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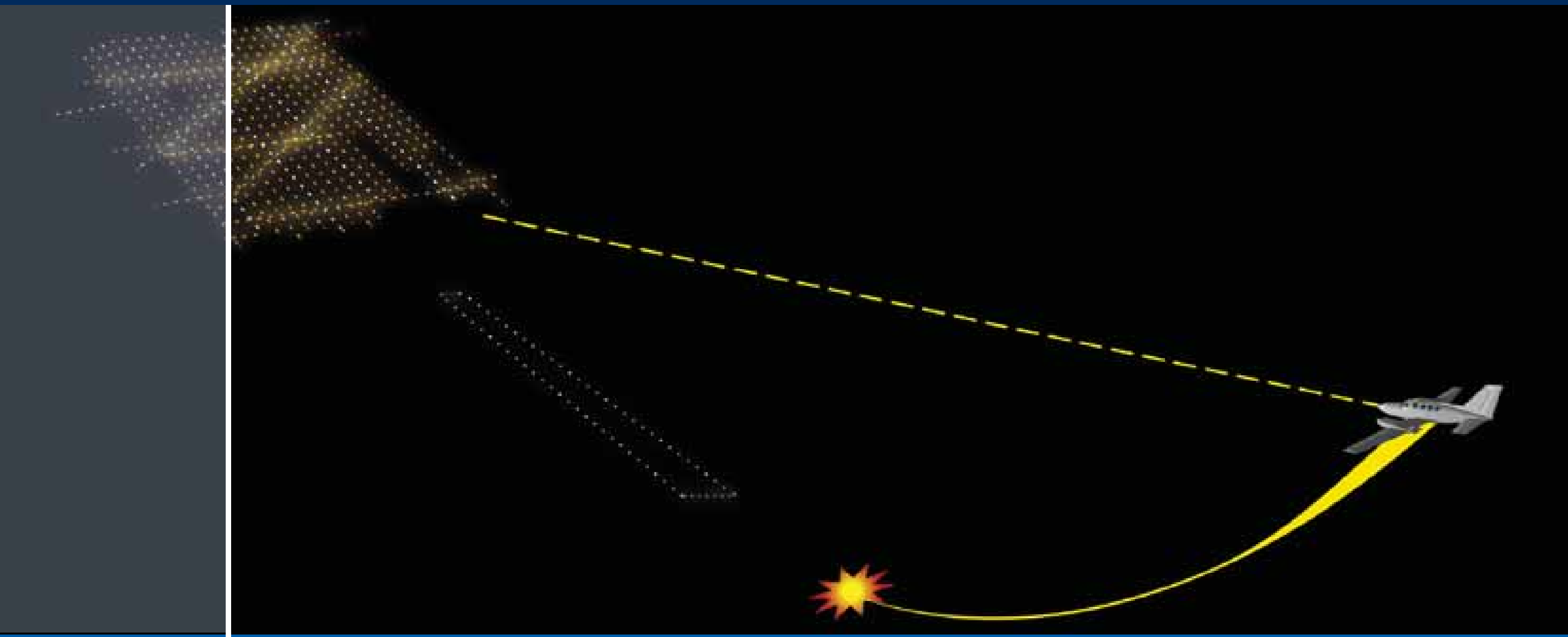

ATSB TRANSPORT SAFETY INVESTIGATION REPORT
Aviation Research and Analysis Report – B2007/0063
Final

An overview of spatial disorientation as a factor in aviation accidents and incidents

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Abstract

Spatial disorientation (SD) is among the most common factors contributing to aviation accidents and incidents, but its true prevalence is difficult to establish. This is because many accidents where SD is cited as a likely factor are fatal, and therefore its role cannot be known with any certainty, but also because in the many instances of SD where an accident doesn’t result, it goes unreported.

This study provides a comprehensive explanation of the various types of SD in the aviation environment, and suggest strategies for managing the risk associated with SD events. This report provides an informative overview of the three basic types of SD, and the circumstances under which disorientation might be more likely. These are of value to all pilots, and especially those who conduct flights in instrument conditions or at night under visual flight rules. Single-pilot operations, particularly where an autopilot is not available, face additional risks and the need to identify and manage SD events.

This report also encourages pilots who have experienced SD episodes to share their experiences with their aviation colleagues, either informally, or through magazines, journals and web-based forums. This will serve to encourage a greater awareness of the incidence of SD, and help reduce the stigma that some pilots might associate with these events. As other studies suggest, SD is likely to be encountered by all pilots during the course of a lifetime’s flying – whether professional or non-professional, experienced or inexperienced. A more open approach to acknowledging and discussing SD and its various causes will make a valuable contribution to a better understanding of this common human factor.

THE AUSTRALIAN TRANSPORT SAFETY BUREAU

The Australian Transport Safety Bureau (ATSB) is an operationally independent multi-modal Bureau within the Australian Government Department of Transport and Regional Services. ATSB investigations are independent of regulatory, operator or other external bodies.

The ATSB is responsible for investigating accidents and other transport safety matters involving civil aviation, marine and rail operations in Australia that fall within Commonwealth jurisdiction, as well as participating in overseas investigations involving Australian registered aircraft and ships. A primary concern is the safety of commercial transport, with particular regard to fare-paying passenger operations.

The ATSB performs its functions in accordance with the provisions of the Transport Safety Investigation Act 2003 and Regulations and, where applicable, relevant international agreements.

Purpose of safety investigations

The object of a safety investigation is to enhance safety. To reduce safety-related risk, ATSB investigations determine and communicate the safety factors related to the transport safety matter being investigated.

It is not the object of an investigation to determine blame or liability. However, an investigation report must include factual material of sufficient weight to support the analysis and findings. At all times the ATSB endeavours to balance the use of material that could imply adverse comment with the need to properly explain what happened, and why, in a fair and unbiased manner.

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Central to the ATSB's investigation of transport safety matters is the early identification of safety issues in the transport environment. The ATSB prefers to encourage the relevant organisation(s) to proactively initiate safety action rather than release formal recommendations. However, depending on the level of risk associated with a safety issue and the extent of corrective action undertaken by the relevant organisation, a recommendation may be issued either during or at the end of an investigation.

The ATSB has decided that when safety recommendations are issued, they will focus on clearly describing the safety issue of concern, rather than providing instructions or opinions on the method of corrective action. As with equivalent overseas organisations, the ATSB has no power to implement its recommendations. It is a matter for the body to which an ATSB recommendation is directed (for example the relevant regulator in consultation with industry) to assess the costs and benefits of any particular means of addressing a safety issue.

About ATSB investigation reports: How investigation reports are organised and definitions of terms used in ATSB reports, such as safety factor, contributing safety factor and safety issue, are provided on the ATSB web site www.atsb.gov.au.

EXECUTIVE SUMMARY

Flying an aircraft is a challenging activity, and exposes the pilot to many potential hazards. One of the most significant of these is spatial disorientation (SD). Spatial disorientation is defined as the inability of a pilot to correctly interpret aircraft attitude, altitude or airspeed in relation to the Earth or other points of reference. It is a very common problem, and it has been estimated that the chance of a pilot experiencing SD during their career is in the order of 90 to 100 per cent. The results of several international studies show that SD accounts for some six to 32 per cent of major accidents, and some 15 per cent to 26 per cent of fatal accidents. The true prevalence of SD events is almost certainly underestimated.

The complex motion environment of flight increases the risk of SD, by exposing the physiological limitations of the normal human orientation systems. Spatial disorientation is thus an ever-present hazard to aircrew, and the vestibular and visual illusions that can occur with this phenomenon can result in loss of situational awareness and aircraft control. The potential for a disastrous outcome in this situation is clearly high. There are several pilot, aircraft, operational, and environmental factors that can contribute, either alone or more commonly in combination, to a SD event. Non-instrument rated pilots flying into instrument meteorological conditions (IMC) are a not infrequent cause of SD accidents.

The chances of a SD event occurring in flight can be reduced by a series of simple preventive measures, many of which can be attended to before flight. These include flying when fit and well to do so, not flying under the influence of alcohol or medications, avoiding visual flight rules into IMC, increasing awareness of SD illusions, and planning for their possible appearance at different stages of flight in the pre-flight planning process.

It is vitally important that pilots are aware that SD happens to normal pilots. It can affect any pilot, any time, anywhere, in any aircraft, on any flight, depending on the prevailing circumstances. Furthermore, experience of SD does not mean it will not ever happen again. Awareness and preparedness are key elements in preventing an SD accident.

ABBREVIATIONS

ATSB	Australian Transport Safety Bureau
BASI	Bureau of Air Safety Investigation
DAME	Designated aviation medical examiner
IMC	Instrument meteorological conditions
NVG	Night vision goggles
SD	Spatial disorientation
UK	United Kingdom
US	United States
VFR	Visual flight rules

1 INTRODUCTION

1.1 What is spatial disorientation?

Flying an aircraft is a challenging activity, and exposes the pilot to many potential hazards. One of the most significant of these is spatial disorientation (SD).

The Federal Aviation Administration provided a simple definition in its 1983 Advisory Circular (AC 60-4A). It stated that spatial disorientation to a pilot means simply the inability to tell which way is "up" (FAA, 1983).

A more complex definition of SD is as follows (Benson, 1988b):

> Spatial disorientation is a term used to describe a variety of incidents occurring in flight where the pilot fails to sense correctly the position, motion or attitude of his aircraft or of himself within the fixed coordinate system provided by the surface of the Earth and the gravitational vertical. In addition, errors in perception by the pilot of his position, motion or attitude with respect to his aircraft, or of his own aircraft relative to other aircraft, may also be embraced within a broader definition of spatial disorientation in flight.

If the disorientation phenomenon is not recognised immediately, it may lead to loss of control of the aircraft or controlled flight into terrain with disastrous consequences. Prevention of SD is thus an important step in enhancing flight safety.

1.1.1 How big is the problem in the aviation environment?

Spatial disorientation is a very common problem, and is a well recognised cause of aviation accidents. Various military forces around the world have examined the issue of SD in terms of its prevalence and contribution to accidents. In general, the results of these studies show that SD accounts for some six per cent to 32 per cent of major accidents, and some 15 per cent to 69 per cent of fatal accidents (Barnum & Bonner, 1971; Braithwaite, Durnford, & Crowley, 1998b; Cheung, Money, Wright, & Bateman, 1995; Gillingham & Previc, 1996; Hixson, Niven, & Spezia, 1972; Knapp & Johnson, 1996; Lyons, Ercoline, O'Toole, & Grayson, 2006; Moser, 1969; Singh & Navathe, 1994).

