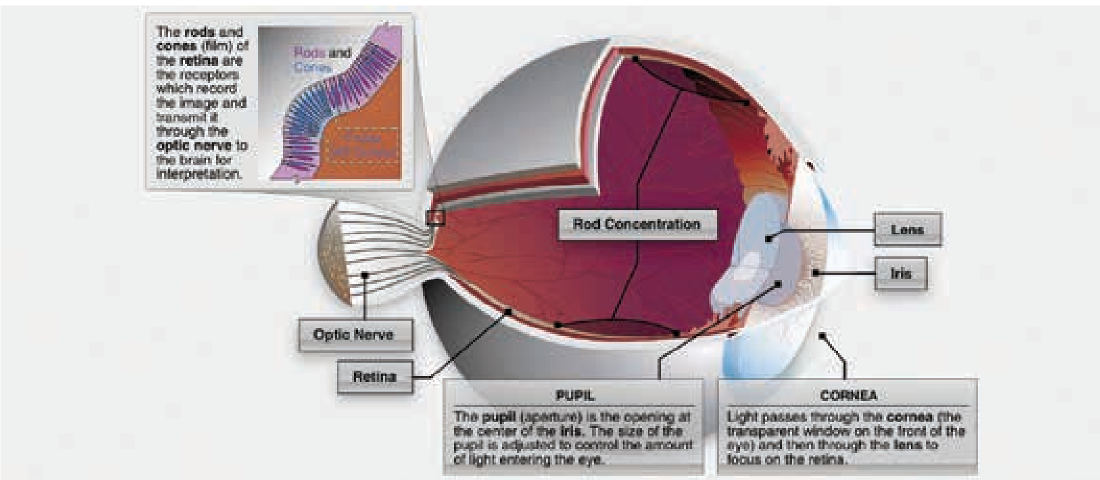



**Figure 2 The structure of the eye**

### EFFECTIVE SCANNING

To scan effectively for conflicting traffic, use short, regularly spaced eye movements that bring successive areas of the sky into the central visual field. Each movement should not exceed 10 degrees, and you should observe each area for at least one second to enable detection.

Develop a pattern that you find most comfortable and stick to it. If there is nothing specific to focus on, our eyes revert to a relaxed intermediate focal distance, which means you are looking without actually seeing anything.

This *empty-field myopia* occurs when the eye defaults to its resting state, in which the lens focuses about one to two metres away. Effectively, this creates a near-sighted state in which distant objects, such as conflicting traffic, appear smaller and further away than they really are. To combat this illusion, it is good practice to focus regularly on a distant object, such as the wing tips, if there is nothing to see out of the windscreen.

Similarly, when transitioning from instruments to visual on approach, try to focus as quickly as possible on the runway or approach lights. Dirty windshields can interfere with a scan for traffic in the distance. Our eyes are naturally drawn to focus on closer objects such as bugs, scratches or water spots, which become focal traps.

## Hearing

We use our hearing to communicate and to monitor aircraft systems. Pilots must undergo hearing assessment regularly as part of their class 1 medical assessment.

As we age, we generally experience a gradual loss of hearing, particularly of higher frequencies. But hearing can also be damaged by loud, or prolonged exposure, to noise, so take appropriate precautions. Hearing protection, including noise-cancelling headsets, is highly recommended.

As well as being the organs of hearing, the ears contain vestibular organs which contribute to our sense of balance. Three interconnected semicircular canals contain fluid and act as a motion sensing system in the roll, pitch and yaw axes, much like a gyroscope. They help us maintain balance and stabilise our eyes when we move.

The vestibular organs detect angular acceleration via small sensory hairs as we turn or move our head. The inner ear fluid's motion deflects the hairs and nerve impulses are sent to the brain, creating the sensation of turning. Figure 3 shows how the inner ear senses movement during a turn.

There are two otolith organs in each ear, one in the vertical and the other in the horizontal plane. These sense gravity and linear acceleration and we can become disoriented when we expect them to cope with forces for which humans weren't evolved, such as those associated with flying. We will look at some specific balance illusions a little later in this section.

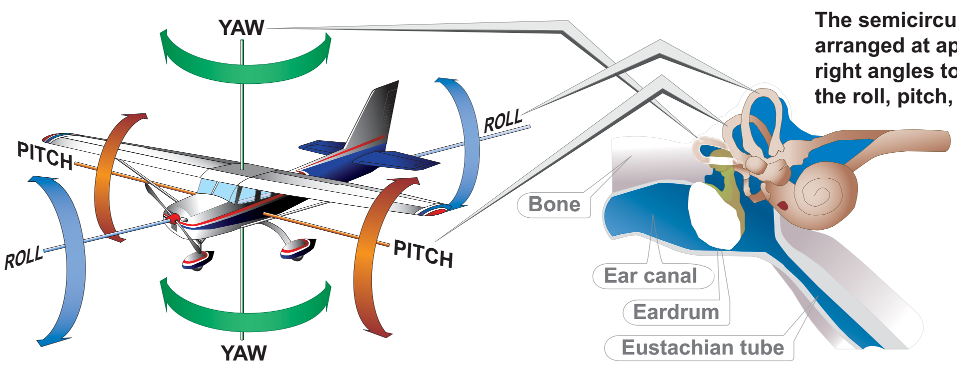



**Figure 3 Vestibular and balance organs, showing movement of fluid during a turn**

# Perceiving and countering illusions

Perception is the way in which the brain understands information acquired through the senses. It makes the connection between external events (such as objects, people, movement, sounds and smells) and our thoughts about them. *Misperception* is when we get this wrong.

