The Human in the Cockpit 12

Human factors, as it relates to flying an aircraft, is the interaction between the pilot, the flying environment, and the aircraft. The area defined by human factors is complex and is where most errors occur. To safely operate an aircraft, you need to develop an awareness of not only the physiological aspect of flying, but also those that influence workload and fatigue, decision making, and situational awareness. It is vital that you, as a pilot, understand and appreciate how these factors affect your everyday flying.



Figure 12-1
The pilot is human.

This chapter will discuss the following elements of the human in the cockpit:

- the physical pilot;
- the flight environment;
- health and well-being;
- vision and visual illusions;
- hearing and balance;
- situational awareness; and
- decision making.

The Physical Pilot

Circulatory System

The circulatory, or cardiovascular, system moves blood around the body, carrying oxygen and nutrients to the cells, and takes away waste products such as carbon dioxide. Blood is composed of plasma that carries red and white blood cells, or corpuscles. The red blood cells contain the iron-rich pigment hemoglobin, the principal function of which is to transport oxygen around the body. The white blood cells, of which there are various types, protect the body against foreign substances and are involved in the production of antibodies. The antibodies attack any substance that the body regards as foreign or dangerous. Platelets in the blood function to form clots when necessary to stop loss of blood from an injury.

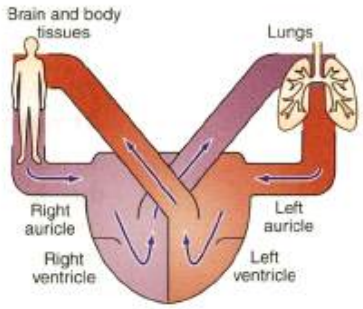


Figure 12-2 Circulatory system.

Heart

The heart is a muscular pump, about the size of a closed fist, that is divided into two sides, each with two chambers. The muscles of the heart contract in a double-action pulse, forcing blood through the one-way heart valves and through the network of arteries. This pump stroke causes a pressure pulse which can be felt at various parts of the body where the arteries are near the surface (such as the wrist and the side of the neck). Blood pressure is a measure of the pressure of the blood against the walls of the main arteries. It is necessary for the blood to be continuously replenished with oxygen, which it gives out to the tissues, and at the same time rid itself of the carbon dioxide that it acquires.

Circulation

On long flights you may be seated and stationary for very long periods. You can improve circulation by contracting and relaxing your stomach diaphragm as well as the leg and buttock muscles. Without the physical demand of activity, the heart will go into a dormant mode and the circulation slows down. This leads to sleepiness and loss of concentration. The muscles atrophy and you could suffer cramps. It is important to change your seating position and, if possible, exercise individual muscles by stretching and straightening the joints, and occasionally shaking a leg or twisting to improve circulation.

Respiratory System

The process of respiration brings oxygen into the body and removes carbon dioxide. The body has a permanent need for oxygen; it is used in the energy-producing burning process that goes on in every cell of the body tissues. The body is unable to store oxygen permanently and hence the need for continuous breathing. Any interruption to breathing lasting more than a few minutes may lead to permanent physical damage, especially of the brain, and to possible death.

Flight Environment

Atmosphere

Air is made up of 21% oxygen, 78% nitrogen, and 1% carbon dioxide and other inert gases.

The earth is surrounded and protected by a life-giving layer called the atmosphere. The atmosphere consists of a transparent mixture of gases that we call air. The atmosphere is held to the earth by the force of gravity and, because air is compressible, it packs in around the earth's surface. As altitude is gained, the air thins with fewer and fewer molecules in the same volume, but the percentage of each of the components of the air does not change. Total air pressure falls with altitude, as does the partial pressure of each of the gases in the air. (Total air pressure is a sum of all of the partial pressures.)

The International Standard Atmosphere

So that we have a common reference, scientists have agreed on average atmospheric conditions called the *International Standard Atmosphere* (ISA) or, simply, standard atmosphere. Like the "average" person, it never exists, but it is an essential yardstick used for comparisons, especially of aircraft performance. The standard atmosphere is as follows:

- sea level temperature: 59°F (15°C);
- lapse rate: –3.5°F (–2°C) per 1,000 feet;
- freezing level (32°F/0°C): 7,500 feet;
- sea level pressure: 29.92 in. Hg (1,013.2 hectopascals);
- tropopause: 36,080 feet; and
- temperature at the tropopause: –56°C.

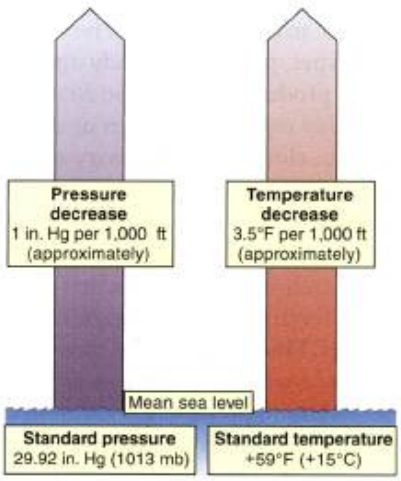


Figure 12-3 Standard atmosphere.

Flying at Altitude

The human body is designed to function in the lower levels of the atmosphere, where the air is fairly dense. Aircraft may operate at quite high altitudes where the air density is very low, exposing the pilot to possible oxygen deficiency and other problems such as low ambient temperatures. There are three major effects of altitude on the human body brought about by pressure changes:

- lower external pressure causes gases inside body cavities to expand;
- lower oxygen pressure causes hypoxia; and
- dissolved gases form bubbles in the blood, also due to decreased external pressure.

Hypoxia

Hypoxia is a deficiency of oxygen in the body.

Hypoxia is a condition in which oxygen concentration in the tissues is less than normal. Total absence of oxygen is called *anoxia*. Hypoxia is a lack of oxygen and may be caused by:

- a lack of oxygen in the air (called *hypoxic hypoxia*);
- a partial pressure of oxygen that is too low; or
- an inability of the blood to carry oxygen (called *anaemic hypoxia*) due to a medical condition (anaemia) or to carbon monoxide poisoning in the blood (from, say, a faulty engine exhaust system or smoking cigarettes).

Air pressure and density decrease with altitude; approximately 18,000 feet is where atmospheric pressure is at 50% of sea level (1,000 mb versus 500 mb). As an airplane climbs, the density of the air in which it is flying gradually reduces. The less dense the air, the lower the mass of oxygen taken into the lungs in each breath. In addition, the lower partial pressure of oxygen at altitude (i.e. fewer percentage of molecules), further reduces the amount of oxygen that will diffuse across the alveoli membranes into the bloodstream. A high cabin altitude therefore means less oxygen will be transported around the body, and less energy will be generated (including in the brain). Hypoxia is subtle and it sneaks up on you, like the effects of that extra glass of wine. Rapid rates of ascent can allow higher altitudes to be reached before severe symptoms occur. In these circumstances, unconsciousness may occur before any or many of the symptoms of hypoxia appear. At 9,000 feet, the partial pressure of oxygen in the air is about *half* that at sea level.

The initial symptoms of hypoxia may hardly be noticeable to the sufferer, and in fact they often include feelings of euphoria. The brain is affected quite early, so a false sense of security and well-being may be present. Physical movements will become clumsy, but the pilot may not notice this. Difficulty in concentrating, faulty judgment, moodiness, drowsiness, indecision, giddiness, physical clumsiness, headache, deterioration of vision, high pulse rate, blue lips and fingernails (cyanosis), and tingling of the skin may all follow, ending in loss of consciousness. Throughout all of this pilots will probably feel euphoric and as if doing a great job.

In this oxygen-deficient condition, a pilot is less able to think clearly and perform physically. The body attempts to compensate by increasing the pulse rate, and the rate and depth of ventilation. Pilots between 25 and 50 years who are in good physical condition and regularly exposed to low oxygen levels have a higher tolerance. Above about 8,000 feet cabin altitude, the effects of oxygen deprivation may start to become apparent in some pilots, especially if the pilot is active or under stress. At 10,000 feet, most people can still cope with the diminished oxygen supply, but above 10,000 feet supplementary oxygen is required (i.e. oxygen supplied through a mask), if a marked deterioration in performance is not to occur. At 14,000 feet without supplementary oxygen, performance will be very poor and, at 18,000 feet, the pilot may become unconscious. This will occur at lower altitudes if the pilot is a smoker, or is unfit or fatigued.

Avoid hypoxia by using supplemental oxygen at high cabin altitudes (above 10,000 feet).

In general terms, 10,000 feet is considered to be the critical cabin altitude above which flight crew should wear an oxygen mask (5,000 feet at night). The effects of oxygen deprivation are very personal in that they may differ from person to person and become apparent at different cabin altitudes. Some people are more resilient than others; however, the event of oxygen deprivation will eventually produce the same effects. For instance, night vision will generally start to deteriorate at a cabin altitude of above 4,000 feet.

Susceptibility to hypoxia is increased by anything that reduces the oxygen available to the brain, such as a high cabin altitude (of course), high or low temperatures, illness, stress, fatigue, physical activity, or smoke in the cockpit. The reduction of the oxygen-carrying capacity of the blood by smoking has the same effect as increasing the cabin altitude by 4,000–5,000 feet and this effect intensifies as the airplane climbs to higher altitudes. The preference of hemoglobin for carbon monoxide, as opposed to oxygen, means that a person who has been smoking has less oxygen circulating than would have been the case had CO not been absorbed. The onset of symptoms of hypoxia will occur at a lower altitude in that person. However, a smoker is acclimated to being hypoxic and may be more tolerant—to a degree.

Tolerance to hypoxia can be reduced by a loss of blood, as is the case after a person has made a blood donation. It is therefore recommended that active pilots do not donate blood. Should you decide you do want to give blood, it is recommended not to fly for 24 hours afterward.

Time of Useful Consciousness. If a person is deprived of an adequate supply of oxygen, unconsciousness will ultimately result. The cells of the brain are particularly sensitive to a lack of oxygen, even for a brief period. Total cessation of the oxygen supply to the brain results in unconsciousness in six to eight seconds and irreversible damage ensues if the oxygen supply is not restored within four minutes. The time available for pilots to perform useful tasks without a supplementary oxygen supply, and before severe hypoxia sets in, is known as the *time of useful consciousness* (TUC), or *effective performance time* (EPT). TUC/EPT reduces with increasing altitude.

Altitude above sea level	Sudden failure of oxygen supply	
	Moderate activity	Minimal activity
18,000 feet	20 minutes	30 minutes
22,000 feet	5 minutes	10 minutes
25,000 feet	2 minutes	3 minutes
28,000 feet	1 minute	1½ minutes
30,000 feet	45 seconds	1¼ minutes
35,000 feet	30 seconds	45 seconds
40,000 feet	12 seconds	15 seconds

Table 12-1 Time of useful consciousness (effective performance time).

Barotrauma

Another effect of increasing cabin altitude is that gases trapped in parts of your body—such as the stomach, intestines, sinuses, middle ear, or in a decaying tooth—will want to expand as external pressure decreases. Either they will be able to escape into the atmosphere, or they may be trapped and possibly cause pain known as *barotrauma*. Pain is most severe on ascent with teeth and intestines and on descent with ears and sinus. Foods such as legumes and leafy greens known to produce gas should be avoided when flying.

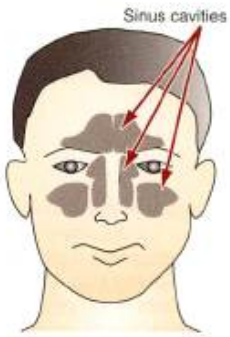


Figure 12-4
Sinus cavities in the skull.

Barotrauma of the Ears. You hear sound because waves of air pressure move a membrane within your ear (eardrum). The cavity behind the eardrum has a small tube (the Eustachian tube) that is open through the nose and allows air pressure on the inside to be balanced with outside air pressure. If you have a head cold or sinusitis, this tube can become restricted or even totally blocked. If this is the case, as the aircraft climbs, the air inside the ear easily escapes through the tube because that is the normal direction of fluid movement. However, when you descend again, you end up in a situation where the air on the outside of the drum is at a higher pressure than the air inside. It may collapse the tube. Because of this restriction, air cannot pass through to balance the pressure and so the eardrum is pushed in. This can be painful or even damaging. The pressure can usually be helped to equalize and open the Eustachian tube by swallowing, chewing, or by blowing with the mouth and nose held shut.

Decompression Sickness (The Bends)

Gas bubbles in the body will cause great pain and some immobilization in the shoulders, arms and joints. This serious complaint is known as *decompression sickness* or *the bends*. The remedy is to subject the body to a region of high pressure for a lengthy period of time (in a *recompression* chamber, for example), and then gradually return it to normal pressures over a period of hours or days. In an aircraft, the best you can do if the bends is suspected is to descend to a low altitude, where air pressure is greater. Even landing may not provide a sufficient pressure increase to remedy the problem, in which case seek medical assistance without delay. Sometimes low altitude pressure will cause nitrogen to form bubbles; however, this is unlikely below 18,000 feet.

Scuba Diving. Decompression sickness can result from flying after scuba diving. When the body is deep under water it is subjected to strong pressures, and certain gases, such as nitrogen, are absorbed into the blood under pressure, because the air cylinders have to be pressurized above the local water pressure so the lungs can inhale increasing the partial pressure of nitrogen. The deeper and longer the dive, the more this absorption occurs. If the pressure on the body is then reduced too quickly—say, by rapidly returning to the surface from a great depth or, even worse, by then flying in an airplane at high cabin altitudes—the gases (especially nitrogen) will come out of the blood solution and form bubbles in the bloodstream and tissues, especially the joints. (You can see the same effect caused by a sudden reduction in pressure when the top is removed from carbonated drinks and bubbles of gas come out.)

Decompression sickness can follow scuba diving.



Figure 12-5
Do not fly within 24 hours of scuba diving.

Rules regarding scuba diving and flying vary slightly from country to country. The current Diver's Alert Network's recommendation is that you do not fly for 12 hours after any single dive without decompression stops. A greater surface interval is needed after multiple dives or dives with decompression stops. Ask your instructor for advice.

Decompression stops are necessary if a dive is deeper than 33 feet. At this depth, the pressure is twice that at sea level, and the amount of nitrogen dissolved increases appreciably.

Snorkeling will not cause decompression sickness as you are not taking in air under pressure. The risk of suffering decompression sickness increases with the depth to which you dive, the rate at which you resurface, how soon after you fly, how high you fly, how quickly the cabin altitude increases, your age, obesity, fatigue, and reexposure to decompression within 24 hours.

Hyperventilation

Hyperventilation is an involuntary and inappropriate increase in breathing rate, and is usually a symptom of psychological distress.

Hyperventilation occurs when the body over breathes due to some psychological distress such as fear or anxiety (gasping for breath). It is most likely to occur with inexperienced pilots in new situations. It is a self-perpetuating cycle, in which a feeling of breathlessness and dizziness develops—one is unable to catch one's breath and so one becomes more stressed—and continues even if the triggering influence is removed.

Carbon Monoxide Poisoning

Engine smells in the cabin are a warning that carbon monoxide may be present.

Carbon monoxide is produced during combustion. It is present in engine exhaust gases and in cigarette smoke, both of which can sometimes be found in the cockpit. Its entry into the cockpit may be from a faulty heating system. Carbon monoxide is a colorless, odorless, tasteless and poisonous gas for which hemoglobin in the blood has an enormous affinity. If carbon monoxide molecules are inhaled, then the hemoglobin will transport them in preference to oxygen, causing the body and the brain to suffer oxygen starvation, even though oxygen is present in the air. Hence, the first cigarette can cause light-headedness. Carbon monoxide poisoning is insidious and can be ultimately fatal. Recovery, even on pure oxygen, may take several hours.

