BUREAU OF AIR SAFETY INVESTIGATION

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Dark Night Take-off Accidents in Australia

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ABBREVIATIONS

AIP	Aeronautical Information Publication
BASI	Bureau of Air Safety Investigation
CAA	Civil Aviation Authority
CAO	Civil Aviation Order
CPL	Commercial Pilot Licence
GFPT	General Flying Progress Test
ft	Feet
ICAO	International Civil Aviation Organisation
IF	Instrument Flight
IFR	Instrument Flight Rules
IMC	Instrument Meteorological Conditions
km	Kilometre
m	Metre
NTSB	National Transportation Safety Board
PPL	Private Pilot Licence
RAF	Royal Air Force
SAR	Search and Rescue
UK	United Kingdom
USA	United States of America
VFR	Visual Flight Rules
VMC	Visual Meteorological Conditions

EXECUTIVE SUMMARY

Between January 1979 and May 1993, 35 aircraft accidents occurred in Australia during the take-off phase of flight at night. A primary factor in 15 of these accidents was considered to be some form of visual or sensory illusion, or spatial disorientation.

Investigation files from the 15 accidents were reviewed in an attempt to identify common elements in which spatial disorientation, or a visual or sensory illusion, was thought to be a contributing factor. Data were gathered on pilot characteristics, such as experience and age, as well as on operational information, such as aerodrome type and weather. Relevant regulations pertaining to the operation of aircraft at night and training for night operations were analysed.

The report concludes that the type of pilot training or pilot qualification did not appear to be a common factor in the accidents under consideration. Pilot experience also did not appear to be a factor in the accidents. The absence of adverse weather may be significant in the onset of illusions. Furthermore, it was considered that the absence of both ground lighting and a horizon was paramount in the development of the accidents, while the combination of a limited horizon with no adverse weather was the most probable condition under which illusions were likely to develop.

BASI issues recommendation R940219 in the report. This recommends that the Civil Aviation Authority:

(i) integrate and expand human performance and limitation considerations into the day VFR syllabus at and above the level of the GFPT for the private pilot licence;

(ii) review the policy on the testing of human performance and limitation considerations and include this area as an examinable part of the syllabus above the level of the GFPT for the private pilot licence;

(iii) review theory requirements of the instructor rating, night VFR and instrument ratings, with emphasis on the specific operational and human-factors considerations that the use of these ratings require as compared to day VFR flight;

(iv) review the practical requirements of the syllabus leading to an instrument rating, to ensure that a candidate has experienced conditions of IMC and flight (including takeoffs and landings) at night, in areas with limited lighting, before being granted a rating;

(v) review the policy applicable to the renewal and recency requirement of the night VFR rating, to ensure renewal and recency requirements are similar to other instrument ratings; and

(vi) educate pilots and operators of the effects of fatigue and the need to establish flight and duty times that are commensurate with the demands of their flight operations. In particular, it should be stressed that the limits imposed by CAO 48.0 are maximum limits and that lower limits may be appropriate to some types of operations.

1. INTRODUCTION

1.1 Definition

For the purposes of this report, a night takeoff refers to any takeoff between the end of evening civil twilight and the beginning of morning civil twilight. A dark night takeoff is a night takeoff where there is no significant ground lighting and a limited horizon, or no horizon. A dark night will usually be accompanied by the absence of moonlight.

1.2 Background

Dark night take-offs can present a number of special problems for pilots, particularly when departing from aerodromes in areas with little or no ground lighting.

Between January 1979 and May 1993, 35 accidents in Australia occurred at night during the take-off phase of flight. In 15 of these accidents, some form of spatial disorientation, visual, or sensory illusion, was thought to be a primary factor.

Specifically, the 'somatogravic illusion'[1] has been suggested as being a contributing factor in the majority of the 15 accidents; however, other forms of visual or sensory illusions cannot be ignored. One of the problems in identifying the role that such illusions play is that, unlike structural or engine failures, there are no signs of a system malfunction. In many cases, a serviceable aircraft had been flown into the ground by a healthy, fully qualified pilot.

> **'The aircraft was conducting a night departure from runway 36 at Wondai, Queensland. After an apparently normal takeoff, it struck the ground 600 m beyond the end of the runway in a shallow, wings-level descent and at high speed. The aircraft was destroyed by impact forces and fire, and five of the six occupants on board were killed.'**
> **(BASI occurrence B/901/1047).**

[1]The 'somatogravic' or 'false climb' illusion was first identified during World War II by an aeronautical scientist, A. R. Collar. It is a form of a sensory illusion that occurs when a pilot who is deprived of outside visual cues attempts to maintain the desired pitch attitude without reference to instruments whilst the aircraft is accelerating. Under these types of conditions, pilots can experience a sensation of excessive pitch-up. The sensation is thought to exist primarily at take-off, go-around and in VFR flight into IMC. Pilots who attempt to correct for this sensation by pushing forward on the control column may fly the aircraft into the ground. For more information on the illusion refer to appendix A.

2. OBJECTIVES

Following a number of night take-off accidents[2] in which visual or sensory illusions were listed as a possible factor, BASI decided to review night take-off accidents in Australia in an attempt to confirm that:

(a) there was no 'at risk' group; and

(b) international research and conclusions on factors in night take-off accidents were valid in Australia.

It was hoped that, following research, suitable recommendations would be formulated to ensure that the incidence of night take-off accidents was reduced.

The objectives required examination of:

(a) the types of conditions that lend themselves to spatial disorientation;

(b) the conduct and requirements of instrument rating tests;

(c) training for ratings and the effectiveness of this training;

(d) regulatory requirements and their effectiveness; and

(e) any possible solutions to the problems identified.

[2]BASI occurrences 9003089, 8141027, 8703483, 8251030 and 9131007 are some of the accidents in which some form of pilot disorientation is thought to be a contributing factor. Specifically, BASI report B/901/1047 lists a number of aspects that warranted further research, including effectiveness of instrument rating tests and training.

3. SCOPE

The project initially attempted to identify common factors in accidents where the somatogravic illusion may have been present, but was later widened to include all types of visual and sensory illusions as well as spatial disorientation.

The project did not include a detailed study of either sensory or visual illusions such as the somatogravic and somatogyral illusions, since a number of published papers already do this adequately; however they are briefly described in appendixes A and B.

> **'No contributory faults could be found with the aircraft or aircraft systems.... on this occasion there was a lack of external visual cues available. It is probable that the pilot became disorientated during the turn after takeoff and lost control of the aircraft.'**
> **(BASI occurrence 8251030).**

4. METHOD

As the first stage of the project, a literature search was completed on the somatogravic and sensory illusions in the aviation context to identify any relevant work.

Secondly, a number of overseas aviation organisations, including the UK CAA, UK Air Accidents Investigation Branch, Transportation Safety Board of Canada, and USA National Transportation Safety Board were approached and asked to provide details of any accidents that had occurred during the take-off phase of flight at night in their countries. The organisations were asked to give particular attention to those accidents in which sensory illusions were considered to be factors.

The third stage of the project involved the identification and subsequent review of night take-off accidents that had occurred in Australia since 1979. Accident files were collected and examined for all accidents in which it was suspected that a visual or sensory illusion was a factor. Data were then analysed.

A final stage involved the identification and review of relevant regulations and training syllabi.

'The following factors were considered relevant to the development of the accident:

1. Very dark conditions for takeoff with no visible horizon.

2. Pilot may have been fatigued.

3. Limited pilot experience in the prevailing conditions.

4. Somatogravic illusion probably encountered by pilot during initial climb.

5. Failure to establish appropriate climb attitude by reference to the flight instruments.'

(BASI occurrence 9131007)

5. LITERATURE REVIEW

"'Spatial disorientation' is a term used to describe a variety of incidents occurring in flight where the pilot fails to correctly sense the position, motion or attitude of his aircraft or of himself within the fixed co-ordinate system provided by the surface of the Earth and the gravitational vertical. In addition, errors in perception of 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.' (Benson, A.J. *Spatial Disorientation - General Aspects,* 1988)

This definition of 'spatial disorientation' includes all forms of visual and sensory illusions that may lead to an error in the perception of an aircraft's attitude. As such, spatial disorientation may be the outcome of an illusion such as the somatogravic illusion.

Studies of accidents related to spatial disorientation (such as night take-off accidents) have shown a large percentage of accidents in which illusions such as the somatogravic illusion were considered to be a factor. Buley & Spelina (1970) noted:

> 'Scrutiny of ICAO Aircraft Accident Digests covering the period 1950 - 1965 discloses 12 out of a total of 44 night takeoff accidents reviewed in which this type of pilot disorientation appears to have played a primary or contributory role.'

Similarly, Lane (1958) noted:

> 'Five out of a total of six Australian DC3 take-off accidents over a period of about ten years followed the 'dark night takeoff' pattern; the probability of such a disproportionate number of accidents occurring under these conditions by chance alone being about 2×10^6.'

