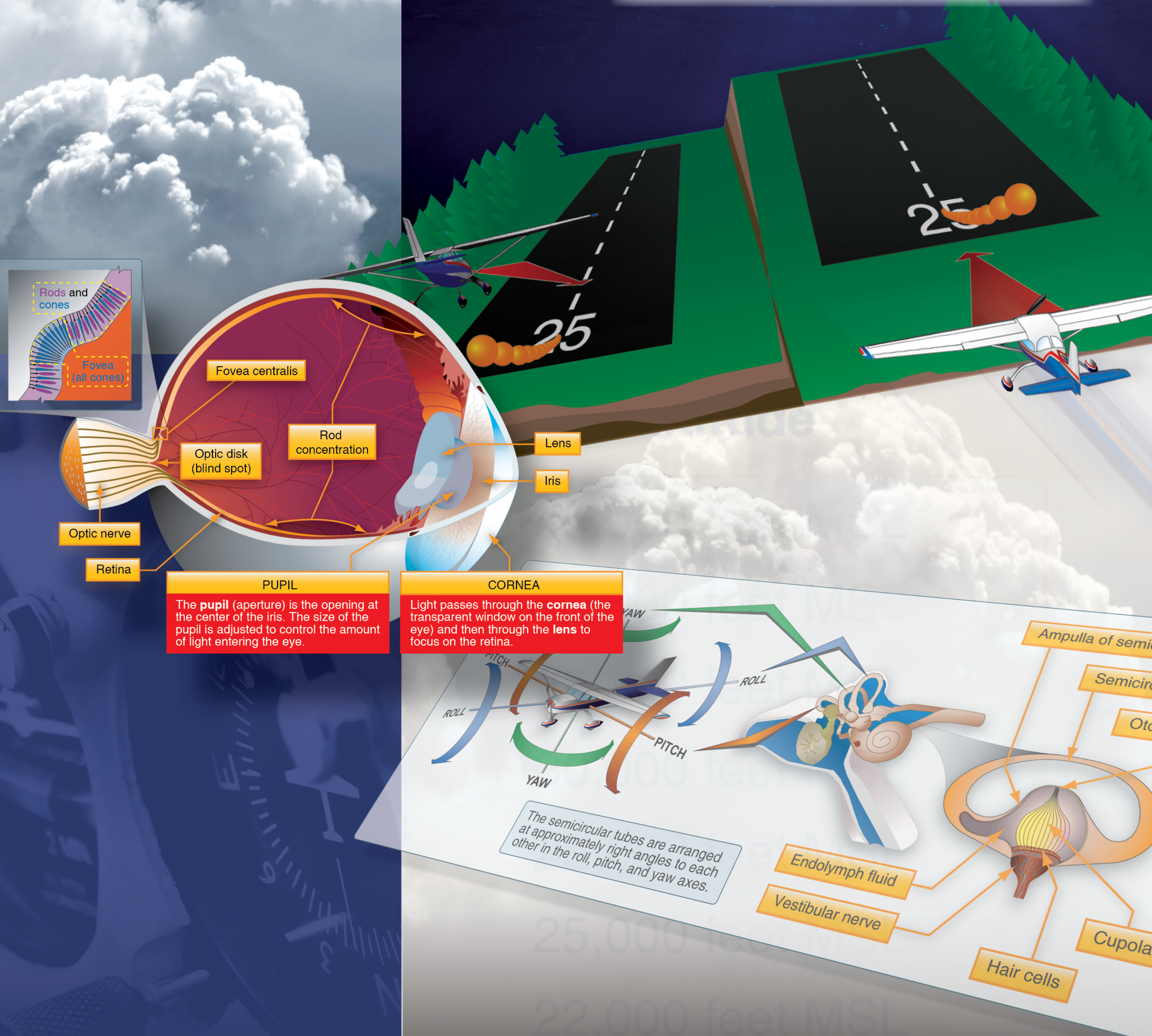
Chapter 17

Aeromedical Factors

Introduction

It is important for a pilot to be aware of the mental and physical standards required for the type of flying performed. This chapter provides information on medical certification and on a variety of aeromedical factors related to flight activities.



Obtaining a Medical Certificate

Most pilots must have a valid medical certificate to exercise the privileges of their airman certificates. Glider and free balloon pilots are not required to hold a medical certificate. Sport pilots may hold either a medical certificate or a valid state driver's license. Regardless of whether a medical certificate or drivers license is required, 14 CFR 61.53 requires every pilot not to act as a crewmember if they know, or have reason to know, of any medical condition that would make them unable to operate the aircraft in a safe manner.

Acquisition of a medical certificate requires an examination by an aviation medical examiner (AME), a physician with training in aviation medicine designated by the Civil Aerospace Medical Institute (CAMI). There are three classes of medical certificates. The class of certificate needed depends on the type of flying the pilot plans to perform.

A third-class medical certificate is required for a private or recreational pilot certificate. It is valid for 5 years for those individuals who have not reached the age of 40; otherwise it is valid for 2 years. A commercial pilot certificate requires at least a second-class medical certificate, which is valid for 1 year. First-class medical certificates are required for airline transport pilots and are valid for one year if the airman is 40 or younger; 40 and older it is valid for 6 months.

The standards are more rigorous for the higher classes of certificates. A pilot with a higher class medical certificate has met the requirements for the lower classes as well. Since the required medical class applies only when exercising the privileges of the pilot certificate for which it is required, a first-class medical certificate would be valid for 1 year if exercising the privileges of a commercial certificate and 2 or 5 years, as appropriate, for exercising the privileges of a private or recreational certificate. The same applies for a second-class medical certificate. The standards for medical certification are contained in Title 14 of the Code of Federal Regulations (14 CFR) part 67 and the requirements for obtaining medical certificates can be found in 14 CFR part 61.

Students who have physical limitations, such as impaired vision, loss of a limb, or hearing impairment may be issued a medical certificate valid for "student pilot privileges only" while learning to fly. Pilots with disabilities may require special equipment to be installed in the aircraft, such as hand controls for pilots with paraplegia. Some disabilities necessitate a limitation on the individual's certificate; for example, impaired hearing would require the limitation "not valid for flight requiring the use of radio." When all the knowledge, experience, and proficiency requirements have been met and a student can demonstrate the ability to operate the aircraft with the normal level of safety, a "statement of demonstrated ability" (SODA) can be issued. This waiver, or SODA, is valid as long as the physical impairment does not worsen. Contact the local Flight Standards District Office (FSDO) for more information on this subject.

The FAA medical standards, 14 CFR part 67, specify fifteen medical conditions that are considered disqualifying by "history or clinical diagnosis." Regardless of when one of these conditions was diagnosed and treated, an airman may not be issued a medical certificate except through a process called a "Special Issuance Authorization," as explained in 14 CFR part 67, section 67.401. A special issuance is a discretionary issuance by the FAA Federal Air Surgeon and requires satisfactory completion of special testing determined by the FAA to demonstrate that an airman is safe to fly for the duration of the medical certificate issued. The specific disqualifying conditions include:

- Diabetes mellitus requiring oral hypoglycemic medication or insulin
- Angina pectoris
- Coronary heart disease that has been treated or, if untreated, that has been symptomatic or clinically significant
- Myocardial infarction
- Cardiac valve replacement
- Permanent cardiac pacemaker
- Heart replacement
- Psychosis
- Bipolar disorder
- Personality disorder that is severe enough to have repeatedly manifested itself by overt acts
- Substance dependence (including alcohol)
- Substance abuse
- Epilepsy
- Disturbance of consciousness and without satisfactory explanation of cause
- Transient loss of control of nervous system function(s) without satisfactory explanation of cause

However, this list includes only the mandatory disqualifying conditions. There are many other medical conditions that fall into the General Medical Condition section of the regulations that are considered by the FAA to be disqualifying even though they are not stated in the regulations. Conditions such as cancer, kidney stones, neurologic and neuromuscular conditions including Parkinson's disease and multiple sclerosis, certain blood disorders, and other conditions that may progress over time require review by the FAA before a medical certificate may be issued.