We generally perceive things we find interesting (that we are looking for, or are sensitive to), that strongly impact on our senses (bright lights, loud noises, irregular movement), or that signal potential danger and trigger fear. We take less notice of things that don't interest us, are not making a large impact, and that don't scare us.

The performance limitations of our sensory organs mean that we also don't always perceive things accurately. This is mainly because of the way the brain reconstructs data. We can be fooled into believing, or literally feeling, a false interpretation of the outside world.

We are all susceptible to misperceptions caused by sensory limitations, and we generally *experience* these misperceptions in the same way. However, as individuals with different experiences and personalities, these experiences can *affect* us in markedly different ways.

Other factors such as concentration, motivation, fatigue, stress, alcohol and other drugs, illness, and medication can also affect our perception. These are discussed in booklet 3, *Human performance*.

Understanding perception is important for all pilots, as it directly influences the decisions we make and the actions we take in response to our perceived situation. We need to understand how to manage the misperceptions and illusions caused by our sensory limitations and subjectivity.

We can do this in-flight by referring to reliable data provided by flight instruments and other sources of information, including fellow crew members, ATC, documents and checklists.

## Confirmation bias

If we *believe* our aircraft is at a certain attitude, or in a particular position or power state, our brain will try to organise the available information to confirm this belief. This is sometime known as confirmation bias. We need to be able to counter these intuitive feelings.

For pilots, there are two typical pathways between *sensing* through *perceiving* to *deciding* and *acting*.

When flying manually, feedback is sensed and perceived instantly, and corrective action applied. If data is misperceived, the response can make things worse.

When making an operational decision such as flying an approach, we should consider all available information, including subjective opinions about our own capabilities and fitness and those of other crew members.

There may be some time between making a decision and taking the action. However, some decisions become points of no return and, if based on incomplete information, can paint us into a corner.

For instance, if we decide to continue to a planned destination having perceived weather conditions, runway distances, aircraft performance, and our own capabilities as acceptable, there may be a point at which diversion to a more appropriate or suitable airport is no longer possible.

## Perceptual illusions

Several perceptual illusions may affect flight safety. These relate mainly to misperceptions about the position of the aircraft, projected flight path in space and in the horizontal plane, and in relation to other objects, such as the runway. They invariably include perception of power (engines/thrust) and aircraft configuration (landing gear, flaps, slats, air-brakes, trim etc.) This is linked to situational awareness and spatial disorientation.

Our visual, kinaesthetic (feedback from muscles and ligaments about how the body is moving), and auditory senses are the most critical for pilot perception and misperception.

## Visual illusions

Visual illusions are familiar to most of us. You have probably seen pictures like the ones in Figure 4 before.


- Which is the longer line – (a) or (b)?
- Do you see a vase or two faces?
- What colour are the dots at the intersection of the lines?

**Figure 4 Basic visual illusions**

The first is the *Müller-Lyer illusion*: lines (a) and (b) are the same length, but the outward fins in (a) make us perceive (a) to be longer. The second is the *Rubin's vase illusion.* The third is the *scintillating grid illusion*. Dark dots seems to appear and disappear at random intersections. If you stare directly at a single intersection, you do not see the dark dot.

These illusions are interesting to look at in the comfort of your home or classroom. But when our eyes play tricks on us while we're flying, there's potential for disaster.

Some visual misperceptions are due to physiological limitations of the eye, such as blind spots and colour blindness, as well as an inability of our eyes to detect objects in very low light conditions (night) or at the other extreme in very bright conditions (looking directly at the sun).

An inability to differentiate colours or tones can have a dramatic effect on how we perceive the runway and associated lights at night. This is why night flying is particularly challenging for visual illusions and disorientation, and can present significant threats.

### PREVENTING VISUAL ILLUSIONS

#### Autokinesis

When we stare at a light against a dark background at night, such as a star, or the light from another aircraft with no other visual references around it, we get the impression that the light is moving. Awareness of this illusion is important; moving the eyes or looking to the side of a lit object can help reduce autokinesis.

#### Black hole approach

The black hole illusion occurs during an approach over a large, unlit area—often, but not only, over water. Without good visual reference or glide slope guidance, it is easy to overshoot or undershoot on a straight-in approach. When experiencing this illusion, we should rely on the aircraft's instruments, remain at an appropriate altitude for distance to threshold and work to maintain a stable approach, including a stable airspeed and descent rate.

A 2001 accident at Mt Gambier which killed an experienced Royal Flying Doctor Service pilot and seriously injured the crew member illustrates the danger of the black hole illusion.[2]

## Mt Gambier accident—the black hole illusion

At approximately 2326, the pilot made a radio transmission on the Mount Gambier mandatory broadcast zone (MBZ) frequency advising that the aircraft was 26 nm north, inbound, had left 5000 ft on descent and was estimating the Mount Gambier circuit at 2335. At about 2327, the pilot started a series of radio transmissions to activate the Mount Gambier aerodrome pilot activated lighting (PAL).

At approximately 2329, the pilot made a radio transmission advising that the aircraft was 19 nm north and maintaining 4000 ft. About three minutes later, he made another series of transmissions to activate the PAL.

At approximately 2333, the pilot reported to ATS that he was in the circuit at Mount Gambier and would report after landing.

Witnesses located in the vicinity of the aircraft's flight path reported that the aircraft was flying lower than normal for aircraft arriving from the northwest.

At approximately 2336 the aircraft impacted the ground at a position 3.1 nm from the threshold of runway (RWY) 18. The pilot sustained fatal injuries and the medical crew member sustained serious injuries.