This type of accident continues to occur, even though the knowledge of such phenomena increases:

> 'Over the last decade there has been little reduction in the proportion of accidents attributable to spatial disorientation, in contrast to the reassuring decrease in accidents due to mechanical or structural failure.' (Benson, A.J. *Spatial Disorientation - General Aspects,* 1988).

In the same publication, Benson also comments that:

> 'Nearly all aircrew experience illusory sensations of aircraft attitude and motion or fail to detect changes in aircraft orientation at some time during their flying career.'

This is because of the physiological limitations of the human sense organs. Incidents of spatial disorientation are

> '...quite normal for they are due, in general, to physiological limitations of sensory mechanisms. Men's sense organs are functionally adapted to terrestrial life in a stable 1*g* environment.' (Benson, A.J. *Spatial Disorientation - General Aspects,* 1988).

As the human senses are adapted to a 1*g* environment, errors will occur when the human senses are incorrectly used for inflight information.

> 'Inflight the information provided by the vestibular apparatus is frequently erroneous because the magnitude and time course of the motions to which the pilot is exposed are atypical and fall outside the normal dynamic range of this system.' (Benson, A.J., *Spatial Disorientation - General Aspects,* 1988).

Spatial disorientation tends to occur in conditions of limited visibility. This is because visual cues play such a large role in human balance and orientation. The significance of visual cues on human balance and orientation may be demonstrated by the short period of time it takes for a person to become spatially disorientated once visual cues are lost:

> 'Disorientation is very uncommon when the pilot has well-defined external visual cues; but when he attempts to fly when sight of the ground or horizon is degraded by cloud, fog, snow, rain, smoke, dust or darkness he quickly becomes disorientated unless he transfers his attention to the aircraft instruments. The ability to maintain control of an aircraft without adequate visual cues is quite short, typically about 60 seconds, even when the aircraft is in straight and level flight at the time vision is lost, and shorter still if the aircraft is in a turn. In such circumstances, loss of control occurs because the non-visual receptors give either inadequate or erroneous information about the position, attitude and motion of the aircraft'. (Benson, A.J. *Spatial Disorientation - General Aspects,* 1988).

'...insufficient attention was paid to the flight instruments subsequent to take-off when external reference was inadequate to maintain spatial orientation.

Probable contributory factors were the pilot's lack of recent night-flying experience, fatigue and the excessive motivation to expedite evacuation of the stranded persons.' (BASI occurrence 8141027).

If pilot training is changed to include sessions where pilot disorientation is experienced, only limited value may be achieved as it has been suggested that experience and exposure to illusions and spatial disorientation will not ensure immunity from the problem:

> '...a high level of flight experience does not produce immunity to spatial disorientation. A pilot can become adapted to inflight motion conditions, but can still experience sensory illusions that can result in spatial disorientation .' (Antunano, J. A. and Mohler, S.R., 1992).

On the issue of exposing pilots to spatial disorientation and the somatogravic illusion during training, Buley and Spelina (1970) noted that

> 'such an exercise would be self defeating since the essential element of 'the dark night takeoff accident' is pilot inattention to flight instruments in deceptively 'visual' conditions.'

Despite these possible downfalls with pilot training, the education of pilots appears to be the primary method available to decrease the number of accidents in which the above factors are predominant.

Benson (*Spatial Disorientation - General Aspects*, 1988) states that

> '...aircrew must be told about the varied perceptual disturbances that can occur in flight; not all will learn about such problems and how to cope with them during the course of flying training and subsequent operational duties',

but does not give any solution as to what amount of knowledge is adequate.

Benson (*The Somatogravic Illusion Revisited*, 1988) has also acknowledged that

> 'it is, of course, more important for aircrew to know about the kinds of disorientating illusions that occur in flight and the manoeuvres that provoke them than about the intricacies of the sensory mechanisms causing the illusions'.

Thus, educating pilots on the types of illusions that may occur to aircrew without being overly specific on their causes may be the solution. Buley and Spelina (1990) noted that

> 'it is perhaps some indication of inadequate understanding of the phenomenon at training, operational and accident investigation levels that 'dark night takeoff accidents' continue to occur and that investigation reports tend to handle this diagnosis very tentatively.'

Additionally, any education should ensure that pilots are aware that in conditions of a limited visual horizon the instruments must be trusted. Collar's first published paper (Collar, A.R., 1946) that dealt with the somatogravic illusion was a brief investigation into a number of relevant accidents, and had a conclusion that is still true today:

> 'The remedy was at hand: it was an insistence on the proper use of instruments. The use of instruments had been stressed at an early age by the Chief Inspector of Accidents; and the investigation described here provided a timely hammer to drive home the necessity of rigorous attention to instruments at night.'

'No evidence was found to indicate that there was any defect or malfunction of the airframe, engine or systems of the aircraft that might have prevented the pilot from exercising normal control of the aircraft. It was possible that the pilot did not adequately monitor the aircraft flight path by reference to the flight instruments and/or he suffered from disorientation.' (BASI occurrence 8131009).

6. THE NIGHT TAKE-OFF ACCIDENT

Information was obtained from overseas aviation authorities in addition to the night take-off accidents that have occurred in Australia between 1979 and 1992. Accidents in Australia in which a visual or sensory illusion was suspected to be a major factor in the development of the accident are considered in detail, with an objective of identifying a common element or elements in accidents.

6.1 Night take-off accidents overseas

International investigation authorities were approached and asked to contribute any data that they felt might be relevant to the project. Replies were received from the USA and British authorities, but they did not contain sufficient depth of data to be used in conjunction with that of BASI files.

6.1.1 UK data

The UK CAA and RAF Institute of Aviation Medicine were only aware of two civil accidents within the last 25 years in which the somatogravic illusion or similar effect may have played a role.

Data available did tend to indicate a trend that may contain some of the answers to questions raised by the significant factors in night take-off accidents. Information received from the British authorities appeared to indicate two distinct periods which should be considered.

The period during World War II, and immediately after, saw an abnormally high number of accidents that fit the 'somatogravic and related illusions' profile as compared to pre- and post-war years. It was, in fact, a rise in the number of night take-off accidents that first prompted aviation medical personnel to study the night take-off accidents, and hence propose the concept of the somatogravic and vestibular illusions. One factor noted when these accidents occurred, was that blackouts were being enforced due to the war.

Before World War II and subsequently, there have only been a few accidents that have had the somatogravic illusion listed as a contributing factor. In fact, one member of the RAF Institute of Aviation Medicine only recalled two accidents in 35 years in which the somatogravic illusion was thought to have played a contributing role.

A possible reason for the low number of accidents throughout the UK may be the fact that the majority of airfields are located near lighted areas, and that a visual horizon is often available for pilots to use.

6.1.2 USA data

The USA NTSB reported that 291 take-off accidents had occurred at night during the period 1983-1993. Two hundred and eighty-one of these accidents involved fixed-wing aircraft, of which 112 (40%) involved non-instrument rated pilots.

As part of its charter, the NTSB is required to attribute a most probable cause of any accident that it investigates. It may also, as part of the investigation, list other possible causes or factors that are relevant to the accident.

The most common cause or factor quoted in night take-off accidents was the environment being a dark night (as opposed to being termed 'night' which was also used as a factor). A total of 153 (54%) accidents had the dark night listed as a possible cause or factor and only one (0.34%) as the most probable cause. These figures did not differentiate between accidents that occurred with the crew suffering from spatial disorientation or other factors such as fatigue. This meant that it would be possible for an accident to have the dark night listed as a contributing factor in the accident due to the pilot not seeing, for example, obstacles on the runway.

Spatial disorientation was listed as being a possible cause or factor in 42 (14%) occurrences, and as the most probable cause in a further 36 (12%) occurrences. This statistic made spatial disorientation a factor in over 78 (26%) night take-off accidents in the USA over the last ten-year period. Furthermore, spatial disorientation was the single largest cause or factor associated with a degradation of flight crew performance.

Fatigue was listed as a possible cause or factor in only seven accidents (less than 3%), and a most probable cause in one (0.34%). Emotional reactions, anxiety, apprehension and pressure were possible causes or factors in eight (3%) accidents and the most probable cause in four (1.3%). The data received from the NTSB was not of sufficient detail to identify the presence of fatigue or personal reactions in accidents where spatial disorientation was a factor (and vice-versa). The NTSB data did not list the somatogravic illusion as a separate cause or factor.

In summary, the most common factor in night take-off accidents in the USA was the presence of a dark night. Pilot disorientation was the most common probable cause or factor associated with flight crew performance, and the second most common probable cause or factor overall. The data did not indicate that these two factors were linked.

6.2 Night take-off accidents in Australia

A review of BASI records indicated that 35 accidents occurred in Australia at night within the take-off phase of flight between the years 1979 and 1992. This represents 0.54% of all accidents recorded over this period, and 15% of all accidents that have occurred at night. Additionally, approximately 40% of the 35 accidents were attributed to the presence of the somatogravic illusion, spatial disorientation or some other form of visual or sensory illusion.