The important thing to remember is that with very few exceptions, all disqualifying medical conditions may be considered for special issuance. If you can present satisfactory medical documentation to the FAA that your condition is stable, the chances are good that you will be able to qualify for an Authorization.

Health and Physiological Factors Affecting Pilot Performance

A number of health factors and physiological effects can be linked to flying. Some are minor, while others are important enough to require special attention to ensure safety of flight. In some cases, physiological factors can lead to inflight emergencies. Some important medical factors that a pilot should be aware of include hypoxia, hyperventilation, middle ear and sinus problems, spatial disorientation, motion sickness, carbon monoxide (CO) poisoning, stress and fatigue, dehydration, and heatstroke. Other subjects include the effects of alcohol and drugs, anxiety, and excess nitrogen in the blood after scuba diving.

Hypoxia

Hypoxia means "reduced oxygen" or "not enough oxygen." Although any tissue will die if deprived of oxygen long enough, the greatest concern regarding hypoxia during flight is lack of oxygen to the brain, since it is particularly vulnerable to oxygen deprivation. Any reduction in mental function while flying can result in life-threatening errors. Hypoxia can be caused by several factors, including an insufficient supply of oxygen, inadequate transportation of oxygen, or the inability of the body tissues to use oxygen. The forms of hypoxia are based on their causes:

- Hypoxic hypoxia
- Hypemic hypoxia
- Stagnant hypoxia
- Histotoxic hypoxia

Hypoxic Hypoxia

Hypoxic hypoxia is a result of insufficient oxygen available to the body as a whole. A blocked airway and drowning are obvious examples of how the lungs can be deprived of oxygen, but the reduction in partial pressure of oxygen at high altitude is an appropriate example for pilots. Although the percentage of oxygen in the atmosphere is constant, its partial pressure decreases proportionately as atmospheric pressure decreases. As an aircraft ascends during flight, the percentage of each gas in the atmosphere remains the same, but there are fewer molecules available at the pressure required for them to pass between the membranes in the respiratory system. This decrease in number of oxygen molecules at sufficient pressure can lead to hypoxic hypoxia.

Dangers of Transporting Dry Ice

Sublimation is a process in which a substance transitions from a solid to a gaseous state without passing through an intermediate liquid state. Dry ice sublimates into large quantities of CO_2 gas, which can rapidly displace oxygen-containing air and potentially cause hypoxia via carbon dioxide intoxication. Case studies have shown that both illness and death can be caused by occupational and/or unintentional exposure when transporting dry ice in small, confined spaces such as a flightdeck or airplane. Exposure to high concentration of CO_2 gas may lead to increased respiration, tachycardia, cardiac arrhythmia, and unconsciousness. Exposure to concentration of CO_2 gas in excess of 10 percent may cause convulsions, coma, and/or death.

The tendency of dry ice to rapidly sublimate also means that without proper ventilation, it can rapidly pressurize. For this reason, dry ice should never be placed inside a sealed transport container (i.e., leak-proof secondary container) and must be placed within an outer shipping container or storage container that allows adequate ventilation to release the CO_2 gas and avoid pressurization. Sealing dry ice within a leak-proof container may result in explosion of the container potentially leading to serious physical injury or death.

Hypemic Hypoxia

Hypemic hypoxia occurs when the blood is not able to take up and transport a sufficient amount of oxygen to the cells in the body. Hypemic means "not enough blood." This type of hypoxia is a result of oxygen deficiency in the blood, rather than a lack of inhaled oxygen, and can be caused by a variety of factors. It may be due to reduced blood volume (from severe bleeding), or it may result from certain blood diseases, such as anemia. More often, hypemic hypoxia occurs because hemoglobin, the actual blood molecule that transports oxygen, is chemically unable to bind oxygen molecules. The most common form of hypemic hypoxia is CO poisoning. This is explained in greater detail later in this chapter. Hypemic hypoxia can also be caused by the loss of blood due to blood donation. Blood volume can require several weeks to return to normal following a donation. Although the effects of the blood loss are slight at ground level, there are risks when flying during this time.

Stagnant Hypoxia

Stagnant means "not flowing," and stagnant hypoxia or ischemia results when the oxygen-rich blood in the lungs is not moving, for one reason or another, to the tissues that need it. An arm or leg "going to sleep" because the blood flow has accidentally been shut off is one form of stagnant hypoxia. This kind of hypoxia can also result from shock, the heart failing to pump blood effectively, or a constricted artery. During flight, stagnant hypoxia can occur with excessive acceleration of gravity (Gs). Cold temperatures can also reduce circulation and decrease the blood supplied to extremities.

Histotoxic Hypoxia

The inability of the cells to effectively use oxygen is defined as histotoxic hypoxia. "Histo" refers to tissues or cells, and "toxic" means poisonous. In this case, enough oxygen is being transported to the cells that need it, but they are unable to make use of it. This impairment of cellular respiration can be caused by alcohol and other drugs, such as narcotics and poisons. Research has shown that drinking one ounce of alcohol can equate to an additional 2,000 feet of physiological altitude.

Symptoms of Hypoxia

High-altitude flying can place a pilot in danger of becoming hypoxic. Oxygen starvation causes the brain and other vital organs to become impaired. The first symptoms of hypoxia can include euphoria and a carefree feeling. With increased oxygen starvation, the extremities become less responsive and flying becomes less coordinated. The symptoms of hypoxia vary with the individual, but common symptoms include:

- Cyanosis (blue fingernails and lips)
- Headache
- Decreased response to stimuli and increased reaction time
- Impaired judgment
- Euphoria
- Visual impairment
- Drowsiness
- Lightheaded or dizzy sensation
- Tingling in fingers and toes
- Numbness

As hypoxia worsens, the field of vision begins to narrow and instrument interpretation can become difficult. Even with all these symptoms, the effects of hypoxia can cause a pilot to have a false sense of security and be deceived into believing everything is normal.

Treatment of Hypoxia

Treatment for hypoxia includes flying at lower altitudes and/or using supplemental oxygen. All pilots are susceptible to the effects of oxygen starvation, regardless of physical endurance or acclimatization. When flying at high altitudes, it is paramount that oxygen be used to avoid the effects of hypoxia. The term "time of useful consciousness" describes the maximum time the pilot has to make rational, life-saving decisions and carry them out at a given altitude without supplemental oxygen. As altitude increases above 10,000 feet, the symptoms of hypoxia increase in severity, and the time of useful consciousness rapidly decreases. *[Figure 17-1]* Since symptoms of hypoxia can be different for each individual, the ability to recognize hypoxia can be greatly improved by experiencing and witnessing the effects of it during an altitude chamber "flight." The Federal Aviation Administration (FAA) provides this opportunity through aviation physiology training, which is conducted at the FAA CAMI in Oklahoma City, Oklahoma, and at many military facilities across the United States. For information about the FAA's one-day physiological training course with altitude chamber and vertigo demonstrations, visit the FAA website at www.faa.gov.