Some conditions make the black hole effect more pronounced. Be alert for the illusion when you observe these conditions:

- An airport that is on the near side of a brightly lit city with few or no terrain features or lights between you and the airport. The brightness of the city lights will give the impression that they are closer than they actually are.
- An airport that is on the coast or in very sparsely settled terrain, such as in the outback.
- At night with extremely clear air and excellent visibility. One of the things we use to judge distance is the hazing usually associated with distance. When the air is very clear, the lack of hazing makes things appear much closer than they really are.

### Straight-in or circuit?

Now that you know what sets you up for the black hole illusion, what can you do to guard against it?

One strategy is to avoid long straight-in approaches where there is no glide slope guidance. The black hole illusion generally disappears within two to three miles of an airport. Using this strategy, you would fly to the airport at a known safe altitude and then descend.

Where no glide slope guidance is available, flying a circuit at night may be a safer option than a straight-in approach. But there is still a danger of disorientation in the circuit, particularly where the pilot is unfamiliar with the conditions, as the following accident report shows.

## The wrong height at the wrong place in the circuit

The owner and pilot of a Piper Saratoga had held a private pilot licence with a night VFR rating for many years. The pilot was not current in night flying. On 30 March 2011, he had flown from Moree to Brewarrina with five passengers, intending to return that evening[3].

On the return flight, the pilot made several detours to allow the passengers to see particular landmarks, and by the time the aircraft returned to Moree, it was dark.

Two legs of the circuit at Moree Airport were flown toward Moree town centre, which provided enough ground lighting to allow the pilot to control the aircraft. The final approach was over a caravan park and highway.

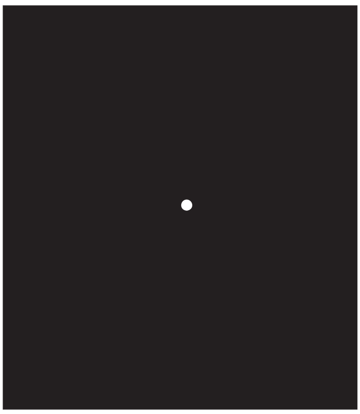
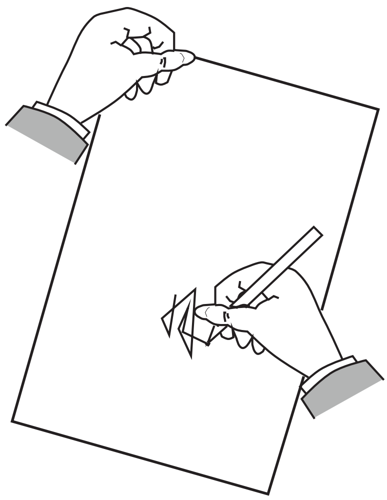


**Figure 5 Black hole illusion**

However, there was relatively limited ground lighting along the aircraft's intended flight path in the last 500 m before the runway, except for the runway lighting ahead.

The aircraft was very low on the final leg of the circuit. The left wing hit the top of a tree in the caravan park, 700 m north of the runway. The aircraft rolled inverted and impacted the ground about 150 m later. Two passengers survived the accident.



## False horizons

VFR pilots rely heavily on the natural horizon to maintain straight and level flight during the day. At night, when there is often no visual horizon, our mind will often try unsuccessfully to find one. We can interpret an inclined cloud or the lights of a highway as a horizon and then bank the aircraft so that its attitude is straight and level in relation to the false horizon. This will result in an undesired consistent turn.

When flying at night, it is vital to rely on primary instruments, including the attitude indicator, horizontal situation indicator and airspeed indicator, to make sure we remain straight and level and recognise false horizons.

## Flicker vertigo

Flicker vertigo is a condition in which our brain doesn't process flickering light accurately. It can be caused by an aircraft's strobe lights at night flickering against clouds, by the propeller, or by sunlight reflecting off the propeller. The result can be disorientation and nausea. If this occurs, you should turn off the lights or turn away from the sun.

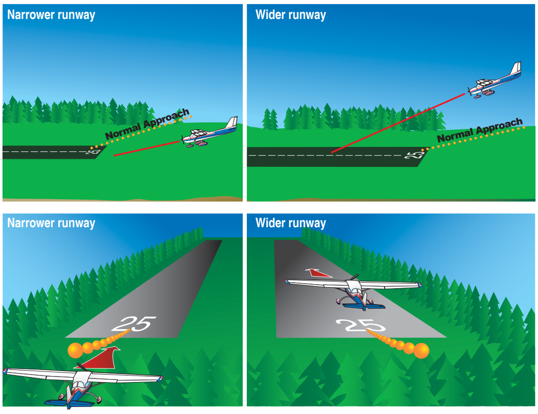
## Runway lights

Bright runway lights can cause us to feel as if the aircraft is lower than it is, resulting in a higher-than-normal approach to compensate. If we don't trust the instruments, this is likely to result in an unstable approach and a higher-than-normal rate of descent on final.

## Runway width

A wider-than-usual runway conflicts with our mental picture of what the runway perspective should look like and cause us to think our approach is too low. In an effort to compensate, we might fly a higher-than-normal approach or pitch up to an unsafe airspeed on final. A narrower-than-usual runway makes us feel we are too high, creating a risk of overcompensating and an urge to 'push forward' resulting in a high rate of descent on final, and potential undershoot.

**Figure 6 Runway width illusions**

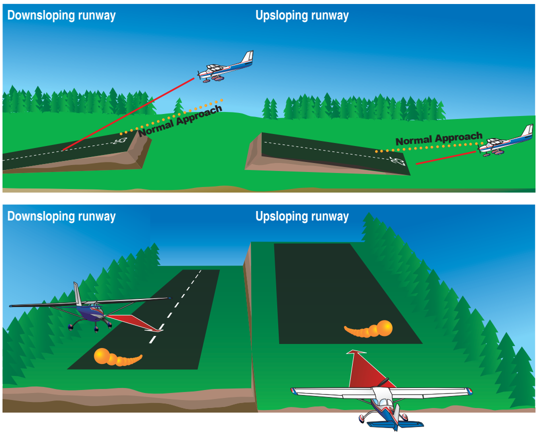



## Sloping terrain

When the terrain slopes upward just before the approach end of the runway, we can be tricked into believing the aircraft is too high, causing us to compensate by flying lower. Conversely, a downhill slope will cause us to think we are too low, resulting in a higher-than-normal glidepath.