The United States (US) Navy has reported that during the period 1980 to 1989, some 112 major aircraft accidents involved SD of the crew (Bellenkes, Bason, & Yacavone, 1992). The US Air Force, for the same period, reported that SD led to 270 major aircraft mishaps (Holland, 1992). Another US Air Force study found that single-pilot aircraft might be more at risk from SD, and that a third of F-15 and F-16 crashes were attributable to SD (Gillingham, 1992). A similar study also showed that Royal Netherlands Air Force pilots in the F-16 experienced 73 per cent more SD than in other types of fighter aircraft (Holland & Freeman, 1995). A US Air Force study, looking at F-16 Class A accidents during the years 1975 to 1993, found that 7.5 per cent of those accidents were due to SD (Knapp & Johnson, 1996). The most recent US Air Force study examined SD across 15 years of accident data, and found that SD accounted for 11 per cent of US Air Force accidents and 69 per cent of accident fatalities during the period 1990 to 2004 (Lyons et al., 2006).

In the United Kingdom (UK) Army, one study suggested that 21 per cent of their accidents were attributable to SD (Vyrnwy-Jones, 1985). Some authors have commented that comparing prevalence and incidence rates among air forces can be problematic depending on how the definition of SD is applied (Navathe & Singh, 1994).

In a recent survey of SD in UK miliary aircrew, the researchers reported that 21 per cent of aircrew who had experienced a disorientation event had regarded it as significant, with a further four per cent regarding the event as severe and a risk to flight safety (Holmes, Bunting, Brown, Hiatt, Braithwaite, & Harrigan, 2003). Another UK study showed that the overall SD accident rate was one per million flight hours (Bushby, Holmes, & Bunting, 2005).

In an Indian Air Force study, the researchers found that proven SD accounted for two per cent of all accidents, and almost eight per cent of fatal accidents (Singh & Navathe, 1994). However, if probable SD was added to proven SD, these figures increased to almost six per cent and 18 per cent respectively. The authors noted the difficulty that investigation boards were faced with in proving SD as a definite cause of the accident.

In the civil aviation environment, prevalence data for SD is less commonly available. However, SD does cause accidents, incidents and loss of life. In recent years there have been some particularly high-profile SD-related accidents, such as that involving John F. Kennedy Jr. In a US study examining disorientation in general aviation, the authors attributed 15.6 per cent of major accidents and 2.5 per cent of fatal accidents to SD (Kirkham, Collins, Grape, Simpson, & Wallace, 1978).

It has been reported that for a given pilot, the career incidence of SD is in the order of 90 to 100 per cent (Braithwaite et al., 1998b; Clark, 1971; Eastwood & Berry, 1960; Edgington & Box, 1982; Patterson, Cacioppo, Gallimore, Hinman, & Nalepka, 1997; Singh & Navathe, 1994; Tormes & Guedry, 1974). In other words, if a pilot flies long enough as a career or even a hobby there is almost no chance that he/she will escape experiencing at least one episode of SD. Looked at another way, pilots can be considered to be in one of two groups: those who have been disorientated, and those who will be.

One of the difficult issues with SD is the reporting of it. If a pilot experiences SD, but recovers and is able to complete the flight, the episode may never be reported and come to light. If no accident or incident occurs, the event may not be reported to the authorities and no-one (other than the affected pilot) ever knows about it. This may be the case if the pilot is reluctant to report such an event in fear of losing their license. Similarly, if an apparently serviceable aircraft and a fit and well pilot are involved in a fatal accident, it may be difficult to positively conclude that the accident was due to a SD event. In many such cases, SD can only be suggested as the most likely or most probable cause of the accident.

The following case serves as an example. On 15 August 2004, a privately operated Mooney M20K aircraft impacted the sea off Queensland while on a visual flight rules (VFR) flight. The pilot was killed. The latter part of the flight had been conducted at night. The Australian Transport Safety Bureau (ATSB) accident report was unable to positively identify the cause of the accident, but reached the following conclusion (ATSB, 2006a):

> The circumstances of the accident are consistent with a loss of control due to the pilot becoming spatially disoriented after flying into an area of minimal surface and celestial illumination. Physiological and cognitive factors may have contributed to the development of the accident. However, the factors that contributed to the aircraft descending into the water could not be conclusively established.

The true prevalence of SD in flight, especially in the Australian aviation context, is therefore difficult to know. It is highly likely, however, that SD is much more common than is reported.

1.1.2 Types of spatial disorientation

Three basic types of SD have been described, for the purposes of classification. These types are Type I (unrecognized), Type II (recognised) and Type III (incapacitating).

Type I (unrecognized)

In this form of disorientation, the pilot is unaware that they are disoriented or that they have lost situational awareness. The pilot, unaware of the problem, continues to fly the aircraft as normal. This is particularly dangerous, as the pilot will not take any appropriate corrective action, since they do not perceive that there is in fact a problem. The fully functioning aircraft is then flown into the ground, with often fatal results. This form of SD is clearly dangerous, and accounts for the majority of SD accidents and fatalities (Braithwaite et al., 1998b).

Type II (recognized)

Type II SD is more common than Type I. In this form of disorientation, the pilot becomes aware that there is a problem. While the pilot may or may not be aware that the problem is SD, in this form of disorientation they are aware that something is not quite right, that their sensory system is giving information that does not agree with the information available from the instruments, or that things just don’t add up. The conflict between their own perceptions and that given to them by the instruments or the outside visual world alerts them to a problem, which they are then in a position to deal with. If this is successfully dealt with, a SD accident does not tend to result. The pilot may then have received a valuable lesson on SD and how to recover from it.

Type III (incapacitating)

In Type III SD, the pilot experiences the most extreme form of disorientation stress. The pilot may be aware of the disorientation, but is mentally and physically overwhelmed to the point where they are unable to successfully recover form the situation. They may freeze at the controls, or make control inputs that tend to exacerbate the situation rather than effect recovery from it. The pilot may fight the aircraft all the way to ground impact, never once achieving controlled flight. Such forms of disorientation are a result of breakdowns in the normal cognitive processes, possibly due to the overwhelming nature of the situation, especially if other factors such as fatigue and high workload are also present.

1.2 The normal process of spatial orientation

It is of fundamental importance that humans have some idea of where they are in time and space, to facilitate normal movements and activities on the surface of the Earth. Humans are equipped with a sophisticated set of systems that provide information on orientation to the brain, which then builds up a composite picture of the relative position in space. This is largely a subconscious process, but the importance of this process is immediately obvious when the system fails and the normal sense of orientation is lost. In order to understand such disorientation, and the crucial role this issue plays in flight safety, it is necessary to first consider how the normal process of spatial orientation works.

Under normal conditions, humans are able to accurately determine which way is up and how they are oriented by using information from three specialized sensory systems:

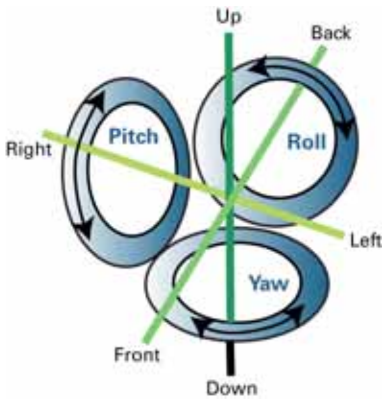
- the visual system;
- the balance organs located in the inner ears (also known as the vestibular system); and
- the proprioceptive system (also colloquially known as the “seat-of-the-pants”).

These three systems rely on various sensory receptors to collect information and then send that information to the brain, which integrates the incoming information into a single model of orientation and under normal conditions, is highly accurate. The integrated information is used to determine our position within a fixed coordinate system provided by the surface of the Earth (as a horizontal reference) and the force of the Earth’s gravity (which provides a vertical reference).

The three systems do not have equal importance in terms of providing orientation information. The visual system is by far the most important of the three systems, providing some 80 per cent of the raw orientation information. In conditions where visual cues are poor or absent, such as in poor weather or at night, up to 80 per cent of the normal orientation information is missing. The remaining 20 per cent is split equally between the vestibular system and the proprioceptive system, both of which are prone to illusions and misinterpretation. In poor or absent visual cue situations, humans are forced to rely on the remaining 20 per cent of orientation information, which is less accurate. In such situations both of these systems now each account for 50 per cent of the orientation information. In the aviation setting, such a situation can then result in any number of well-described SD illusions being experienced by the pilot. This is even more dangerous when the pilot has no idea that they are disorientated, believing that their sensory information is correct when in fact it is not. Clearly, the absence of good visual cues deprives us of the vast majority of orientation information. It is therefore little wonder that the majority of disorientation events are associated with poor visual cues (as in IMC or night flight).

The vestibular system consists of two important components: the semi-circular canals and the otolith organs. There are three semi-circular canals in each ear, and in functional terms they operate as three matched pairs, in each of the three primary axes of motion. The canals in each ear are all at right angles to each other, and function as angular accelerometers. Significantly, they have a stimulation threshold of 2^0/sec^2[1], below which they are not able to detect angular motion. This is of crucial significance in the aviation setting – if a turn is made (intentionally or otherwise) at a rate of angular acceleration less than this threshold, the canals will not register the turn. In the absence of visual cues that a turn is happening, and with the force of gravity still in the head-to-foot direction and as such giving unchanged proprioceptive information, the pilot will not realise that a turn is underway and will feel straight and level.

Figure 1: The three semicircular canals operate in each of the three primary axes



There are two otolith organs in each ear, one in the vertical plane and the other in the horizontal plane. These organs operate as linear accelerometers, and under normal conditions the vertical otolith signals the effect of the Earth's gravitational field.

The vestibular system is extremely important for normal human spatial orientation. It performs a complex series of integration functions of angular and linear acceleration, and via its myriad neural connections with the eyes and the motor coordination centres in the brain, helps to regulate postural tone, maintain balance and achieve coordinated, clear vision during motion.

This latter function of maintaining good quality visual information during motion, (especially of the head), is a function of the vestibulo-ocular reflex. This reflex means that if, for example, the head is turned to the left while focusing on a given object, the eyes will automatically be moved as a coordinated pair in the opposite direction, to maintain a tightly focused view of the object. This automatic response is crucial for clear, focused and stabilized vision.

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1 The semi-circular canals sense angular rotation about each of the three axes. Angular acceleration within the canals is measured in terms of degrees per second squared.

The proprioceptor system consists of pressure sensors throughout the body, especially in the joints, tendons, ligaments, muscles and skin. Under normal conditions, the pressure exerted on a given set of pressure receptors helps contribute to the overall sense of orientation. For example, the pressure receptors in the soles of the feet and the joints of the ankle and knee signal to the brain that upright posture is being maintained.