Susceptibility to carbon monoxide poisoning increases as the cabin altitude increases because there is already an oxygen deficiency. Many cabin heating systems use warm air from around the engine and exhaust manifold as their source of heat. Any leaks in the engine exhaust system can allow carbon monoxide to enter the cabin in the heating air and possibly through open windows and cracks. To minimize the effect of any carbon monoxide that enters the cockpit in this way, fresh air should always be used in conjunction with cabin heating. Regular checks and maintenance of the aircraft are essential. Even though carbon monoxide is odorless, it may be associated with other exhaust gases that do have an odor. Engine smells in the cabin are a warning that carbon monoxide may be present. Symptoms of carbon monoxide poisoning include the following:

- headache, dizziness and nausea;
- deterioration in vision;
- impaired judgment;
- personality change;
- impaired memory;
- slower breathing rate;
- cherry-red complexion;
- loss of muscular power;
- convulsions; and
- coma and eventually death.

Carbon monoxide poisoning is serious and can be fatal!

If carbon monoxide is suspected in the cabin, carry out the following actions:

- shut off the cabin heat;
- stop all smoking;
- increase the supply of fresh air through vents (except exhaust ones) and windows; and
- land as soon as possible.

Many operators place carbon monoxide detectors in the cockpit. The most common type contains crystals that change color when carbon monoxide is present. These detectors are inexpensive and are a wise investment, but they do have a limited life, so check the expiration date. If the detector is date-expired, it is not reliable. Indeed, the crystal-type detector may not be as reliable as first thought. Increasingly, the more costly, but more effective, electronic detectors are being recommended. Be aware that carbon monoxide is not the only toxic chemical to which you may be exposed in aircraft operations (agricultural pilots especially). Vapors and fumes from fuels and lubricants, poorly packed dangerous goods, and other products of combustion may produce a range of symptoms including skin, eye and lung irritation, dizziness, drowsiness, confusion and loss of consciousness.

Dehydration

Dehydration is not only associated with hot days and intense sporting activities when you don't drink enough. It is also a problem when sitting relatively still when flying. As you climb, the atmosphere becomes less dense and is much colder. Both decreased density and temperature means less water is available in the atmosphere. So just by breathing, you are going to lose moisture from your lungs at a greater rate than you would at sea level. On large aircraft, the pressurization and air conditioning tend to reduce the moisture content of the air still further. Aircraft manufacturers incorporate humidifiers in these systems to keep the cabin environment comfortable. On any flight of more than an hour or so and especially in summer, always carry drinking water and sip it regularly. Don't wait until you are thirsty. Dehydration can quickly affect the brain's ability to function rationally.

Condition	Cause/ Altitude	Common Symptoms	Notes	Actions
Hypoxia	Rare below 10,000 feet.	Euphoria, visual disturbances, dizziness, light-headedness, confused thinking, apprehension, sense of well-being.	May be unaware of condition due to decreased partial pressure of oxygen.	Descend. Use oxygen. 10,000–33,700 feet—air-oxygen mix. 33,700–40,000 feet—100% oxygen.
Hyper-ventilation	Anxiety. Any altitude.	Light-headedness, dizziness, tingling, numbness, visual disturbances, confused thinking, tremors, faintness.	Overbreathing reduces carbon dioxide level in the blood.	Control breathing rate. Breathe into hand or bag. If above 10,000 feet, suspect hypoxia.
Carbon monoxide poisoning	Faulty exhaust heating. Smoking. Any altitude.	Headache, breathlessness, sluggishness, impaired judgment, feeling of warmth, cherry-red skin.	Hemoglobin has greater affinity for CO than for oxygen. (Smoking makes night vision poor.)	Immediate fresh air. Oxygen. Land and seek medical attention.
Decompression sickness	Flying after diving. Unlikely below 18,000 feet.	Headache, pain (joints), paralysis, choking, skin irritation.	Nitrogen forms bubbles in lungs (chokes), joints (bends), skin (creeps), central nervous system (paralysis).	Do not fly for 4 hours for dives less than 30 feet; wait longer if deeper dive.
Dehydration	Workload. Radiant heat. Perspiration.	Darker urine, dryness.	Carry drinking water in the cockpit. Cover exposed skin.	Sip water regularly in-flight.

Table 12-2 Summary of symptoms.

Health and Well-Being

General Health and Well-Being

The effects of flight on the human body and mind are representative of an average human in good health. Obviously, ill physical or psychological health adversely affects all of your capabilities, capacities, stamina, concentration, memory, and tolerances to the stresses of flight.

Health Indicators

You are the result of two primary influences: heredity (*nature*) and environment (*nurture*). One of the most reliable indicators of general health is the parentage from which you are born. If your parents were healthy and lived long lives then all you need to worry about are the environmental factors.

Blood Pressure

There are two levels of blood pressure:

- *systolic*, which is when the heart pumps (should be around 120 mm Hg); over
- *diastolic*, which is when it pauses (should be around 80 mm Hg).

The resting (diastolic) blood pressure is a good indicator of potential problems. High blood pressure can pertain with no apparent, underlying cause. It can be controlled with medication. If identifiable, the cause of the high blood pressure (*hypertension*) should also be addressed, whether it be physical or psychological.

Cholesterol

Cholesterol is formed by the body in response to dietary intake. There are two levels of cholesterol in the blood:

- low-density lipoprotein (LDL), which is related to animal fats; and
- high-density lipoprotein (HDL), which is related to exercise.

The former is not good and should be controlled by diet and exercise.

Obesity

You should maintain a reasonable degree of physical fitness. It allows better physical and mental performance during flight, and, in the long term, improves your chances of a long and healthy life. Physical fitness helps pilots cope better with stress, fatigue, and the reduced availability of oxygen. Diseases that have been directly related to obesity include osteoarthritis, hypertension (and risk of cardiovascular problems), and gout.

Medical Fitness

Disqualifying Illnesses

Disqualifying illnesses are conditions likely to restrict or deny the issue of a medical certificate either temporarily or permanently. They include heart attack, stroke, diabetes, kidney stones and ulcers.

Debilitating Illnesses

Migraines and Headaches. Headaches can be compromising due to stress, pain, distraction and reduced attention. Migraine headaches are due to the constriction of the arteries in a particular part of the brain. They can be totally incapacitating if accompanied by vision impairment, nausea, vomiting, oversensitivity to light and sound, and severe pain. Rarely, migraine attacks are accompanied by temporary, partial paralysis (one arm or one side of the body). They seem to be triggered by allergic reactions to certain foods such as cheese or chocolate, by stress, or by the removal of stress. Many are short lived and may be related to temporary circumstances, but do seek medical advice. There are treatments that are sometimes, but not always, effective. Heredity seems to be a significant factor in your susceptibility to migraine attacks.

Viruses/Colds/Flu/Middle-Ear Infections. Each eardrum has ambient pressure from the atmosphere or cabin on one side and air pressure in the middle ear on the other side, the middle ear being connected to ambient air via the Eustachian tube. During a climb, atmospheric pressure decreases and the differential pressure across the eardrum forces out the eardrum, as well as causing air to flow from the middle ear through the Eustachian tubes into the throat. In this way, the pressure differential is equalized. Any prevention of this equalization process is hazardous because of the pain and the potential to perforate the membrane of the eardrum.

Most pressurized aircraft have a low rate of climb (500 feet per minute or less) for the cabin and cockpit, allowing adequate time for pressure equalization to occur through the Eustachian tubes. This means that ear problems during the climb are generally not serious. During descent, however, difficulties with the ears may be more serious due to high rates of descent and problems with pressure equalization within the middle ear (the air finds it easier to escape through the collapsed tubes during the climb but cannot pass through the collapsed tube during the descent).

Further, the greatest proportional pressure differential occurs at lower altitudes and so the first few thousand feet on the way up and the last few on the way down are the difficult ones. Although the cockpit may be kept at 5,000 feet, the pressure change is very significant. Moreover, a depressurization with blocked Eustachian tubes could be overwhelming. High rates of descent worsen the situation. Pain in the ears can be debilitating, and there is a danger of the eardrums collapsing inward as the external pressure builds up, giving rise to a loss of hearing that may be permanent. In extreme cases, the balance mechanisms could be affected—a situation known as *pressure vertigo.* Blocked ears can sometimes be cleared by holding the nose and blowing hard (a technique known as the *Valsalva maneuver*), by chewing, swallowing or yawning. It is best not to risk flying with a head cold if you have difficulty clearing your ears. Problems can also arise in the sinuses, the cavities in the skull connected by narrow tubes to the nasal/throat passages. Blockages can cause severe pain, equivalent to the most severe headache, such that you cannot concentrate on flying.

Gastroenteritis. Gastrointestinal disorders are the most common cause of in-flight incapacitation. They may result from an improperly prepared meal (food poisoning), impure drinking water, or infection. Onset may be almost immediate following consumption of the food or drink, or it may not become evident for some hours. Even then, onset may be very sudden. The stomach pains, nausea, diarrhea and vomiting that accompany food poisoning can make it physically impossible to perform pilot duties. Some of the reflexes are uncontrollable (projectile vomiting and diarrhea, sometimes simultaneously). A wise precaution is never to have the same meal as your crew.

For the day prior to flight, avoid foods that are associated with food poisoning, including shellfish, fish, mayonnaise, creams, overripe and thin-skinned fruits, uncooked foods such as salads and raw foods, and old, tired food (e.g. food that has been cooked, then stored for some time or reheated several times). If you suspect that some symptoms of food poisoning are present or forthcoming, don't take a chance—don't fly. After the event, you will be dehydrated and weak—very weak indeed. You should not fly for at least 72 hours after the last symptoms of even a mild case of food poisoning. Gastroenteritis, flu, food poisoning, and dysentery can leave you sitting on the toilet and vomiting simultaneously. You cannot possibly fly with those symptoms. You are literally and totally incapacitated.

Cardiovascular Diseases. Diseases affecting the heart and circulatory system include the following:

- *thrombosis*—a *coronary thrombosis* is caused by blood clots (*embolisms*) obstructing the flow of blood to the heart. The heart muscle may go into irregular spasms (*fibrillation*);
- *myocardial infarction* (*heart attack*)—sudden blockage may result in the death of heart tissue;
- *angina*—part of the heart may be deprived of oxygen by a reduced blood flow when demand is increased. It is felt as pain in the chest, neck, shoulders and arm, especially the left, that comes and goes with exercise. If untreated, angina causes heart inefficiency and gradual or sudden heart failure;
- *arteriosclerosis*—the arteries can be blocked by fats, often as a the result of high cholesterol due to poor diet and lack of exercise;
- *aneurism*—a bursting of an artery, generally in the brain; and
- *stroke*—the blood flow in some part of the brain may be interrupted, leaving loss of sensation or paralysis in any part of the body but commonly on one side of the face.

Cardiovascular risk factors, in order of priority, appear to be: family history of heart disease, smoking, high blood pressure, high cholesterol, obesity, lack of exercise, diabetes and stress. Excessive alcohol consumption may also be an influence, but moderate consumption may actually be beneficial in controlling stress and cholesterol. All the above factors relate to inheritance or lifestyle, and pilots particularly need to manage the latter.

The normal electrocardiogram, or resting ECG, is a sensor that measures the heartbeat at 12 locations. It is carried out while the body is resting to check whether there is a deficiency in the action of the heart muscle. It is a here-and-now indicator that shows congenital or preexisting defects, but it cannot predict future problems.

Physical and Mental Fitness

Exercise

Keeping fit takes some effort, and this effort must be continually maintained for fitness to be retained; but it can also be good fun and very recreational. Walking, jogging, digging in the garden, cycling, swimming, in fact anything that steadily raises your pulse rate, will improve your fitness. If you are grossly unfit or obese, then allow yourself several diet-conscious months with moderate exercise that is gradually increased, and consider medical supervision. It might seem like a long haul, but the quality of life and your self-esteem will improve along with your fitness.

Fatigue and Sleep Deprivation

Do not fly when fatigued. It shows poor judgement.

Fatigue, tiredness and sleep deprivation can lower a pilot's mental and physical capacity quite dramatically. Fatigue can become deep-seated and chronic. If personal, psychological or emotional problems are not resolved, they prevent deep rest and good sleep over a prolonged period. Chronic fatigue won't be cured until the problems are resolved, or at least are being addressed, and the person can relax and unwind. You should prohibit yourself from flying if the distress is distracting.

Short-term fatigue can be caused by overwork, mental stress, an uncomfortable body position, a recent lack of sleep, living-it-up a little too much, lack of oxygen or lack of food.

Stress

Stress management includes the following:
1. *Identifying hazardous attitudes.*
2. *Learning to modify your behavior.*
3. *Recognizing and coping with stress.*
4. *Developing a method to assess risks.*
5. *Using all your resources.*
6. *Being able to evaluate your performance.*

Stress is part of our lifestyle. It is inevitable but manageable. Management of stress is relatively easy, once learned. You have to learn a way that best suits you. You need to find the particular technique that tickles your own fancy. The objective is not to confront stress head on. Like a kite it will climb against the wind and become even more challenging. The idea is to defuse it—to divide it into bite-size chunks—and remind yourself that it is temporary. It will pass and there is a future. Alcohol doesn't defuse stress: it defers it and then it is added to the next day's lot.

Coping/defusing techniques include:

- *exercise/sports*—physical demands that take your mind off mental problems are good for you. Physical demand that also requires mental concentration is even better; for example, golf, skiing or sailing are more diverting and therefore relaxing than jogging;
- *fresh air*—the wide world around you keeps everything in perspective and reinforces your hope and realization that you are both small and large in the scheme of things;
- *diversions/hobbies*—the mental and manipulative occupation of hobbies are a marvellous relaxant as their appeal usually claims one's total concentration; and
- *relaxation therapy and meditation*—these use the same technique of mental occupation and diversion so the build-up of stress is deflated by inattention. It is not the same as lying in the sun and snoozing as the brain dwells on the problem. They are effective and easy to learn techniques for focusing the single-channel processor of the conscious mind on a trivial routine symbol.

Diet and Nutrition

We are what we eat. Diet concerns what you eat, how much and in what proportions. It receives much attention in the media these days because in western society our dietary intake is poorly managed: too much animal fat, too much processed sugar, too few vegetables, cereals and fruit. In all, too much quantity and too little exercise. The suggested eating pattern is to have smaller, more varied servings often, rather than larger serves less frequently. Snacks, such as fruit, muesli bars and cereals, keep the hunger at bay and avoid the temptation to eat a large meal too quickly. Eating slowly allows the digestive system to process the food and to feel satisfied with a lesser quantity.

Water is best. Drink lots of it. Don't wait until you feel thirsty. The color of your urine should be light straw or paler. Any darker means potential dehydration. Too much fruit juice can cause bowel problems and also adds calories. Mineral-enriched health drinks are for athletes. Use them for severe exercise; otherwise, drink water. Avoid too much of the sugary soft drinks, as they make you even thirstier.

Tea and Coffee. Caffeine is a drug and stimulant. Coffee contains the most, especially espresso. Caffeine increases the pulse rate, prevents sleep, increases urination and therefore fluid loss (it is a *diuretic*), causes headaches and increases the level of stress. It may wake you up but it won't let you rest. There are also withdrawal symptoms when you stop consuming it.

Dependencies

Alcohol

Do not fly under the influence of alcohol.

Even small quantities of alcohol in the blood can impair one's performance, in addition to the danger of relieving anxiety so that the person believes he or she is performing marvelously. Alcohol severely affects a person's judgment and abilities. Reduced oxygen worsens the effect. Alcohol is a depressant. It lowers the body's natural sensitivities, cautions and fears (shown as overconfidence) and, at the same time, it lowers capabilities—a deadly combination as demonstrated by the road accident statistics. It also represses social mores and allows emotions, that would otherwise be controlled, to run free, such as aggression, anger, passion, violence, showing-off and taking risks. In some personalities, it causes depression and low self-esteem.

It takes time for the body to remove alcohol. As a general rule, a pilot must not fly for at least 8 hours after drinking small quantities of alcohol and increase this time if greater quantities are consumed. After heavy drinking, alcohol may be present in the blood 24 hours later. Sleep will not speed up the removal process; in fact, it slows the body processes down and the elimination of alcohol may take even longer. Exercise is better. Having coffee, soup or water between drinks only helps if they are taken *instead* of an alcoholic beverage. Otherwise, the body receives the same total amount of alcohol in the same time, so it takes the same time for it to be discarded and for its effects to be removed.

Tobacco

Smoking is detrimental to good health, both in the short term and long term. Smoking also significantly decreases a pilot's capacity to perform by reducing the amount of oxygen carried in the blood, replacing it with the useless, poisonous byproducts of cigarette smoke. A pilot does not have to be the active smoker to suffer the effects. Second-hand smoke is also detrimental.