There are numerous accidents and near-misses where this has happened; for example, the 2016 close call when a charter pilot in a Cessna 441 with nine passengers hit a power wire.[4] The pilot was unfamiliar with the South Australian landing area and made too low an approach because of sloping terrain. Luckily, there was only minor damage to the aircraft, and following a go-around, the pilot landed safely.

**Upslope and downslope runway illusions**



### Precipitation

Rain, fog and haze can all cause pilots to perceive distance inaccurately.

Rain can cause approach and runway lights to seem brighter at night, resulting in us feeling we are lower than we should be, and forcing us to overcorrect to a higher-than-normal approach.

Fog and haze can make the runway look further away than it is, creating an illusion of being too high. Similarly, fog or rain at the end of the runway can cause the illusion of a higher-than-normal approach, especially after becoming visual from an instrument approach. This can cause pilots to push forward and 'duck under' the approach path.

Consider the information contained in the 2013 ATSB report on night visual flight accidents in Australia.[5] Key messages from the report include:

- Some nights and some terrain are darker than others. Excellent visibility conditions can still result in no visible horizon or contrast between sky and ground. Inadvertently flying into instrument meteorological conditions (IMC) is also harder to avoid at night.
- Always know where the aircraft is in relation to terrain, and the altitude you need to fly to avoid unseen terrain and obstacles.
- Remain aware of illusions that can lead to spatial disorientation—they can affect anyone. Know how to avoid and recover from illusions by relying on your flight instruments.

### OVERCOMING VISUAL ILLUSIONS

For almost all these illusions, the solution is to focus on, and trust, your instruments. Maintain a stable approach speed and appropriate altitudes and rates of descent for the approach being flown, and be mentally prepared to recognise an illusion. You can prevent spatial disorientation from these illusions only by visual reference to reliable fixed points on the ground, or to flight instruments.

- Anticipate the possibility of visual illusions during approaches to unfamiliar airports, particularly at night, or in adverse weather.
- Consult airport diagrams for information on runway slope, terrain, obstacles and lighting.
- Check the altimeter and rates of descent frequently, especially during approaches.
- Inspect unfamiliar airports visually from the air before landing, if possible.
- Use an electronic glide slope, or approach guidance systems such as a T-VASI or PAPI whenever they are available, as a back-up to a visual approach reference.
- Use the visual descent point found on many non-precision (non-ILS) instrument approach procedure charts.
- If you intend to fly at night, maintain your night currency, and include cross-country and local operations at different airports.
- When flying at night or in reduced visibility, focus on your flight instruments.
- Rely on instrument indications unless the natural horizon or surface reference is clearly visible.
- Check weather forecasts before departure, en route, and at destination. Update these regularly to monitor trends and be alert for any significant weather deterioration.
- Do not attempt visual flight when there is a possibility of becoming trapped in deteriorating weather, and always plan your 'escape route' for weather or terrain avoidance.

## Kinaesthetic illusions

Kinaesthetic perception relies on our somatosensory (whole body) system to detect touch and pressure, combined with the vestibular system (the inner ear) to detect movement.

When combined with sight and hearing, we can generally perceive the world accurately while on the ground. But flying exposes us to situations where we cannot fully trust our kinaesthetic perception; especially if we don't have visual and auditory cues.

All pilots will experience some level of spatial disorientation; even flying through cloud on an IFR flight is not without risk. According to a 2013 ATSB report, around 10 per cent of all general aviation accidents result from spatial disorientation, which occurs when we incorrectly interpret the aircraft's attitude, altitude or airspeed. Significantly, 90 per cent of these accidents result in fatalities.

Let's look at two examples of loss of control from spatial disorientation.

- On 29 January 2016, a PA-28 on a private flight from Moorabbin to King Island entered an area of low visibility after passing over Point Lonsdale. The pilot turned 180° and initially tracked back towards Point Lonsdale, before heading south over the ocean. After about two minutes, the aircraft turned right before entering a rapid descent and hitting the water. All four occupants of the aircraft were killed. The ATSB report found that due to the presence of low cloud and rain, the pilot probably experienced a loss of visual cues and became spatially disoriented, resulting in a loss of control. The risk of loss of control in these conditions was increased by the pilot's lack of instrument flying proficiency.[6]
- On 1 December 2013, an Aerospatiale AS350B2 helicopter was on a return flight to Davis Base, Antarctica, with a pilot and two passengers on board. Because of a rapid reduction in visual cues, the pilot maintained about 150 ft above ground level before deciding to turn back to the fuel cache to wait out the deteriorating weather. During the turn back, the helicopter descended and hit the ice shelf. The pilot and two passengers were seriously injured and the helicopter was destroyed. The ATSB report found that the pilot did not detect the descent during the turn back to the fuel cache and probably became spatially disoriented due to the reduction in visual cues.[7]

Also see Resource booklet 6 Situational awareness page 7.

So how do we get into these situations, and what can we do about it? Let's consider six types of vestibular system illusions you can suffer flying in cloud, and how you can manage them.

### 'THE LEANS'

'The leans' happen when you enter a banked turn too slowly or maintain a banked turn for some time. For instance, if you roll at a very slow rate into a left turn, the fluid in your ears won't start moving, and your brain thinks you're still straight and level. If you correct your wings back to level flight abruptly, your ears and brain think they're banking in the opposite direction (to the right).