Hyperventilation

Hyperventilation is the excessive rate and depth of respiration leading to abnormal loss of carbon dioxide from the blood. This condition occurs more often among pilots than is generally recognized. It seldom incapacitates completely, but it causes disturbing symptoms that can alarm the uninformed pilot. In such cases, increased breathing rate and anxiety further aggravate the problem. Hyperventilation can lead to unconsciousness due to the respiratory system's overriding mechanism to regain control of breathing.

Pilots encountering an unexpected stressful situation may subconsciously increase their breathing rate. If flying at higher altitudes, either with or without oxygen, a pilot may have a tendency to breathe more rapidly than normal, which often leads to hyperventilation.

Since many of the symptoms of hyperventilation are similar to those of hypoxia, it is important to correctly diagnose and treat the proper condition. If using supplemental oxygen, check the equipment and flow rate to ensure the symptoms are

Altitude	Time of useful consciousness
45,000 feet MSL	9 to 15 seconds
40,000 feet MSL	15 to 20 seconds
35,000 feet MSL	30 to 60 seconds
30,000 feet MSL	1 to 2 minutes
28,000 feet MSL	2½ to 3 minutes
25,000 feet MSL	3 to 5 minutes
22,000 feet MSL	5 to 10 minutes
20,000 feet MSL	30 minutes or more

Figure 17-1. *Time of useful consciousness.*

not hypoxia related. Common symptoms of hyperventilation include:

- Visual impairment
- Unconsciousness
- Lightheaded or dizzy sensation
- Tingling sensations
- Hot and cold sensations
- Muscle spasms

The treatment for hyperventilation involves restoring the proper carbon dioxide level in the body. Breathing normally is both the best prevention and the best cure for hyperventilation. In addition to slowing the breathing rate, breathing into a paper bag or talking aloud helps to overcome hyperventilation. Recovery is usually rapid once the breathing rate is returned to normal.

Middle Ear and Sinus Problems

During climbs and descents, the free gas formerly present in various body cavities expands due to a difference between the pressure of the air outside the body and that of the air inside the body. If the escape of the expanded gas is impeded, pressure builds up within the cavity and pain is experienced. Trapped gas expansion accounts for ear pain and sinus pain, as well as a temporary reduction in the ability to hear.

The middle ear is a small cavity located in the bone of the skull. It is closed off from the external ear canal by the eardrum. Normally, pressure differences between the middle ear and the outside world are equalized by a tube leading from inside each ear to the back of the throat on each side called the Eustachian tube. These tubes are usually closed but open during chewing, yawning, or swallowing to equalize pressure. Even a slight difference between external pressure and middle ear pressure can cause discomfort. *[Figure 17-2]*

During a climb, middle ear air pressure may exceed the pressure of the air in the external ear canal causing the eardrum to bulge outward. Pilots become aware of this pressure change when they experience alternate sensations of "fullness" and "clearing." During descent, the reverse happens. While the pressure of the air in the external ear canal increases, the middle ear cavity, which equalized with the lower pressure at altitude, is at lower pressure than the external ear canal. This results in the higher outside pressure causing the eardrum to bulge inward.

This condition can be more difficult to relieve due to the fact that the partial vacuum tends to constrict the walls of the Eustachian tube. To remedy this often painful condition, which also causes a temporary reduction in hearing

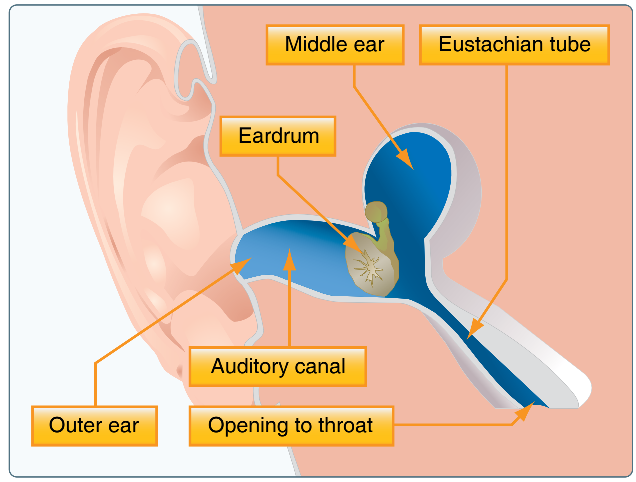


Figure 17-2. *The Eustachian tube allows air pressure to equalize in the middle ear.*

sensitivity, pinch the nostrils shut, close the mouth and lips, and blow slowly and gently into the mouth and nose.

This procedure forces air through the Eustachian tube into the middle ear. It may not be possible to equalize the pressure in the ears if a pilot has a cold, an ear infection, or sore throat. A flight in this condition can be extremely painful, as well as damaging to the eardrums. If experiencing minor congestion, nose drops or nasal sprays may reduce the risk of a painful ear blockage. Before using any medication, check with an AME to ensure that it will not affect the ability to fly.

In a similar way, air pressure in the sinuses equalizes with the pressure in the flight deck through small openings that connect the sinuses to the nasal passages. An upper respiratory infection, such as a cold or sinusitis, or a nasal allergic condition can produce enough congestion around an opening to slow equalization. As the difference in pressure between the sinuses and the flight deck increases, congestion may plug the opening. This "sinus block" occurs most frequently during descent. Slow descent rates can reduce the associated pain. A sinus block can occur in the frontal sinuses, located above each eyebrow, or in the maxillary sinuses, located in each upper cheek. It usually produces excruciating pain over the sinus area. A maxillary sinus block can also make the upper teeth ache. Bloody mucus may discharge from the nasal passages.

Sinus block can be avoided by not flying with an upper respiratory infection or nasal allergic condition. Adequate protection is usually not provided by decongestant sprays or drops to reduce congestion around the sinus openings. Oral decongestants have side effects that can impair pilot performance. If a sinus block does not clear shortly after landing, a physician should be consulted.

Spatial Disorientation and Illusions

Spatial disorientation specifically refers to the lack of orientation with regard to the position, attitude, or movement of the airplane in space. The body uses three integrated systems that work together to ascertain orientation and movement in space.

- Vestibular system—organs found in the inner ear that sense position by the way we are balanced
- Somatosensory system—nerves in the skin, muscles, and joints that, along with hearing, sense position based on gravity, feeling, and sound
- Visual system—eyes, which sense position based on what is seen

All this information comes together in the brain and, most of the time, the three streams of information agree, giving a clear idea of where and how the body is moving. Flying can sometimes cause these systems to supply conflicting information to the brain, which can lead to disorientation. During flight in visual meteorological conditions (VMC), the eyes are the major orientation source and usually prevail over false sensations from other sensory systems. When these visual cues are removed, as they are in instrument meteorological conditions (IMC), false sensations can cause a pilot to quickly become disoriented.

The vestibular system in the inner ear allows the pilot to sense movement and determine orientation in the surrounding environment. In both the left and right inner ear, three semicircular canals are positioned at approximate right angles to each other. *[Figure 17-3]* Each canal is filled with fluid and has a section full of fine hairs. Acceleration of the inner ear in any direction causes the tiny hairs to deflect, which in turn stimulates nerve impulses, sending messages to the brain. The vestibular nerve transmits the impulses from the utricle, saccule, and semicircular canals to the brain to interpret motion.

The somatosensory system sends signals from the skin, joints, and muscles to the brain that are interpreted in relation to the Earth's gravitational pull. These signals determine posture. Inputs from each movement update the body's position to the brain on a constant basis. "Seat of the pants" flying is largely dependent upon these signals. Used in conjunction with visual and vestibular clues, these sensations can be fairly reliable. However, the body cannot distinguish between acceleration forces due to gravity and those resulting from maneuvering the aircraft, which can lead to sensory illusions and false impressions of an aircraft's orientation and movement.