Drugs and Medication

Recreational drugs such as marijuana, cocaine and LSD must never be mixed with flying. Persons who are dependent on such drugs are not permitted to hold a pilot certificate.

All drugs affect the body (as well as the disease they are taken to combat). They may be incompatible with flying. Sedatives, and their side effects, are a prime example of this, also antihistamines. Some drugs may have long *half-lives*; that is, their concentration stays too high for too long, e.g. certain sleeping pills. Other drugs, called potentiating agents, change or exaggerate the effect of other drugs taken in combination with them, especially alcohol. Until cleared by a doctor, it is safest to assume that *any* drug or medication will temporarily ground you. *Don't accept or use non-prescribed drugs.*

Toxic Substances

Some pilots will come in contact with toxic substances—fuel additives, cleaning agents, aerial agriculture sprays and powders, defoliants, compressed gases and extinguishants. Don't ever take shortcuts. Observe the special precautions and protections required for each. If in doubt, don't fly.

Vision and Visual Illusions

Eyes provide the brain with a visual image of the environment. Each eye acts as a natural and very sophisticated digital camera. Its basic function is to collect light rays reflected from an object, using the lens to focus these rays into an image on a screen (the retina), and then converting this image into electrical signals that are sent via the optic nerve to the brain. This is how you *see*. The brain matches the image to previously stored data so you recognize (*perceive*) the object. The connection of the optic nerve to the brain is so close and integral, and the importance of the messages sent to the brain is so dominant, that the eyes can almost be considered an extension of the brain.

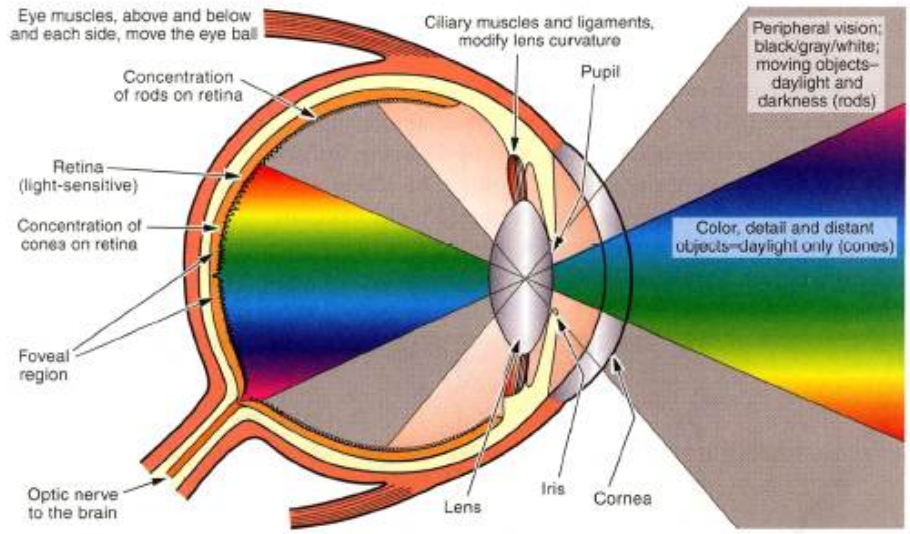


Figure 12-6 Structure of the eye.

Binocular Vision

Binocular vision describes the process whereby optical information is received and processed from two eyes. To track a moving object with both eyes, they need to move in harmony, and this means coordinated control of the two sets of muscles by the brain. In a fatigued person, this coordination sometimes fails, and the result is quite different images from each eye resulting in double vision.

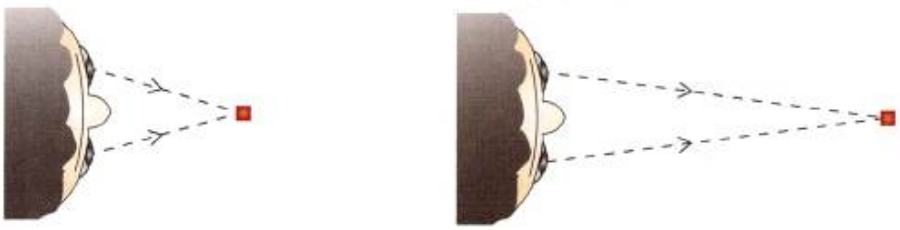


Figure 12-7 Binocular vision.

Blind Spot

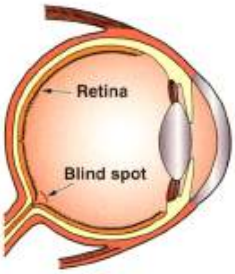


Figure 12-8
Blind spot.

Rods and cones are the nerve endings that feed the optic nerve.

Absolute distance can only be judged by triangulation (the convergence of sight lines) and this is the prime reason for binocular vision. The other reason is to compensate for the blind spot in each eye. The blind spot is the small area on the retina of the eye where the nerve fibers from the light-sensitive cells (rods and cones) on the retina lead into the optic nerve. At this point, there is no coating of light-sensitive cells, and hence any light falling here will not register; that is, it is literally a blind spot. However, it is not possible for an image to fall on the blind spot of both eyes simultaneously because it will be in different relative position for each. Even when an image falls on the blind spot of one eye, and is therefore not registered, the brain will receive a message from the other eye and so the object will still be seen.

You can observe the existence of the blind spot in each eye by viewing figure 12-9. Hold the page at arm's length, cover your right eye, and then with your left eye focus on the airplane on the right. It will be clearly recognizable as a biplane because it will be focused on your retina. Move the page closer and as you still focus on the biplane, you will notice that the helicopter will eventually disappear. Its image has fallen on the position on the retina occupied by the optic nerve. In practice you must be careful when you are scanning the sky that another aircraft is not blocked from view by the magnetic compass or some part of the windshield structure. If it is blocked from the view of both eyes, you will not see it at all; if it is blocked from the view of only one eye, you will lose the blind-spot protection provided by binocular vision.



Figure 12-9 Example of blind spot.

Vision Limitations

Rods and cones are the endings of the optic nerve. As an extension of the brain, they will be affected by anything that affects the brain. With a shortage of oxygen (hypoxia), or an excess of alcohol, medication, or other drugs, sight is one of the first senses to suffer. High positive g-loadings, as in strenuous aerobatic maneuvers, will force the blood into the lower regions of the body and temporarily starve the brain and eyes of blood, leading to a grayout (black-and-white tunnel vision) or unconsciousness (blackout).

Vision Defects

With normal vision, the lens focuses an inverted image of the object on the rear of the eyeball (the retina). The shape of the lens changes to adjust for the distance of the object from the lens to ensure the visual data is focused on the retina. Inability to focus may result naturally from a lens that has become less flexible with age, or it may result from a lens or eyeball that is not shaped correctly. In almost all cases, artificial lenses in the form of spectacles or contact lenses can be made to correct the specific deficiency and restore sharp vision, just like the focus of a camera. Since good eyesight is essential for safe flight, professional assistance is required whenever there is a problem.

Visual Acuity (Clarity or Focus of What We See)

Visual acuity is the ability of the eye to see clearly and sharply. Perfect visual acuity (focus) means that the eye sees the object exactly as it is, clearly and without distortion, no matter how distant the object is. The degree of visual acuity varies between different people and also between the two eyes of any one person, as well as for the single eye at different times. This depends upon whether the person is fatigued, suffering hypoxia (lack of oxygen), or under the influence of alcohol or some other drug. To describe differences in visual acuity, the standard is considered to be what a normal eye is capable of seeing clearly at a particular distance. The eye test chart usually has lines of letters readable for a normal eye from 120, 80, 60, 40, 30, 20 and 16 feet respectively.

The standard testing distance between the eye and the eye chart is 20 feet; the normal eye is capable of clearly seeing letters of a certain size at this distance. If another eye at 20 feet cannot read the 20-foot line clearly, and can only identify letters on the chart that a normal eye can see clearly at 30 feet, then the abnormal eye is said to have 20/30 vision. This is compared with the 20/20 vision of the so-called normal eye. As a rule of thumb, pilots should be able to read a car license plate at a distance of approximately 130 feet.

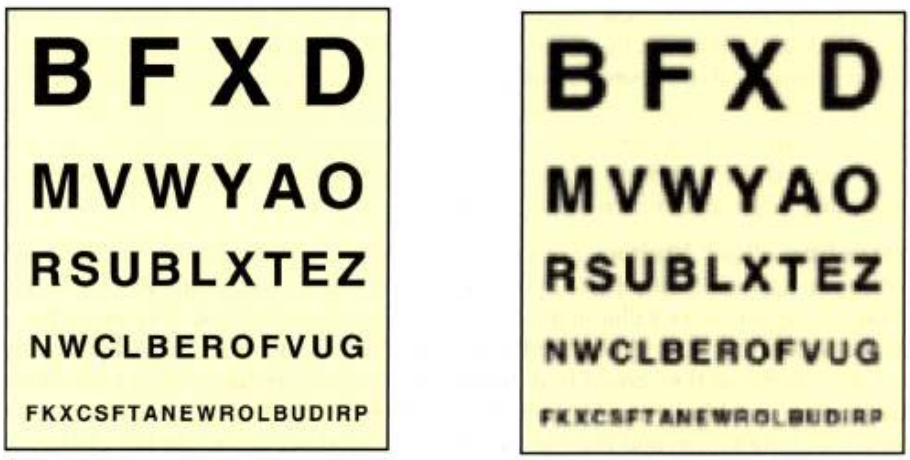


Figure 12-10 An eye chart seen with 20/20 vision and 20/30 vision.

Perfect visual acuity within the individual eye occurs when the image is focused sharply by a high-quality cornea and lens onto the central foveal region of a healthy retina, where the cone receptors predominate. The cone receptors are very sensitive to small details and send very sharp, colorful images to the brain. Light rays that are focused on the retina away from the central foveal region in areas where there are not so many cone receptors but more rod receptors will not be seen as clearly nor will they be in color. Visual acuity (focus) will therefore be less for these images. To illus-

trate the difference between central and peripheral vision, look at the words on this page. You must move your eyes so that the image of the word that you want to read falls on the central foveal region. While you can clearly read the word you are looking at right now, you will not be able to read words some distance away from it—up, down, or sideways from it—unless you move your eyeball so that the image of that word falls on the central high visual acuity area of the retina.

Color Vision

Colors are detected in the central foveal region of the retina by the cone receptors, which are only active in fairly bright light. There are some eyes that cannot distinguish any colors at all, even in bright light. Males are more susceptible to color blindness. Defective color vision shows up as difficulty in distinguishing between red and green. It may cause problems during night flying, as well as in poor visibility, with the white, red and green navigation lights of other aircraft used for recognition, with red or green taxiway or threshold lighting, and also with visual light signals from the control tower used in a radio-failure situation instead of radio voice messages (an uncommon event nowadays).

Night Vision

Cockpit lighting should be dimmed at night.

Adaptation of the Eyes to Darkness. At night, there are some special considerations regarding vision. Your attention during night flying is both inside and outside the cockpit. It takes the eyes some minutes to adapt to a dark environment, as experienced when walking into a darkened cinema stumbling over other patrons in an attempt to find an empty seat. As mentioned, night vision is susceptible to hypoxia: it is affected by cabin altitudes above 4,000 feet. The time it takes for the eyes to adapt depends, to a large extent, on the contrast between the brightness of light previously experienced and the degree of darkness of the new environment. Conversely, when the lights are turned on at the end of a movie the opposite effect takes place. Whereas the cones, concentrated in the central region of the retina, adjust quickly to variations in light intensity (about seven minutes to return to normal), the rods (which are most important for night vision) take some 30 minutes to adapt fully to darkness. In dim light, the cones become less effective, or even totally ineffective, and there is a chemical change in the rods to increase their sensitivity. Thus we adapt more quickly to brightening lights rather than dimming light.

Adapt your eyes to darkness before night flying by avoiding bright lights for at least 30 minutes before flight.

Protecting Night Vision. It is a common misconception that, at night, you are using your night vision in the cockpit or looking at the runway. When you are looking at something that is well illuminated, you are using normal vision. The night fighter pilots of World War II sat blindfolded in darkened rooms and used red cockpit lighting (and ate carrots) so they could look for other aircraft or ground features not illuminated due to the blackout. The only equivalent situation for today would be when you are looking for ground features like lakes or coastlines or the shadows of hills on a moonlit night; otherwise, you use normal vision. The disadvantage of red lighting is that red lines or tints on maps do not show up.

Keep the internal lighting to an acceptably low level to minimize reflections and to allow best transmission of light through the transparencies. It's the same as other natural process; the transmission depends on the energy difference—outside to in. More light outside and less light inside provides best transmission of light through the windows. Even wear a dark-colored shirt for night flying as the traditional white pilot's shirt adds considerably to the reflections off the face of the instrument glass. Avoid brilliant lights as they temporarily reduce the sensitivity of the eyes to less well-

lit objects. Be especially careful of viewing sunsets and then trying to see down-sun at the darkened earth. Exposure to glare and bright sunlight should be avoided before night flights, possibly by wearing sunglasses. Vision is also affected by reduced oxygen levels and so, at night in an unpressurized aircraft, avoid smoking and use supplemental oxygen (recommended above 5,000 feet).

Protection of Vision

Safety Glasses. A pilot's vision is precious. Always wear eye protection for sports, when using tools, or when gardening.

Sunglasses. When flying into a rising or setting sun or above cloud layers, the pilot is exposed to very high intensity light coming from all angles. The eyes are protected from light coming from above by the forehead, eyebrows, eyelashes, and strong upper eyelids, they are not so well protected from light coming from below. Bright sunlight reflected from cloud tops, for instance, can be particularly bothersome because of this lack of natural protection. In conditions of glare, it is advisable to protect your eyes by using high quality sunglasses that reduce glare but not your visual acuity. The contrast between the glare of a very bright outside environment and the darker cockpit interior may also make it difficult for the eyes to adjust quickly enough to read instruments and charts inside the cockpit. Sunglasses should be impact resistant, having thin metal frames. They should transmit 10 to 15% of the light, filtering out damaging ultraviolet rays. They should not be worn in decreased light.

When landing directly facing the sun, 100% of your vision can be lost at the moment of flare. Even when the sun is 40° to the side, vision is reduced by 42%.

Visual Scanning

Scanning by Day

The central (foveal) region of the retina provides the best vision, and in full color but only during reasonable daylight. Objects are best seen by day if you can focus their image on the foveal region, and you do this by looking directly at them. The most effective method of scanning for other aircraft for collision avoidance during daylight hours is to use a series of short, regularly spaced eye movements to search each 10° sector of the sky. Systematically focusing on different segments of the sky for short intervals is a better technique than continuously sweeping the sky. This is sometimes called the *saccade/fixation cycle*, where the saccade or movement takes about one-third of a second.



Figure 12-11 Methodical scan.

Relative Movement. If there is no apparent relative motion between you and another aircraft, you may be on a collision course, especially if the other aircraft appears to be getting bigger and bigger in the windshield. Due to the lack of movement across your windshield, an aircraft on a collision course with you will be more difficult to spot than one that is not on a collision course.

Any relative movement of an object against its background usually makes it easier to notice in your peripheral vision. The image of the other aircraft may not increase in size much at first, but, shortly before impact, it would rapidly increase in size. The time available for you to avoid a collision may be quite brief, depending upon when you see the other aircraft and the rate of closure.