Seven (20%) of the 35 'night take-off' accidents were reported to have an engine malfunction, failure or fire as the major contributing factor (see figure 1). Four accidents (11%) involved a loss of control as a primary factor[3], and three of these occurred on the ground.

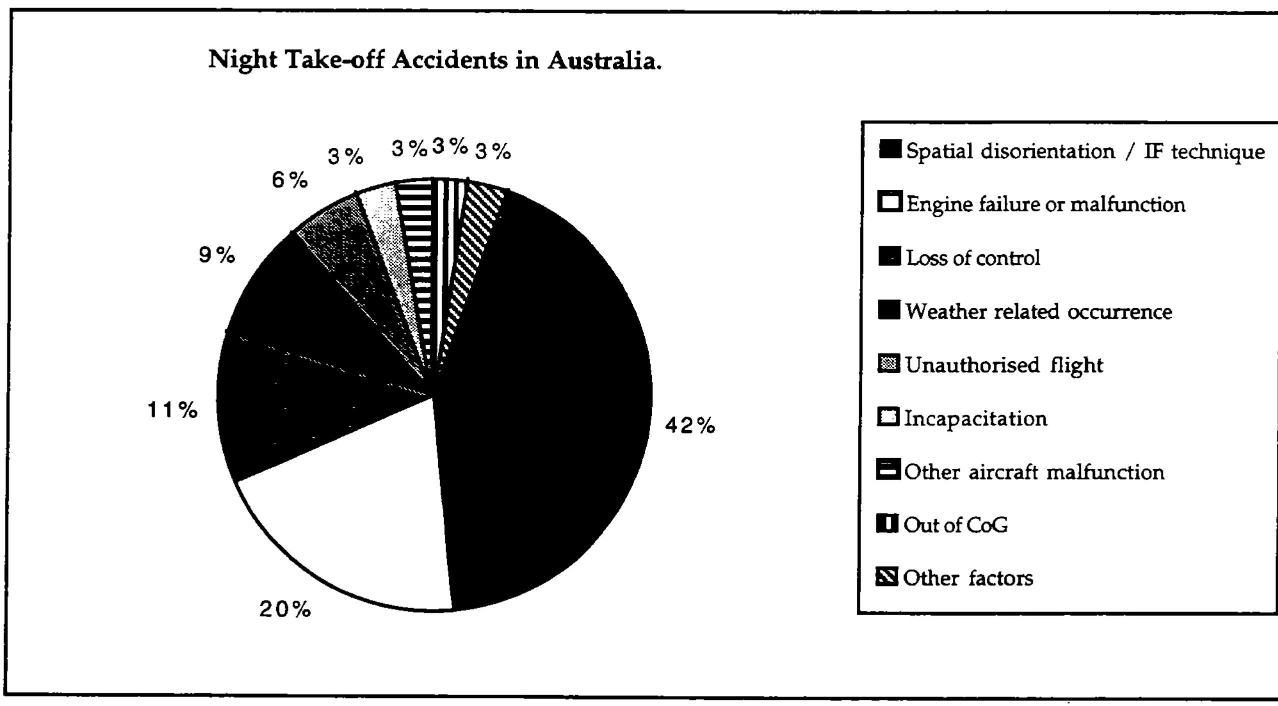

Figure 1 : Major Factors in Night Take-off Accidents in Australia

A further three accidents (9%) listed weather as a major factor. In two of the three accidents a change in wind direction or strength (due to frontal activity) was the significant weather component. The other weather-related accident was due to a microburst, also originating from frontal activity. Two accidents (6%) occurred when unlicensed personnel attempted to pilot a stolen aircraft.

Incorrectly loaded aircraft, medical incapacitation, and other aircraft

[3]Loss of control in this instance does not include occurrences where the weather was a significant factor in controlling the aircraft, nor does it include a loss of control due to sensory illusions, spatial disorientation, or poor IF technique.

malfunctions or factors were considered to be factors in four accidents (12%).

The 15 remaining accidents (or 42% of all night take-off accidents) had spatial disorientation, the somatogravic illusion, or another sensory or visual illusion listed as a probable and often significant factor[4]. Additionally, nine of these accidents (or 25% of all night take-off accidents) were recorded as likely to have had the somatogravic illusion as a principal factor in the development of the accident.

These statistics show that, although accidents in the take-off phase at night are relatively infrequent, a large percentage of accidents have factors attributable to visual and/or sensory perception and spatial orientation/disorientation.

Of the 15 accidents in which a sensory or visual illusion was determined to be a factor, ten (67%) involved fatalities (see figure 2).

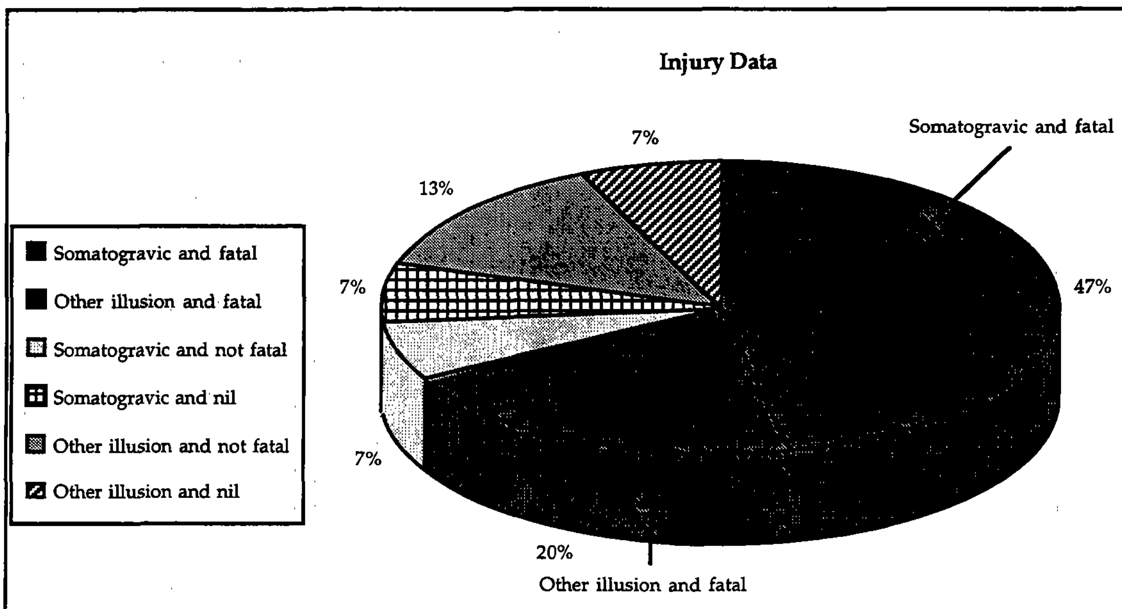

Figure 2 : Injury Data in Night Take-off Accidents

Of the nine accidents in which the somatogravic illusion was considered to be a contributing factor, seven involved fatalities. Only two of the 15 accidents under consideration resulted in no injuries.

Given the number of fatal accidents, it is necessary to identify the factors which

[4]In many cases investigation of the fifteen accidents revealed that the flight was correctly planned, crewed and performed in an aircraft that showed no signs of malfunction. Similarly, many of the post mortems performed on pilots involved in the accidents did not expose any medical conditions that may have impaired pilot judgement or performance to a degree where an accident would be predictable. 'Human performance' factors were considered for any role they may have played in the development of the accident and, in many cases, were often assigned as possible causal factors.

increase a pilot's susceptibility to visual or sensory illusions. A pilot's physiological condition, age, experience and qualifications, environmental surroundings (aerodrome and weather) and operational details have all been thought to have some role in accidents at some time. These issues, and their relevance to the dark night take-off accident, are presented and discussed in the following pages.

> **'The pilot had limited experience in night operations. Until this flight, all night takeoffs since obtaining his Command instrument rating had been conducted from airports in well-lit areas......**
>
> **No faults were found with the aircraft or aircraft systems that may have contributed to the occurrence. It was likely that the pilot had hurried the after-takeoff checks, and had not adequately monitored the attitude of the aircraft.' (BASI occurrence 8811021).**

6.3 Elements of the dark night take-off accident

Factors that may be relevant to the onset and promotion of visual and/or sensory perceptions may be broken into two areas. These are:

(a) data specific to the pilot such as pilot age, experience, qualifications, physiological condition; and

(b) data specific to the operation of the aircraft such as environmental conditions at the time of the accident, weather, aerodrome site and lighting, type of operation.

The 15 accidents in which a visual and/or sensory perception was deemed to be a major factor were reviewed, and data specific to each of the areas is presented under these categories in section 6.3.1.

6.3.1 Pilot specific data

6.3.1.1 Pilot age

The age of a person is often considered in analysis of data specific to a cross-section of the community. Medical specialists often associate the probability of a medical condition with a specific age grouping. As the types of illusions considered in this report are physiologically based, it would be worthwhile to examine if pilot age is related to susceptibility to these illusions.