Under normal flight conditions, when there is a visual reference to the horizon and ground, the sensory system in the inner ear helps to identify the pitch, roll, and yaw movements of the aircraft. When visual contact with the horizon is lost, the vestibular system becomes unreliable. Without visual references outside the aircraft, there are many situations in which combinations of normal motions and forces create convincing illusions that are difficult to overcome.

Prevention is usually the best remedy for spatial disorientation. Unless a pilot has many hours of training in instrument flight, flight should be avoided in reduced visibility or at night when the horizon is not visible. A pilot can reduce susceptibility to disorienting illusions through training and awareness and learning to rely totally on flight instruments.

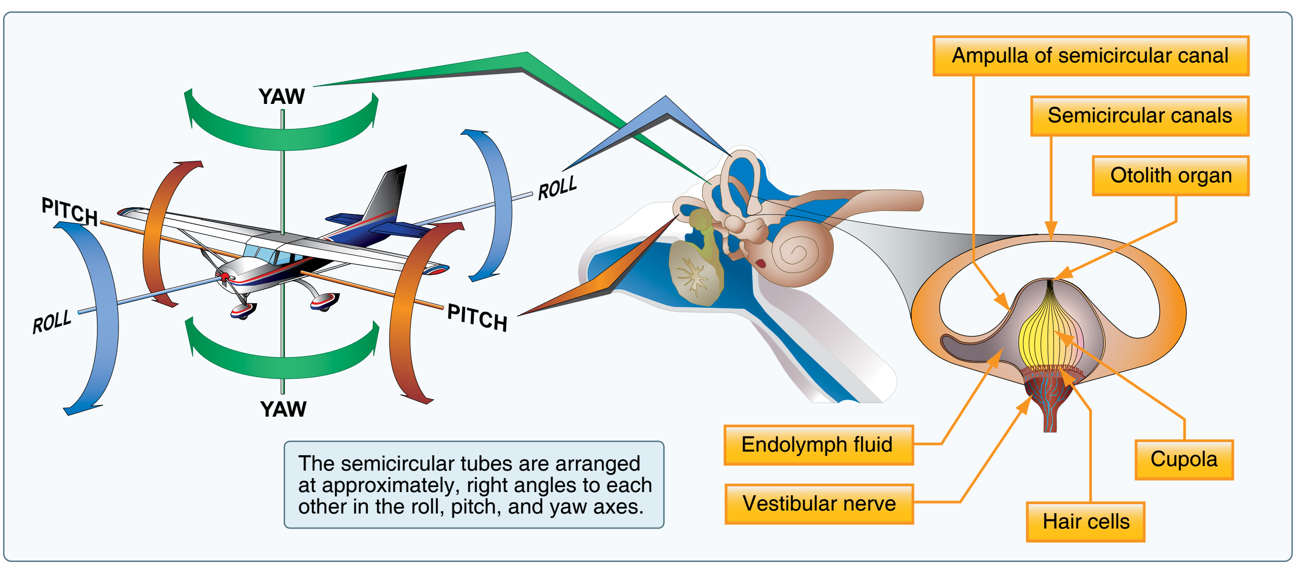


Figure 17-3. *The semicircular canals lie in three planes and sense motions of roll, pitch, and yaw.*

Vestibular Illusions

The Leans

A condition called the leans, is the most common illusion during flight and is caused by a sudden return to level flight following a gradual and prolonged turn that went unnoticed by the pilot. The reason a pilot can be unaware of such a gradual turn is that human exposure to a rotational acceleration of 2 degrees per second or lower is below the detection threshold of the semicircular canals. *[Figure 17-4]* Leveling the wings after such a turn may cause an illusion that the aircraft is banking in the opposite direction. In response to such an illusion, a pilot may lean in the direction of the original turn in a corrective attempt to regain the perception of a correct vertical posture.

Coriolis Illusion

The "coriolis illusion" occurs when a pilot has been in a turn long enough for the fluid in the ear canal to move at the same speed as the canal. A movement of the head in a different plane, such as looking at something in a different part of the flight deck, may set the fluid moving, creating the illusion of turning or accelerating on an entirely different axis. This action causes the pilot to think the aircraft is performing a maneuver it is not. The disoriented pilot may maneuver the aircraft into a dangerous attitude in an attempt to correct the aircraft's perceived attitude.

For this reason, it is important that pilots develop an instrument cross-check or scan that involves minimal head movement. Take care when retrieving charts and other objects in the flight deck—if something is dropped, retrieve it with minimal head movement and be alert for the coriolis illusion.

Graveyard Spiral

As in other illusions, a pilot in a prolonged coordinated, constant-rate turn may experience the illusion of not turning. During the recovery to level flight, the pilot will then experience the sensation of turning in the opposite direction causing the disoriented pilot to return the aircraft to its original turn. Because an aircraft tends to lose altitude in turns unless the pilot compensates for the loss in lift, the pilot may notice a loss of altitude. The absence of any sensation of turning creates the illusion of being in a level descent. The pilot may pull back on the controls in an attempt to climb or stop the descent. This action tightens the spiral and increases the loss of altitude; this illusion is referred to as a "graveyard spiral." *[Figure 17-5]* This may lead to a loss of aircraft control.

Somatogravic Illusion

A rapid acceleration, such as experienced during takeoff, stimulates the otolith organs in the same way as tilting the head backwards. This action may create what is known as the "somatogravic illusion" of being in a nose-up attitude, especially in conditions with poor visual references. The disoriented pilot may push the aircraft into a nose-low or dive attitude. A rapid deceleration by quick reduction of the throttle(s) can have the opposite effect, with the disoriented pilot pulling the aircraft into a nose-up or stall attitude.