A disoriented pilot will feel the need to roll the aircraft to the left again to 'level' the wings. This may result in a further or steeper turn to the left, or if level flight is maintained, the pilot will feel compelled to lean in the perceived vertical plane until this illusion subsides.

The best way to prevent the leans is to use a standard rate of turn when in cloud and maintain an appropriate selective instrument scan, focusing on primary turn indications: attitude, angle of bank, airspeed, and the turn-and-slip indicator or 'skid ball'. Don't over-control your aircraft, but make sure you're authoritative with your flight controls, making positive, steady inputs.

### CORIOLIS ILLUSION

The Coriolis illusion happens when you're in a constant turn long enough for the fluid in your ears to stop moving and for your brain to think it is straight and level. At this point, if you move your head too quickly, such as looking at something in the cockpit, you can start the fluid in your ears moving on a different axis. This makes you feel as if the aircraft is manoeuvring in a way that it isn't, and if you aren't careful, you can put your aircraft in a dangerous attitude.

To prevent this, never move your head quickly, and if you feel you're becoming disoriented, focus on your instrument scan pattern and bring the aircraft to straight and level flight.

## SPIRAL DIVE OR 'GRAVEYARD' SPIRAL

As the name suggests, the graveyard spiral is not one to try, but here's how it can happen.

If you stay in a turn long enough, the fluid in your ears stops moving. As you return to level flight, you feel you've turned in the opposite direction, and you resume the original turn. Because the aircraft loses altitude in a turn unless the pilot applies back pressure, it starts descending. You think you're in a wings-level descent, so you pull back on the yoke. But what really happens is you tighten the spiralling turn and lose even more altitude.

## SOMATOGRAVIC ILLUSION

The somatogravic illusion happens when you accelerate quickly, such as during take-off or a go-around, when there is no horizon visible. The otolith organs in your ears make you think you are pitching up. As the aircraft accelerates, this pitch-up sensation increases, which causes you to want to push the nose of the plane forward, resulting in a nose-low dive attitude. The opposite is true of rapid deceleration. As you slow, you feel you're pitching forward, and you tend to pitch up into a nose-high attitude, resulting in a stall. Let's have a look at an accident where the somatogravic illusion was a factor.

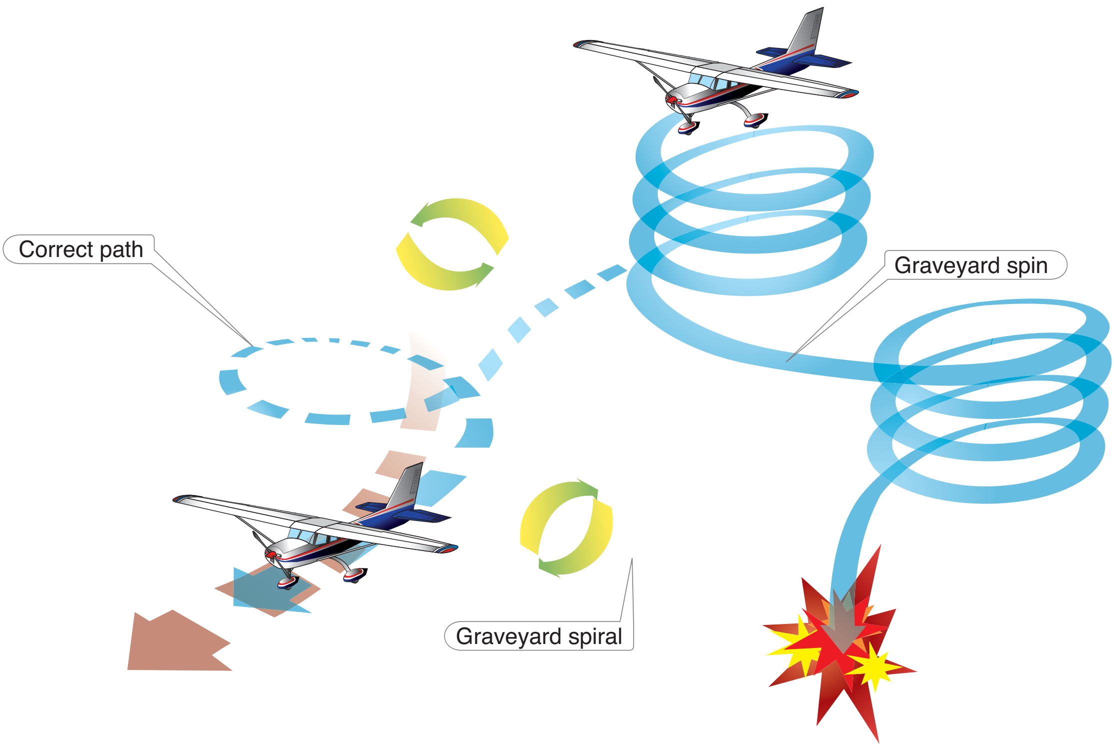



**Figure 8 The graveyard spiral illusion**

## Take-off towards blackness

On 5 February 2011, a number of aircraft were chartered to return passengers from Darwin to two different Tiwi islands. One of these aircraft was a Cessna 310R. This aircraft flew from Darwin to Bathurst Island with five passengers who disembarked there. The single pilot then took off to the north-west to return to Darwin.[8]

The terrain to the north-west of Bathurst Island aerodrome is flat and there is no ground lighting, with mangroves leading to the sea. The take-off occurred about an hour after the end of daylight, and the moon had set at about the same time. Effectively, there was nothing to see outside the aircraft after it had passed the far end of the runway, and control could only be maintained by reference to the aircraft's flight instruments. This aircraft type normally accelerates quickly from about 100 kt to 120 kt immediately after take-off once the landing gear is retracted.