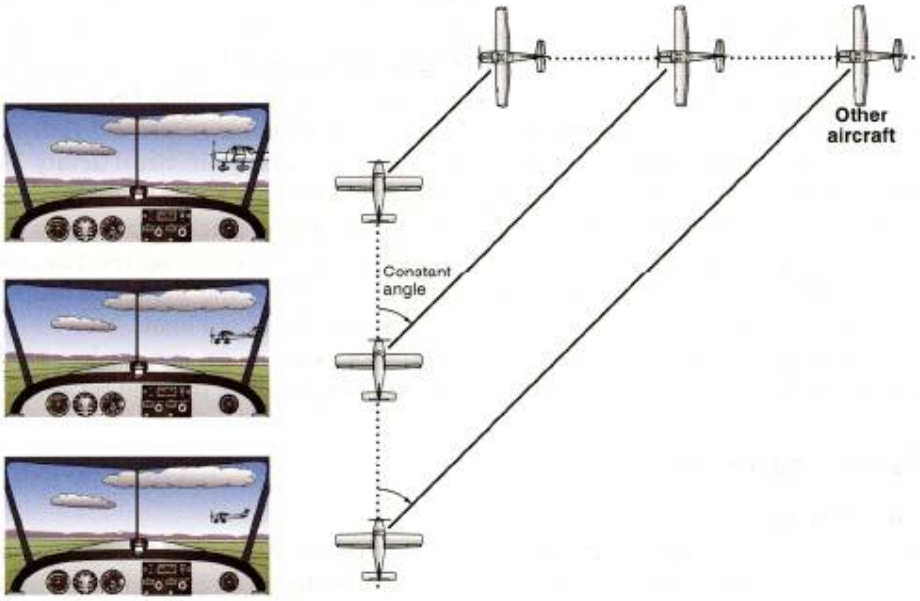


Figure 12-12 Constant relative position = collision course.

If you are flying at 100 knots and it is flying at 500 knots in the opposite direction, the rate of closure is 600 knots, i.e. ten nautical miles per minute. If you spot the other aircraft at a distance of one nautical mile, you only have ⅙ of a minute (six seconds) to potential impact. If you are a vigilant pilot and spot it at 3 nautical miles you have eighteen seconds in which to act.

In hazy conditions, objects may be closer than they appear.

In hazy or low-visibility conditions, your ability to see other aircraft and objects with edges that might be blurred will be diminished and, if you can see them, they may appear to be further away than their actual distance. You might be closer than you think.

Empty-Field Myopia. When trying to search for other aircraft in an empty sky, the natural tendency of a resting eye is to focus at about six feet. Consequently, distant aircraft may not be noticed. To avoid this empty-field myopia, you should focus on any available distant object, such as a cloud or a landmark, to lengthen your focus. If the sky is empty of clouds or other objects, then focus briefly on a relatively distant part of the airplane like a wing tip as a means of lengthening your focus. Having spotted an airplane in an otherwise empty sky, be aware that it could be closer to you than it appears to be, because you have no other object with which to compare its size.

Specks. A small, dark image formed on the retina could be a distant aircraft, or it could be a speck of dirt or dust, or an insect spot, on the windshield. Specks, dust particles, a scratch, or an insect on the windshield might be mistaken for a distant airplane. Simply moving your head will allow you to discriminate between marks on the windshield and distant objects.



Figure 12-13 Specks?

Scanning by Night

At night, scan slowly using your peripheral vision.

The central (foveal) region of the retina containing mainly cones is not as effective at night, causing an area of reduced visual sensitivity in your central vision. Peripheral vision, provided by the rods in the outer band of the retina, is more effective albeit color blind. An object at night is more readily visible when you are looking to the side of it by ten or twenty degrees, rather than directly at it. Color is not perceived by the rods, and so your night vision will be in shades of gray. Objects will not be as sharply defined (focused) as in daytime foveal vision.

The most effective way to use your eyes during night flight is to scan small sectors of sky more *slowly* than in daylight to permit off-center viewing of objects in your *peripheral vision,* and to deliberately focus your perception (mind) a few degrees from your visual center of attention (that is, *look at* a point but *look for* objects around it).

Since you may not be able to see the aircraft shape at night, you will have to determine its direction of travel making use of its visible lighting:

- the flashing red beacon;
- the red navigation light on the left wing tip;
- the green navigation light on the right wing tip; and
- a steady white light on the tail.

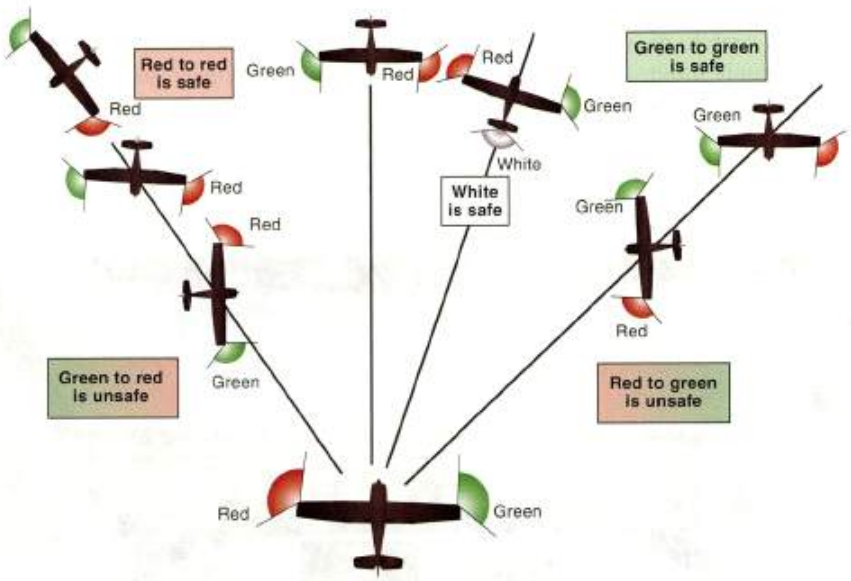


Figure 12-14 Position lights.

Visual Judgment on Approach

The eyes and brain use many clues and stored images of known objects to help in judging distance, size and height. The relative size and relative clarity of objects give clues to their relative distances: a bigger object is assumed to be nearer than a smaller one and a more clearly defined object nearer than a blurry one. When the object is near, binocular vision (the slightly different images of a nearby object relative to its background seen by each eye) assists in depth perception.

Texture also assists in depth perception: the more visible the texture, the closer the object appears to be. On final approach as you near the aim point, the surface texture will appear to flow outward in all directions from the point on which you are focused.

This is one means by which you can visually maintain the flight path to the aim point: adjust the attitude and heading so that the point from which the texture appears to be moving outward remains the desired aim point.

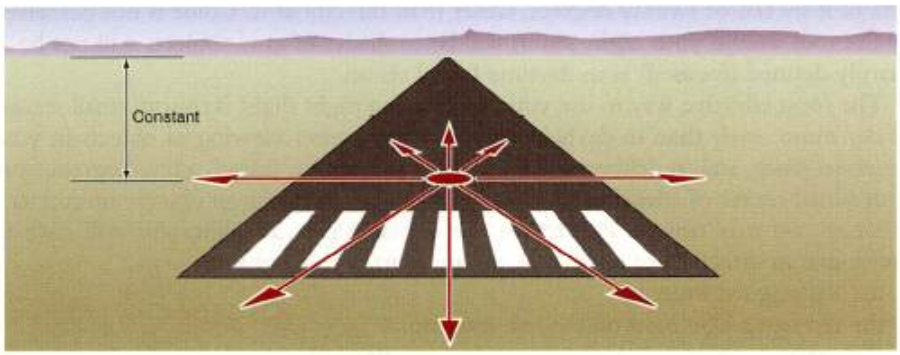


Figure 12-15 Aim point.

Texture is also used for the estimation of height; for instance, as you approach flare height for a landing, the actual texture of the runway or the grass passing by the cockpit becomes increasingly noticeable. Relative motion also aids in depth perception. Near objects generally appear to pass by faster than more distant objects. This helps a visual pilot estimate height above the runway before and during the flare: the closer the airplane is to the runway, the faster the runway surface and the surrounding environment appears to pass by.

Depth perception can be difficult in hazy or misty conditions, where edges are blurred, colors are muted, and light rays may be refracted unusually. This gives the impression of greater distance, an impression reinforced by the fact that we often have to look at distant objects through a smoggy or hazy atmosphere. This illusion is referred to as *environmental perspective*. In hazy conditions, the object might be closer than it seems; in very clear conditions, the object might be further away than it seems. On hazy days, you might touch down earlier than expected; on very clear nights, you might flare a little too soon.

Visual Illusions

Sometimes what we perceive in our brain (what we think we see) is not actual because images sent from the eyes can sometimes be misinterpreted by the brain.

Autokinesis

The visual illusion of autokinesis (self-motion) can occur at night if you stare continuously at a single light against a generally dark background. It will appear to move, perhaps in an oscillating fashion, after only a few seconds of staring at it, even though in fact it is stationary. You could lose spatial orientation if you use it as your single point of reference. The more you try to concentrate on it, the more it may appear to oscillate. You can guard against autokinesis at night by maintaining movement of your eyes in normal scanning, and by monitoring the flight instruments frequently to ensure correct attitude.

Unless you have a distant object in view at night, your eyes will tend to focus at a point about three to six feet ahead of you, especially if you are an older person, and you may miss sighting distant objects. This empty-field myopia or night myopia (short-sightedness) can be combated by searching for distant lights and focusing briefly on them. Beware also of false horizons at night (see later in this chapter).

Haze

In hazy conditions, you may be closer to the runway than you appear to be, an illusion that may lead to an unnecessarily hard landing if you are not prepared for the effect of haze on your vision. This also has an effect on your ability to estimate distances to the airport or checkpoints. The effect of haze over featureless terrain or over water virtually eliminates any reference to the horizon.

On hazy days, objects appear closer.
On clear days, objects seem farther away.

False Horizons

Sloping layers of cloud by day, angled lines on the ground, lights along a coastline at night, or areas of lights by night can present a pilot with a false horizon, which can be very misleading. This is not uncommon with a ragged, lowering cloud base and associated drizzle or rain obscuring the horizon.

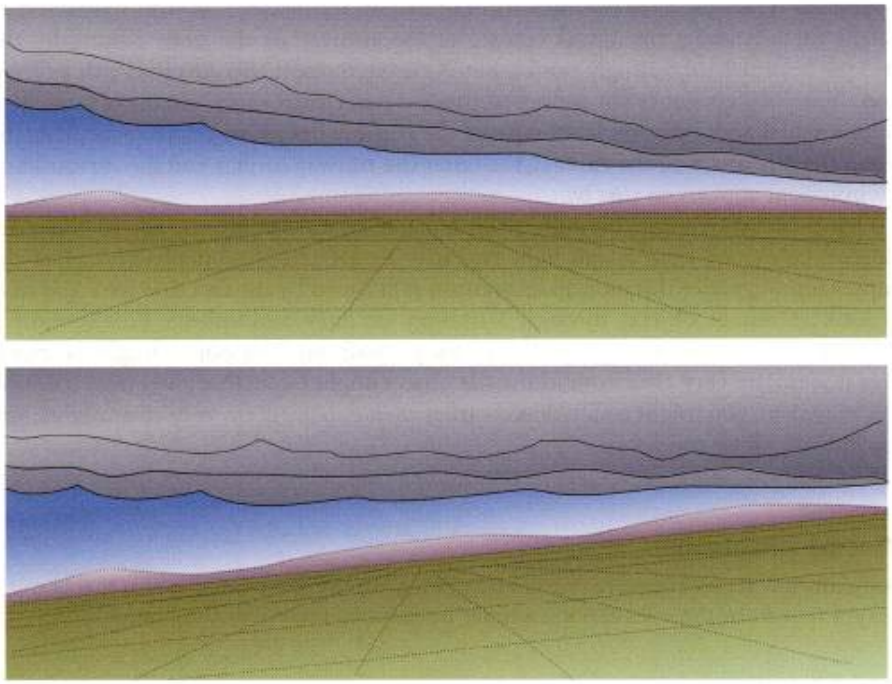


Figure 12-16 False horizon.



Figure 12-17 False level.

Visual Illusions In the Pattern

Visual Estimation Of Height. A pilot flying a right traffic pattern may get the impression that the aircraft is higher than normal. This illusion could occur to a pilot who has developed the habit of visually judging pattern altitude and position by relating the position of the runway lights to some feature of the aircraft, such as a particular position in a side window. Such a rule of thumb that worked satisfactorily for the more typical left patterns could lead a pilot to descend lower to achieve the same picture when making right traffic patterns. Like most habits, such a practice could happen unconsciously.

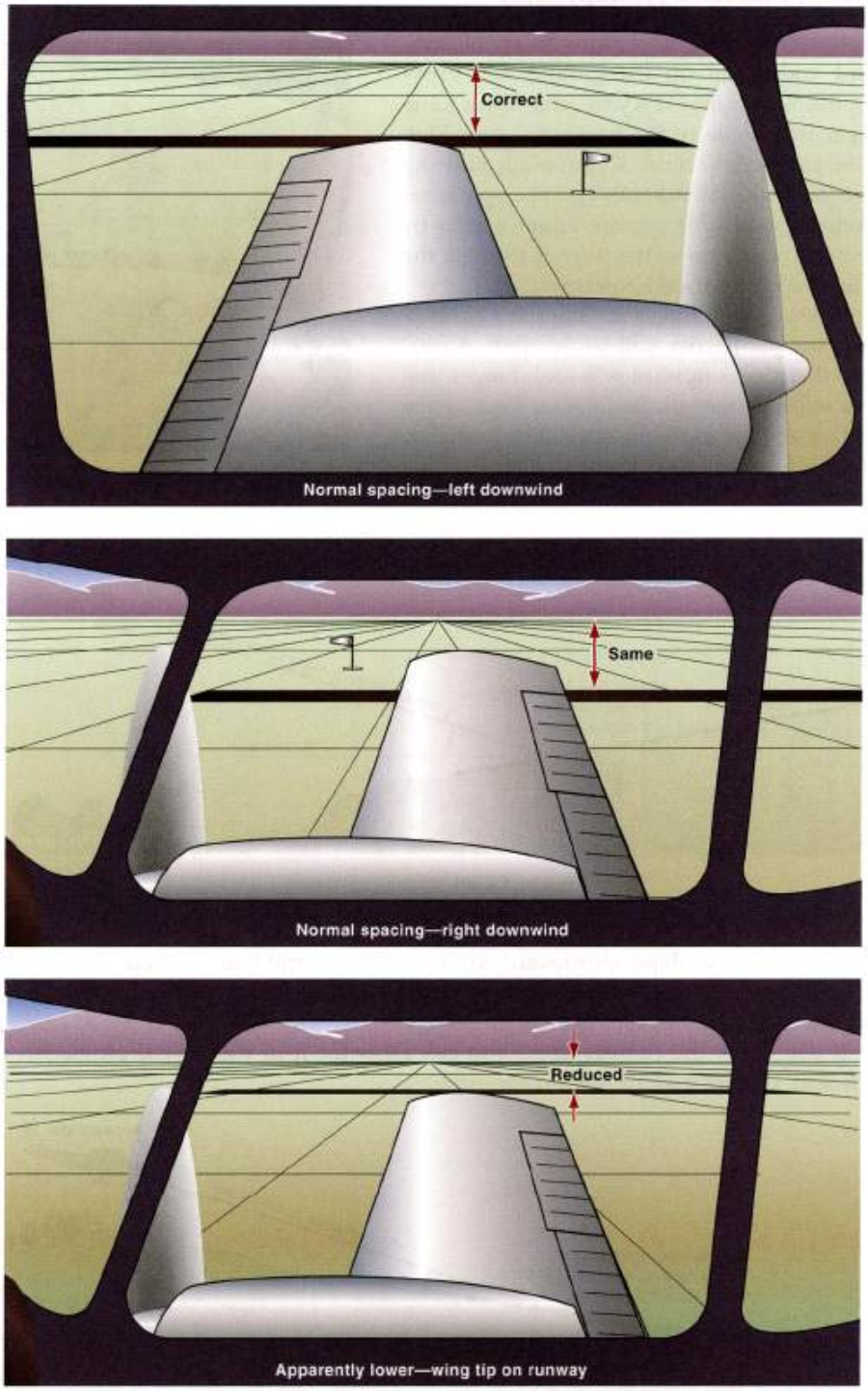


Figure 12-18 Downwind spacing in the traffic pattern.

Visual Illusions on Approach

Runway Slope. Most runways are of standard width and on flat ground. On every approach, you should try to achieve the same flight path angle to the horizontal, to which your eyes will become accustomed, allowing you to make consistently good approaches along an acceptable approach slope merely by keeping your view of the runway through the windshield in a standard perspective.