Table 1 displays the number of pilots involved in accidents by age grouping[5]. The table only relates to those accidents where visual/sensory perception is considered a contributing factor.

Pilot Age	Number of Pilots
Under 20	0
20 - 24	5
25 - 29	2
30 - 34	0
35 - 39	0
40 - 44	3
45 - 49	3
50 - 54	1
55 - 59	2
60 and over	2
Total	18

Table 1 : Number of Accidents by Pilot Age.

To compare this information with the pilot population in Australia, the CAA medical branch provided information to display the pilot age distribution (see figure 3).

The curve constructed from CAA data is representative of the binomial distribution type of curve expected in a large population. Figure 3 also contains a bar-chart overlay showing the number of accidents by age of pilots in night takeoff accidents (the data contained in table 1) in which a visual or sensory illusion is expected to have been a factor.

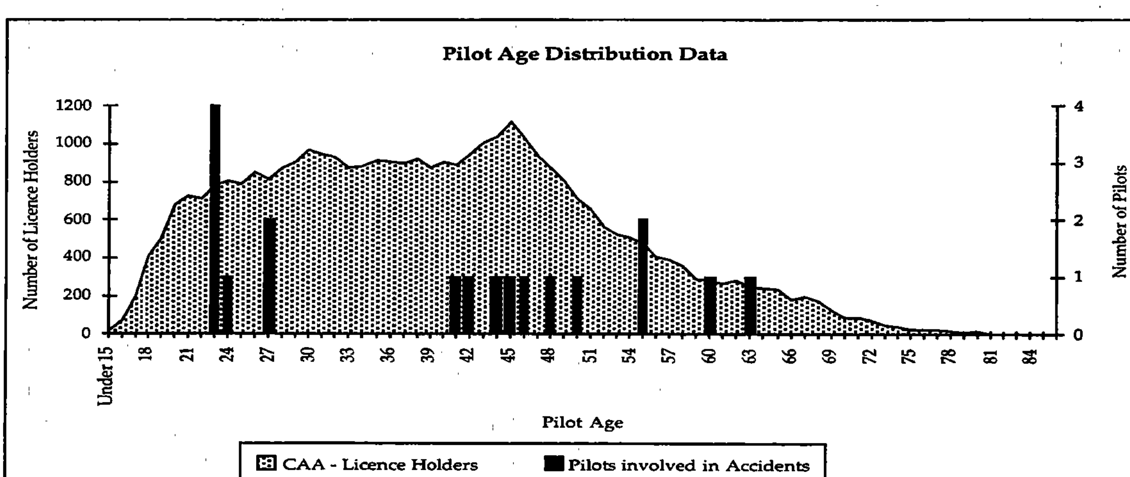

Figure 3 : Pilot Age Distribution Data

[5]Data in table 1 indicates that 18 pilots were involved in only 15 accidents. In three of the 15 accidents, two pilots were on board at the time of the accident; this may further indicate the significant physiological effects felt with this type of accident.

'It was also possible that, if for some reason the pilot was not monitoring his flight instruments as the aircraft entered the fog, he suffered a form a spatial disorientation known as the somatogravic illusion. This illusion has been identified as a major factor in many similar accidents following night takeoffs....In this particular case, the pilot would probably have been more susceptible to the disorientating effects, because he was suffering from a bronchial or influenzal infection.' (BASI occurrence 8711030).

Table 1 shows that seven (39%) pilots, involved in accidents where illusions were suspected to play a major role, were under 30 years of age. Five (28%) pilots, were less than 24 years of age. Conversely, pilots between the ages of 30 and 40 feature less in the statistics. This was confirmed by the overlay presented in figure 3, which indicates that pilots between the ages of 30 and 40 seem to be less susceptible to the illusion than pilots of other ages. The data tends to indicate that the age group in which the illusion is most predominant is below 30 years of age. One factor that should be remembered when considering these figures is that the population consists of only 18 pilots. A limitation on the integrity of the data occurs because of this small population.

If the Australian age profile data from the CAA is compared to the accident data received from the NTSB, a more accurate comparison between age and pilot susceptibility may be made (the larger population of the USA statistics should give less biased data). When a comparison is made in this manner,[6] there appears to be no age group that is more likely to be involved in the types of accidents under consideration. A logical conclusion, based on this data, is that the age of a pilot is not a common factor in night take-off accidents.

'The weather conditions at Goulburn were fine; and the wind was a light south-easterly, there was some scattered cloud at about 8,000 ft. However, it was very dark, and although the stars were visible there was no moon. Takeoff on runway 22 was towards an unpopulated area and the horizon was not visible. It was necessary to rely on flight instruments to maintain spatial orientation.' (BASI occurrence 7921040).

[6]This type of comparison assumes that:

(i) the Australian age profile is similar to that in the US; and

(ii) the training and regulations relating to night operations in the USA are similar to those in Australia.

6.3.1.2 Pilot qualifications, ratings and experience

The types of ratings held by the pilots involved in the night take-off accidents are presented graphically in figure 4.

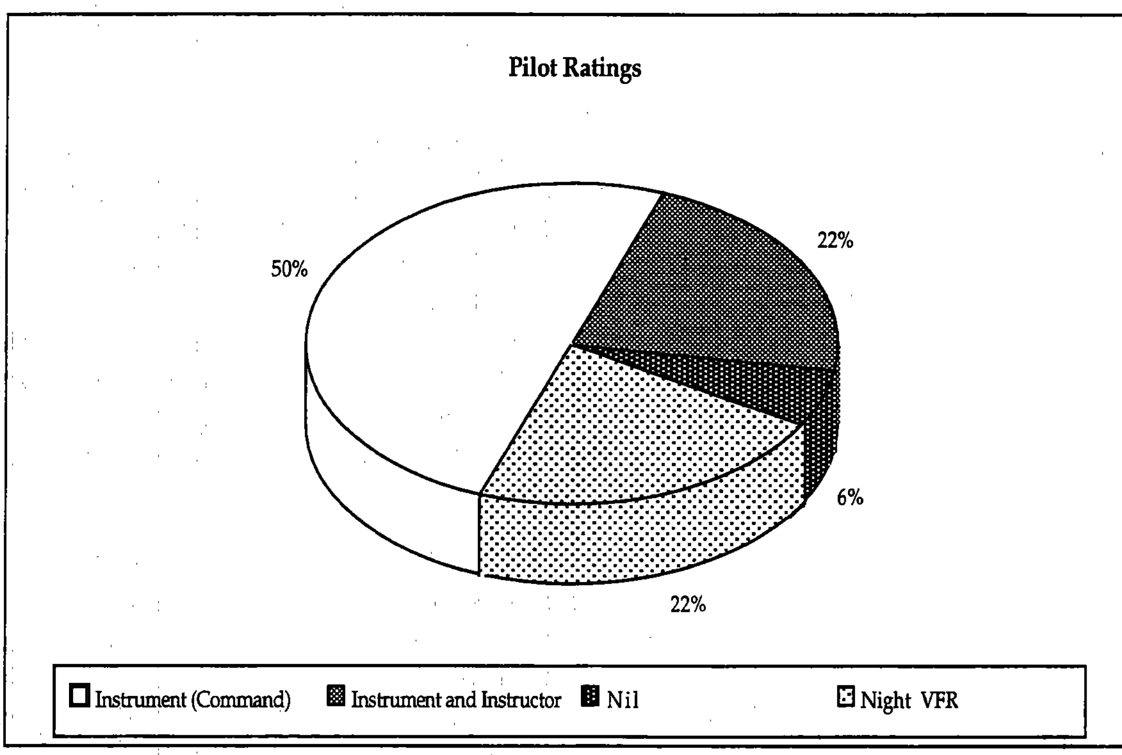

Figure 4 : Pilot Ratings

Of the 18 pilots involved in the 15 accidents, 17 (94%) had some form of instrument rating. A total of 13 pilots (72%) had command instrument ratings, of which 12 (67%) were valid. Four (22%) of these pilots also held instructor ratings. The remaining four pilots (22%) held valid night VFR or class IV instrument ratings.

Additionally, 12 (67%) pilots had commercial licences, the other six (33%) held private licences. No senior commercial or airline transport pilot licence holders were involved in the 15 accidents under consideration.

Information obtained regarding recency and validity of licences and ratings shows that only two (11%) of the pilots were legally unable to perform the flight because they did not hold the required rating.

From the accidents under consideration, it was obvious that commercial pilots as well as private pilots were susceptible to visual and sensory illusions. From the available information, it was unrealistic to compare the probability of a commercial pilot experiencing an illusion to that of a private pilot.

The fact that the data indicated 12 (67%) of the pilots held commercial licences indicates that the training and experience required for the issue of a commercial licence does not ensure immunity from these illusions.