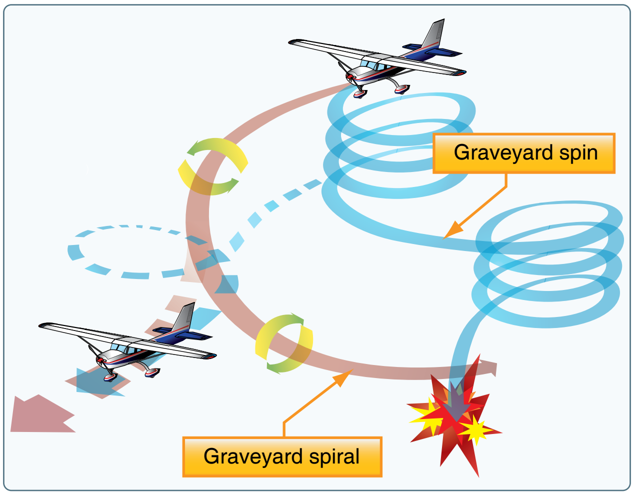


Figure 17-5. *Graveyard spiral.*

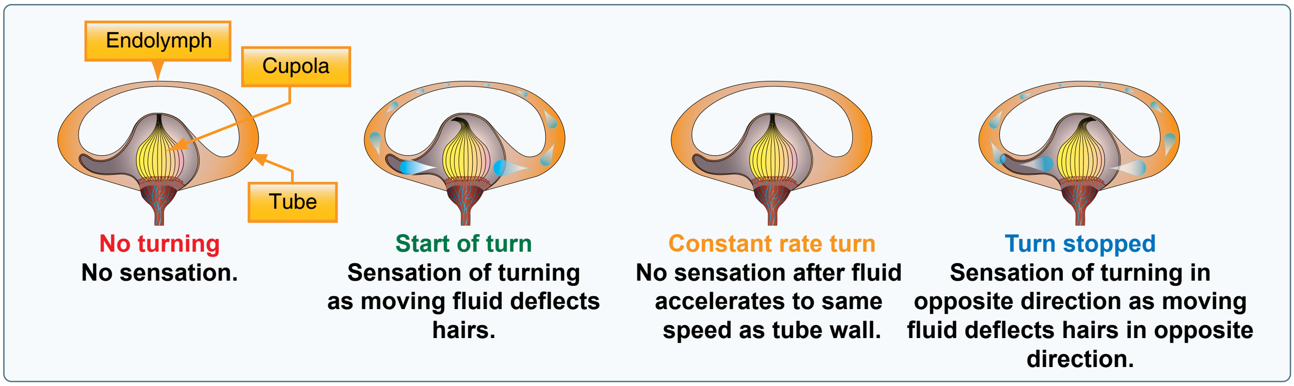


Figure 17-4. *Human sensation of angular acceleration.*

Inversion Illusion

An abrupt change from climb to straight-and-level flight can stimulate the otolith organs enough to create the illusion of tumbling backwards, known as "inversion illusion." The disoriented pilot may push the aircraft abruptly into a nose-low attitude, which may intensify this illusion.

Elevator Illusion

An abrupt upward vertical acceleration, as can occur in an updraft, can stimulate the otolith organs to create the illusion of being in a climb. This is known as "elevator illusion." The disoriented pilot may push the aircraft into a nose-low attitude. An abrupt downward vertical acceleration, usually in a downdraft, has the opposite effect with the disoriented pilot pulling the aircraft into a nose-up attitude.

Visual Illusions

Visual illusions are especially hazardous because pilots rely on their eyes for correct information. Two illusions that lead to spatial disorientation, false horizon and autokinesis, affect the visual system only.

False Horizon

A sloping cloud formation, an obscured horizon, an aurora borealis, a dark scene spread with ground lights and stars, and certain geometric patterns of ground lights can provide inaccurate visual information, or "false horizon," when attempting to align the aircraft with the actual horizon. The disoriented pilots as a result may place the aircraft in a dangerous attitude.

Autokinesis

When flying in the dark, a stationary light may appear to move if it is stared at for a prolonged period of time. As a result, a pilot may attempt to align the aircraft with the perceived moving light potentially causing him/her to lose control of the aircraft. This illusion is known as "autokinesis."

Postural Considerations

The postural system sends signals from the skin, joints, and muscles to the brain that are interpreted in relation to the Earth's gravitational pull. These signals determine posture. Inputs from each movement update the body's position to the brain on a constant basis. "Seat of the pants" flying is largely dependent upon these signals. Used in conjunction with visual and vestibular clues, these sensations can be fairly reliable. However, because of the forces acting upon the body in certain flight situations, many false sensations can occur due to acceleration forces overpowering gravity. *[Figure 17-6]* These situations include uncoordinated turns, climbing turns, and turbulence.

Demonstration of Spatial Disorientation

There are a number of controlled aircraft maneuvers a pilot can perform to experiment with spatial disorientation. While each maneuver normally creates a specific illusion, any false sensation is an effective demonstration of disorientation. Thus, even if there is no sensation during any of these maneuvers, the absence of sensation is still an effective demonstration because it illustrates the inability to detect bank or roll.

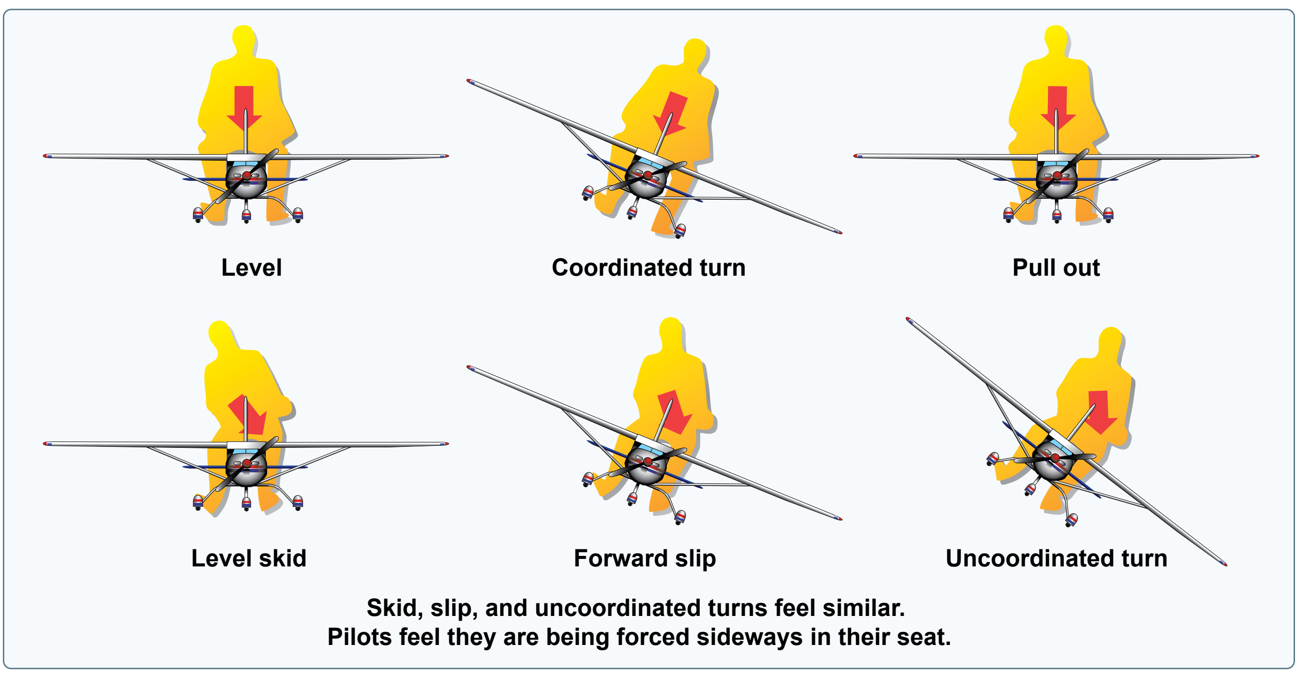


Figure 17-6. *Sensations from centrifugal force.*

There are several objectives in demonstrating these various maneuvers.

1. They teach pilots to understand the susceptibility of the human system to spatial disorientation.
2. They demonstrate that judgments of aircraft attitude based on bodily sensations are frequently false.
3. They help decrease the occurrence and degree of disorientation through a better understanding of the relationship between aircraft motion, head movements, and resulting disorientation.
4. They help instill a greater confidence in relying on flight instruments for assessing true aircraft attitude.

A pilot should not attempt any of these maneuvers at low altitudes or in the absence of an instructor pilot or an appropriate safety pilot.

Climbing While Accelerating

With the pilot's eyes closed, the instructor pilot maintains approach airspeed in a straight-and-level attitude for several seconds, then accelerates while maintaining straight-and-level attitude. The usual illusion during this maneuver, without visual references, is that the aircraft is climbing.

Climbing While Turning

With the pilot's eyes still closed and the aircraft in a straight-and-level attitude, the instructor pilot now executes, with a relatively slow entry, a well coordinated turn of about 1.5 positive G (approximately 50° bank) for 90°. While in the turn, without outside visual references and under the effect of the slight positive G, the usual illusion produced is that of a climb. Upon sensing the climb, the pilot should immediately open the eyes to see that a slowly established, coordinated turn produces the same sensation as a climb.