All of this sensory information is constantly being sent to the brain for processing, so as to maintain an accurate sense of orientation with respect to the surface of the Earth and the gravitational vertical. It is important to remember that these systems, on which humans depend so much, are not designed to operate in the three-dimensional environment of flight. In that environment, it is possible to operate independently of the normal visual cues (as in bad weather or night flying) and both the magnitude and applied direction of gravity can be altered. The complex motion environment of flight thus dramatically increases the risks of SD by exposing the physiological limitations of the normal human orientation systems.

2 SPATIAL DISORIENTATION ILLUSIONS

A comprehensive analysis of all potential illusions is beyond the scope of this review. We will concentrate on the more common examples, and consider some actual cases where these illusions resulted in an accident or incident.

2.1 Vestibular illusions

As discussed previously, the vestibular system consists of the balance organs in both inner ears. They are designed for motion detection during surface of the Earth operations, and as such their inherent limitations make them susceptible to error during flight. Some of the more common vestibular illusions that can occur are:

- the somatogravic illusion (pitch-up illusion);
- the somatogyral illusion (grave-yard spin or spiral);
- the leans;
- the Coriolis illusion; and
- the G-excess illusion.

2.1.1 The somatogravic illusion

The somatogravic illusion is also known by various other descriptive terms, such as the dark night take-off illusion, the pitch-up illusion and the inversion illusion (Benson, 1988a; Buley & Spelina, 1970; Campbell & Bagshaw, 2002; Gillingham & Previc, 1996; Lane, 1958). At the heart of this illusion is a strong sensation of pitching up during aircraft acceleration, as would be experienced during take-off. The illusion generally occurs in conditions of poor visual cues, such as night operations or instrument meteorological conditions (IMC). During a take-off in such conditions, the vestibular system (in particular, the otolith organs) will accurately register the linear acceleration involved in the take-off process. However, in the absence of visual information that would confirm the actual flight path of the aircraft, the brain instead assumes that the linear acceleration is in fact a pitch up event. The unwitting pilot then pushes forward on the control column, in order to cancel out the sensation of too much pitch up, and to achieve a feeling of normal pitch. This manoeuvre then results in a pitching down of the aircraft, and since this illusion generally occurs during a low altitude setting with takeoff, the inherent risk is that the aircraft is flown into the ground. Such an illusion of strong pitch-up during a take-off at night is potentially very dangerous, and has resulted in several accidents over the years.

A report from the then Bureau of Air Safety Investigation (BASI), now part of the Australian Transport Safety Bureau (ATSB), examined dark night take-off accidents in Australia between January 1979 and May 1993, and found that of the 35 accidents in this period, 15 of them (42 per cent) involved spatial disorientation (SD) as a primary factor (BASI, 1995). In that report, a similar study from the US National Transportation Safety Board was cited, in which 78 per cent of the 291 night take-off accidents in the period 1983 to 1993 involved SD.

The opposite form of this illusion can occur during flight when a sudden deceleration occurs. If this occurs in conditions of poor visual cues, the pilot may experience a sensation of strong pitching down. This may lead the pilot to inadvertently pull back on the control column, in the mistaken belief that this will prevent pitch down and maintain level flight. However, the aircraft then actually pitches up, and may in fact stall[2]. If there is sufficient altitude, and the pilot recognizes what has happened, recovery may be possible. However, the situation can rapidly deteriorate if the pilot becomes truly disoriented and confused. A loss of control and fatal accident may then result.

2.1.2 The somatogyral illusion

The somatogyral illusion is also known as the graveyard spin or spiral (Benson, 1988a). It is again a function of how the vestibular system works. During the entry into a spiral turn or a spin (deliberately or inadvertently), the vestibular system (in particular the semi-circular canals) will register the initial angular acceleration. This of course assumes that the entry into the turn is above the threshold for activation of the semi-circular canals.

Once the spiral turn or spin is stabilized, the angular acceleration will tend towards zero, with a constant velocity turn (ie no acceleration). In this situation the semi-circular canals will not be stimulated, as they only register a change in angular velocity. The canals will effectively then signal that there is no turn happening. The visual system, however, being the dominant orientation mechanism, will over-ride the vestibular system signals and confirm the ongoing turn, due to the outside visual world rotating as the turn continues.

However, if there are poor visual cues, the pilot may experience a sensation that they are no longer turning. When the spiral turn or spin is halted, and a return to straight and level flight affected, the semi-circular canals may register the change in angular velocity associated with the cessation of turning. This can then create an illusion within the pilot that they are now turning in the opposite direction to the original turn. This strong sense of false rotation may lead, in the absence of good visual cues, to a re-entry into the original turn or spin. This may cancel out the false sense of rotation, with the pilot now believing that they are straight and level, but in fact they have re-entered the original turn or spin, and be losing altitude as a result. Unless this dangerous situation is recognised and appropriate recovery steps taken, impact with the ground will inevitably result.

The link between the visual and vestibular systems (as mentioned previously) is very obvious during the somatogyral illusion. Upon recovery from the spin or prolonged spiral turn, the semi-circular canals signal the false sense of rotation in the opposite direction. This vestibular input then can result in a series of involuntary oscillatory eye movements known as nystagmus. This can then lead to the oculogyral illusion, where the visual field appears to move, and in so doing tends to reinforce the false sense of rotation. In effect, the pilot then gets apparently confirmatory visual evidence of rotation, which can lead the pilot to re-enter the original turn. This combined effect makes this illusion extremely dangerous.

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2 Stall: an aerodynamic condition where the airflow along the upper surface of an aerofoil (eg wing) separates resulting in a loss of lift (Kumar, 2004).

Vestibular stimulation generally results in visual changes, such as nystagmus. The visual effects of vestibular stimulation reflect the very close connection between the two systems, which are critically important for normal orientation.

Once the sense of nystagmus has worn off, clear visual information may then be available to the pilot. Looking at the instruments may reveal that the original turn has been re-entered. The pilot may then recover, but in so doing may then get the false sense of rotation again, and succumb to the illusion once more by inadvertently re-entering the original turn. Nystagmus may then reappear, and only when it resolves will the pilot see what is happening and then recover. However, it can be seen that this cycle of turn, recover, turn and recover can continue right up to ground impact, with the pilot experiencing multiple episodes of the illusion. The pilot can of course become completely disoriented and confused and lose all control of the aircraft. Tightening of the turn can also exacerbate the sense of false rotation.

This is a particularly dangerous illusion, and has claimed many lives.

2.1.3 The leans

The leans has been well recognised as the most common form of disorientation (Benson, 1988a; Holmes et al., 2003; Navathe & Singh, 1994; Sipes & Lessard, 2000). If a pilot experiences disorientation during their career, they will almost certainly experience this form of disorientation at some point. Fortunately, episodes of the leans are generally of a minor nature.

The leans is manifested by a false sensation of roll. It is extremely common, and is so named because it may cause pilots to lean to one side in order to cancel out the false sensation. The leans can occur in conditions of good visual cues.

The typical situation in which the leans may occur involves a pilot flying an aircraft, trimmed for straight and level flight. For whatever reason (wind gust, etc) one wing may drop and the aircraft may then enter a gentle turn. This turn is at a rate of angular acceleration less than the threshold for activation of the semi-circular canals. The result of this is that the pilot (who is generally head-down in the cockpit, studying a map for example) believes that they are still straight and level, while the aircraft is in a turn. As soon as the pilot looks up and out of the aircraft or at the instruments, the inadvertent turn is recognised and immediate recovery actions taken to restore actual straight and level flight. However, the crucial element here is that return to straight and level flight is generally made at a rate of angular acceleration greater than the threshold for activation of the semi-circular canals. As such the first input the canals receive is when the aircraft returns to straight and level flight. However, the canals now register an apparent change from straight and level flight to a turn in the opposite direction.

Hence, if the initial inadvertent turn was to the left, the pilot now sits in a straight and level aircraft with the canals now signalling an apparent turn to the right. In order to effectively make their head fell straight and level, the pilot leans in the direction of the initial turn (in this case, to the left). This may feel bizarre, with the pilot seeing the aircraft straight and level, and at the same time feeling straight and level but being aware of themself leaning to one side. Fortunately, if this is maintained the erroneous sensation of roll will wear off and leaning to one side is no longer required. Clearly, though, there is potential for disorientation and confusion to develop, and in a worst case scenario the pilot may become incapacitated by the unusual sensations and lose control of the aircraft.

2.1.4 The Coriolis illusion

The Coriolis phenomenon (also known as cross-coupled stimulation) is a severe tumbling sensation brought on by moving the head out of the plane of rotation, simultaneously stimulating one set of semi circular canals and deactivating another set.

The Coriolis illusion is manifested by a very strong and unpleasant sensation of tumbling, which often has a rapid onset. The tumbling can be severe enough to lead to feelings of nausea. The illusion is caused by a pilot moving their head out of the plane of rotation. For example, a pilot may be making a coordinated turn as part of their approach to land. The canals in the plane of rotation of this turn will signal the angular acceleration, but the other two sets of canals, sitting in different axes, will not signal any thing. If the pilot then moves their head, such as looking back into the turn, down into the cockpit, or up into the sky (as in looking for other traffic), the result is what is known as cross-coupled stimulation of the semi-circular canals. The set of canals that were originally signalling the turn are now taken out of the plane of rotation of the turn, and signal a deceleration. At the same time, a new set of canals is brought into this plane of rotation as a result of the head movement, and these canals signal an acceleration. The brain then receives two sets of contradictory signals, one signalling acceleration and the other signalling deceleration. The result is a complex series of tumbling movements being suddenly experienced by the pilot, which can be extremely strong and disorientating. The degree of tumbling sensation is a function of the magnitude of the initial turn, the direction of head movement and the speed at which the head movement is made.

2.1.5 The G-excess illusion

The G-excess illusion is a potentially very dangerous illusion, especially if it occurs during low altitude and high speed operations (Ercoline, DeVilbiss, Yauch, & Brown, 2000). In such settings, the illusion can lead to erroneous control inputs, which can be disastrous given the limited time available to recognize and recover from the illusion.

The G excess illusion is a complicated phenomenon, involving multiple inputs to the vestibular system. In practical terms, a pilot who enters a turn at a level of G greater than the normal +1 Gz[3], and then looks back into the turn, may experience a phenomenon where they feel that the initial angle of bank is reducing. During a +2 Gz turn, a pilot may experience an apparent underbank of at least 10 to 20 degrees. In order to maintain the desired bank angle, the pilot may apply more bank, with the unintended consequence being a significant overbank phenomenon. This can then result in a dramatic loss of altitude and/or stall, which can lead to ground impact if the situation is not recognised quickly and swiftly recovered from.

3 +Gz: Gravitational force acting through the vertical access of the body (head-to-foot).