The total of hours flown has traditionally provided a way of measuring a pilot's experience. Data obtained from the accidents surveyed indicated pilot experience ranging from 189 hours to 19,006 hours (see table 2). The average number of hours flown was 3,849; however it is difficult to draw conclusions from this data due to the spread of experience and the small population under consideration.

The spread of total aeronautical experience indicates that a lack of pilot experience is not a recurring element in accidents where visual or sensory illusions have been suspected. Five (28%) pilots had less than 500 hours total experience, and another six (33%) had between 500 and 2,000 hours (of which five pilots had experience over 1,000 hours).

Experience Level (hours)	Number of Pilots
0-100	0
100-200	2
200 - 300	1
300 - 400	0
400 - 500	2
500 - 600	0
600 - 700	0
700 - 800	1
800 - 900	0
900 - 1,000	0
1,000 - 1,250	2
1,250 - 1,500	2
1,500 - 2,000	1
2,000 - 2,500	1
2,500 - 5,000	1
5,000 - 7,500	2
7,500 - 10,000	0
10,000 - 15,000	2
15,000 and over	1

Table 2 : Pilot Experience Levels.

Additionally, the accident files show that total instrument and/or night experience varied from <50 hours to >2500 hours. The average instrument or night experience was over 700 hours, suggesting that low-time, inexperienced pilots are no more susceptible to factors in dark night take-off accidents than more experienced crews.

In summary, even with the small population under consideration, it can be seen that any pilot, regardless of experience or qualification, can fall victim to various types of illusions. It is important that pilots be aware of the sensations that may occur with the various types of flight and flight conditions. The power of the sensations associated with various illusions is further demonstrated by the number of accidents which occurred with two pilots on board.

6.3.1.3 Pilot fatigue, physiological and psychological fitness.

Thirteen of the 15 accidents involved fatalities. The post-mortem examinations of the pilots revealed only one case where a medical condition was present. This same accident was the only case where traces of any drug were found and that was a drug prescribed to treat the pilot for a medical condition.

The presence of certain medical conditions and/or drugs are known to have adverse effects on the performance of pilots. The lack of any medical condition in 17 (94%) of the pilots indicates that the somatogravic and other visual and sensory illusions can exist without the presence of any diagnosed medical conditions. Similarly, the results indicate that the illusions may occur in the absence of any drugs[7].

Stress is another factor often linked to flight crew performance. The presence of stress was thought to be a factor in eight of the 15 accidents (53%). The witness interviews conducted in three of the eight accidents revealed that the pilots had conveyed some urgency that the flight be completed. Two of these three accidents involved aircraft in SAR or ambulatory functions. The other five accidents involved pilots who may have had stress associated with 'life related' events such as family, business or financial worries.

The number of accidents under consideration here is small, and results do not conclusively show that the presence of stress is a major factor in night take-off accidents. However, research has shown that a person's performance can be degraded when influenced by overload or stress.

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[7] A pilot who has a medical condition or is taking over-the-counter and prescription drugs may be more susceptible to visual or sensory illusions. Although it is beyond the scope of this report, many over-the-counter and prescription drugs are known to have side effects that include nausea, disorientation and reduced *g* tolerance. Furthermore, some drugs can affect judgement, comprehension, co-ordination and reaction times. It is important to note that there are very real dangers involved in the mixing of drugs and flying, even if they are not apparent in the accidents under consideration.

The skills and concentration involved in night flying and the added pressure involved in the take-off phase of flight make it possible that stress would increase the chance of a night take-off accident.

The Bureau of Air Safety Investigation's explanatory factor definition of fatigue is:

> 'a decreased capability to perform some specified task due to prolonged and/or extreme mental or physical activity, or sleep deprivation. This includes circadian rhythm upset as a result of crossing several time zones quickly or working different shifts without adequate transition time.'

This definition suggests that longer duty times and flight times may be related to the onset of fatigue. The CAA has published regulations (CAO 48.0) that limit the times pilots are allowed on duty, and this should ensure that pilots are well rested prior to attempting tasks associated with flight.

Most pilots involved in the accidents discussed here flew within the legal flying time limits of CAO 48.0; however BASI files indicate that pilots' duty hours at times exceed the legal limit. (See table 3).

Duty Time (hours)	Number of Cases
less than 1 hour	0
1 - 1.9	2
2 - 2.9	0
3 - 3.9	0
4 - 4.9	2
5 - 5.9	1
6 - 6.9	0
7 - 7.9	0
8 - 8.9	2
9 - 9.9	0
10 - 10.9	0
11 - 11.9	1
12 - 12.9	1
13 - 13.9	1
14 - 14.9	1
15 and over	1
unknown	6
Total	18

Table 3 : Duty Times prior to accident.

Another factor commonly related to fatigue is the number of hours that a pilot has been awake. The investigations show that 11 pilots (60%) were awake for more than 13 hours before their accident. (See figure 5).

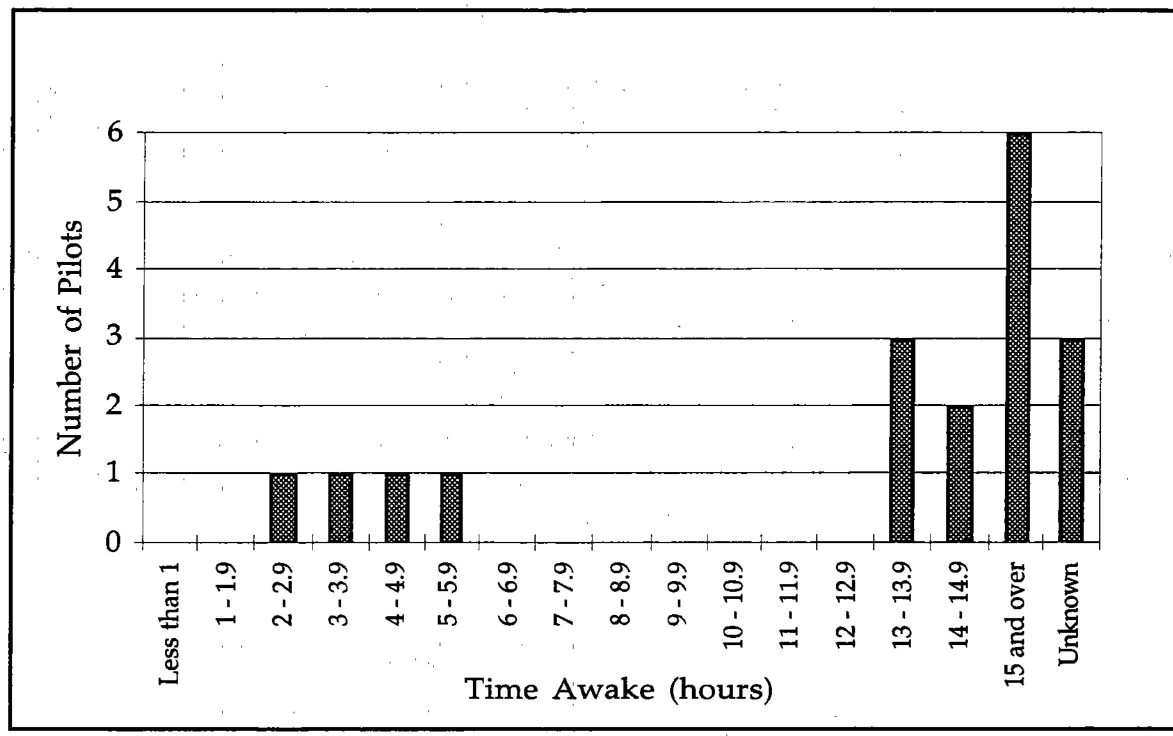

Figure 5 :Number of Pilots vs Time Awake

The amount, and adequacy, of rest a pilot has had prior to flying is also a factor that should be considered as part of pilot fatigue. Seven of the 15 BASI accident files did not indicate this data and, as such, the remaining population is not large enough to show accurate trends.

In addition, the presence of stress may also cause a pilot to become fatigued. A dark night takeoff may involve additional pressures and considerations not encountered with day VFR flight and these pressures, coupled with fatigue, may have placed the pilots under conditions where illusions were more likely to occur.

> **'The pilot had been awake for almost 18 hours prior to the accident and may have been fatigued. His night flying experience, particularly related to dark night takeoffs remote from ground lights, was limited. The circumstances of the accident were consistent with the pilot suffering the effects of somatogravic illusion, a very subtle form of disorientation to which even experienced pilots can fall victim.'**
> **(BASI occurrence 9131007).**

It is difficult to attribute an accident to fatigue, because firstly, there are no reliable indicators of fatigue and secondly, even if it could be proved that the pilot was fatigued, it still remains to establish a causal link between fatigue and the accident. However, investigators have suggested that pilot fatigue may have been a contributing factor in as many as 13 (72%) of the 18 pilots considered here. Given the time of day at which these accidents occurred, and the type of flight involved, fatigue must be acknowledged as a possible factor.