Diving While Turning

Repeating the previous procedure, but with the pilot's eyes should be kept closed until recovery from the turn is approximately one-half completed, can create the illusion of diving while turning.

Tilting to Right or Left

While in a straight-and-level attitude, with the pilot's eyes closed, the instructor pilot executes a moderate or slight skid to the left with wings level. This creates the illusion of the body being tilted to the right.

Reversal of Motion

This illusion can be demonstrated in any of the three planes of motion. While straight and level, with the pilot's eyes closed, the instructor pilot smoothly and positively rolls the aircraft to approximately 45° bank attitude while maintaining heading and pitch attitude. This creates the illusion of a strong sense of rotation in the opposite direction. After this illusion is noted, the pilot should open his or her eyes and observe that the aircraft is in a banked attitude.

Diving or Rolling Beyond the Vertical Plane

This maneuver may produce extreme disorientation. While in straight-and-level flight, the pilot should sit normally, either with eyes closed or gaze lowered to the floor. The instructor pilot starts a positive, coordinated roll toward a 30° or 40° angle of bank. As this is in progress, the pilot tilts his or her head forward, looks to the right or left, then immediately returns his or her head to an upright position. The instructor pilot should time the maneuver so the roll is stopped as the pilot returns his or her head upright. An intense disorientation is usually produced by this maneuver, and the pilot experiences the sensation of falling downward into the direction of the roll.

In the descriptions of these maneuvers, the instructor pilot is doing the flying, but having the pilot do the flying can also be a very effective demonstration. The pilot should close his or her eyes and tilt the head to one side. The instructor pilot tells the pilot what control inputs to perform. The pilot then attempts to establish the correct attitude or control input with eyes closed and head tilted. While it is clear the pilot has no idea of the actual attitude, he or she will react to what the senses are saying. After a short time, the pilot will become disoriented and the instructor pilot will tell the pilot to look up and recover. This exercise allows the pilot to experience the disorientation while flying the aircraft.

Coping with Spatial Disorientation

To prevent illusions and their potentially disastrous consequences, pilots can:

1. Understand the causes of these illusions and remain constantly alert for them. Take the opportunity to experience spatial disorientation illusions in a device, such as a Barany chair, a Vertigon, or a Virtual Reality Spatial Disorientation Demonstrator.
2. Always obtain and understand preflight weather briefings.
3. Before flying in marginal visibility (less than 3 miles) or where a visible horizon is not evident, such as flight over open water during the night, obtain training and maintain proficiency in aircraft control by reference to instruments.
4. Do not fly into adverse weather conditions or into dusk or darkness unless proficient in the use of flight instruments. If intending to fly at night, maintain

night-flight currency and proficiency. Include cross-country and local operations at various airfields.

5. Ensure that when outside visual references are used, they are reliable, fixed points on the Earth's surface.
6. Avoid sudden head movement, particularly during takeoffs, turns, and approaches to landing.
7. Be physically tuned for flight into reduced visibility. Ensure proper rest, adequate diet, and, if flying at night, allow for night adaptation. Remember that illness, medication, alcohol, fatigue, sleep loss, and mild hypoxia are likely to increase susceptibility to spatial disorientation.
8. Most importantly, become proficient in the use of flight instruments and rely upon them. Trust the instruments and disregard your sensory perceptions.

The sensations that lead to illusions during instrument flight conditions are normal perceptions experienced by pilots. These undesirable sensations cannot be completely prevented, but through training and awareness, pilots can ignore or suppress them by developing absolute reliance on the flight instruments. As pilots gain proficiency in instrument flying, they become less susceptible to these illusions and their effects.

Optical Illusions

Of the senses, vision is the most important for safe flight. However, various terrain features and atmospheric conditions can create optical illusions. These illusions are primarily associated with landing. Since pilots must transition from reliance on instruments to visual cues outside the flight deck for landing at the end of an instrument approach, it is imperative that they be aware of the potential problems associated with these illusions and take appropriate corrective action. The major illusions leading to landing errors are described below.

Runway Width Illusion

A narrower-than-usual runway can create an illusion that the aircraft is at a higher altitude than it actually is, especially when runway length-to-width relationships are comparable. *[Figure 17-7]* The pilot who does not recognize this illusion will fly a lower approach, with the risk of striking objects along the approach path or landing short. A wider-than-usual runway can have the opposite effect with the risk of the pilot leveling out the aircraft high and landing hard or overshooting the runway.

Runway and Terrain Slopes Illusion

An upsloping runway, upsloping terrain, or both can create an illusion that the aircraft is at a higher altitude than it actually is. *[Figure 17-7]* The pilot who does not recognize this illusion will fly a lower approach. Downsloping runways and downsloping approach terrain can have the opposite effect.

Featureless Terrain Illusion

An absence of surrounding ground features, as in an overwater approach over darkened areas or terrain made featureless by snow, can create an illusion that the aircraft is at a higher altitude than it actually is. This illusion, sometimes referred to as the "black hole approach," causes pilots to fly a lower approach than is desired.

Water Refraction

Rain on the windscreen can create an illusion of being at a higher altitude due to the horizon appearing lower than it is. This can result in the pilot flying a lower approach.

Haze

Atmospheric haze can create an illusion of being at a greater distance and height from the runway. As a result, the pilot has a tendency to be low on the approach. Conversely, extremely clear air (clear bright conditions of a high attitude airport) can give the pilot the illusion of being closer than he or she actually is, resulting in a high approach that may result in an overshoot or go around. The diffusion of light due to water particles on the windshield can adversely affect depth perception. The lights and terrain features normally used to gauge height during landing become less effective for the pilot.

Fog

Flying into fog can create an illusion of pitching up. Pilots who do not recognize this illusion often steepen the approach abruptly.

Ground Lighting Illusions

Lights along a straight path, such as a road or lights on moving trains, can be mistaken for runway and approach lights. Bright runway and approach lighting systems, especially where few lights illuminate the surrounding terrain, may create the illusion of less distance to the runway. The pilot who does not recognize this illusion will often fly a higher approach.

How To Prevent Landing Errors Due to Optical Illusions

To prevent these illusions and their potentially hazardous consequences, pilots can:

1. Anticipate the possibility of visual illusions during approaches to unfamiliar airports, particularly at night or in adverse weather conditions. Consult airport