When approaching a sloping runway, however, the perspective will be different. A runway that slopes upward will look longer, and you will feel that you are high on slope, when in fact you are right on slope. The tendency will be for you to go lower or make a shallower approach.



Figure 12-19 Runway slope.

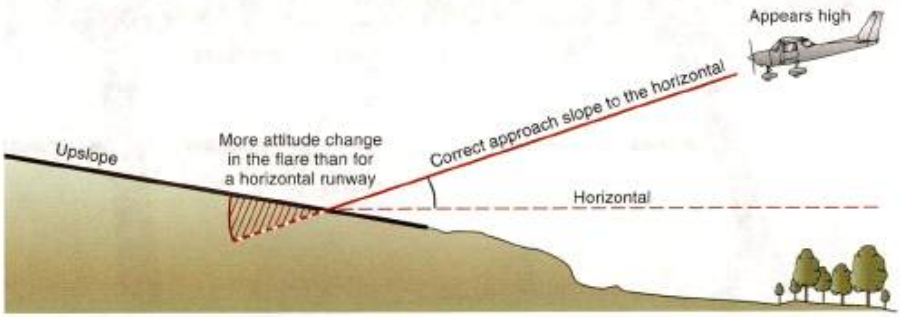


Figure 12-20 Upsloping runway.

A runway that slopes downward will look shorter, and you will feel that you are low when in fact you are on the correct path. The tendency will be for you to go higher and make a steeper approach.

If you know the runway slope, you can allow for it in your visual estimation of whether you are high or low on approach.

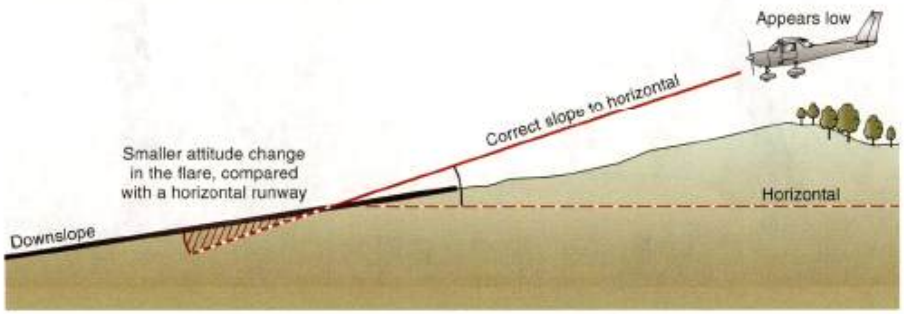


Figure 12-21 Downsloping runway.

Runway Width. A runway that is wider than usual will appear to be closer than it really is. Conversely, a runway that is narrower than usual will appear to be further away than it really is. A wide runway, because of the angle at which you view it peripherally in the final stages of the approach and landing, will also cause an illusion of being too low, and you may flare and hold off too high as a result. This may lead to "dropping in" for a heavy landing.

Conversely, a narrow runway will cause an illusion of being too high, and you may delay the flare and make contact with the runway earlier (and harder) than expected. If you know that the runway is wider or narrower than what you are familiar with, then you can allow for this in your visual judgment of flare height.

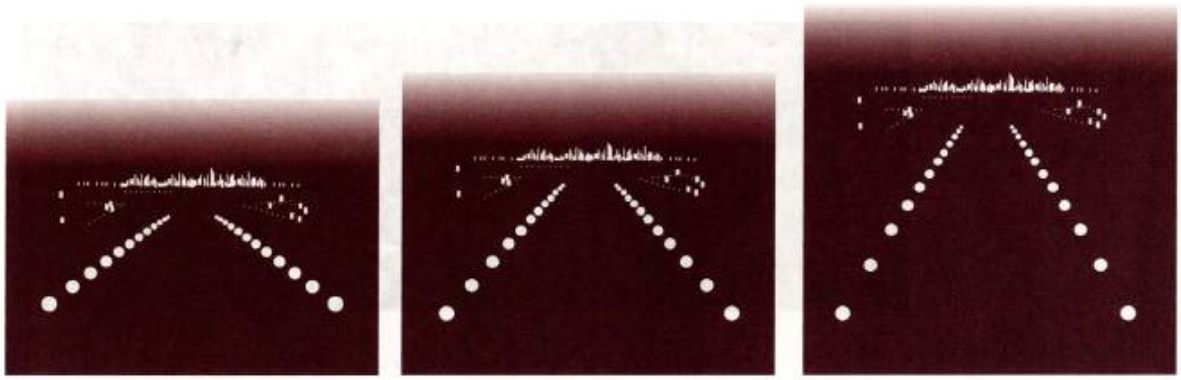


Figure 12-22 Runway width.

Night Approach. A powered approach is preferred. Power gives the pilot more precise control, a lower rate of descent and a shallower approach path. The approach to the aim point should be stabilized as early as possible (constant airspeed, path, attitude, thrust and configuration). Use all the available aids, such as the runway lighting and a visual approach slope indicator (VASI).

If the runway edge lighting is the only aid, correct tracking and slope is achieved when the runway perspective is the same as in daylight. On centerline, the runway will appear symmetrical.

Guidance on achieving the correct approach slope is obtained from the apparent spacing between the runway edge lights and the distance of aim point below the horizon. If the aircraft is low, the runway lights will appear to be closer together or closing. If above slope, the runway lights will appear to be further apart and separating. VASI will provide correct indications, but the perspective provided by runway edge lighting may be misleading due to runway slope or width.



Becoming low
Light spaces decreasing

Correct

Becoming high
Light spaces increasing

Figure 12-23 Night runway aspect.

Black-Hole Approach. Flying an approach to a runway with no other visible references can often be difficult. This can occur when approaching a runway on a dark night where the only lights visible are the runway edge lights, with no town lights or street lights to be seen, and no indication of the nature of the surrounding terrain. This is what is known as a *black-hole approach.* Alternatively, there could be city lights in the area beyond the airfield but no visual cues near the threshold. Black-hole approaches also occur on tropical atolls, at remote desert airfields, or on approaches to runways that are surrounded by water.

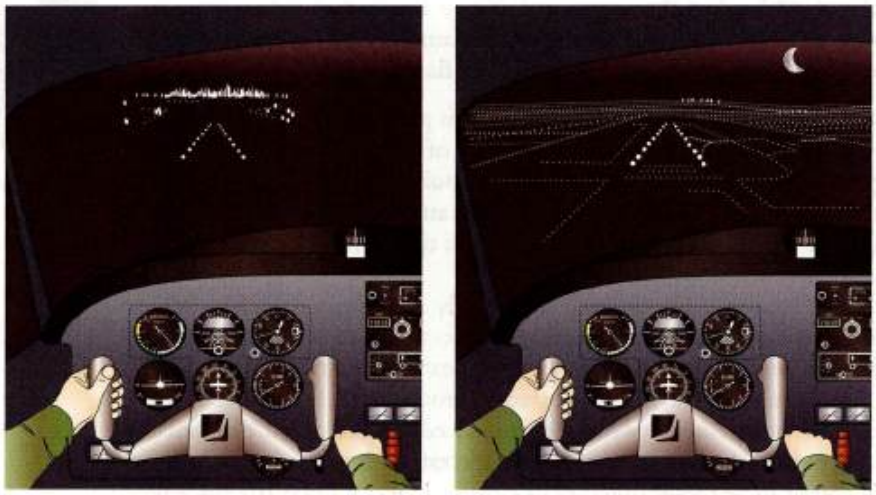


Figure 12-24 Black-hole approach.

The tendency is to think that you are higher than in fact you are, resulting in an urge to fly down and to fly a shallower approach—to sink into the abyss, the black hole.

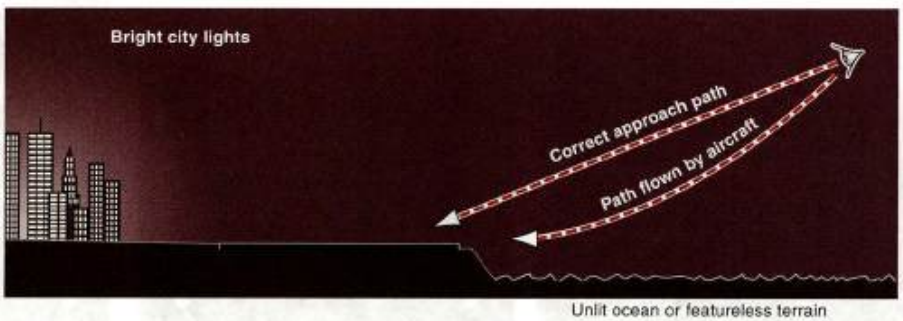
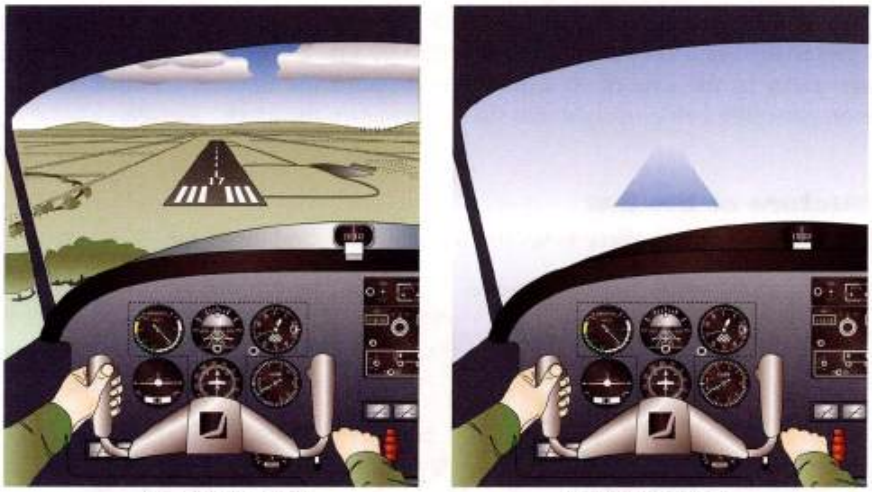


Figure 12-25 Black hole with high-contrast illumination.

The worst black-hole problem of all is to be found in remote airfields on a dark night (say, under cloud) where there is no other light source or any ground texture, and autokinesis might generate an impression of movement when there is none. Rely on the instruments, not your eyes, to maintain horizontal and vertical navigation plots.

If VASI is not available, crosscheck the vertical speed indicator (VSI) to ensure that the rate of descent is proportional to the approach speed (V_{REF}). As a guide, the rate of descent should be close to five times the groundspeed for a 3° approach. The glidepath is approximately 300 feet of altitude AGL for every mile from the runway, i.e., you should be at 900 feet AGL if you are on a three-mile final. Target an altitude of 300 feet one mile from the runway with a rate of descent of approximately 450 feet per minute with a 90-knot approach speed (use DME or GPS distance from the threshold, if available, to better plan descents).

Similar situations to a black-hole approach arise in conditions where the ground is covered with snow, making it featureless (white-out approach). The lack of a horizon and details around the runway threshold make depth and slope perception much more difficult.



Normal perspective Obscured approach

Figure 12-26 Reduced visibility.

A variety of atmospheric and terrain conditions may produce visual illusions on approach. When you encounter such situations, anticipate and compensate for them.

Situation	Illusion	Result	
Upslope runway or terrain	Greater height	Lower approaches	Shallower
Narrower-than-usual runway	Greater height	Lower approaches	
Featureless terrain	Greater height	Lower approaches	
Rain on the windshield	Greater height	Lower approaches	
Haze	Greater height	Lower approaches	
Downslope runway or terrain	Less height	Higher approaches	Steeper
Wider-than-usual runway	Less height	Higher approaches	
Bright runway and approach lights	Less distance	Higher approaches	

Table 12-3 Visual illusion on approach.

Hearing and Balance



Figure 12-27
Ears aren't only for hearing.

The ears provide two senses: hearing and balance. Hearing allows you to perceive sounds and to interpret them; the sense of balance lets you know which way is up and whether you are accelerating or not. Balance is the next most important sense for a pilot after vision.

Sound is defined as energy that you can detect with your ears. It is often very useful and pleasant, as with voice messages and music; however, excessive sound may be annoying and fatiguing, and can even lead to damage within the ear. Irregular, unwanted and unpleasant sound is called noise and is best filtered out. Sound signals are caused by pressure waves traveling through the air, and these cause the eardrum to vibrate. The inner ear converts these pressure vibrations into electrical signals that are sent via the auditory nerve to the brain where they are interpreted.

Similarly, balance and acceleration signals from the balance mechanism in the inner ear pass to the brain as electrical signals for interpretation. The interpretation is sometimes tricky in the case of an airborne pilot, since the brain is accustomed to the person generally being upright and slow moving on the earth's surface.

Structure of the Ear

The ear is divided into three areas: the outer, middle, and inner ear.

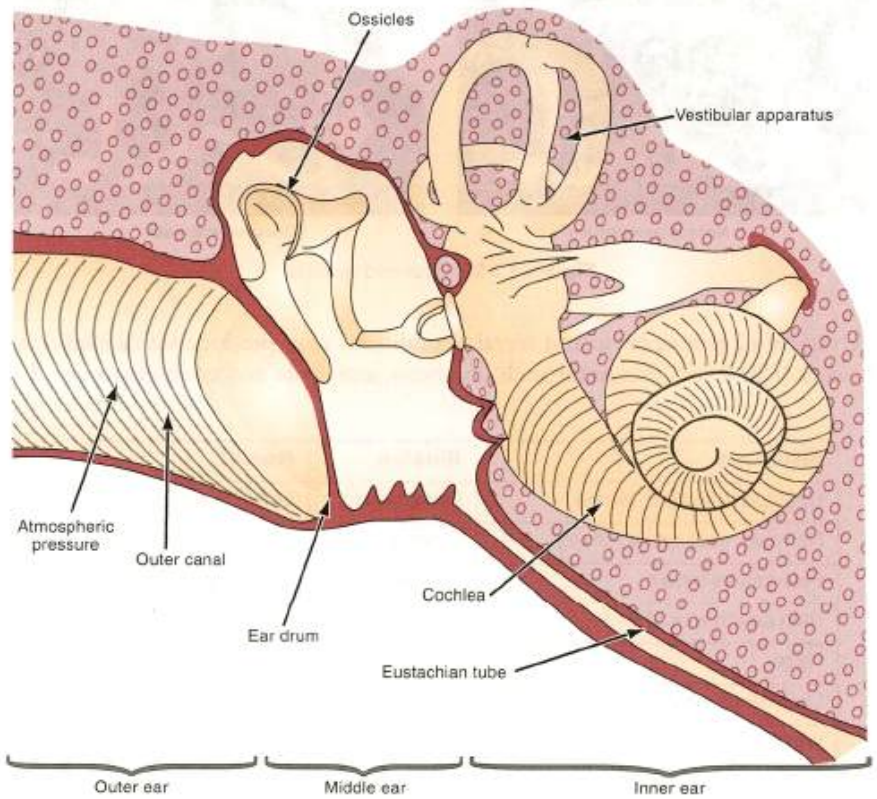


Figure 12-28 Structure of the ear.

Hearing

The ear is never switched off. Loud or particular noises to which you have a conditioned response can always stir you from the deepest sleep. A quiet room is essential for sound sleep. It is also interesting to note that you can extract messages important for you out of a noisy background; for instance, a radio message directed at you, the sound of your own child on a crowded beach, or your own name mentioned in a distant conversation can all be discerned. This is known as the *cocktail party effect*.

The region of the middle ear has much to do with your sensations of movement and balance. It is for that reason that people with middle-ear infections often lose their sense of balance. Furthermore, disturbed signals from these sensors lead to a feeling of nausea. In extreme cases, *vertigo*, the total loss of balance with massive and disturbing disorientation, results. The comments that follow apply to the hearing aspects of the ear; balance is discussed later in the chapter.