The aircraft crashed at high speed into the mangroves about one kilometre beyond the end of the runway, with the engines at a high-power setting and the wings level. It looked as if the take-off and initial climb had been normal before the aircraft was controlled into descending flight instead of climbing flight, until it crashed.

The pilot had been flying as a commercial pilot for three years, and he had recently flown the same aircraft to the same location at night. There was nothing to indicate the pilot was not properly qualified, trained or competent, and there was nothing to indicate any pre-existing defect in the airframe, engines or flight instrumentation. The pilot had a command instrument rating.

The pilot may have experienced somatogravic illusion that could have led him to believe that the aircraft was at a higher nose-up attitude, and he may have compensated for this illusion without sufficient reference to the flight instruments, particularly the attitude indicator. The pilot's perceived workload would have been high just after take-off, with a number of tasks to distract him from monitoring the flight instruments to ensure that the aircraft continued to climb.

The effect of somatogravic illusion can be exacerbated as the pilot leans forward to reach the gear lever. As the pilot's head tilts back into the normal flying position, there can be a further sensation that the nose of the aircraft is pitching up. This causes the pilot to counter by pushing forward, causing the aircraft to enter a controlled descent, which the pilot incorrectly perceives as a steady climb.

### INVERSION ILLUSION

The inversion illusion happens when you pitch down too quickly from a climb to straight-and-level and get the illusion that you're tumbling backwards. The danger is that it makes you want to push the aircraft even more nose-low into a dive attitude. Even worse, the more you push forward, the more intense the illusion can become. Slow, steady control inputs are the key to prevention when you're transitioning from a climb to straight-and-level flight.

### ELEVATOR ILLUSION

The elevator illusion happens when you catch an updraft, and the aircraft is abruptly accelerated upwards. Even though the aircraft is most likely in straight-and-level flight, you feel as if you need to push the nose forward, entering a dive. A strong downdraft has the opposite effect.

To prevent this, maintain your instrument scan pattern in turbulence, and if the updrafts and downdrafts become so strong that you are unable to maintain altitude, fly the attitude indicator, maintain a constant attitude and keep the wings level.

## Coping with spatial disorientation

The sensations that lead to illusions during instrument flight conditions are normal experiences for pilots. It is therefore generally a case of when, not if, you will experience them.

We know that through training and awareness, pilots can ignore or suppress illusions by relying on the flight instruments. As you gain proficiency in instrument flying, you become less susceptible to these illusions and their effects. We must trust the instruments and learn how to disregard our sensory perceptions.

### Try it for yourself—safely

You can easily demonstrate spiral illusions and the graveyard spin using a rotating chair.

- Sit a volunteer wearing earmuffs and an eye mask in the chair at its maximum height so their legs dangle above the floor.
- Slowly rotate the chair and ask your volunteer to indicate with their thumbs which way they are going. Repeat the question after 15–20 seconds of constant rotation. They will most likely indicate that they have stopped spinning.
- Then stop or slow the chair. The volunteer will probably indicate that they are spinning in the opposite direction. When you try this yourself you'll find the sensation is overwhelming.

To demonstrate the Coriolis illusion, spin the volunteer with their eyes closed and head down, and then ask them to open their eyes and look up. Keep a bucket handy just in case nausea and vertigo gets the better of them! Your volunteer should allow sufficient time for the vestibular system to recover before flying.

CASA's safety video *Spatial Disorientation* shows Richard de Crespigny's experience in the Barany chair. Find it on CASA's YouTube channel, CASABriefing.

These illusions are something you really need to experience to believe. If you experience them on the ground, hopefully you can recognise and respond to them if they happen in the air.

## Auditory misperception

When pilots misperceive a verbal message, such as mishearing an instruction from ATC or an answer from a crew member, it can generally be attributed to one of three things:

1. unclear transmission—unfamiliar language or accent, rapid delivery, ambiguous wording, or too much information
2. unsuitable transmission medium—badly attenuated radios, atmospheric interference, or a noisy environment
3. lack of attention by the receiver—hearing what we expect (and want) to hear, also known as expectation and confirmation bias.

The first two are usually obvious and the solution is to request a retransmission and to read back messages to check they have been accurately understood. The third requires the listener to be aware of possible inattention or expectation bias, and to guard against it.

The use of standard phraseology and consistent read-back and hear-back checks are important to avoid miscommunication.

## Managing misperception

Developing a training program to protect pilots from the natural tendency to misperceive is fairly straightforward, as there is a lot of good information available. However, ensuring we apply these lessons in the air when the solution goes against our gut feelings is more difficult. Pilots often need to experience illusions and misperceptions in a real or simulated environment.

A program aimed at protecting pilots from misperceptions could include:

- medical checkups to ensure that senses are functioning properly
- human factors awareness training in basic human performance and limitations, as outlined elsewhere in this resource kit
- discussions and analyses of occurrences involving illusions and misperceptions
- where possible, practical simulator and classroom experience of various illusions
- procedures and practices for pilots to employ when in doubt, and practising them in realistic and relevant scenarios.

The take-home messages are:

- illusions are among the most common factors contributing to fatal aircraft accidents
- various complex motions and forces, as well as some visual scenes encountered in flight, can create disorienting illusions of motion and position
- the degree of disorientation may vary considerably between pilots, as do the conditions which induce the problem and the time taken to become disoriented
- spatial disorientation from these illusions can be prevented only by visual reference to reliable fixed points on the ground or reference to flight instruments.