2.2 Visual illusions

The visual system can also suffer from misinterpretation. Given that the visual system is the dominant system for normal orientation, a visual illusion can be very powerful. Visual illusions can occur even in perfect weather, and in many cases the illusions that occur depend on expectations of what the pilot “should” be seeing. Common visual illusions include:

- sloping cloud banks and false horizons;
- illusions relating to runway size, shape and slope;
- autokinesis; and
- the blackhole approach.

2.2.1 False horizons

Normally, flying is associated with reference to a horizontal surface, such as the horizon or the top of a cloud layer. There are circumstances, however, where the visual system can perceive a horizontal reference when in fact the feature is not level. Sloping cloud banks can catch out a pilot who climbs up through a cloud layer and finds themselves on top. Under visual flight conditions, the tendency is very strong to use the top of the cloud bank as a horizontal reference. However, if the cloud bank is actually sloping, the pilot may inadvertently fly with some degree of bank in order to maintain what they perceive as straight and level flight. This will make keeping an accurate heading somewhat problematic. Reference to the instruments will show the aircraft continually drifting off the intended course. A UK study showed that such sloping horizon situations accounted for 75 per cent of SD episodes (Holmes et al., 2003).

Similarly, a night approach to a coast line at an angle may also set up a false horizon illusion. If there is a coastal highway with lights, the line of lights may lead the pilot to fly against it as a reference. Since the flight path of the aircraft is at an angle to the line of lights, using the lights as a horizontal reference will put the aircraft into a degree of bank. This false horizon illusion can be dangerous if the aircraft is operating at speed and low altitude. If unrecognised, the situation can lead to a ground impact relatively quickly.

2.2.2 Runway shape and slope illusions

Landing an aircraft is generally a visual activity. The approach to the runway is monitored and its accuracy assessed by the relative shape of the runway and its position relative to the aircraft. There are well defined illusions that can catch pilots out, depending on the shape, size and slope of the runway (Benson, 1988a; Campbell & Bagshaw, 2002), especially if the pilot is unaware that the runway they are approaching is different from what they are expecting.

For example, flying an approach to a down-sloping runway means that at a certain altitude and distance from the runway, less will be seen of the runway compared with a normal, completely flat runway. If the pilot does not know that the runway is down-sloping, the pilot may perceive that they are low on approach, since they are seeing less of the runway. As a result, the pilot may fly higher, to make the runway look like it normally does when they are at that height and distance.

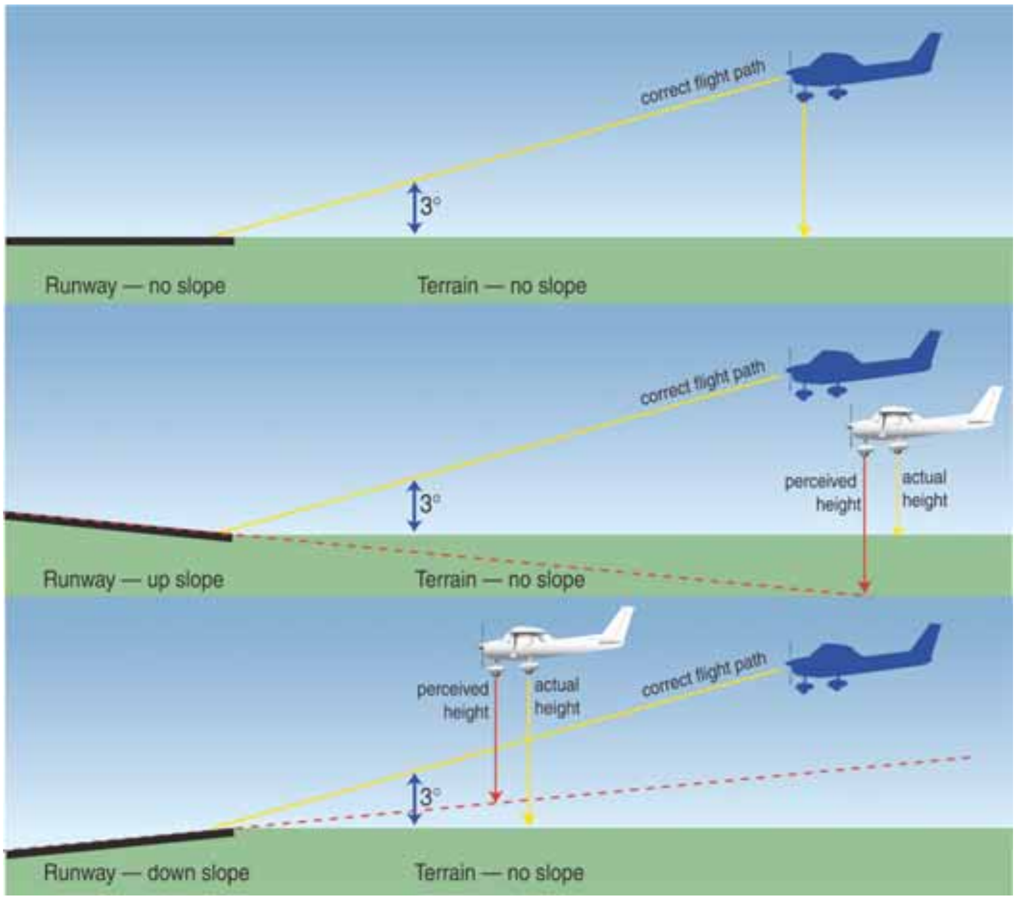
However, the unsuspecting pilot, although feeling on the correct glideslope and approach angle, is actually higher than they should be. The end result may be a less stabilised approach and a landing well down the length of the runway. This may be a problem if there is then insufficient runway remaining to stop the aircraft.

The opposite may occur if the runway is upsloping. The pilot may feel too high, and consequently fly a lower than normal approach, in the mistaken belief that they are now on glideslope. The problem here is that the aircraft may land short of the runway, or not achieve sufficient clearance from obstacles (for example, power lines) in the approach path.

The width of the runway can also give an illusion to an unsuspecting pilot. A runway wider than the pilot is used to may make them feel lower and closer, making them fly higher than normal. Conversely, a narrower runway may make them feel further away and higher than normal, making them fly lower. Longer than usual runways give an illusion of height, and shorter than usual runways give an illusion of being lower than normal.

Clearly all these runway illusions can be mitigated against by pilots being aware of the characteristics of their destination airfield in advance, and by being aware of the potential for such illusions to occur.

Figure 2: Sloping runways can cause illusions that can lead to incorrect perceptions of height above the ground during approach



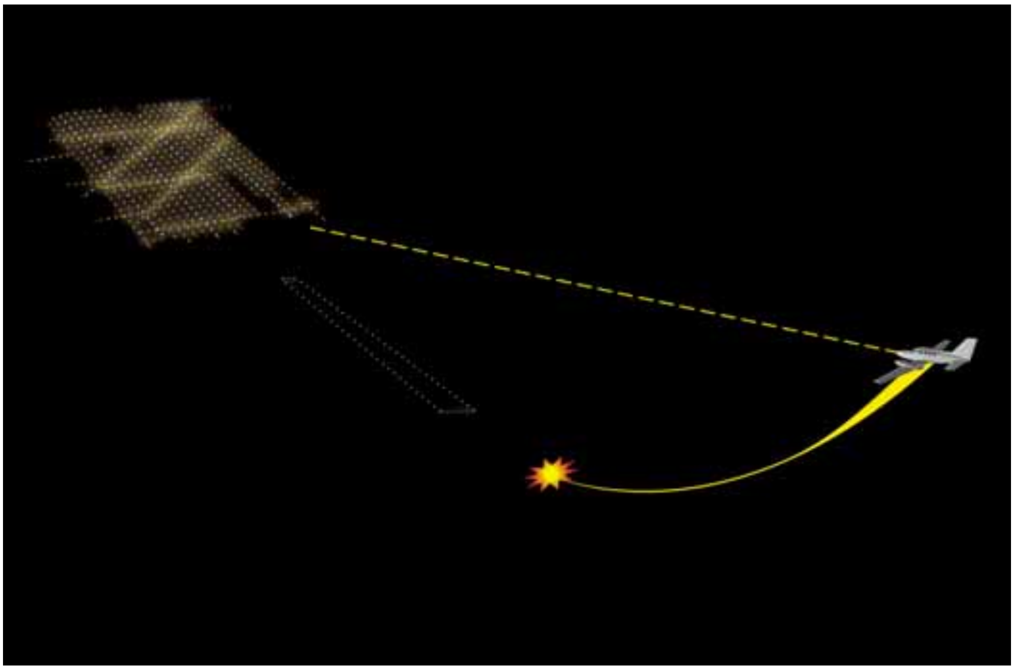
2.2.3 Autokinesis

The autokinesis phenomenon occurs at night or in conditions of poor visual cues, where there is a single point source of light (ie a single landing light or a star). As the pilot fixates on this single light source, the light appears to oscillate randomly and move around in the visual field. The pilot may believe that the light is that of another aircraft, for example. The reason this occurs is because of the normal very small movements of the eyes. In conditions of poor visual cues with a single point source of light, the normal eye movements are interpreted by the brain as movements of the object being viewed. An approach to a landing using only a single point source of light (as in a helicopter flying into a confined space at night) can result in a less than stable approach.

2.2.4 The blackhole approach

The blackhole approach has resulted in several accidents over the years. As the name suggests, it involves an approach to land at night where there is nothing to see between the aircraft and the intended runway – there is just a visual “blackhole” before the runway. The absence of peripheral visual cues, especially below the aircraft, can give an illusion of height, and result in the pilot inadvertently flying lower than necessary. This can result in landing short of the runway or impacting terrain below the glideslope if the illusion is not recognised and corrected quickly. Pilots need to monitor the aircraft attitude closely, and maintain an effective instrument scan to ensure that speed, distance and altitude information is consistent with a normal approach. The pilot can be trapped into keeping a constant visual angle with the runway during the approach. This tends to result in a curving approach, marked by an initially steep descent, which then progressively flattens out into a much lower than normal approach.

Figure 3: The blackhole approach can be a hazard during night visual approaches to some aerodromes



2.2.5 Vection illusions

Vection illusions give a false sense of motion (Benson, 1988a; Braithwaite et al., 1998b; Ungs, 1990)). They occur as a function of the power of peripheral vision. An example of such an illusion occurs when stopped at a traffic light in a car. Movement forward of the car next to you may be interpreted by you as your car moving backwards, leading you to stomp on the brake. Vection illusions can occur with helicopter flight, especially during hovering. If the helicopter is hovering over long grass or water, the rotor wash moving through the grass or water may lead to the pilot feeling that they are moving backwards, rather than remaining stationary. In an attempt to counteract this sensation, the pilot may move the control column forward. This will result in forward flight rather than a hover, and in severe cases the helicopter can pitch forward and make contact with the ground or water.