Sound is what you hear, and each sound can be defined by the following qualities:

- *frequency* or *pitch*, which is the number of pressure waves per second (or hertz, Hz) that the sound source produces. Perfect human hearing is in the range of 20 Hz to 20,000 Hz, and voices use the frequency range 500 Hz to 3,000 Hz;
- *loudness* or *intensity*, which is the strength or amplitude of the pressure waves, measured in decibels (dB), a logarithmic scale where an increase of 20 dB signifies an increase in intensity of ten times. (20 dB is ten times as loud as 0 dB, the threshold of hearing; 40 dB is ten times louder again, i.e. 100 times as loud as 0 dB; 60 dB is 1,000 times as loud as 0 dB and 100 times as loud as 20 dB); and
- *duration*, which is how long the sound lasts.

Fatigue and Damage From Noise

Unwanted sound, especially if it is loud and disagreeable, is *noise*. It can be mentally fatiguing through its effect on our ears, but it also affects the rest of our body, especially if it is associated with vibration as is often the case. Noise can interfere with communications, and with concentration. Extreme noise levels can also do permanent physical damage to our ears, with duration and recurrence of exposure being as important as loudness.

Loss of Hearing

A person can experience a temporary hearing loss after exposure to noise. The noise of an engine, for instance, may no longer be heard after a while even though the engine noise is still there. Some factory workers lose the ability to hear frequencies they are subjected to all day long. A temporary hearing loss may disappear after a few hours.

Exposure to high noise levels (greater than 80 dB) for long periods can also lead to a permanent hearing loss, especially in the high-frequency range. This is a risk area for pilots who are exposed to a noisy work environment for long periods. Put it together with visits to the car races, noisy night clubs, plus a top set of speakers at home and you are in a high-risk environment from the point of view of your hearing.

Very, very gradually, and imperceptibly, a person can lose the ability to hear certain sounds clearly, speech becomes more difficult to comprehend and radio communications become more difficult. Sudden, unexpected loud noises (greater than 130 dB), such as an explosion or the sound of an impact, can cause damage to hearing, possibly even physical damage to the eardrum or to the small and delicate ossicles.

Level (dB)	Situation
130	Standing near a jet aircraft (noise becoming painful).
120	Standing near a piston-engine aircraft (noise becoming uncomfortable). Several hours per day for three months could lead to deafness.
110	Maximum recommended for up to thirty minutes' exposure.
100	Maximum recommended for two hours' exposure.
90	Maximum recommended for eight hours' exposure (a working day).
80	Standing near heavy machinery. Above 80 dB for long periods can lead to temporary or permanent hearing loss.
60	Loud street noise, trucks, etc.
50	Conversation in a noisy factory.
40	Office noise.
30	Quiet conversation.
20	Whispering.
0	The threshold of hearing.

Table 12-4 Noise levels of typical sounds.

Aircraft Type	Takeoff	Cruise	Landing
Aero Commander 680	102	92	83
Beechcraft A36	97	86	75
Cessna 172	94	89	75
Piper Pawnee	103	102	89
Bell 206	91	92	89

Table 12-5 Indicative cockpit noise levels (decibels).

Hearing loss can also result from:

- problems in the conduction of the sound due to a blocked outer canal (ear wax), or fluid or pressure problems in the middle ear, e.g. barotrauma or damaged ossicles (known as *conductive hearing loss*);
- loss of sensitivity of the hair cells in the cochlea due to exposure to noise, infection, or age (known as a *sensory* or *noise-induced hearing loss*);
- *presbycusis*, a natural loss of hearing ability with increasing age, especially in the higher frequencies (down about 5% by age 60 and 10% by age 70); and
- excessive use of alcohol or medications.

Precautions for Minimizing Hearing Loss. A noise-induced hearing loss may develop gradually over a period of years without the person noticing. It is something that cannot be reversed, hence the need for prevention rather than cure. As a pilot, you are lucky in that you will have regular audiometry tests that can be compared over the years to look for any gradual loss of hearing, especially in the higher frequencies. Wear hearing protection when in noisy areas. A good noise-canceling headset is highly recommended for the cockpit, and earplugs or earmuffs for when you are moving around outside the aircraft. Earplugs can reduce noise by about 20 dB, and

good earmuffs by about 40 dB. The radio headset, especially if it is well sealed, will block out background noise. Unprotected, close exposure to jet-engine noise can be hazardous to the balance mechanism in the ears also, which is another reason to wear hearing protection on the tarmac.

Balance

The sense of balance makes it possible for you to remain upright. The most powerful reference is visual. If you can see, you can tell directly whether you are vertical (if there is a vertical or horizontal reference). If you close your eyes, things are not so easy. Try standing on one leg and closing your eyes.

The secondary sensing mechanisms are those devices (other than vision) from which your brain might be sent orientation messages. The secondary signals are very feeble indeed, compared to visual cues. They really only supplement visual perception. In other words, they can only make sense in partnership with the vastly more powerful visual picture. These sensory mechanisms were designed for three-dimensional orientation but not three-dimensional motion or accelerations. However, if you have no visual horizon, these other sensors will supply fall-back information, but it is not totally reliable.

In the absence of a powerful visual cue, your system will crave orientation signals and accord them equal weight. The secondary sensing mechanisms will be sensed very strongly indeed, but they are always misleading. You cannot rely on any of them. You must never use them to judge your flight path. You can only guard against that by knowing what they will try to tell you, and by becoming familiar with their illusive signals. To be confident and competent in cloud requires training, experience and recency in cloud or in a motion simulator.

Spatial Orientation

Avoid spatial disorientation by looking outside or by looking at the flight instruments. Do not rely on body signals.

Orientation is the ability to determine your position and alignment in space. It is usually achieved by a combination of three senses:

- vision, the most powerful sense;
- balance, the *vestibular* sense (gravity, acceleration, and angular acceleration); and
- "seat-of-the-pants" (bodily feel or the *proprioceptive* sense).

The brain uses all information that it has available to assemble a picture. If there are conflicting signals, vision is given first priority. In most situations, each of the three senses reinforce the others; however, in flight, this is not always the case. Each of these senses can sometimes have its messages misinterpreted by the brain. Not knowing your attitude (i.e. which way is up) is *spatial disorientation*. When you are denied external vision, and flying is solely by reference to the instruments, a range of false sensations can be perceived. Hence, the need to rely totally on your flight instruments (but also scan to check that they agree with each other).

Human Balance Mechanism: The Vestibular Apparatus

The balance mechanism is designed to keep you upright—i.e. vertical and balanced—while standing or moving without input from the eyes. In the absence of visual references, the inner ear can sense what it believes is vertical by two means:

- sensing tilt angle; and
- sensing tilting motion (backward/forward or left/right).

The angle of tilt is sensed by the equivalent of a pendulous mass (which senses gravity as vertical) and the tilting motion by the fluid-filled semicircular canals.

Sensing Gravity (Verticality)

Your body can sense accelerations (g-forces).

Gravity is detected by sensory hairs in a sac filled with gelatinous material, commonly known as the *otolithic organ* or *utricle*. The sac's outer membrane is studded with small crystals of calcium carbonate. These are called *otoliths* and give the organ its name.

The otolithic organ has a resting position when the head is upright. The brain interprets the message sent from the small hairs at this time as *up*; that is, the sac is affected by a 1g force directly downward. If the head is tilted to one side, or forward or backward, then the otoliths act as weights moving the sac under the force of gravity and taking up a new position, thus bending the hairs, which sends a different signal to the brain.

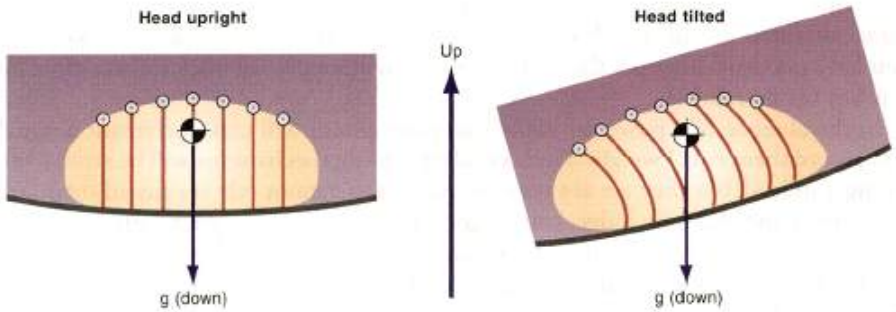


Figure 12-29 Sensing vertical.



Figure 12-30 Pendulous effect.

The otolithic organ detects the direction of g-forces but cannot distinguish their origin; that is, it cannot tell whether it is the force of gravity or a centripetal force pulling you into a coordinated turn. You must remember that the body was designed for fairly slow motion on the face of the earth, with a consistent 1g force of gravity exerted on it, and not for the three-dimensional forces you experience in flight (or zero g for that matter). In a turn, it will recognize the direction of the total load factor as a false vertical.

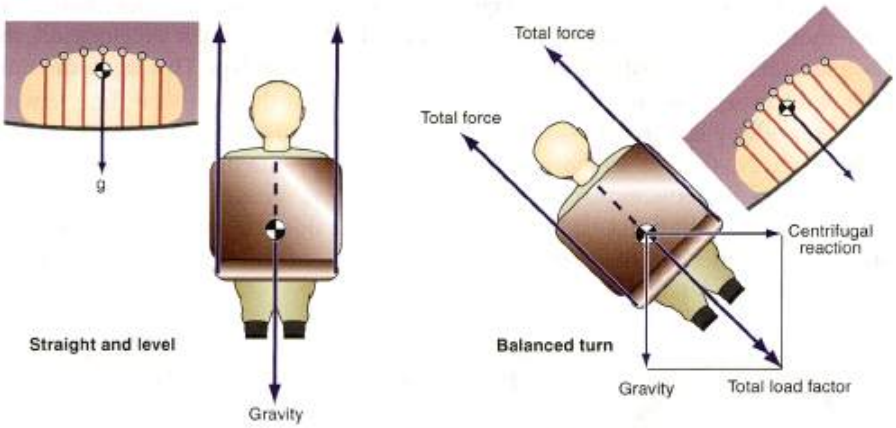


Figure 12-31 Apparent vertical—straight and turning flight.

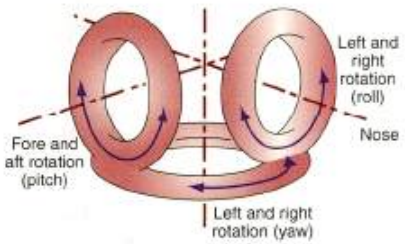


Figure 12-32 Semicircular canals.

Sensing Angular Movement (Rotation). The three semicircular canals of the inner ear—the vestibular apparatus—contain fluid. These three semicircular canals are at right angles to each other (they are orthogonal) like the pitch, roll and yaw planes of an airplane, and therefore they can detect angular accelerations (change in the rate of rotational speed) in pitch, roll and yaw.

The *cupula* is a saddle-shaped chamber at the base of each canal as depicted in the diagram opposite. It has a cluster of fine hairs that protrudes into the fluid. Movement in the fluid is sensed by these hairs. Nerve endings at their base send corresponding signals to the brain for interpretation (perception).

The semicircular canals are *not* designed to detect linear changes in motion or linear acceleration, because the upper and lower volumes of fluid are self-canceling. For example, if the fluid at the top of the semicircular canal tries to move counterclockwise around the canal due to an acceleration forward, then the fluid at the bottom will try to move around clockwise to the same degree.The net effect is no relative movement of the fluid and the sensory hairs of the cupula will remain straight.

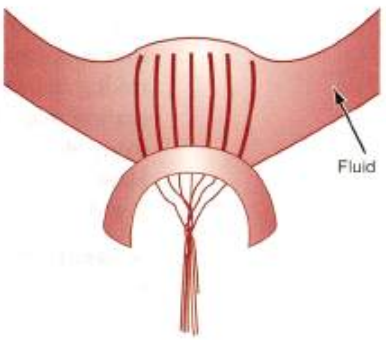


Figure 12-33 Cupula.

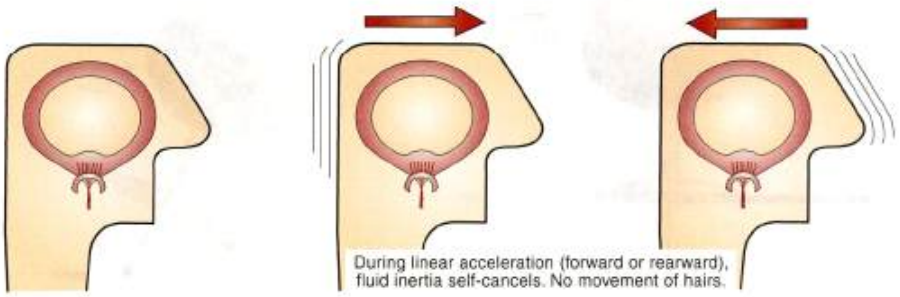


Figure 12-34 Linear acceleration.

The vestibular apparatus senses angular acceleration by recognizing changes in rotary motion due to the lag of the viscous fluid. During angular acceleration, the relevant semicircular canal moves around a mass of fluid that lags. This lag in the fluid bends the sensory hairs to send a signal to the brain that the head is rolling, yawing or pitching (three dimensions—three channels—three canals). Once the rate of roll steadies—that is, there is no more angular acceleration—the fluid will catch up with the surface of the semicircular canals, straightening the sensory hairs of the cupula. This means you will detect the entry to the roll but not its continuing steady state. Similarly, you will sense the opposite acceleration as you stop the roll (decelerate) at the required bank angle.

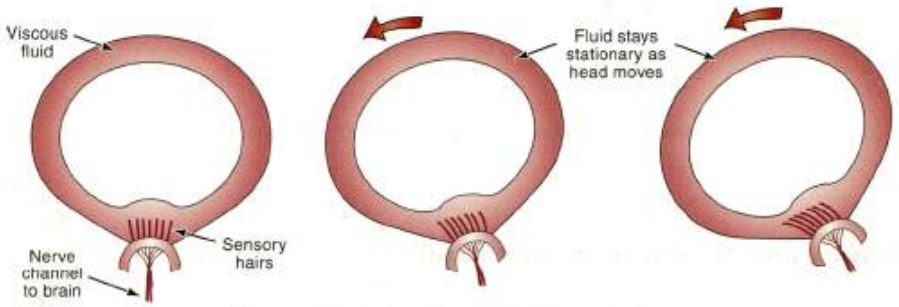


Figure 12-35 Angular acceleration—rotation.

In flight, the sensory mechanisms are suppliers only of crude and potentially deceptive messages (compared to the direct orientation images flowing through the sight channel). As is the case with any stimulus or sensation, there is a threshold below which movement will not be detected. For example, you will sense a rapid change in roll rate, but not a gentle one. In reality, you do not necessarily detect the angular acceleration that commences the roll as a rolling sensation. You may feel the entry into the roll as a rolling sensation if the roll is rapid enough. Similarly, you may sense the rotary deceleration that stops the roll at the selected bank angle. You may also sense rolling signals from adjustments to the control input while adjusting either roll rate or angle of bank. However, in many flight regimes, your control inputs will be so gentle that you will not detect any rolling sensation at all. The potential for confusion is serious.

Sensations in Turning Flight. In a balanced turn, a full glass of water on top of the instrument panel will remain unspilled; it will remain level with respect to the glass. It is as if the weight of the fluid is acting through the aircraft's vertical axis. It is. The apparent weight is the result of gravity and centrifugal reaction.

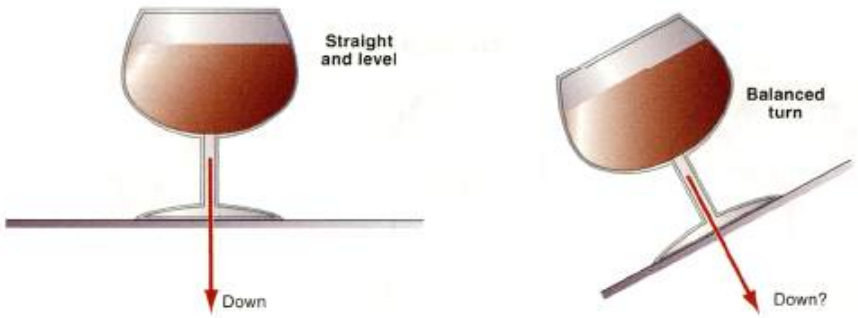


Figure 12-36 Sensed vertical.