6.3.2 Operational data

6.3.2.1 Weather and related conditions

Of the 15 recorded accidents, ten (67%) occurred in conditions that may be referred to as CAVOK.[8] Six (40%) of these accidents occurred in conditions of no high or low level cloud and four (27%) in conditions with scattered high level cloud.

Of the other five accidents, two (13%) were in conditions of VMC, with a sky clear of precipitation or weather. Visibility in these two accidents was greater than 10 km, however cloud was scattered at or above 2,000 ft.

The remaining three (20%) accidents occurred in conditions of IMC, with two of the aircraft entering fog shortly after takeoff. The other accident occurred in conditions of light rain. These three accidents had pilot/spatial disorientation listed as a contributing factor.[9] The training of the pilots and their IF technique were also listed as contributing factors in these accidents.

If the flight time in all accidents[10] is considered in relation to the reported weather, the possibility that 12 (80%) of the aircraft had entered instrument conditions is remote. Weather and the proximity of cloud were therefore deemed not to be common factors in the development of accidents in which visual and/or sensory illusions were suspected.

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[8]The AIP defines CAVOK as conditions in which visibility is 10 km or more, no cloud existing below 5000 ft or below the highest minimum sector altitude (whichever is the greater), no cumulonimbus, and no precipitation, thunderstorm, shallow fog, low drifting snow or dust devils.

[9]A number of papers discussing the somatogravic illusion have suggested that the illusion may occur during a climb from VFR to IFR conditions. Certainly, the necessary mechanisms for the onset of the somatogravic illusion are present in the instance of a climb, so it is impossible to rule out the presence of illusions as factors in these three accidents.

[10]In 12 of the 15 accidents flight time was recorded as being less than one minute. Allowing for a climb and descent it is very unlikely that the any of the aircraft under consideration reached any height greater than 500 feet. Even this requires a rate of climb and descent of 1,000 ft/min.

6.3.2.2 Light conditions, proximity of ground lighting and visible horizon.

The amount or intensity of light available to the pilots may be significantly different at night depending on factors such as moonrise and moonset, cloud cover, and weather, all of which will significantly affect the availability of any useful horizon.

In all 15 accidents, the night was described by witnesses as being extremely dark, and in 12 (80%), the absence of any moon was specifically mentioned. Further investigation revealed that the moon was either obscured by cloud or had not risen. In six (40%) accidents, stars were reported to be obscured or absent.

Fourteen (93%) accidents occurred in conditions, or towards a direction, which would have limited the availability of a useful, visible horizon. The other accident occurred near a central Australian town, following a total blackout of the township lights, shortly after takeoff. In three (20%) accidents, pilots had chosen to take off away from townships close by, thereby missing any benefit of a horizon that lighting from the township may have provided.

Given the discussion above, it would be reasonable to assume all the accidents occurred in conditions which required a sound instrument take-off procedure.

6.3.2.3 Aerodrome type lighting and proximity and aircraft attitude at impact and instrument error

Of the 15 accidents, all but two occurred at aerodromes that were suitable (and legal) for the operation both in terms of adequate runway lighting and runway dimensions. The other two accidents (13%) occurred at aerodromes where runway lighting was not available; however, in both of these accidents, the aircraft had obtained heights in excess of 200 ft before any loss of control occurred. The adequacy of the aerodrome for the type of aircaft operation and the availability of suitable aerodrome lighting were therefore not considered factors in the development of the accidents.

The fact that the aircraft reached heights in excess of 200 ft indicates that the problems encountered became critical after rotation in the initial acceleration and climb. This is the regime of flight where sensory illusions are thought to be most dominant. It is also that part of flight where any external references provided from runway and terminal area lighting are first likely to be lost. This would suggest that the presence of aerodrome lighting and proper facilities does not safeguard against sensory and/or visual illusions.

In all the accidents the aircraft impacted the ground within 3 nm of the airfield, and within one minute of becoming airborne. None occurred within the aerodrome boundaries. Thirteen aircraft (87%) impacted to the left or right of the extended centreline.

Furthermore, these 13 accidents occurred with little or no bank angle at the time of impact. The attitude of these 13 aircraft at the time of impact was generally no more than 10° nose-down, and wings-level.

If a common factor exists in these 13 accidents, it would appear to be reasonably subtle. This is due to the similarity of aircraft positioning and attitude at the time of contact with the ground. Analysis of the aircraft damage found that the majority of aircraft appeared to have been under control at the time of the accident. That is, aircraft damage was consistent with the pilot being unaware of any unusual attitude or flight profile. As further investigation of these accidents showed that all instruments were working, the major factor in any of the accidents may have been related to the interpretation of, or response to, the instruments.

Witnesses to the other two (13%) accidents stated that the aircraft appeared to fly normally and then adopted an unusual attitude. Witnesses also said that the aircraft did not abruptly change to an unusual attitude, but that the aircraft attitude changed smoothly and constantly as if the pilot was instigating a turn. This type of statement suggests that the pilot was overcome by some form of spatial disorientation.

6.3.2.4 Type of operation, other operational data

Of the 15 accidents, three (20%) were engaged in commercial (cargo) charter operations, three were involved with commercial (passenger carrying) charter operations and two (13%) were involved with commercial (airwork) operations. A further three (20%) were engaged in non-commercial (business) operations and two (13%) in non-commercial (pleasure) operations. The remaining three (20%) were involved in SAR or aerial ambulance activities. These figures are presented in figure 6.

'At the time the takeoff was commenced, the night was very dark with no moon and the stars were not visible. Once the aircraft passed the boundary of the aerodrome there was no known ground lighting in the area, and the pilot would have to operate the aircraft by reference to the instruments to ensure a safe climbing attitude. The reason the aircraft failed to climb away normally could not be determined; however it was possible that the pilot was attempting to gain external visual reference and was not adequately monitoring the flight indications. Under such conditions the possibility that he suffered from spatial disorientation could not be discounted.' (BASI occurrence 8131009).

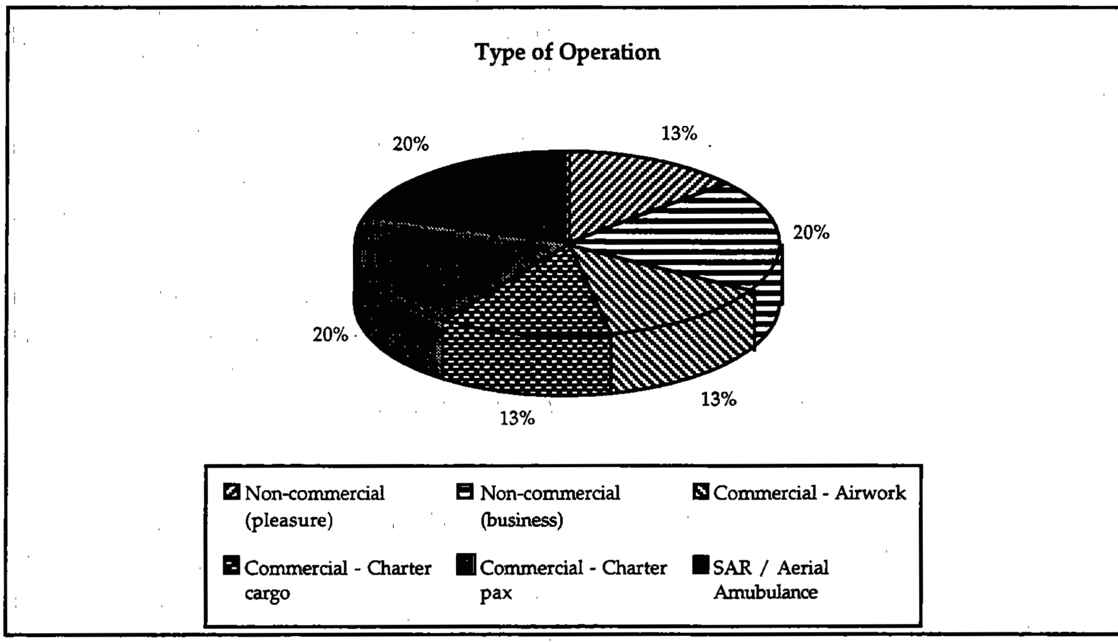

Figure 6 : Accident by Operational Type

A comparison between aircraft types involved in the accidents did not reveal any commonalities, either in aircraft type, take-off speed or climb speed. The 15 accidents involved 12 different aircraft types ranging from Cessna 172s through to Cessna 402s, Beech Bonanza V35s and a Kingair E90, Piper PA31 Navajo and PA32 Saratogas. This wide range of aircraft types was matched by the varying experience levels of the pilots.

6.4 Summary of common factors in night take-off accidents

It is possible to draw together a number of conclusions and summarise the common factors in night take-off accidents in which the somatogravic or some other visual or sensory illusion may have been present.

1. The pilot most likely had been awake for an extended period of time (possibly more than 15 hours), and may have been fatigued.