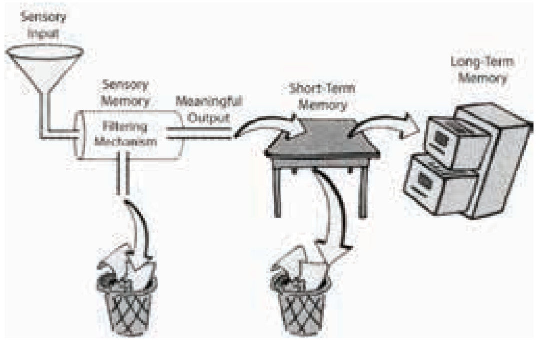



**Figure 9 Strategies to enhance learning**

# Short- and long-term memory

Decision making, or determining our intention to act, uses information in both our active working memory and long-term memory, in which we keep learned knowledge and rules.

It is a complex process and we are prone to various errors when adding information into our memory and recalling it later—we can forget things at any point especially when tired, stressed, distracted or just not paying attention!

So, what do pilots need to know about memory?

## Working memory

We use working memory when doing any task. It holds small amounts of information for a short time for immediate use.

We can read back an ATC instruction to descend and change the transponder code and keep these numbers in our working memory long enough to write them down or enter them into the relevant systems. Mental repetition may be required to achieve the task, and once completed the information is lost within 30 seconds and replaced with the next set of information we need to work with.

Typically, the capacity of our working memory is seven items +/-2. We can use this more effectively by grouping or 'chunking' items into meaningful blocks. Chunking can also be usefully employed to access long-term memory through the use of mnemonics and other memory aids. The more times that data is used in our working memory, the more likely it is to enter our long-term memory.

Because flying involves a lot of memory it is important to have an easy way to remember specific steps or checklists, whether they are used regularly, occasionally or in an emergency.

The Aircraft Owners and Pilots Association (AOPA) suggests mnemonic phrases, or simple memory joggers, to help pilots remember key tasks.[9] Examples are:

Fitness to fly: PAVE

- **P**ersonal minimums, such as health
- **A**ircraft—weight and balance, airworthiness
- en**V**ironment—such as weather
- **E**xternal pressure, such as stress

Run-up or aircraft ground check: CIGAR

- **C**ontrols check
- **I**nstruments set
- **G**as (fuel) on, pump on
- **A**ttitude flaps and trim set
- **R**unup

Before take-off: Lights, Camera, Action

- **L**ights—strobe, landing light, and navigation lights
- **C**amera—transponder on
- **A**ction—fuel boost pump, controls check, flaps, and trim

Are you safe to fly this particular day: IMSAFE

- **I**llness—are you physically well? You don't need to be flying if you are sick. Consider cancelling your flight or making other arrangements.
- **M**edication—are you taking any medications, prescription or over-the-counter, that would make you unsafe? Cold medications often make you sleepy, and a sleepy pilot is definitely not a safe pilot.
- **S**tress—are you under stress or an emotionally draining situation? If so, you don't belong in an aircraft.
- **A**lcohol—alcohol and aircraft don't mix well.
- **F**atigue—are you tired and worn out? If so, you definitely should not be flying or driving to work.
- **E**ating—have you eaten properly so you can work effectively? A can of Red Bull and some chocolate do not count as a nutritious meal.

While mnemonics won't ensure you remember everything all the time, they complement established flying checklists and provide extra confidence that you are on top of things.

## Long-term memory

There are two main types of long-term memory: *procedural* (or implicit) memory and *declarative* (or explicit) memory.

Procedural memory (knowing how) is the unconscious memory of skills and how to do things, such as the physical actions of flying a plane or driving a car. These memories are typically acquired through repetition and practice and comprise behaviours that are so deeply embedded, we are no longer aware of them. These body memories allow us to carry out ordinary motor actions automatically.

- Procedural memory is sometimes referred to as implicit memory, because previous experiences help the performance of a task without explicit and conscious awareness of these previous experiences.
- Declarative memory (knowing what) is memory of facts and events that can be consciously recalled. It can be subdivided into *episodic memory* (experiences) and *semantic memory* (facts, concepts).
  - Episodic memory represents our memory of experiences and specific events in a serial form, from which we can reconstruct past-life events. This is how you remember your last flight examination, when the flight instructor spilled coffee all over the paperwork during the post-flight debrief.

» Semantic memory is a more structured record of facts, meanings, concepts and knowledge. It refers to general factual knowledge, shared with others and independent of personal experience or the context in which it was acquired, such as dates and the details of watershed aviation accidents.

Semantic memories may once have had a personal context, but now stand alone as simple knowledge. They include such things as types of aircraft, airport designators, object functions and understanding of aerodynamics.

Semantic memory is generally derived from episodic memory as we learn new facts or concepts from our experiences. For example, you remember your first landing in Brisbane and the events that happened that day through episodic memory, but you recall the location and direction of the taxiways, the uphill slope to the parking bays, or the bumps in the runway from semantic memory, and from repetition of experiences which build knowledge.

The more times data is accessed in our long-term memory, the more likely we are to be able to recall it when needed. This supports training called 'over learning', where we repeat a procedure or task many times to perform it to a satisfactory level.

Repeated practice, mental rehearsal or discussion guards against forgetting important things that have been learned and stored in long-term memory but may not have been performed for a long time, such as emergency procedures. We use checklists to prevent forgetting tasks beyond regularly accessed 'instant recall' ones.

An interesting alternative classification of long-term memory is based on whether we are looking forward or backward.

- *Retrospective memory* is where the content to be remembered (people, words, events, etc.) is in the past. It includes declarative memory in general, although it can be either explicit or implicit.
- *Prospective memory* is where the content is to be remembered in the future and may be defined as 'remembering to remember' or to perform an intended action. It may be either event-based or time-based, often triggered by a cue such as turning on final and selecting gear down or cancelling your SARTIME after landing.