Your body will also sense up and down as acting in that same axis. There will no longer be any rolling sensation, nor is there any other sensation source other than seat-of-the-pants. In other words, once you are established in a turn, you will feel that you are in straight and level flight. And that feeling will be the same regardless of the bank angle, except that the load factor is increased. When you bring together this feeling of certainty of where down is and the sensation of rolling, things can become very confusing, a condition generally known as *the leans*. The leans can profoundly interfere with your mental equilibrium, but only if you let them.

Disorientation and Illusions

The Leans

Let's look at another situation. If the turn entry is very gentle, it is not sensed by the semicircular canals, but the stop-roll deceleration is detected. The end result is quite discomforting:

- the gentle onset of roll into the turn is not perceived;
- next, no sensation is available during the steady-state roll;
- but, when the stop-roll control movements are made briskly, the angular deceleration that stops the roll and establishes the bank angle is felt—strongly;
- however, it is felt as a roll to the left; and
- as there is no canceling sensation available, the sensation of rolling—continuous rolling—persists, though it will slowly dissipate as the fluid stops moving and the sensory hairs get to stand up straight again.

In entering this turn, the only sensation perceived was the stop-roll angular deceleration. The signal sent to your brain is read as a roll to the left. With no corresponding canceling sensation, it will be a sensation of continuously rolling. When you then roll out of the turn, and the rollout is briskly commenced (enough to be detected), you will then experience the sensation that the left-roll movement has become faster.

Perception of rapid roll rates can quickly produce strong sensations of disorientation. You can get the leans from turn entries or exits. That is:

- you might be wings level and yet absolutely convinced you are rolling into or established in a turn; or
- equally, you can be in the turn and certain that your wings are level.

Slow rates of roll (or movement around the other two axes) will not be detected. Brisk control inputs will induce sensations, and the brisker, the stronger. A common leans scenario is the following:

- you slowly let a wing drop then suddenly notice the wing-low condition;
- you spontaneously and rapidly roll to wings level (and perhaps be looking down at a map or over your shoulder for the runway after a night takeoff); and
- you feel a strong rolling sensation.

Nose-Up Pitch Illusion of Linear Acceleration

The otoliths are tiny weights on the membrane enclosing the utricle sac and its sensing hairs. When you tilt your head back, or lean backward, the weights cause the sac to slump in that direction. The corresponding sensor-hair movement tells your brain that your vertical axis is now inclined rearward.

The same sensation is caused by linear acceleration. Under acceleration, the sac lags behind, and sensor hairs send a message of tilting backward. This sensation of the

nose rising as you accelerate is known as the *somatogravic illusion* (*somato* meaning originating in the body, *gravic* meaning sense of gravity). The greater the acceleration, the stronger the feeling. Obviously, it is not a problem when there are clear visual cues, but it can have very serious consequences when there are few, or none, as on a dark night. The forward acceleration through takeoff and then to climb speed will be sensed as backward tilt or, rather, as a higher nose-attitude and pitch-up than actually exists. There is a temptation to lower the nose with sometimes fatal consequences.

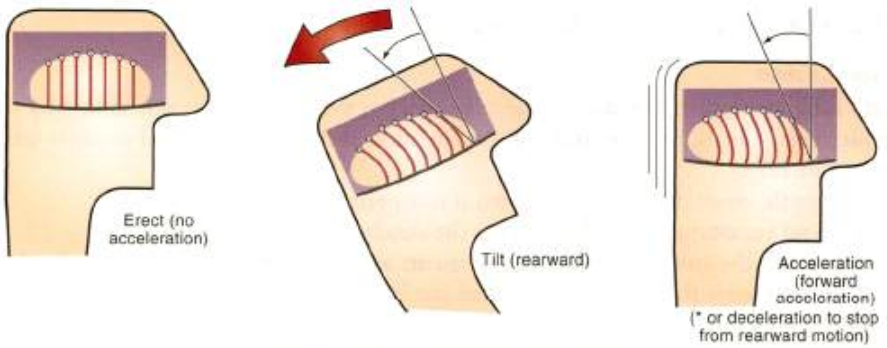


Figure 12-37 Rearward tilt or acceleration?

Nose-Down Pitch Illusion of Linear Deceleration

There is a converse to the somatogravic illusion, but not as serious, as it is less likely to happen near the ground. Deceleration in flight is sensed as tilting forward. It is particularly noticeable in higher performance aircraft when reducing thrust and extending the speed brakes. If the aircraft is already descending, the deceleration will be sensed as a steepening descent.

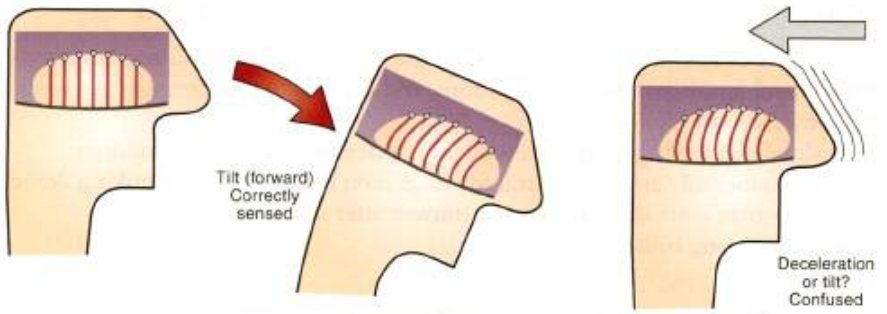


Figure 12-38 Forward tilt or deceleration?

Again, if there is clear visual reference, the sensation is hardly noticeable. If the horizon is less clear, then they are more powerful. Fly attitude as depicted on your flight instruments.

Motion Sickness

Motion sickness is usually caused by the balance mechanisms of the inner ear being overstimulated by motion. This can be caused by turbulence, or maneuvers such as steep turns or spins, in which forces other than the normal will be experienced, especially if there is no clear horizon. A hot, smelly cockpit does not help. Psychological aspects can also play a role in the onset of motion sickness. Anxiety, in particular, will make the condition worse by causing the sufferer to lose control over where he or she looks and focuses attention. Visual scanning is likely to become purposeless, random or fixed.

The visual channel is, by far, the most powerful spatial orientation reference. If the messages coming in through non-visual channels—the balance organs—are accorded priority, the sensory confusion causing airsickness will predominate. If the airsick person focuses on the horizon, the visual messages will be given a chance to assert their authority and to tone down the strength of the signals coming from other sources.

Many pilots have experienced airsickness, especially early in their training when stress levels are higher, and unusual attitudes and g-forces are encountered perhaps for the first time, so do not be discouraged if you experience it occasionally.

To avoid airsickness:

- anticipate and avoid areas of turbulence, known from weather forecasts and any local effects such as the side of hills (if not a local, seek the views of someone who is);
- eat lightly before flight, but do eat something (don't fly on an empty stomach);
- fly the airplane smoothly, gently and maintain trim and balance;
- focus on the horizon as much as you can;
- avoid maneuvers involving unusual g-forces; and
- ventilate the cabin with a good supply of cool, fresh air.

If turbulence is encountered:

- fly at best speed;
- relax, don't fight, and maintain attitude;
- occupy a potentially airsick passenger in the flight, especially with looking outside the airplane into the distance or at the horizon;
- as a last resort, recline the airsick passenger's seat to reduce the effect of the vertical accelerations and keep an airsickness bag handy; and
- land as soon as is reasonably possible (if necessary).

Load Factor

Speed has relatively little effect on the human body, whereas acceleration or deceleration may produce pronounced effects ranging from the fatiguing characteristics of flight to a complete collapse of the cardiovascular system. In aviation, acceleration is usually expressed in multiples of the acceleration due to gravity of 32.2 fps^2 (9.81 m/s^2) and is represented by the symbol g.

The brain and eyes need a continuous supply of oxygen. They have little storage capacity, so strong or prolonged g-forces, which reduce the supply, lead to reduced visual acuity, loss of color vision, loss of sight and even unconsciousness. When the acceleration is centripetal, as in turn or pitching maneuvers, it is felt by the pilot as an increase in weight. In a 60°-banked level turn, you will experience +2g, or feel you are twice as heavy.

All parts of the body are affected by g-force. The blood, for instance, will also get heavier. It therefore is harder to pump and circulate, and tends to pool in the legs and lower abdomen. At higher load factors of, say, +3.5g and upward, this can produce physiological symptoms.

Reduced blood circulation diminishes the transport of oxygen and sugar to the head. That is manifested as less blood supply and reduced local blood pressure. As there is very little stored oxygen and sugar in the head (as opposed to muscles, which have some storage capacity), the reduced blood supply can cause an immediate effect.

The first to notice anything is the eyes. As the eyeballs must remain balls—as opposed to being squashed by surrounding tissue—they are inflated to positive internal pressure (they feel hard to the touch.) A side-effect of this necessary condition is that blood flow to the eyes, and the oxygen and sugar supply it carries, is inhibited. It's an uphill slope.

If g-force is reducing the blood pressure in the head, then the eyes will be affected first because of this pressure gradient. The supply of oxygen and sugar is necessary to process sight signals. As g increases, sight becomes affected, with color vision the first to go. If you are not used to high load factors, this stage of the phenomenon might occur at +3.5 to +4.5g. It is called *grayout*. All images are seen as shades of gray and white.

If the g keeps building, the field of view will begin to shrink, starting from the sides. This limiting vision effect is called tunnel vision. Still increasing g-forces will lead to total loss of vision, or blackout. At this point, the pilot is temporarily blind, though still conscious. Further g increase will inevitably lead to insufficient oxygen and sugar supply to keep the brain functioning—loss of consciousness.

So far, we have only talked about positive g—the plane is the right way up. If the aircraft is inverted, the effect of negative g is not only uncomfortable, it is potentially dangerous. It's one thing for large amounts of blood under higher pressure to be accumulating in the legs and lower abdomen, surrounded by tough and flexible muscle. To have that happening in the head around all that delicate machinery is another thing altogether.

Most pilots, once they have accommodated to aerobatic maneuvering, can withstand up to negative 2.5g. If, however, you push beyond that, you will encounter the phenomenon called *redout*. When you red out, the impression is of total loss of sight, because a red veil is in the way. The reason for it is that your lower eyelid muscles have evolved to match the human bodies needs. As we mostly stand erect, blinking requires the lower eyelid to move only upward. Gravity will organize the return journey. There is no corresponding muscle group to "unblink" the lower eyelid. So if you are inverted, and push to a certain negative g limit, the lower eyelid will drop, covering the pupil, and you cannot force it out of the way.

Many pilots will never experience any of these g-related phenomena. However, some will go on to learn aerobatic maneuvers, or to fly military jets capable of high g-forces in turns and maneuvering. For those who do, there is an especially insidious potential trap: *g-induced loss of consciousness* or *g-loc*.

We saw earlier how positive g-force brings on a sequence of sight-related changes before getting to the point of unconsciousness—grayout, tunnel vision, blackout. As all of these occur while conscious, they can be controlled and relieved. Relaxing the back pressure on the controls will bring nearly instantaneous relief from the degraded sight condition. Indeed, in the case of blackout, the reaction to diminish the g-force by easing the control forces is nearly reflexive. However, g-loc occurs with high rates of onset of g where the warning symptoms are overruled.

As the graph in figure 12-39 shows, the grayout to blackout phenomena acts as a threshold or warning of unconsciousness. It enables forewarning and the chance to reduce the control pressure. There is appreciable delay before the effects are felt and therefore time to return to normal. That is what happens at the normal rate of g onset.

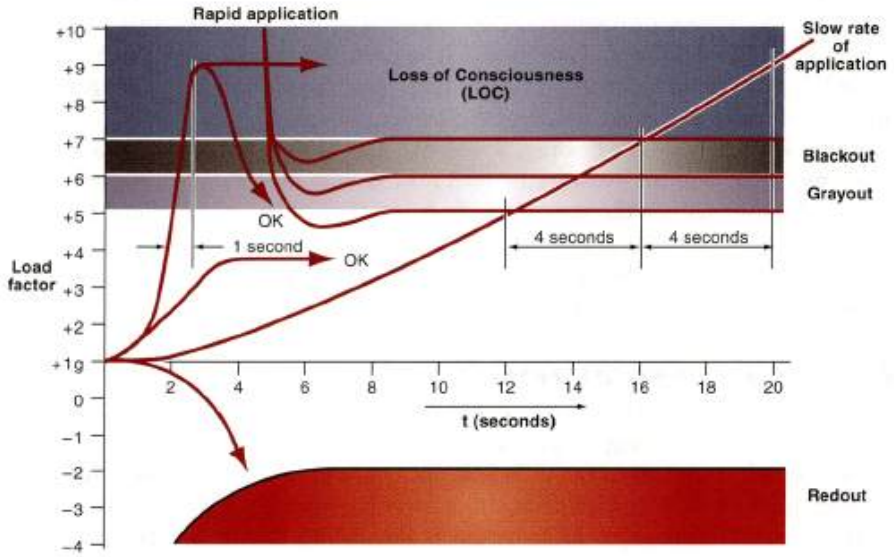


Figure 12-39 Physical response to load factor.

If, however, the rate of onset of g is rapid, the warning signals of degraded sight will be bypassed. The pilot will become instantly unconscious. If you blackout, you will, intuitively relax the control pressure to reduce the g, and immediately regain full sight and you remain conscious throughout. However, if you lose consciousness, it takes at least 15 seconds to recover. Loss of consciousness is a debilitating experience. Think of the last time you saw someone faint: recall how disoriented and incapable they were during the ensuing period. Momentary loss of consciousness in an aircraft can never be safe. Being out of control for 15 seconds will often prove fatal. However, only aerobatic aircraft have the structure and control power for flight capable of causing g-loc.

Coping With High Load Factors

Your personal resistance to g-forces is highest not only if you are physically fit but also toughened—hardened by regular exposure. Serious exercise is a good idea for all pilots, but it is especially so for those who want to be good at aerobatics. On the other hand, no matter how fit you are, there will be times in your life (or day) when your resistance levels are down, like when recovering from illness, tired after a long day, under domestic stress or suffering work problems.

A-loc

Another term that has been recently coined is *a-loc*. A-loc is *almost* loss of consciousness due to g. The reason for the differentiation is that, even if the pilot does not lose consciousness, there is a temporary period of confusion and even euphoria, where the pilot either does not recognize, or does not care about, the seriousness of the situation. It is momentary, but it is believed to have caused some otherwise unexplained pilot lack-of-response during recovery from high-g maneuvers.

Situational Awareness

We tend to think of piloting an airplane as a physical skill. However, there is more to it—much more. Aircraft control, the manipulation of controls to achieve a desired performance, is important, but it is only one element of the pilot's total task. The pilot must assemble information, interpret the data, assess its importance, make decisions, act, communicate, correct and continuously reassess. We call this total process *piloting*. But let's start with the control process so that, once the aircraft is under control, we can be sensitive to and more aware of the bigger picture.

Where am I, where am I going, when will I get there, with how much fuel, at what time, what will the weather be like, how well is the aircraft performing, how tired am I, how well are the passengers, how do I get to the town after I land, how to avoid weather, how to avoid airspace, what calls I have to make . . . this is situational awareness. It is a total appreciation of where you are at, where you want to be and how best to get there safely and on time.

How You Process Information

The main feature of your brain, as a central decision-maker, is that it can only function as a *single-channel* computer, which means that you can consider only one problem at a time. Conscious decisions are therefore not made simultaneously, but sequentially. They are placed in a queue according to a priority—but not always logically.

How the brain processes information is fascinating. There are six fundamental stages:

- *stimulation* and *sensation* where sensors receive a signal;
- *perception* for recognition, classification and remembering;
- *analysis* to work out what to do (make a decision);
- *action* for doing something (or nothing);
- *feedback* to check results; and
- *correction* to achieve acceptable standards of accuracy.

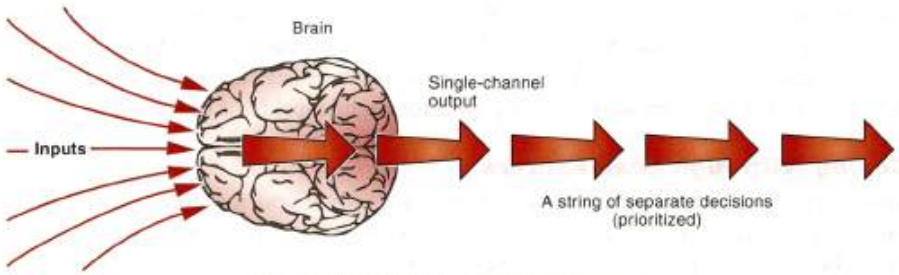


Figure 12-40 Single-channel processing.