2.2.6 Height perception illusions

Flight over featureless terrain can give a pilot few visual cues as to their height above ground level. This can give an illusion of lack of movement, since the normal passage of visual details is missing. It can also give the pilot a false sense of their height above ground. Controlled flight into terrain may result from such a misperception of height.

2.3 Other illusions

While the visual and vestibular illusions discussed above are the more common forms of disorientation, there are some other illusions that occur less frequently and are a function of the integrating ability of the brain, depending on the circumstances prevailing at the time. These so-called ‘central errors’ or dissociative illusions can result in bizarre forms of SD. These include such illusions as:

- the ‘break-off’ phenomenon;
- the ‘knife-edge’ illusion; and
- the ‘giant hand’ illusion.

The break-off phenomenon is associated with feelings of unreality and detachment from the environment (Benson, 1988a; Braithwaite et al., 1998b; Gillingham & Previc, 1996). In some cases, pilots may feel that they are sitting out on the wing of their aircraft, watching themselves flying the aircraft. The knife edge and giant hand illusions are both related to a false sense of aircraft movement and operability, but are opposite to each other. The knife edge illusion gives the pilot a sensation that the aircraft is precariously positioned in space, and extremely sensitive to control inputs. By contrast, the giant hand illusion gives the pilot the opposite sensation, that the aircraft is intolerable of control inputs and seemingly immovable in the air, as if held aloft by a giant hand.

While seemingly bizarre, these illusions are generally associated with high altitude flight where the pilot has a relatively low level workload (ie, autopilot-controlled transit flight). Under such ‘fish-bowl’ conditions, the brain can wander and generate these strange illusions.

3 CONTRIBUTORY FACTORS TO SPATIAL DISORIENTATION EVENTS

There are several factors that help contribute to a spatial disorientation (SD) event. Broadly speaking, these factors can be grouped into four distinct (yet overlapping) sets of factors: pilot, aircraft, operational, and environmental factors. Some of these factors are clearly a function of operating aircraft (eg night time operations and poor weather) but others (such as pilots flying while unwell) can be addressed prior to flight and as such go a long way to minimising the potential for a SD event to occur during the flight.

3.1 Pilot factors

The pilot is the one who ultimately becomes disoriented, so any factor likely to increase their susceptibility to disorientation is of importance.

Any illness that affects the vestibular system is likely to increase the risk of disorientation during flight. As such, pilots should not fly when not physically or mentally well. Even the common cold can affect the function of the ear, and lead to such problems as pressure vertigo and viral labyrinthitis. Anxiety and stress can lead to more perceptual errors being made by the pilot, and this can clearly be a problem during flight, making disorientation more likely, as well as making recognition of and recovery from disorientation more problematic.

Any medication (prescribed or even over-the-counter) may affect the functioning of the central nervous system or the sensory systems that feed into it. Such functional impairment can affect the quality of the sensory information going into the brain, or the quality of the integration that the brain performs on the incoming sensory information, or both. Clearly such impairment can increase the chances of disorientation occurring in the three-dimensional environment of flight. Pilots should not fly while under the influence of any medication that may affect sensory system function or central nervous system function. Medications that are capable of such effects include some common cold medications, anti-motion sickness medications, allergy medications and some pain killers, to name a few.

The effect of alcohol on the potential for SD has been extensively reviewed in a recent Australian Transport Safety Bureau (ATSB) research report (Newman, 2004). Alcohol is known to have significant effects on both the vestibular and visual systems (Newman, 1999, 2004). Alcohol changes the specific gravity of the endolymph fluid within the vestibular system, making it more dilute and thus signalling an exaggerated degree of vestibular stimulation during movement (Gibbons, 1988; Newman, 2004). The nystagmus that results from Coriolis stimulation can be similarly exaggerated and prolonged.

Alcohol has been shown to significantly interfere with the normal functioning of the visual system. It can reduce the visual system's ability to suppress nystagmus, especially during dynamic tracking tasks (Gilson, Schroeder, Collins, & Guedry, 1972; Guedry, Gilson, Schroeder, & Collins, 1975). It has also been shown to reduce the speed and latency of eye movements, as well as affecting the eye's ability to change the shape of its internal lens when re-focusing, leading to blurred vision and difficulty with distance vision (Katoh, 1988; Levett & Hoeft, 1977; Levett & Karras, 1977). This phenomenon has also been found to be worse at night with reduced display illumination.

The practical implications of this are clear: pilots may not be able to see their instruments properly during dynamic flight (especially at night) if they are under the influence of alcohol. This leads to blurring of vision, impaired visual fixation, reduced perception of attitude, poor tracking performance and increased potential for SD (Gilson et al., 1972; Modell & Mountz, 1990; Ryback & Dowd, 1970). Furthermore, the alcohol-induced impairment of vestibular function (which may persist for many hours) can decrease perception of aircraft attitude, and impair tracking ability and visual fixation (Burton & Jaggars, 1974; Schroeder, 1971; Schroeder, Gilson, Guedry, & Collins, 1973).

It is not just the acute effects of alcohol that are important. The effect of alcohol on the vestibular and visual systems can persist for up to several days after blood alcohol levels have returned to zero (Gibbons, 1988; Modell & Mountz, 1990; Newman, 2004; Oosterveld, 1970; Ryback & Dowd, 1970). The implications of this in the aviation environment can be significant.

On 26 September 2002, a Piper Cherokee Six departed from Hamilton Island, with six persons on board. According to witness statements the engine was behaving abnormally. The aircraft attempted a turn back towards the runway, but entered a descent and impacted the ground. The aircraft was destroyed and all six persons on board sustained fatal injuries. The ATSB investigation was complex and involved consideration of many factors, including the potential for drugs and alcohol to have affected the pilot's ability to handle the emergency situation. In particular, the report noted that (ATSB, 2004):

> There was insufficient evidence to definitively link the pilot's prior intake of alcohol and/or cannabis with the occurrence. However, the adverse effects on pilot performance of post-alcohol impairment, recent cannabis use and fatigue could not be discounted as contributory factors to the occurrence. In particular, the possibility that the pilot experienced some degree of spatial disorientation during the turn as a combined result of the manoeuvre, associated head movements and alcohol-induced balance dysfunction could not be discounted.

Fatigue can also increase the chances of SD. A fatigued pilot is generally operating at a less than optimal level, and their state of arousal both physiological and cognitive may be adversely reduced. They may not attend to their in-flight situation as well as they otherwise might, and their fatigue-affected performance may hinder their ability to recognise the onset of a disorientating event and to then take the necessary recovery actions. Similarly, the presence of high levels of stress and anxiety may cloud the pilot's cognitive abilities and reduce their coping mechanisms, both of which will increase the chances of a SD event either being unrecognised or developing into a Type III event.

On 3 August 2000, a Cessna 206 on a charter passenger-carrying flight in accordance with visual flight rules (VFR) impacted the water, fatally injuring the pilot and passenger. The flight had departed later than planned, such that the latter stages were conducted in non-VFR conditions, for which the aircraft was not equipped and the pilot was not qualified. The ATSB accident report concluded (ATSB, 2001):

> Anxiety produced by the delayed departure, deteriorating weather conditions and darkness, would have combined to increase the pilot's level of stress. The likelihood of fatigue affecting the pilot's cognitive and motor skills due to the mental and physical demands of flying the aircraft, especially in the latter stages of the flight, may have been considerably increased. High stress levels, fatigue and lack of external visual reference most likely contributed to the pilot experiencing spatial disorientation and subsequent loss of control.

Since every pilot has a high chance of being disorientated at some point in their flying career, lack of awareness of SD is a pilot-based factor that increases the chance of disorientation. Not only that, but it increases the chances of a disorientation event being unrecognised and/or potentially incapacitating. As such, it increases the probability that the outcome of the disorientation event will be significant, if not fatal.

Following on from this, if the pilot fails to adequately plan for the possibility of SD, the chances of detecting an illusion and adequately recovering from it are diminished. Moreover, if the pilot lacks the skills to safely fly on instruments, through lack of an instrument rating or insufficient recency and/or currency, then the chances of successfully flying out of a disorientation event if it should happen during flight are similarly reduced.

3.2 Aircraft factors

There are several aircraft factors that can contribute to SD. Single pilot operations face a more serious challenge identifying and handling disorientation, as the single pilot has no other person to check information with, or to hand over control to if disorientation occurs. It should be remembered, however, that it is possible for all crew members to experience disorientation, but in multi-crew operations there is the possibility of the non-handling pilot taking over from the disorientated handling pilot.

An aircraft equipped with an autopilot system will allow a disoriented pilot to maintain safe flight even while disoriented if the autopilot is engaged appropriately. This may allow a disoriented pilot to overcome their erroneous sensations while the aircraft's fate is not threatened by inappropriate control inputs from the disoriented pilot. The lack of an autopilot system, or the presence of an autopilot that subsequently fails, can help contribute to a SD problem in the operating pilot. Rotary wing aircraft are inherently less stable platforms than fixed wing aircraft, yet helicopters are less likely to be fitted with an autopilot system. There is a strong argument in favour of fitting autopilot systems to rotary wing aircraft as a risk control against SD.

In general, the aircraft instruments do not suffer from disorientation. The only time they may contribute to a SD event is when they fail to operate normally. The information from aircraft instruments should ideally be readily interpretable and non-ambiguous, and should not be overwhelming in terms of the information load presented and the resultant perceptual load on the pilot. In short, the instrumentation should present a clear and intuitive sense of position, which the pilot under conditions of high stress and workload can instantly achieve an idea of what the aircraft is doing.

Failure of the aircraft instruments should hopefully never occur. However, in the event that it does, the pilot needs to receive clear and non-ambiguous indications of instrument failure. If a key instrument fails, such as the attitude indicator, the pilot needs to know that it has failed so that they no longer depend on its information.

On 24 April 2001, a Grob 115C aircraft undertaking a solo night VFR circuit impacted the ground shortly after take-off. The aircraft was able to climb away from the initial impact, and made a successful return to the airfield and landed. The student pilot received no injuries. The student reported difficulties with the instruments, including an unreliable attitude indicator. The instruments were later checked and found to be serviceable. The ATSB accident report determined that (ATSB, 2002a):

> The circumstances of the accident were consistent with the student becoming disorientated after take-off, possibly associated with the change in aircraft configuration during completion of the after take-off checklist. The student was in the early phase of his night flying training and, although he reported that an unserviceable attitude indicator had contributed to his disorientation, he had only limited instrument flying experience. He had not completed the training required in the operator's syllabus prior to commencing night flying and, most probably, had not developed his instrument flying skills to the standard normally required for this stage of training…it is possible that fatigue had also affected the student's performance and his ability to maintain control of the aircraft with reference to the flight instruments.