2. The aerodrome from which the flight commenced is likely to have been suitable for the type of operation that the pilot was conducting, but the area surrounding the terminal area was most likely devoid of lighting. It is probable that the pilot elected to takeoff in a direction away from any other useful lighting such as lighting that may be associated with a nearby township.

3. The weather was likely to have been CAVOK, with any cloud being high level cloud.

4. The moon was most likely to have been absent, and any stars were

probably obscured by high level cloud.

5. A useful horizon may not have been available, requiring that the pilot perform an instrument takeoff.

In summary, the most common factors appear to be associated with factors that are not pilot-specific. Statistics indicate that the development of these accidents may be promoted by psychophysiological considerations, particularly fatigue, which are associated with dark night take-off accidents. Statistics also indicate that the major factor associated with dark night take-off accidents is the type of environment in which the accident occurs. The accidents are more probable on dark nights, with limited horizons, in conditions where there is no adverse weather or cloud. Furthermore, the illusions associated with night take-off accidents are most likely to occur during, or shortly after, rotation in areas that have no appreciable ground lighting.

It would appear that the data gathered in this project supports the research completed by international organisations. Given that the aircraft and instrumentation of all aircraft involved in the accidents were serviceable, the common factor most likely is that the pilots involved failed to adequately monitor or believe instrument indications. Collar's conclusion would therefore seem to be as relevant in Australia today as it was overseas in 1946:

> 'The remedy was at hand: it was an insistence on the proper use of instruments. The use of instruments had been stressed at an early age by the Chief Inspector of Accidents; and the investigation described here provided a timely hammer to drive home the necessity of rigorous attention to instruments at night.'

7. A DISCUSSION OF RELEVANT REGULATIONS AND REQUIREMENTS

It is appropriate to discuss relevant regulations and the training required of pilots before they may fly as pilot-in-command at night. The adequacy of pilot education is considered as it relates to the somatogravic and other sensory illusions.

To legally be pilot-in-command of an aircraft flying cross-country at night, a pilot is required to have a night VFR rating or a command instrument rating, in addition to having to hold a valid pilot licence.

7.1 Syllabus requirements for the issue of a student, private, and commercial pilot licence (as required by the day VFR syllabus)

7.1.1 Theory and/or ground requirements

A candidate is required, by the CAA, to have a basic knowledge of human performance and limitations before being granted a private, or higher level, pilot licence. These requirements are set by the CAA and are presented in section 11 of the day VFR Syllabus – Aeroplane.

As related to factors discussed in this report, the syllabus requires that a candidate have a basic knowledge of concepts relating to:

(i) effects of stress and fatigue on pilot performance;

(ii) the effects of over-the-counter and prescription drugs (and, more specifically, drugs that are likely to be used by pilots, such as aspirins, and antihistamines);

(iii) a basic knowledge of vision, spatial disorientation, and illusions; and

(iv) human factors considerations including concepts of information processing and decision, and the influence of factors such as anxiety and overconfidence.

Specifically, section 11.7 deals with vision, spatial disorientation and illusions and includes requirements to describe illusions associated with factors such as the 'leans' and linear and angular accelerations (section 11.7.10).

Section 11.7.11 requires that candidates know:

'(a) that sensory illusions usually occur when external visual clues are poor or ambiguous and that they are predictable;

(b) the importance of an artificial visual reference system and a pilot's ability to use the system;

(c) the factors that may make a person more susceptible to disorientation; and

(d) how to overcome sensory illusions.'

Even though the day VFR syllabus requires that a knowledge of the above factors is gained as part of a ground training syllabus, paragraph 1.5.4. of the day VFR Syllabus – Aeroplanes states that:

> 'Human performance and limitations (subsection 11) will not be tested in CAA examinations. This subject is to be covered by the student completing, under supervision, a self-learning text available from the CAA Publications Centre'

Thus, a candidate may be granted any level of pilot licence with no formal checks or examinations made by the CAA on the candidate's knowledge of human performance and limitations. Furthermore, only minimal supervision is required.

7.1.2 Flight requirements/knowledge

As part of the day VFR syllabus, a candidate, prior to attempting the GFPT, must have consistently demonstrated proficiency using a full instrument panel whilst performing the following manoeuvres:

- straight and level;
- climbing;
- descending; and
- turning.

In addition to this, the candidates should have had some training in unusual attitudes with a full instrument panel. The level of skill and knowledge specified by the day VFR syllabus is 'not necessarily sufficient skill or understanding of the techniques involved for solo operations'.

There are no additional standards to be reached prior to the issue of a private pilot licence in relation to instrument flight or knowledge of visual or sensory illusions.

Standards to be achieved prior to a commercial pilot licence test are such that a candidate must have demonstrated a high level of proficiency in conducting the following instrument flying exercises when under pressure with both full and limited panel:

- straight and level;
- climbing;
- turning;
- descending; and
- unusual attitudes.

There are no further requirements relating to factors involving sensory or visual illusions in the practical part of the day VFR syllabus.

7.1.3 Summary.

The CAA day VFR syllabus has no requirement for a pilot to experience spatial disorientation, or any visual or sensory illusions. In addition to this, candidates are not examined on the mechanisms involved in, or symptoms of, human performance and limitations up to this point in their flying training.

Current regulations do not allow a pilot to be the pilot-in-command of an aircraft flying cross-country at night unless he/she holds a valid night VFR or command instrument rating.

7.2 Syllabus requirements for the issue of a night VFR rating

Note: The night VFR rating was previously known as a Class 4 Instrument rating.

7.2.1 Theory and/or ground requirements.

There is no set theory or ground training syllabus that must be met for a candidate to be eligible for a night VFR rating, however CAO 40.2.2, section 5 ('Aeronautical Knowledge') provides for the following:

> '5.1 - Before undertaking a flight test required by subsection 7 an applicant for a night VFR rating or a night VFR agricultural rating shall pass an examination conducted or set by a CAA flying operations inspector or an approved pilot.
>
> The examination for the night VFR rating shall include night VFR procedures, airfield lighting requirements, alternate requirements and the particular radio navigation aids for which the applicant seeks endorsements...'

Apart from the above, there is no requirement for a candidate to be aware of the human factors or operational differences that relate specifically to night flying.

Similarly, there is no requirement for a pilot who flies at night to have a greater understanding of any operational or human performance limitations than for day operations, although those factors are significantly different, or more likely to be present at night.

Therefore, apart from the provisions given in CAO 40.2.2, section 5.1, the only additional requirements for a night VFR rating relate to aeronautical experience.

7.2.2 Flight requirements/knowledge

CAO section 40.2.2 requires that additional flying training be completed before a night VFR rating may be issued. In addition to completing extra flying training, the candidate must demonstrate proficiency in the use of instruments during specific phases of flight (but not takeoff or landing) and during specific flight manoeuvres (including climbing and descending, turning and straight and level flight). The candidate must also demonstrate proficiency in using visual clues at night through other manoeuvres such as takeoff, circuit and landing, and a baulked approach.

As part of the additional flying training, CAO 40.2.2 paragraph 1.3 requires that at least one flight undertaken towards the training for a night VFR rating

> '...include at least one landing at an aerodrome:
> (a) that is not the aerodrome from which the flight commenced; and
> (b) that is not in an area that has sufficient ground lighting to create a discernible horizon.'

Thus, as part of the night VFR rating, it is expected that a candidate will complete at least one takeoff in conditions that do not provide an adequate horizon.

7.2.3 Summary

The night VFR rating syllabus does not call specifically for a candidate to have additional knowledge in areas of night flying apart from those listed in CAO 40.2.2, section 5.1, nor does it require a candidate to demonstrate an ability to take-off specifically on instruments. The syllabus does require a takeoff from an airfield without a discernible horizon.

There are no examinations, conducted by the CAA, that would ensure that candidates are aware of the additional hazards and considerations involved in night flying.

Although individual flying schools may have set syllabi relating to training for a night VFR rating, there appears to be little guidance material issued from the CAA on the type of coursework required for a pilot to be proficient in night operations.

Additionally, the night VFR rating remains valid until the holder of the rating no longer holds a flight crew licence, the only requirement to exercise the night VFR rating being recent experience as set out in CAO 40.2.2 subsection 9. There are no requirements to renew the night VFR rating once it has been issued.

7.3 Syllabus requirements for the issue of an instrument rating

7.3.1 Theory and/or ground requirements.

CAO 40.2.1 and its related appendixes require that an applicant pass both a written test and a practical flight test (including an oral test) before being eligible for the issue of an instrument rating. CAO 40.2.1 also requires that a candidate for an instrument rating pass examinations in meteorology, radio navigation aids, and airways operating procedures before applying for an instrument rating.

Syllabus requirements for the issue of an instrument rating are presented in CAO section 40.2.1 appendix III. The syllabus provides details of both flying training and aeronautical knowledge requirements for the issue of an instrument rating.