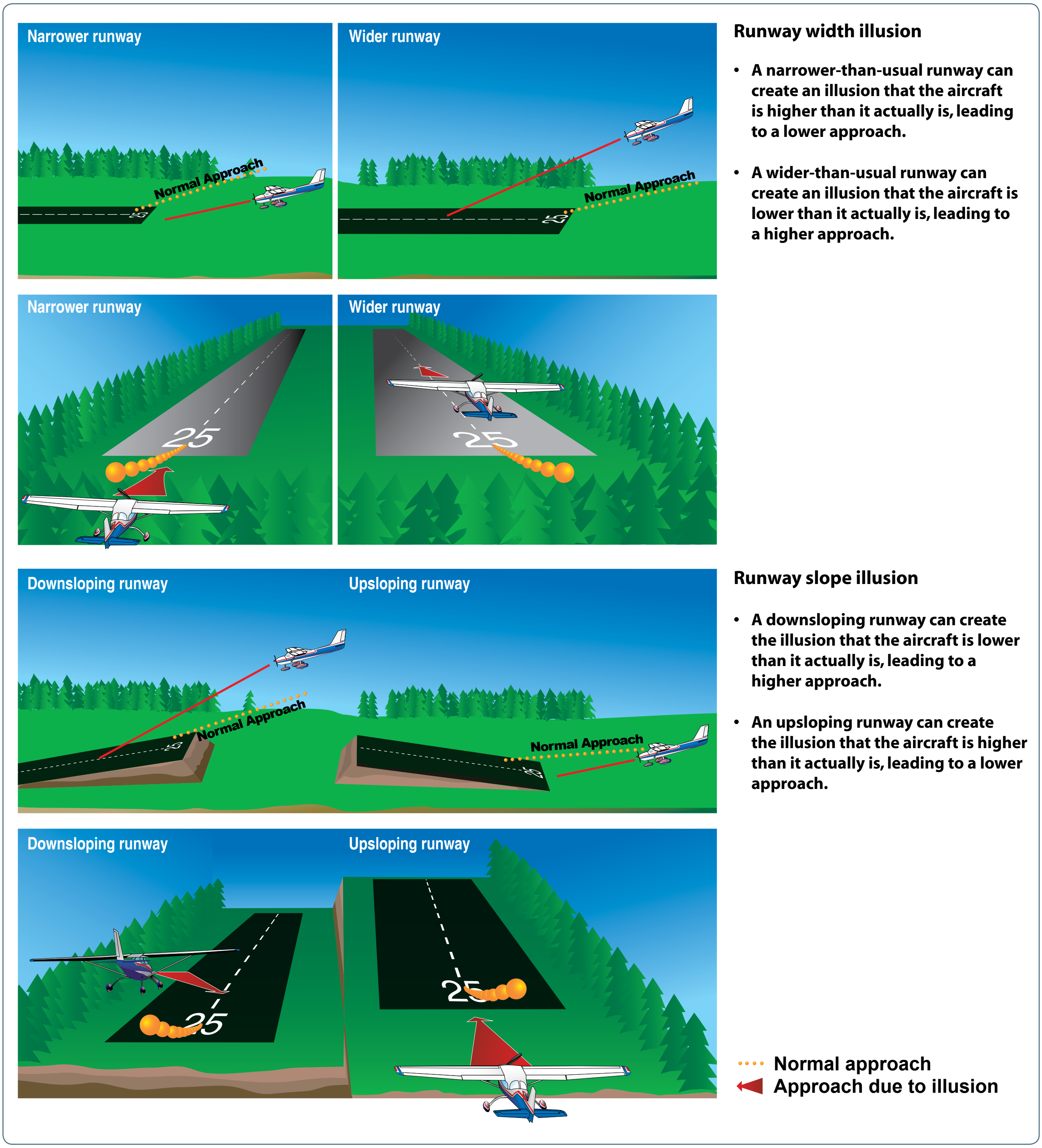


Figure 17-7. *Runway illusions.*

diagrams and the Chart Supplement U.S. (formerly Airport/Facility Directory) for information on runway slope, terrain, and lighting.

2. Make frequent reference to the altimeter, especially during all approaches, day and night.

3. If possible, conduct an aerial visual inspection of unfamiliar airports before landing.

4. Use Visual Approach Slope Indicator (VASI) or Precision Approach Path Indicator (PAPI) systems for a visual reference, or an electronic glideslope, whenever they are available.

5. Utilize the visual descent point (VDP) found on many nonprecision instrument approach procedure charts.

6. Recognize that the chances of being involved in an approach accident increase when an emergency or other activity distracts from usual procedures.
7. Maintain optimum proficiency in landing procedures.

In addition to the sensory illusions due to misleading inputs to the vestibular system, a pilot may also encounter various visual illusions during flight. Illusions rank among the most common factors cited as contributing to fatal aviation accidents.

Sloping cloud formations, an obscured horizon, a dark scene spread with ground lights and stars, and certain geometric patterns of ground light can create illusions of not being aligned correctly with the actual horizon. Various surface features and atmospheric conditions encountered in landing can create illusions of being on the wrong approach path. Landing errors due to these illusions can be prevented by anticipating them during approaches, inspecting unfamiliar airports before landing, using electronic glideslope or VASI systems when available, and maintaining proficiency in landing procedures.

Motion Sickness

Motion sickness, or airsickness, is caused by the brain receiving conflicting messages about the state of the body. A pilot may experience motion sickness during initial flights, but it generally goes away within the first few lessons. Anxiety and stress, which may be experienced at the beginning of flight training, can contribute to motion sickness. Symptoms of motion sickness include general discomfort, nausea, dizziness, paleness, sweating, and vomiting.

It is important to remember that experiencing airsickness is no reflection on one's ability as a pilot. If prone to motion sickness, let the flight instructor know, there are techniques that can be used to overcome this problem. For example, avoid lessons in turbulent conditions until becoming more comfortable in the aircraft or start with shorter flights and graduate to longer instruction periods. If symptoms of motion sickness are experienced during a lesson, opening fresh air vents, focusing on objects outside the airplane, and avoiding unnecessary head movements may help alleviate some of the discomfort. Although medications like Dramamine can prevent airsickness in passengers, they are not recommended while flying since they can cause drowsiness and other problems.

Carbon Monoxide (CO) Poisoning

CO is a colorless and odorless gas produced by all internal combustion engines. Attaching itself to the hemoglobin in the blood about 200 times more easily than oxygen, CO prevents the hemoglobin from carrying oxygen to the cells, resulting in hypemic hypoxia. The body requires up to 48 hours to dispose of CO. If severe enough, the CO poisoning can result in death. Aircraft heater vents and defrost vents may provide CO a passageway into the cabin, particularly if the engine exhaust system has a leak or is damaged. If a strong odor of exhaust gases is detected, assume that CO is present. However, CO may be present in dangerous amounts even if no exhaust odor is detected. Disposable, inexpensive CO detectors are widely available. In the presence of CO, these detectors change color to alert the pilot of the presence of CO. Some effects of CO poisoning are headache, blurred vision, dizziness, drowsiness, and/or loss of muscle power. Any time a pilot smells exhaust odor, or any time these symptoms are experienced, immediate corrective action should be taken including turning off the heater, opening fresh air vents and windows, and using supplemental oxygen, if available.

Tobacco smoke also causes CO poisoning. Smoking at sea level can raise the CO concentration in the blood and result in physiological effects similar to flying at 8,000 feet. Besides hypoxia, tobacco causes diseases and physiological debilitation that can be medically disqualifying for pilots.

Stress

Stress is the body's response to physical and psychological demands placed upon it. The body's reaction to stress includes releasing chemical hormones (such as adrenaline) into the blood and increasing metabolism to provide more energy to the muscles. Blood sugar, heart rate, respiration, blood pressure, and perspiration all increase. The term "stressor" is used to describe an element that causes an individual to experience stress. Examples of stressors include physical stress (noise or vibration), physiological stress (fatigue), and psychological stress (difficult work or personal situations).

Stress falls into two broad categories: acute (short term) and chronic (long term). Acute stress involves an immediate threat that is perceived as danger. This is the type of stress that triggers a "fight or flight" response in an individual, whether the threat is real or imagined. Normally, a healthy person can cope with acute stress and prevent stress overload. However, ongoing acute stress can develop into chronic stress.

Chronic stress can be defined as a level of stress that presents an intolerable burden, exceeds the ability of an individual to cope, and causes individual performance to fall sharply. Unrelenting psychological pressures, such as loneliness, financial worries, and relationship or work problems can produce a cumulative level of stress that exceeds a person's ability to cope with the situation. When stress reaches these levels, performance falls off rapidly. Pilots experiencing this level of stress are not safe and should not exercise their airman privileges. Pilots who suspect they are suffering from chronic stress should consult a physician.