In general terms, the design of cockpits, and the layout and presentation of instruments are all important in creating a user-friendly and disorientation-resistant environment for the pilot. If key items of equipment are located in difficult positions, their use may entail unnecessary head movements during critical phases of flight, which can increase the chances of a Coriolis illusion developing. Cockpit ergonomics need to take these factors into account, so that the pilot during critical phases of flight where manoeuvring is likely (as in landing and takeoff) is not required to make lots of head movements.

Increasingly, pilots are using a variety of vision enhancement devices during flight. These devices include night vision goggles (NVG), which have been used in military aviation for quite some time but are now increasingly being used by helicopter crews engaged in emergency services operations.

The potential safety implications of NVGs were highlighted in a research report released by the ATSB in April 2005. This report reviewed the benefits and risks associated with helicopter operations using NVGs, and examined their potential use for civil helicopter operations in Australia (ATSB, 2005b). In the September 2007 edition of *The CASA Briefing*, it was announced that Emergency Management Queensland Helicopter Rescue will be the first Australian operator to carry out approved flights using NVGs under Civil Aviation Order 82.6.

While these devices tend to increase the information available to a pilot, they can significantly increase the chances of disorientation (Braithwaite, Douglass, Durnford, & Lucas, 1998a). Pilots need to be aware of such potential when they use these devices. In a recent UK military study, 48 per cent of respondents had experienced SD associated with NVG use (Holmes et al., 2003).

3.3 Operational factors

One of the tremendous advantages of modern aviation is that aircraft can operate at any time of the day or night, in almost any type of weather condition. However, night flight operations and flight into instrument meteorological conditions (IMC) require orientation information to be derived from secondary visual cues (as in the flight instruments), rather than the more normal outside visual world. As such, these sorts of aviation operations are generally associated with a higher risk of SD.

Pilots need to be aware of the sort of flight operations that carry a risk of disorientation. Pressing on into IMC conditions with no instrument rating carries a significant risk of severe SD (Frederick, 2002; Batt & O'Hare, 2005; Transportation Safety Board of Canada, 1990; NTSB, 1989). Indeed, one US study showed that non-instrument rated pilots would on average lose control of their aircraft within 178 seconds after all visual references were lost (Bryan, Stonecipher, & Aron, 1954). Similarly, frequent alternating between visual flight and instrument flight increases the chances of confusion and disorientation, as does late switching to instrument flight once IMC conditions have been entered. It takes time to establish an instrument scan – if switching to IFR is delayed or is too slowly achieved, then there is a not inconsiderable risk that the pilot may become disorientated first. Pilots need to be aware of their own limitations, and avoid situations which impose a high risk of disorientation.

On 6 October 2005, a Robinson R22 Beta helicopter departed at 1800 hours Central Standard Time on a private flight, with a pilot and one passenger aboard. The helicopter subsequently collided with the ground, fatally injuring the pilot and leaving the passenger with serious injuries. The ATSB accident investigation report determined that the pilot was not qualified for the intended flight, as he did not hold a night VFR rating. The helicopter was also not adequately equipped for the flight. These factors were considered to have increased the risk of disorientation in the prevailing dark night conditions. The report found that (ATSB, 2006b):

> The pilot became disorientated at a height from which recovery was not possible before the helicopter impacted the ground.

Visual flight rules flight into IMC represents a significant cause of aircraft accidents and fatalities. A US study showed that in the years 1975 to 1986, VFR flights into IMC accidents were associated with a fatal outcome in 72 per cent of cases, compared with an overall general aviation fatality rate of 17 per cent (NTSB, 1989). Thus, there was a four times greater chance of fatality in a VFR flight into IMC accident than any other sort of accident (Batt & O'Hare, 2005; NTSB, 1989). A study in Canada produced a similar result: a 50 per cent VFR flight into IMC fatality rate compared with 13 per cent for all other accident types, in the period 1976 to 1985 (Transportation Safety Board of Canada, 1990). In the year 2001, the VFR flight into IMC fatality rate in the US was 84 per cent (Frederick, 2002). An Australian study found remarkably similar results: 75.6 per cent of VFR flights into IMC accidents resulted in fatalities (Batt & O'Hare, 2005).

On 11 January 2002, a Cessna 206 operating on a VFR commercial flight arrived in the vicinity of the intended aerodrome where the weather conditions were less than visual meteorological conditions. The aircraft held pending the clearing of the weather over the runway. A short time later a MAYDAY broadcast was heard. Wreckage of the aircraft was subsequently found floating on the sea. The pilot, who had limited instrument flight recency, was not found. The ATSB accident report concluded (ATSB, 2002b):

> The circumstances of the occurrence were consistent with a loss of control at low level and at an altitude from which recovery was not considered possible. Due to the limited information available to the investigation, the reason for the loss of control could not be determined. However, the circumstances were consistent with VFR flight into IMC.

There are some other types of operations and aircraft manoeuvres which are likely to lead to disorientation. Flight conditions involving prolonged accelerations can lead to somatogravic illusions and the G-excess illusion during turns. Prolonged turns as in spiral dive or spinning manoeuvres can lead to the somatogyral illusion, and if these are combined with head movements then the Coriolis illusion can also be generated. The problem with prolonged turns is that if the angular acceleration becomes zero (as with a constant velocity turn) then the semi-circular canals will no longer signal motion, leading to false sensation of rotation and nystagmus on recovery.

High workload situations can limit the capacity of the pilot to deal with in-flight problems and resolve any episodes of disorientation. In such settings the coping ability of the pilot may be exceeded, and incapacitating disorientation may result, often with catastrophic outcomes.

3.4 Environmental factors

The major environmental factors are related to time of day and the ambient weather conditions. Poor visual cues are a function of most disorientation illusions, so flight at night or in conditions of bad weather can set a pilot up for a disorientation experience. Flight in IMC involves deriving orientation information from the aircraft instruments. This may occur while erroneous information is being sent to the brain from the vestibular and proprioceptive systems in the absence of good quality visual cues. This is more likely to result in SD when the aircraft instruments are not used appropriately or at all.

On 8 September 2004, a Robinson R44 helicopter collided with the ground while on a private flight, fatally injuring both pilot and passenger. The aircraft, operating under VFR, was being flown at night at low altitude and with cloud and rain in the area. There was little lighting in this area to provide any consistent visual reference. The pilot had no helicopter instrument flight experience. The ATSB accident report found that (ATSB, 2006c):

> The investigation found that there was no evidence of a pre-existing defect in the helicopter that may have contributed to the occurrence, nor was there any evidence of a medical condition that could have affected the pilot's ability to control the helicopter. Consequently, the investigation concluded that in the prevailing environmental conditions, the accident was consistent with pilot spatial disorientation.

The location of the intended runway can also be an environmental factor contributing to the development of SD. Such a factor is often seen in combination with other factors, such as an approach at night or in bad weather. For instance, if the approach to land is made at night over water, there is the potential for a black hole illusion to develop.

Night flight is associated with poor visual cues, which can lead to problems with height perception, as well as autokinetic illusions if there are insufficient lights. Ground/sky confusion can also occur, especially if there are similarly spaced stars in the sky and houses with lights on the ground, often in conjunction with an indistinct horizon. Deciding which way is up based purely on the visual information from the outside world can be problematic for a pilot in such a situation.

Similarly, flight over featureless terrain (such as large bodies of water, desert sands etc) can lead to false sensations of height above the surface, which may ultimately result in disorientation and controlled flight into terrain.

On 27 April 2001, a Bell 407 helicopter was conducting a night-time search and rescue mission for a distressed yacht. On a searchlight-assisted approach to the stricken yacht, the helicopter descended into the water. Both crew members escaped without injury. According to the ATSB accident report (ATSB, 2003):

> The high rate of descent flown during the latter stages of the approach was an inappropriate technique applied by the pilot. That was probably a result of the inadequate operator procedures and the pilot's lack of recency and proficiency in over-water night operations. Although the pilot was using the searchlight to assist him make a visual approach, the pilot lost situational awareness and did not visually comprehend the high rate of descent or the amount of power and control movement required to arrest the rate of descent. The pilot's loss of situational awareness was probably due to the lack of visual cues in the dark-night conditions and the lack of ground definition in the beam of the searchlight.

Finally, false horizons may be seen when climbing out of weather and arriving on top of an unrecognised sloping cloud bank. High altitude flight can also lead to problems with false horizon illusions and various dissociative phenomena, as a function of reduced visual cues.

3.5 Case report

On the evening of 17 October, 2003, a Bell 407 helicopter departed Mackay for Hamilton Island, Queensland, to collect a patient, with the intent being to transfer the patient to Mackay Hospital. On board the helicopter was a pilot, a crewman and a paramedic. Approximately half an hour into the flight, contact was lost with the helicopter. A second helicopter was launched on a search and rescue mission. Wreckage was found floating on the sea about 3 miles east of Cape Hillsborough, Queensland. No survivors were found.

The accident happened on a dark night, with no celestial or ground lighting available. The weather in the area suggested the possibility that cloud might have been encountered at the altitude flown by the helicopter. In addition, the forecast weather included the chance of rain and storms, as well as thick smoke, all associated with reduced visibility. According to the technical investigation of the wreckage, the aircraft was serviceable at the time of the accident. It was determined that the helicopter impacted the water at high speed, in a left skid-low, nose-down attitude.

According to the ATSB accident investigation report (ATSB, 2005a):

> The investigation was unable to determine, with certainty, what factors lead to the departure from controlled flight of the helicopter. The possibility of pilot incapacitation was considered, but viewed as unlikely because of the pilot's age, recent medical examination results and available technical evidence. The forecast weather and ambient lighting conditions on the night of the flight represented several factors which are known to contribute to spatial disorientation. In the absence of any radio broadcasts from the pilot in command, and technical evidence of the helicopter's serviceability, the circumstances of the accident were consistent with loss of control due to spatial disorientation of the pilot in command.

This tragic accident highlights many of the contributory factors that have been discussed in this report. Specifically, and as noted in the ATSB accident investigation report:

- the helicopter was not equipped for flight in IMC;
- the pilot, while night VFR qualified, did not hold an instrument rating and had only limited instrument flying experience;
- while the weather was interpretable as suitable for VFR flight, there was a risk of encountering cloud at the cruise level chosen by the pilot; and
- the lack of good visual cues (due to the absence of celestial or ground/surface lighting) resulted in the pilot not having visual reference to the horizon during the over water part of the flight.