When we are distracted before completing an intended action we can think we have done it. This may explain why some gear-up landings occur, even when a checklist is being used.

## Motor skills memory

When we are highly skilled at a task, we can perform it seemingly without much conscious effort. Strangely though, the more we think about how we are doing something, the less skilful we may become. An example is a landing in a strong crosswind if the pilot suddenly becomes conscious of what they are doing and over-controls.

Remember that like so many aspects of our information processing ability, a healthy diet, adequate sleep and exercise, and reduced alcohol and drugs all improve our memory and ability to focus.

# Deciding and acting

In the early stages of flying training, we focus on learning and developing motor skills until they become automatic. As training progresses, we begin to learn a broader range of skills that require judgment, such as communicating, problem solving, following procedures, decision making and planning. We also need to learn skills that require knowledge, such as aircraft performance, software and systems management.

The *deciding* stage is selecting the action which best suits the current task. The actions we choose can be skill-based, rule-based or knowledge-based.

## Vigilance, attention and distraction

Vigilance refers to our state of awareness to external stimuluses, an intention to be ready to react to a range of inputs. It is an energetic state that we can turn up and turn down at will, but which can also drop off during periods of low stimulus, boredom, fatigue and stress. Pilots need to remain vigilant for data from engine, navigation, communication and other aircraft systems, as well as events occurring outside the aircraft.

Our sensory and perception mechanisms cannot attend to everything and make sense of this information at the same time. We need to pay attention to the most important stimulus in the moment, or divide our attention when several important things require observation and response. Therefore, it is important to establish a good instrument scan appropriate to the phase of flight, and appropriate work cycles to constantly analyse data and maintain situational awareness in order to make good decisions.

While we cannot truly do two or more things at the same time, we can rapidly switch our attention. The most complex or unfamiliar tasks usually require our full attention, making us less likely to perceive other things. For example, when focused on flying an unfamiliar non-precision approach in poor weather at night, we might fail to retune the navigation aids at the appropriate point.

This is why some systems use visual and aural alarms to break our focus and grab attention. We need scans for the same reason; they temporarily broaden our attention and allow us to sense other critical information.

We are also easily distracted by our own thoughts about current, past and future events, often completely unrelated to the task at hand. Internal distractions are more likely to occur when we are fatigued, stressed or ill.

Pilots are trained to manage more than one task concurrently, but a preoccupation with one task to the detriment of others is one of the main causes of operational error in the cockpit. The ATSB has reported that there were 325 occurrences involving pilot distraction on Australian-registered aircraft from 1997 to 2004.[10] It grouped distractions under many categories including information processing.

## Personal issues

The pilot of a Cessna operating a charter flight from Goulburn Island to Darwin was alerted by radio that the landing gear had not extended. On late final, the pilot began an overshoot but was unable to prevent the aircraft from contacting the ground.
The investigation concluded that:

*It was likely that the pilot's personal and other problems, and the resulting interrupted sleeping and eating patterns, diminished the pilot's ability to manage the tasks necessary to prepare the aircraft for landing. That degradation in performance was compounded by the in-flight distractions that coincided with when the pilot would have normally conducted his sequence of pre-landing actions and checks. The result was that the pilot unwittingly omitted to lower the aircraft's landing gear.*[11]

The ATSB report suggested ways to reduce the possibility of in-flight distractions, including:

- Exercising discretion in talking with others on board the aircraft, particularly during pre-flight checks and critical phases of flight.
- If economically viable, commercial GA pilots should consider leaving the right front seat vacant to minimise conversation with passengers.
- Where possible, operating procedures which require tasks to be conducted concurrently should be replaced with those which require tasks to be conducted sequentially.
- If a checklist is interrupted, pilots should consider starting the checklist again.
- Simulator training should incorporate scenarios that require pilots to manage distractions, interruptions and concurrent tasks.

# Key points for professional pilots

We have looked at how the human information processing system works and considered its limitations. The way in which we perceive and misperceive information can, through various illusions, trick us and lead to accidents.

We not only need to be aware of what can go wrong but also how insidious misperception can be. Even the most experienced pilots can be caught out.

The extra risks inherent in visual flight at night are from reduced visual cues and the increased likelihood of perceptual illusions, which can increase the risks of spatial disorientation.

Aircraft need to be appropriately equipped—ideally with an autopilot to maintain stable flight if the pilot becomes disoriented. This is especially true for inherently less stable rotary aircraft.

Most importantly, pilots need to practise and maintain their instrument flying skills, especially for low visibility and night conditions. Regular disciplined instrument scanning and trusting the gauges can make the difference when our senses are not telling us the full story.

Charter operators need to ensure their pilots are aware of the types of illusions and distractions they can encounter and how to guard against them. This includes providing their pilots, under safe and controlled conditions, opportunities to experience and counter these illusions and distractions. Experiencing disorientation and practising recovery is quite different from just reading about it.

# Resources

## KEY TERMS

**distraction** Having attention diverted from what we should be focusing on at the time.

**human information processing** The ability to effectively process information and make a suitable response.

**Illusions** Misperceptions of reality when our senses are 'tricked' so that what we think we see or feel is not what is really happening.

**memory** The storage and recall of information in our brain.

**perception** The brain's understanding of information acquired through our senses, making the connection between external events and our thoughts about them.

**sensing** The brain's interpretation of information it receives from our senses to determine our body's condition and our interaction with the environment.

**situational awareness** Knowing what is going on around you to be able to predict what is likely to happen next.

**vigilance** A positive intention to be ready to react to a range of inputs relating to a low to high state of awareness to external stimuluses.

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