The ground/theory training syllabus requires an applicant to have a sound knowledge of the operational aspects relating to IFR flight (including radio navigation aids, relevant regulations and requirements). Candidates are also required to have a better knowledge of meteorology than their day VFR counterparts.

Apart from the operational and meteorological considerations, the syllabus does not require that additional considerations associated with IFR flight be covered. Specifically, the syllabus does not require that candidates demonstrate knowledge of, or complete a course of study on, the human performance and limitation considerations associated with instrument flight.

7.3.2 Flight requirements/knowledge.

The practical part of the syllabus for the issue of a command instrument rating requires that a candidate demonstrate proficiency in using instruments as the sole means of navigation and flight. The syllabus requires that a certain amount of aeronautical experience be achieved in cross-country flight, instrument flight, and night flying (unless the rating is to be used during day operations only).

Unlike the night VFR rating, the syllabus does not require the completion of at least one flight in which a takeoff is performed from an aerodrome where there is no discernible horizon; however, the conditions under which an instrument rating will remain current (after it has been issued) are more stringent.

The holder of an instrument rating is required to renew his or her rating every 12 months, and must take a practical test to do so. Similarly, the holder of an instrument rating is required to have completed certain minimum requirements (usually at 90-day intervals) to be able to use his or her rating.

7.3.3 Summary.

The requirements for the issue of an instrument rating are much better defined than those for the issue of a night VFR rating; however, the issue of human performance limitations and considerations of flight under IFR and at night are not covered outside the scope of operational considerations.

Additionally, the first time that an instrument-rated pilot actually flies into cloud (or out of an aerodrome with no visual horizon) may be a number of years after the rating is issued, there being no requirement for candidates to have experienced actual instrument conditions (or takeoff with no visual horizon) as part of their training. If pilots have not been fortunate enough to have had proper tuition on human performance considerations (both ground and flight based), there is a possibility that they may not be able to cope if visual or vestibular illusions occur.

7.4 Syllabus requirements for the issue of an instructor rating

7.4.1 Theory and/or ground requirements

The syllabus for the issue of an instructor rating requires a course of at least 12 hours in duration that includes topics such as learning theory, perception, instructional techniques, and behavioural objectives. The full syllabus may be found in CAO section 40.1.7 appendix I. In addition to these requirements, CAO section 40.1.7 appendix II details the subjects to be included in the flight instructor (grade 1) examination.

Appendix II requires that the written examination include topics such as sensory perception, factors affecting perception, dealing with stress, abnormal reactions to airborne stress situations, and psychological problems of both student and experienced pilots. Note that this appendix relates only to applicants who are applying for a grade 1 instructor rating and, as such, not all instructors are required to have completed this course of training.

The majority of the theory training syllabus relates to student comprehension and learning considerations. Areas of human performance outside of this area are not required to be learnt as part of an instructor rating.

7.4.2 Flight requirements/knowledge.

In addition to completing at least 12 hours of ground training, candidates are required to complete at least 50 hours of flight training before being eligible to sit a flight test for the issue of an instructor rating. The 50 hours flight time includes the candidate conducting simulated teaching, or observing teaching demonstration, of sequences from all parts of the syllabus. Included in the 50-hour syllabus are 2 hours and 40 minutes dual and 2 hours and 20 minutes mutual covering the following aspects:

- Basic instrument flying:
  - spatial disorientation;
  - instrument interpretation and selective cross reference techniques;
  - instrument errors;
  - instrument flying techniques (full and limited panel);
  - steep turns; and
  - recovery from unusual attitudes (full and limited panel).

The syllabus also outlines 1 hour and 10 minutes dual and 2 hours and 20 minutes mutual of the following type of flying:

- Night flying:
  - take-off and circuit procedures.

7.4.3 Summary.

The additional training required for the issue of an instructor rating does not ensure that instructors are more highly qualified in the areas of human performance considerations. They are not required to have knowledge of visual or sensory illusions beyond that which is required for a commercial pilot licence.

8. CONCLUSIONS

The review of night take-off accidents has identified a number of factors in accidents where visual or sensory illusions are considered to have been present. The project has also identified a number of deficiencies in the training and checking of pilots that fly at night. These aspects and deficiencies are summarised below.

1. Type of experience or qualification did not appear to be a common factor in pilots involved in the accidents. Pilots involved in night take-off accidents had experience levels ranging from greater than 15,000 hours to less than 200 hours. Pilots involved had a variety of different licence types and different ratings, with most pilots satisfying the regulatory requirements that applied to their flight.

2. Fatigue was likely to have been present in the majority of accidents, despite the fact that, in the majority of accidents, the provisions of CAO 48.0 (relating to duty time limits) had not been exceeded. Many of the pilots had been awake for extended periods of time before being on duty (contributing to a presence of fatigue). Stress and other 'flight' pressures were not notable as a factor in the majority of the accidents.

   Although the factors discussed above were not present in all situations, it is impossible to conclude that they did not play an important role in the development of some of the accidents under consideration.

3. Almost all of the accidents occurred in CAVOK conditions. The absence of weather may be significant in the onset of illusions as it may tend, in some circumstances, to encourage the relaxation of a pilot's instrument scan.

4. All accidents occurred in conditions that precluded a discernible horizon. A number of accidents occurred when no moonlight was present. Ground lighting in the vicinity of the aerodrome was, in most circumstances, negligible.

   The absence of lighting and a horizon is considered to be paramount in the development of the accidents, in that all flights (including night VFR) would require an instrument take-off procedure even if there was no cloud.

   It appears that the combination of a limited horizon with no notable weather are the conditions that may allow the illusions to develop.

5. There appears to be deficiencies in a number of the syllabi relating to the granting of a pilot licence and ratings.

9. RECOMMENDATIONS

As a result of this research project the Bureau of Air Safety Investigation issues the following recommendation:

R940219.

The Bureau of Air Safety Investigation recommends that the Civil Aviation Authority:

(i) integrate and expand human performance and limitation considerations into the day VFR syllabus at and above the level of the GFPT for the private pilot licence;

(ii) review the policy on the testing of human performance and limitation considerations and include this area as an examinable part of the syllabus above the level of the GFPT for the private pilot licence;

(iii) review theory requirements of the instructor, night VFR and instrument ratings, with emphasis on the specific operational and human-factors considerations that the use of these ratings require as compared to day VFR flight;

(iv) review the practical requirements of the syllabus leading to an instrument rating, to ensure that a candidate has experienced conditions of IMC and flight (including takeoffs and landings) at night, in areas with limited lighting, before being granted a rating;

(v) review the policy applicable to the renewal and recency requirement of the night VFR rating, to ensure renewal and recency requirements are similar to other instrument ratings; and

(vi) educate pilots and operators of the effects of fatigue and the need to establish flight and duty times that are commensurate with the demands of their flight operations. In particular, it should stressed that the limits imposed by CAO 48.0 are maximum limits and lower limits may be appropriate to some types of operations.

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APPENDIX A - The Somatogravic Illusion

Somatogravic Illusion

'If one considers an aircraft flying straight and level and accelerating along the direction of flight because of an increase in power, for example, then the direction of the inertial force due to the acceleration is to the rear of the aircraft and for the purposes of this discussion can be assumed to be along the longitudinal axis of the aircraft. This inertial force combines with the force of gravity to produce a resultant which is inclined to the rear of the aircraft. If this resultant is then used by the pilot as the vertical reference, then the pilot will incorrectly sense that the aircraft is in a nose-up attitude. If the pilot then trims or eases forward on the control column to correct for this nose-up perception, the nose of the aircraft will drop and the airspeed will increase. This change in attitude will change the direction of the resultant force vector in such a manner as to maintain and perhaps magnify the illusory perception of a nose-up attitude.

Significant errors in perception can develop within the first few seconds of a change in the force environment. Experiments carried out in flight have shown that there is little lag in the onset of the illusion and that there is a relatively rapid increase in its magnitude during the initial six to eight seconds. This illusion is known as the somatogravic illusion, and it is particularly dangerous when it occurs on take-off or when overshooting, especially at night or in poor visibility. An aircraft deceleration will result in the opposite effect, that is, a perceived nose-down attitude.'

Transportation Safety Board of Canada, Report 89H0007

APPENDIX B - The Somatogyral Illusion

Somatogyral Illusion

'The simplest example of a somatogyral illusion is the inability of a pilot to sense accurately, other than by visual cues, the angle of bank during a prolonged coordinated turn. The pilot does have some information about the bank angle as the aircraft enters the turn from the semicircular canals which are stimulated by the angular rolling motion. Once a steady rate of turn and constant bank angle are established, however, the resultant of the force of gravity and the inertial force due to the curved flight path is parallel to the pilot's vertical axis and he perceives the aircraft to be wings level. If the recovery from the turn is made abruptly, the roll-out will be perceived as a roll-in and the illusion of a turn in the opposite direction will exist. This phenomena, commonly referred to as the leans, has been experienced by most aircrew at some time.'

Transportation Safety Board of Canada, Report 89H0007