The ATSB accident report also noted several organisational and regulatory issues that were relevant to the accident, including diffused responsibility for safety oversight of the helicopter's operations. These are fully detailed in the ATSB report.

4 PREVENTIVE MEASURES

Having analysed the different types of spatial disorientation (SD) illusions, and the various factors that contribute to a SD event, it is worthwhile now considering what preventive measures might be employed by pilots in order to minimise the risk of a disorientation-related aircraft accident or incident

Firstly, it is important to emphasise to all pilots that SD happens to normal pilots, and that if a pilot flies for long enough, eventually they will experience SD. As discussed previously, disorientation simply occurs because aviation takes place in a three-dimensional complex motion environment, and the inherent limitations of the normal human orientation systems are exposed in this environment. These systems are designed primarily for surface-of-the-Earth operations and not for flight. Experiencing a SD event should therefore not be assumed to reflect a fundamental abnormality on the part of the pilot.

While SD is an ever-present risk to aviation, there are many steps that can be taken to minimise the risk of disorientation occurring or of such an event leading to an incident, accident or fatality. In general terms, preventive measures involve mitigating the various pilot, aircraft, operational and environmental factors that contribute to disorientation, as discussed in the previous section.

The majority of these preventive mechanisms can be achieved before flight is undertaken. Pilots should take care of the following factors (which in some cases are covered in the Civil Aviation Regulations), which are grouped into three sub-headings:

Health and fitness to fly:

- Do not attempt flight when not physically and mentally fit to do so. If in doubt, a Designated Aviation Medical Examiner (DAME) should be consulted.
- Do not fly when under the influence of drugs (prescribed medications, over-the-counter medications or illicit drugs). In some cases it is safe and permissible to fly while taking some prescribed medications – pilots should consult with a DAME before flight.
- Pilots should not fly while under the influence of alcohol, or while suffering from the after-effects of alcohol ingestion (post-alcohol impairment).
- Pilots should ensure that they have had adequate rest prior to flight and are not suffering from the effects of fatigue.
- Pilots should ensure that they are adequately hydrated and have eaten appropriately prior to flight.
- Pilots should manage their personal and professional stress appropriately, and not fly when suffering from high levels of stress and anxiety.

Planning and preparation:

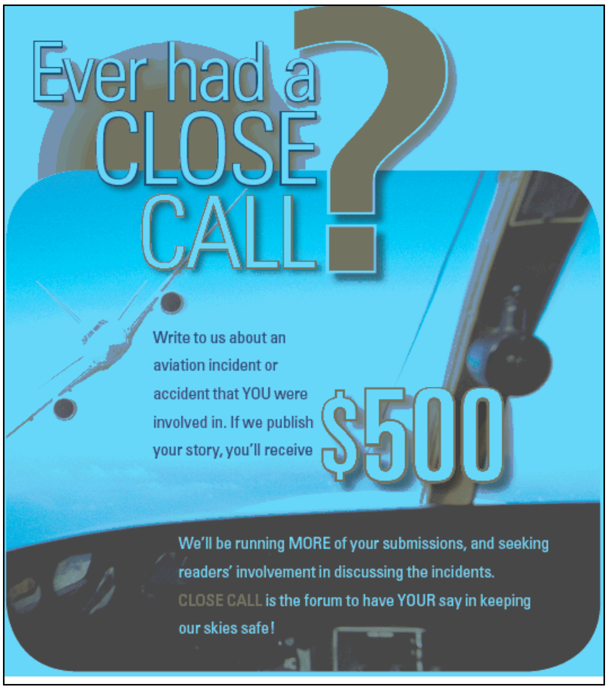
- Pilots should be aware of the potential for disorientation to occur at various stages of their intended flight, as part of their pre-flight planning activities. For example, if a remote landing at night is planned, pilots should remind themselves of the possibility of experiencing the blackhole illusion and be prepared for it. This may require them to monitor their descent and approach very carefully, to avoid undershooting.

- Pilots should familiarise themselves with the characteristics of the destination runway, especially if it is unfamiliar to them. This will help prepare them for the visual illusions inherent in approaching a down-sloping runway, for instance.
- Pilots should seriously weigh the option of rescheduling a flight if it would otherwise involve night VFR operations. If night VFR operations are conducted, then pilots need to consider the amount of celestial light that will be available, including information about the phase of the moon, and whether high level cloud will reduce the amount of light that would increase the challenges of night operations.
- Pilots should not attempt to fly into instrument meteorological conditions (IMC) under visual flight rules (VFR). Pilots should develop a plan prior to takeoff as to what they will do if the weather en route is different from expected or deteriorates. This plan should consider a requirement to divert or turn back prior to entering IMC. Such a plan should ensure that a VFR flight into IMC does not occur.

<u>Training and education:</u>

- It is advisable for pilots to undertake regular instrument flight exposures, preferably with an experienced instructor. This can be combined with some in-flight disorientation demonstrations and upset/unusual attitude recovery practice (Braithwaite, 1997; Collins, Hasbrook, Lennon, & Gay, 1978). The ability to properly use the flight instruments may make the difference between survival and not.
- If a disorientation event occurs, it is extremely helpful to share the experience with other pilots. This can be done through aviation industry magazines, journals, and increasingly through on-line forums, for example. The more pilots are aware of disorientation, the more prepared they can be.

Figure 4: This regular feature in the *Flight Safety Australia* magazine is an example of a way in which pilots can share their experiences with others in the aviation community.



There are also some measures that a pilot can take in-flight if a disorientation event still occurs. If possible, control of the aircraft can be handed over to a second pilot. Getting out of the weather or clouds and into good VFR conditions as soon as possible will help resolve sensory conflicts by providing good visual cues as to the horizon and other orientation references. Help can always be requested from air traffic control. They may, for example, be able to relay appropriate track information to get disoriented pilots out of the poor visual environment, or to vector another aircraft to act as an escort, or to simply provide reassurance and encouragement.

Fortunately, aircraft instruments are not prone to the same misperceptions as the human operators of the aircraft. Believing the instruments is the best way to minimise the effects of SD, even in the face of powerful visual and vestibular sensations that seem to directly contradict what the instruments are saying. Pilots who are experiencing disorientation should not only believe their instruments, but they should do whatever is necessary to 'make them read right'. That is, if a pilot feels the aircraft is flying straight and level, but a look at the instruments reveals inverted flight, the pilot should make the appropriate control inputs to make the instruments read upright, straight and level. Internal sensory systems should be ignored while this is being done. If these generally erroneous inputs are not ignored, an internal struggle can develop within the pilot, who alternates between what the instruments tell them and what their sensory systems tell them. This is a recipe for setting up a Type III disorientation event.

After achieving instrument-based straight and level flight, despite the erroneous and sometimes powerful sensory information, the next step is to maintain straight and level flight. The absence of ongoing manoeuvres will mean that the sensory systems no longer have to deal with angular and linear accelerations, and can eventually register the correct situation of straight and level flight. Once this has happened, the pilot has successfully flown out of the disorientation event. It is then important to quickly establish geographical orientation, especially with respect to underlying terrain.

One final point is worth emphasising. Experience does not protect a pilot from SD (Holmes et al., 2003). It is not the junior pilot who gets disorientated –some studies show that the more at risk pilot is a highly proficient one (Lyons, Ercoline, Freeman, & Gillingham, 1994). The truth of the matter is that disorientation can affect any pilot, any time, any where, in any aircraft, on any flight, depending on the prevailing circumstances. Experience of disorientation does not mean it won't ever happen again. It does, however, allow the disorientation phenomenon to be recognised more readily in the future. Awareness and preparedness are key elements in preventing the SD accident.

5 CONCLUSION

Spatial disorientation (SD) is always a risk to pilots. It is a function of the inherent operating limitations of the normal human orientation systems in the three-dimensional, complex motion environment of flight. It can happen to any normal pilot at any time. There are many different illusions and disorientating phenomena that pilots may experience, depending on the nature of their operations and the phase of flight. There are many steps that can be taken by pilots to minimise their risk of experiencing SD on a given flight, many of which involve pre-flight planning and adequate preparation. Being aware of the risk of SD is one of the key elements in preventing a SD accident.

6 REFERENCES

ATSB. (2001). *Cessna Aircraft Company P206C, VH-EFA* (200003233). Canberra: Australian Transport Safety Bureau.

ATSB. (2002a). *Burkhart Grob Flugzeugbau G-115C2, VH-BGQ* (200101929). Canberra: Australian Transport Safety Bureau.

ATSB. (2002b). *Cessna Aircraft Company U206F, VH-STL* (200200035). Canberra: Australian Transport Safety Bureau.

ATSB. (2003). *Bell Helicopter Co. 407, VH-WOQ* (200102083). Canberra: Australian Transport Safety Bureau.

ATSB. (2004). *Hamilton Island aerodrome, Piper PA-32-300, VH-MAR, 26 September 2002* (200204328). Canberra: Australian Transport Safety Bureau.

ATSB. (2005a). *Bell 407, VH-HTD, Cape Hillsborough, Qld* (200304282). Canberra: Australian Transport Safety Bureau.

ATSB. (2005b). *Night vision goggles in civil helicopter operations* (B2004/0152). Canberra: Australian Transport Safety Bureau.

ATSB. (2006a). *Mooney Aircraft Corporation M20K, VH-DXZ* (200403006). Canberra: Australian Transport Safety Bureau.

ATSB. (2006b). *Robinson Helicopter Co. R22 Beta, VH-HUZ* (200504925). Canberra: Australian Transport Safety Bureau.

ATSB. (2006c). *Robinson Helicopter Co. R44, VH-JWX* (200403351). Canberra: Australian Transport Safety Bureau.

Barnum, F., & Bonner, R. (1971). Epidemiology of USAF spatial disorientation aircraft accidents, 1 Jan 1958-31 Dec 1968. *Aerosp Med, 42*, 896-898.

BASI. (1995). *Dark night take-off accidents in Australia.* (SAB/RP/95/01). Canberra: Bureau of Air Safety Investigation.

Batt, R., & O'Hare, D. (2005). Pilot behaviours in the face of adverse weather: A new look at an old problem. *Aviat Space Environ Med, 76*, 552-559.

Bellenkes, A., Bason, R., & Yacavone, D. (1992). Spatial disorientation in naval aviation mishaps: A review of class a incidents from 1980 through 1989. *Aviat Space Environ Med, 63*, 128-131.

Benson, A. (1988a). Spatial disorientation – common illusions. In J. Ernsting & P. King (Eds.), *Aviation medicine* (pp. 297-317). London: Butterworths & Co. Ltd.