Fatigue

Fatigue is frequently associated with pilot error. Some of the effects of fatigue include degradation of attention and concentration, impaired coordination, and decreased ability to communicate. These factors seriously influence the ability to make effective decisions. Physical fatigue results from sleep loss, exercise, or physical work. Factors such as stress and prolonged performance of cognitive work result in mental fatigue.

Like stress, fatigue falls into two broad categories: acute and chronic. Acute fatigue is short term and is a normal occurrence in everyday living. It is the kind of tiredness people feel after a period of strenuous effort, excitement, or lack of sleep. Rest after exertion and 8 hours of sound sleep ordinarily cures this condition.

A special type of acute fatigue is skill fatigue. This type of fatigue has two main effects on performance:

- Timing disruption—appearing to perform a task as usual, but the timing of each component is slightly off. This makes the pattern of the operation less smooth because the pilot performs each component as though it were separate, instead of part of an integrated activity.
- Disruption of the perceptual field—concentrating attention upon movements or objects in the center of vision and neglecting those in the periphery. This is accompanied by loss of accuracy and smoothness in control movements.

Acute fatigue has many causes, but the following are among the most important for the pilot:

- Mild hypoxia (oxygen deficiency)
- Physical stress
- Psychological stress
- Depletion of physical energy resulting from psychological stress
- Sustained psychological stress

Sustained psychological stress accelerates the glandular secretions that prepare the body for quick reactions during an emergency. These secretions make the circulatory and respiratory systems work harder, and the liver releases energy to provide the extra fuel needed for brain and muscle work. When this reserve energy supply is depleted, the body lapses into generalized and severe fatigue.

Acute fatigue can be prevented by proper diet and adequate rest and sleep. A well-balanced diet prevents the body from needing to consume its own tissues as an energy source. Adequate rest maintains the body's store of vital energy.

Chronic fatigue, extending over a long period of time, usually has psychological roots, although an underlying disease is sometimes responsible. Continuous high-stress levels produce chronic fatigue. Chronic fatigue is not relieved by proper diet and adequate rest and sleep and usually requires treatment by a physician. An individual may experience this condition in the form of weakness, tiredness, palpitations of the heart, breathlessness, headaches, or irritability. Sometimes chronic fatigue even creates stomach or intestinal problems and generalized aches and pains throughout the body. When the condition becomes serious enough, it leads to emotional illness.

If suffering from acute fatigue, stay on the ground. If fatigue occurs in the flight deck, no amount of training or experience can overcome the detrimental effects. Getting adequate rest is the only way to prevent fatigue from occurring. Avoid flying without a full night's rest, after working excessive hours, or after an especially exhausting or stressful day. Pilots who suspect they are suffering from chronic fatigue should consult a physician.

Exposure to Chemicals

When conducting preflight and post-flight inspections, pilots must verify that the fluid levels in their aircraft meet the levels specified for safe operations as stated in the Pilot's Operating Handbook. These fluids include, but are not limited to hydraulic fluid, engine oil, and fuel.

It is important that every pilot recognize the potential hazards of working with these fluids as well as the recommended first aid measures to follow should any of these fluids come in contact with their eyes, skin, and/or respiratory system. As the specific first aid measures for dealing with exposure to these chemicals can vary by chemical type, it is important that every pilot be familiar with the location and use of the Material Safety Data Sheet (MSDS) for each chemical they encounter.

The procedures described in the following sections are minimum guideline for first aid for each of the indicated scenarios. Ultimately, the pilot should consult the MSDS for first aid procedures specific to the type of chemical and exposure scenario.

Hydraulic Fluid

- Eye Contact—immediately flush the eyes with clean water and seek medical attention if irritation occurs.
- Skin Contact—remove all contaminated clothing and thoroughly cleanse the affected areas with mild soap and water or a waterless hand cleaner. If irritation or redness develops and persists, seek medical attention. Should the hydraulic fluid get into or under the skin, or into any other part of the body, regardless of the

appearance of the wound or its size, seek medical attention immediately.

- Inhalation—if respiratory symptoms develop, move away from the source of exposure and into fresh air in a position comfortable for breathing. If symptoms persist, seek medical attention.
- Ingestion—first aid is not normally required; however, if swallowed and symptoms develop, seek medical attention.

Engine Oil

- Eye Contact—immediately flush the eyes with clean water and seek medical attention if irritation occurs.
- Skin Contact—remove all contaminated clothing and thoroughly cleanse the affected areas with soap and water. Launder contaminated clothing before reuse.
- Inhalation—move away from the source of exposure and into fresh air. If respiratory irritation, dizziness, nausea, or unconsciousness occurs, seek immediate medical attention. If breathing stops, assisted ventilation is required via a bag-valve-mask or cardiopulmonary resuscitation (CPR).
- Ingestion—seek immediate medical attention. If immediate medical attention is not available, contact a regional poison control center or emergency medical professional regarding the induction of vomiting or use of activated charcoal. Vomiting should never be induced to a person who is groggy or unconscious.

Fuel

- Eye Contact—immediately flush the eyes with clean water for at least 15 minutes and seek medical attention immediately.
- Skin Contact—remove all contaminated clothing and thoroughly cleanse the affected areas with mild soap and water or a waterless hand cleaner. If skin surface is damaged, apply a clean dressing and seek medical attention. If irritation or redness develops, seek medical attention. Launder contaminated clothing before reuse.
- Inhalation—move away from the source of exposure and into fresh air. If breathing stops, assisted ventilation is required via a bag-valve-mask or cardiopulmonary resuscitation (CPR). Once breathing is restored, the use of additional oxygen may be necessary. Seek medical attention immediately.
- Ingestion—seek immediate medical attention. Do not induce vomiting or take anything by mouth as this may cause the material to enter the lungs and cause severe lung damage. Should vomiting occur, keep head below the hips to reduce the risks of aspiration. Monitor for breathing difficulties. Rinse out any material which enters the mouth until the taste is dissipated.

Dehydration and Heatstroke

Dehydration is the term given to a critical loss of water from the body. Causes of dehydration are hot flight decks and flight lines, wind, humidity, and diuretic drinks—coffee, tea, alcohol, and caffeinated soft drinks. Some common signs of dehydration are headache, fatigue, cramps, sleepiness, and dizziness.

The first noticeable effect of dehydration is fatigue, which in turn makes top physical and mental performance difficult, if not impossible. Flying for long periods in hot summer temperatures or at high altitudes increases the susceptibility to dehydration because these conditions tend to increase the rate of water loss from the body.

To help prevent dehydration, drink two to four quarts of water every 24 hours. Since each person is physiologically different, this is only a guide. Most people are aware of the eight-glasses-a-day guide: If each glass of water is eight ounces, this equates to 64 ounces, which is two quarts. If this fluid is not replaced, fatigue progresses to dizziness, weakness, nausea, tingling of hands and feet, abdominal cramps, and extreme thirst.

The key for pilots is to be continually aware of their condition. Most people become thirsty with a 1.5 quart deficit or a loss of 2 percent of total body weight. This level of dehydration triggers the “thirst mechanism.” The problem is that the thirst mechanism arrives too late and is turned off too easily. A small amount of fluid in the mouth turns this mechanism off and the replacement of needed body fluid is delayed.

Other steps to prevent dehydration include:

- Carrying a container in order to measure daily water intake.
- Staying ahead—not relying on the thirst sensation as an alarm. If plain water is not preferred, add some sport drink flavoring to make it more acceptable.
- Limiting daily intake of caffeine and alcohol (both are diuretics and stimulate increased production of urine).

Heatstroke is a condition caused by any inability of the body to control its temperature. Onset of this condition may be recognized by the symptoms of dehydration, but also has been known to be recognized only upon complete collapse.