Benson, A. (1988b). Spatial disorientation – general aspects. In J. Ernsting & P. King (Eds.), *Aviation medicine* (pp. 277-296). London: Butterworths & Co. Ltd.

Braithwaite, M. (1997). The British Army Air Corps in-flight spatial disorientation demonstration sortie. *Aviat Space Environ Med, 68*, 342-345.

Braithwaite, M., Douglass, P., Durnford, S., & Lucas, G. (1998a). The hazard of spatial disorientation during helicopter flight using night vision devices. *Aviat Space Environ Med, 69(11)*, 1038-1044.

Braithwaite, M., Durnford, S., & Crowley, J. (1998b). Spatial disorientation in US Army rotary-wing operations. *Aviat Space Environ Med, 69*, 1031-1037.

Bryan, L., Stonecipher, J., & Aron, K. (1954). 180-degree turn experiment (Vol. 54(11), pp. 1-52): University of Illinois Bulletin.

Buley, L., & Spelina, J. (1970). Physiological and psychological factors in “the dark night takeoff accident”. *Aerosp Med, 41*, 553-556.

Burton, R., & Jaggars, J. (1974). Influence of ethyl alcohol ingestion on a target task during sustained +gz centrifugation. *Aerospace Med, 45*, 290-296.

Bushby, A., Holmes, S., & Bunting, A. (2005). An assessment of the influence of spatial disorientation upon British military aircraft accidents from 1983 to 2002 [abstract #217]. *Aviat Space Environ Med, 76*, 256.

Campbell, R., & Bagshaw, M. (2002). Human performance and limitations in aviation. In (3rd ed., pp. 87-90). Oxford: Blackwell Science.

Cheung, B., Money, K., Wright, H., & Bateman, W. (1995). Spatial disorientation-implicated accidents in the Canadian forces, 1982-92. *Aviat Space Environ Med, 66*, 579-585.

Clark, B. (1971). Pilot reports of disorientation across 14 years of flight. *Aerosp Med, 42*, 708-712.

Collins, W., Hasbrook, H., Lennon, A., & Gay, D. (1978). Disorientation training in FAA-certified flight and ground schools: A survey. *Aviat Space Environ Med, 49*, 947-951.

Eastwood, H., & Berry, C. (1960). Disorientation in helicopter pilots. *Aerosp Med, 31*, 191-199.

Edgington, K., & Box, C. (1982). Disorientation in Army helicopter operations. *J Soc Occup Med, 32*, 128-135.

Ercoline, W., DeVilbiss, C., Yauch, D., & Brown, D. (2000). Post-roll effects on attitude perception: 'the gillingham illusion'. *Aviat Space Environ Med, 71*, 489-495.

FAA. (1983). *Pilot's spatial disorientation* (AC 60-4A). Washington, DC: Federal Aviation Administration.

Frederick, M. (2002). *AOPA Air Safety Foundation. 2002 Nall report: Accident trends and factors for 2001*: AOPA Air Safety Foundation.

Gibbons, H. (1988). Alcohol, aviation and safety revisited: A historical review and a suggestion. *Aviat Space Environ Med, 59*, 657-660.

Gillingham, K. (1992). The spatial disorientation problem in the United States Air Force. *J Vestib Res, 76*, 297-306.

Gillingham, K., & Previc, F. (1996). Spatial orientation in flight. In R. DeHart (Ed.), *Fundamentals of aerospace medicine* (2nd ed., pp. 309-397.). Baltimore: Williams & Wilkins.

Gilson, R., Schroeder, D., Collins, W., & Guedry, F. (1972). Effects of different alcohol dosages and display illumination on tracking performance during vestibular stimulation. *Aerospace Med, 43*, 656-660.

Guedry, F., Gilson, R., Schroeder, D., & Collins, W. (1975). Some effects of alcohol on various aspects of oculomotor control. *Aviat Space Environ Med, 46*, 1008-1013.

Hixson, W., Niven, J., & Spezia, E. (1972). *Major orientation error accidents in regular Army UH-1 aircraft during FY 1969. Accident factors report namrl-1169*. Pensacola, FL: Naval Aerospace Medical Research Laboratory.

Holland, D. (1992). Loss of situational awareness (LSA) and spatial disorientation (SDO) related mishaps in the United States Air Force 1980-89. *Aviat Space Environ Med, 63*, 395.

Holland, D., & Freeman, J. (1995). *A ten-year overview of USAF mishap attributes from 1980-89.* Paper presented at the Proceedings of the Human Factors and Ergonomics Society 39th Annual Meeting, San Diego, CA.

Holmes, S., Bunting, A., Brown, D., Hiatt, K., Braithwaite, M., & Harrigan, M. (2003). Survey of spatial disorientation in military pilots and navigators. *Aviat Space Environ Med, 74*, 957-965.

Katoh, Z. (1988). Slowing effects of alcohol on voluntary eye movements. *Aviat Space Environ Med, 59*, 606-610.

Kirkham, W., Collins, W., Grape, P., Simpson, J., & Wallace, T. (1978). Spatial disorientation in general aviation accidents. *Aviat Space Environ Med, 49*, 1080-1086.

Knapp, C., & Johnson, R. (1996). F-16 class a mishaps in the U.S. Air Force, 1975-93. *Aviat Space Environ Med, 67*, 777-783.

Kumar, B. (2004). *An illustrated dictionary of aviation*. New York: McGraw-Hill.

Lane, J. (1958). *Disorientation as a cause of some takeoff accidents.* Paper presented at the Proc Third European Cong of Av Med, Louvain.

Levett, J., & Hoeft, G. (1977). Voluntary eye movements and alcohol. *Aviat Space Environ Med, 48*, 612-616.

Levett, J., & Karras, L. (1977). Effects of alcohol on human accommodation. *Aviat Space Environ Med, 48*, 434-437.

Lyons, T., Ercoline, W., Freeman, J., & Gillingham, K. (1994). Classification problems of U.S. Air Force spatial disorientation accidents, 1989-91. *Aviat Space Environ Med, 65*, 147-152.

Lyons, T., Ercoline, W., O'Toole, K., & Grayson, K. (2006). Aircraft and related factors in crashes involving spatial disorientation: 15 years of U.S. Air Force data. *Aviat Space Environ Med, 77*, 720-723.

Modell, J., & Mountz, J. (1990). Drinking and flying – the problem of alcohol use by pilots. *New Engl J Med, 323*, 455-461.

Moser, R., Jr. (1969). Spatial disorientation as a factor in accidents in an operational command. *Aerosp Med, 40*, 174-176.

Navathe, P., & Singh, B. (1994). Prevalence of spatial disorientation in Indian Air Force aircrew. *Aviat Space Environ Med, 65*, 1082-1085.

Newman, D. (1999). How much is too much? *Flight Safety Australia, Jul-Aug*, 43-44.

Newman, D. (2004). *Alcohol and human performance from an aviation perspective: A review*. Canberra, ACT: Australian Transport Safety Bureau.

NTSB. (1989). *Safety report: General aviation accidents involving visual flight rules flight into instrument meteorological conditions* (NTSB-SR-89-01). Washington, DC: National Transportation Safety Board.

Oosterveld, J. (1970). Effect of gravity on positional alcohol nystagmus (PAN). *Aerospace Med, 41*, 557-560.

Patterson, F., Cacioppo, A., Gallimore, J., Hinman, G., & Nalepka, J. (1997). Aviation spatial orientation in relationship to head position and attitude interpretation. *Aviat Space Environ Med, 68*, 463-471.

Ryback, R., & Dowd, P. (1970). After-effects of various alcohol beverages on positional nystagmus and coriolis acceleration. *Aerospace Med, 41*, 429-435.

Schroeder, D. (1971). Influence of alcohol on vestibular responses to angular accelerations. *Aerospace Med, 42*, 959-970.

Schroeder, D., Gilson, R., Guedry, F., & Collins, W. (1973). Effects of alcohol on nystagmus and tracking performance during laboratory angular accelerations about the y and z axes. *Aerospace Med, 44*, 477-483.

Singh, B., & Navathe, P. (1994). Indian Air Force and world spatial disorientation accidents: A comparison. *Aviat Space Environ Med, 65*, 254-256.

Sipes, W., & Lessard, C. (2000). A spatial disorientation survey of experienced instructor pilots. *Institute of Electrical and Electronics Engineers (IEEE) Eng Med Biol Mag, 19 (Pt 2)*, 35-42.

Tormes, F., & Guedry, F. (1974). Disorientation phenomena in naval helicopter pilots. *Aviat Space Environ Med, 46*, 387-393.

Transportation Safety Board of Canada. (1990). *Report of a safety study on VFR flight into adverse weather* (90-SP002.). Gatineau, Canada: Transportation Safety Board of Canada.

Ungs, T. (1990). The occurrence of the vection illusion among helicopter pilots while flying over water. *Aviat Space Environ Med*, *61*, 1098-1111.

Vyrnwy-Jones, P. (1985). A review of Army Air Corps helicopter accidents, 1971-1982. *Aviat Space Environ Med, 56*, 403-409.

7 MEDIA RELEASE

ATSB study reviews spatial disorientation

An ATSB research report released today examines the problem of spatial disorientation.

Flying an aircraft is a challenging activity that exposes pilots to many potential hazards. One of the most significant of these is spatial disorientation. Spatial disorientation is a condition where the pilot is unable to correctly interpret aircraft attitude, altitude or airspeed in relation to the Earth. The resulting disorientation can lead to a loss of control of the aircraft.

Spatial disorientation is a very common problem. It is vitally important that pilots are aware that it can affect any pilot, any time, anywhere, in any aircraft, on any flight, depending on the prevailing circumstances. It has been estimated that the chance of a pilot experiencing spatial disorientation during their career is in the order of 90 to 100 per cent. In other words, if a pilot flies long enough as a career, or even a hobby, there is almost no chance that he/she will escape experiencing at least one episode of spatial disorientation.

The Australian Transport Safety Bureau (ATSB) commissioned aviation medicine specialist, Dr David Newman, to explore the various types of spatial disorientation in the aviation environment, and to suggest strategies for managing the risk associated with these events.

The ATSB report explains that the chances of a spatial disorientation event occurring in flight can be reduced by a series of simple preventive measures, many of which can be attended to before flight. These include flying when fit and well to do so, not flying under the influence of alcohol or medications, avoiding visual flight rules into instrument meteorological conditions, increasing awareness of spatial disorientation illusions and planning for their possible appearance at different stages of flight in the pre-flight planning process.

The ATSB report encourages pilots who have had a spatial disorientation event to share their experiences with their aviation colleagues, either informally, or through magazines, journals and web-based forums.

A more open approach to acknowledging and discussing spatial disorientation and its various causes will make a valuable contribution to a better understanding of this common human factor.