Assembling the Big Picture

The pilot's task involves two processes:

- being in *control* of the airplane; and
- being in *command* of the situation.

Situational awareness is the process whereby the pilot gathers data from his or her own senses via sight, hearing, smell, taste, touch, and feel. For a pilot, the eyes and ears are the primary sensors—although control feel and "seat-of-the-pants" are important cues for aircraft control. In addition to direct sight and sound, the eyes and

ears are used to gather information from the instruments, radios, and NAVAIDs so that the pilot can build and maintain an awareness of position, time, fuel, weather, traffic, and aircraft status. From these data, the pilot can prioritize the importance of the information, anticipate trends, assess the need for urgency, and make decisions. The primary task of being the pilot in command is decision making. The quality of the decision depends upon the quality, completeness, and timeliness of the data—and is affected by pilot aptitude, training, fatigue, stress, and personality.

The process of assembling data, making a decision, acting and correcting is called the pilot's *control loop.*

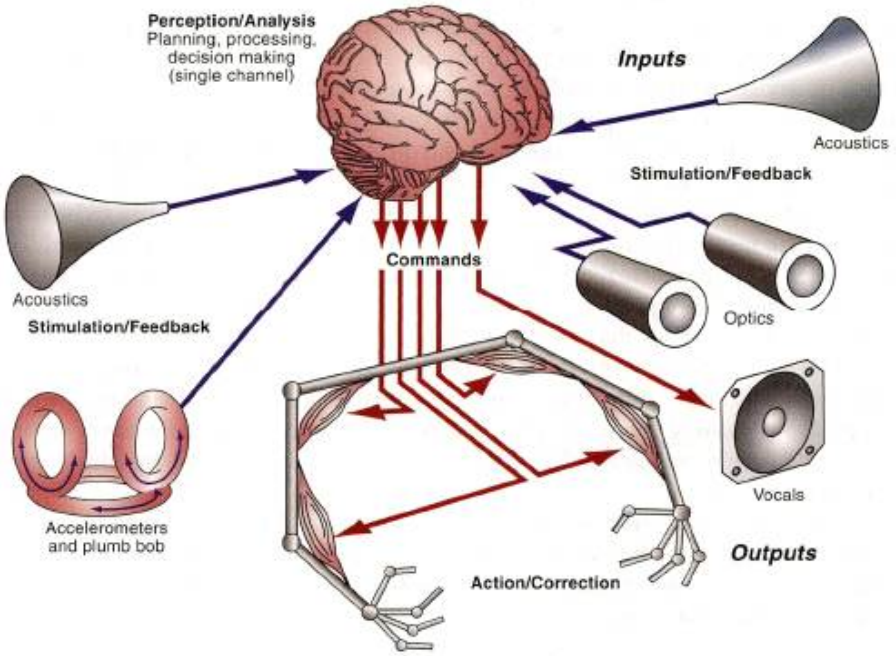


Figure 12-41 The pilot's central role in the control loop.

Flying as a Learned Set of Skills

While a student pilot is concentrating on learning to fly safely and accurately, the central decision-maker will be almost fully occupied. There will be very little spare capacity for other tasks such as navigation and radio calls—or even listening to the instructor. Once the student has learned the motor skills and practiced them until they are second nature, flying the airplane will occur with little conscious thought. In this case, a string of activities is run autonomously in the brain, leaving the central decision-maker available for higher-level decisions. Strings (or sets) of skills are often initiated by the central decision-maker. You might make a decision to get up and walk toward the door, but once this decision has been made, the central decision-maker can drop out of the picture temporarily and let the motor program run the activity. As well as initiating the activity, the central decision-maker will also return to monitor the motor program from time to time, to check that the proper skill sequence is in use, and to check progress and decide when to stop.



Figure 12-42
The primary pilot–airplane interface.

If skills are not used regularly, they deteriorate, and an activity that was once run automatically by a single thought may now have to be managed by conscious decision-making. This will occupy the central decision-maker and, as a result, you can expect a temporary deterioration in the performance of other tasks. Professional pilots returning from a holiday break notice this, as do musicians and others who have to perform skilled tasks. We can certainly *do* more than one thing at a time, thanks to skill programming, but we can only *think* about one thing at a time.

Response Time

The time it takes for any initial stimulus to be perceived, considered, and acted upon can take between a fraction of a second and several seconds, depending upon the complexity of the decision to be made, the action to be taken and the acceptability of the degree of deviation. In a control loop, such as an autopilot, this is known as the *gain*—high gain means a quick response to any deviation, and low gain is a sluggish response. High gain is less tolerant of deviations but can mean a rough ride and so autopilots have a soft-ride or half-bank mode for less disturbances and a more comfortable flight.

Responding to a stimulus often requires a series of sequential decisions to be made: this of course needs time due to the single-channel nature of the brain's central decision-maker. On approach to land, for instance, the landing gear has been selected down and a horn unexpectedly sounds.

Some of the decisions that now need to be made are the following:

- *establish a safe flight path*—in this case, a go-around is essential to gain time and place you into a position where you can sort out the problem. Continuing with the approach is pushing you to a higher workload, with more critical demands on time;
- *silence the horn to remove the distraction*—the horn has been heard and the warning has been noted;
- *what does the horn mean?*—is it landing gear not down, or something else? It means that the landing gear has been selected down, but is not actually down;
- *radio call*—declare emergency to tower, ATC or other traffic; and
- carry out checklist items.

Throughout the decision-making process following a very simple unexpected event, you must continue to switch attention through the tasks of aviating, navigating, and communicating to allocate priorities and to trigger skilled responses. In a situation like that above, you removed the pressure of time by deciding to make a missed approach, and then allowing the learned skill to fly the aircraft. Once the safe response was seen to be in progress, the conscious mind then established the next priority. Time was thus made available to solve the problem. In other situations, you may not have that luxury—e.g. in a takeoff that is rejected at a high speed on a limiting runway. This will require a split-second decision and immediate actions. If the pilot of a large aircraft suspects a problem during the takeoff run, especially as the decision speed is approached, there is only two seconds to decide what to do: *stop or go?* Stopping may not be possible if a tire has blown and reduced the wheel-braking capability. Continuing the takeoff may not be possible if the problem is with the flight controls, or if the problem is multiple engine failure due to bird strikes. The enormous pressure of limited time between input and a necessary decision can sometimes lead to a faulty decision and response.

The risk of making a poor decision, no decision, or an incorrect response is minimized by maintaining a high level of knowledge, and by practicing a maneuver frequently so that it becomes a conditioned response. The decision/response is thus based on the probability of the best course of action and accepting the smallest odds. Simulators can play a big role here, particularly when practicing critical maneuvers.

Mental Workload

Best performance is achieved by a combination of high levels of skill, knowledge, and experience (consistency and confidence), and with an optimum degree of arousal. Skill, knowledge and experience depend upon the training of the pilot; the degree of arousal depends not only upon the pilot's flying ability but also upon other factors, such as the design of the cockpit, air traffic control, as well as upon the environment, motivation, personal life, weather, and so on. Low levels of skill, knowledge and experience, plus a poorly designed cockpit, bad weather, and poor controlling will lead to a high mental workload and a poor performance. If the mental workload becomes too high, decision making will deteriorate in quality, or maybe not even occur. This could result in concentrating only on one task (sometimes called *tunnel vision*) with excessive or inappropriate load-shedding. You can raise your capability by studying and practicing, and by being fit, relaxed and well rested.

The pilot's tasks need to be analyzed so that at no time do they demand more of the pilot than the average, current and fit pilot is capable of delivering. There should always be some reserve capacity to allow for handling unexpected abnormal and emergency situations. At the aircraft design stage, the pilot is taken to be of an average standard. On this basis, skills and responses are established during testing so that the aircraft can be certificated as compliant. But there is some argument that the specimen should not be the average pilot, because half of the pilot population would be below this standard.

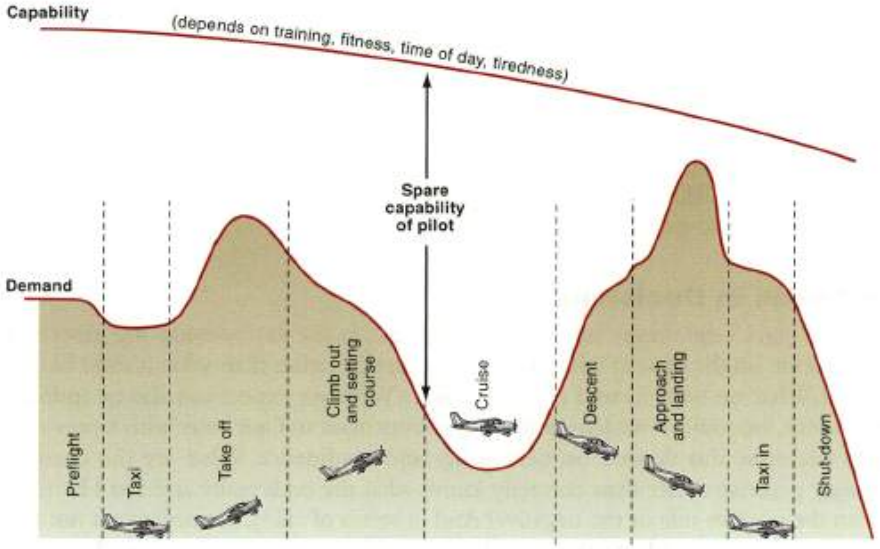


Figure 12-43 Reserve capability.

The legislators establish the minimum acceptable standards for licensing but the marginal pilot, who maintains only the minimum required standard, is not really of an acceptable standard. You can each ensure that you are at an acceptable standard by honestly reviewing the demand that the aircraft and the flight placed upon you. If your capabilities, mental or physical, were stretched at all, then you need more practice, more study or more training—at least in those aspects that challenged you. Many pilots feel that, under normal conditions, they should be able to operate at only 40–50% of capacity, except during takeoffs and landings, when that might rise to 70%. This leaves some capacity to handle abnormal situations.

Aeronautical Decision Making



Figure 12-44
Make conscious decisions.

The essential, fundamental role of the pilot is to make decisions—reliably, safely and timely. But fortunately or unfortunately, pilots are only human.

Information Processing

The decision-making process is one of assembling data, assessing its importance and urgency, making the optimum decision (based on experience and training) and then taking the appropriate action. The quality of this action reflects the pilot's aptitude, skill, discipline, training and recent experience (on the aircraft type, in those conditions and for the particular phase of flight). The quality of the decision depends very much on having complete and recent data (such as position, weather and traffic) for both existing conditions and the likely trends. This big picture is called *situational awareness.* Then there is the dimension that must have a high priority in the pilot's mind: the "fourth dimension."

The Fourth Dimension

An airplane operates in four dimensions:

- three-dimensional space; and
- time.

Everything in flight is changing, and the rate of change varies enormously. Learning to fly is very much a process of being conditioned to the rate at which things happen.

The other aspect of time is that it is finite. You run out of fuel, daylight and clear weather. You become tired. You may have limited time and space in which to make a decision or to maneuver the aircraft.

Thus situational awareness for a pilot is knowing more than where you are. It is knowing the aircraft's position, environment and status, all in the context of time—time gone, time to go and time available.

Emotions in Decisions

Emotion plays a significant, often a dominant role, in the decision-making process. We often decide on the basis of what we want to happen rather than what is most likely to happen. What we hope instead of what is likely. What we expect can also be ambitious or cautious, especially if we have pushed the boundaries and got away with it previously. Thus decisions also depend on personality and confidence. What are the chances I wrongly perceive rather than correctly know what the odds really are? Do I by nature err on the positive side or the negative? And in terms of safety, the negative is not a bad thing. It is cautious and survival-oriented rather than goal/success oriented. *I made it!* You must learn to make as much of a song-and-dance about sensible, reserved decisions and actions, as you do about taking a risk and getting away with it.

Decisions and Stress

Keep stress down by: avoiding high risk flights; knowing your personal limits; staying proficient in your aircraft; concentrate on flying the aircraft, first and foremost.

Internal Stressors

Decisions not taken cause stress. While you are deciding, and are under pressure to decide, the level of stress can become unreasonable. Avoiding a decision also causes stress because you know that ultimately the problem will have to be addressed. It won't go away. The solution is to make the decision and go for it. Stress is relieved by action, either fight or flight.

External Stressors

External pressures have a significant effect on your decisions. You have human wants, needs and fears: wanting to please, wanting to impress friends or siblings, wanting to earn more money or be promoted, needing to be loved, needing to be noticed, needing to be rewarded, fearing criticism or ridicule, fearing to lose a job, or fearing injury. A completely rational decision is made in isolation and such decisions can often only be made retrospectively: what you should have decided rather than what you did decide. Accident investigations are largely of this ilk because they do not—cannot—know the pressures under which the particular decision was made. We can rationalize why the pilot should have made the correct decision when we read the accident report. It's obvious. What is not obvious is the emotional strings attached to that decision. Making correct decisions sometimes takes considerable courage or, to use the old term, *moral fortitude*.

Destination Obsession

Destination obsession (also known as "get-there-itis") is getting there, today, at all costs. It seems not to be the result of a conscious, foolish decision, but more likely delaying a decision to turn back and land until it is no longer safe to do so. Illusions and misinterpretation of the seriousness of the deteriorating situation complicate the decision.

Low Cloud, Pressing On

The problem with pilots pressing on under lowering cloud is well-known within the aviation industry, and yet it just doesn't go away. (Fatal accidents continue to occur due to this problem.) The solution to the problem is elusive. The process involved obviously affects judgment of distances—distance from cloud and height above the terrain. Incredibly visual meteorological conditions (VMC) do not require a visual horizon! True we can estimate the horizontal by perceiving the vertical—by looking down—but this is not always reliable. What if the terrain is not level?

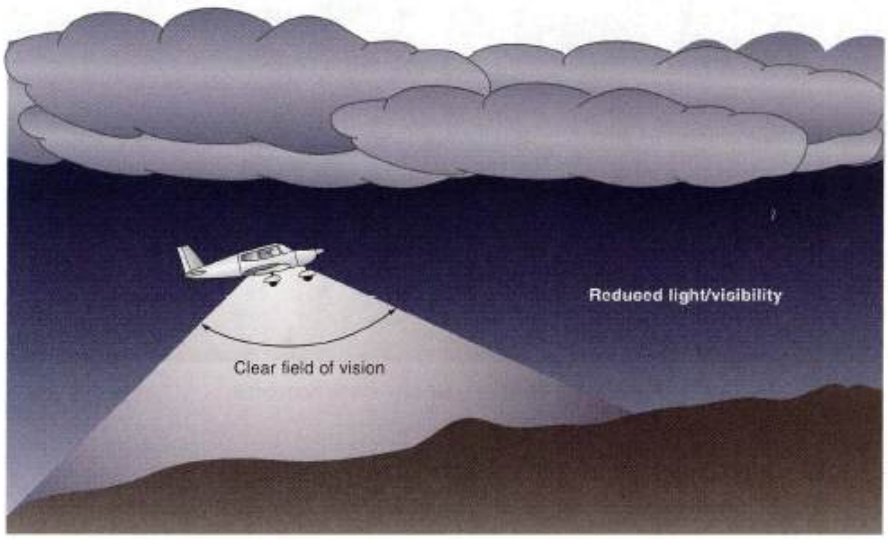


Figure 12-45 Limited cone of vision.

With fewer cues available, those that can be read are given greater importance. They appear more pronounced, more compelling in their meaning. They invite greater reliance on what they are telling you. The main effect will be to deny a proper and accurate assessment of height above terrain, distance from obstacles and cloud and you have a false appreciation of level attitude.

With restricted forward visibility, your judgment of height and distance will be so distorted as to be next to useless. You could become very close to the trees or ground without realizing. But, by then, it's far too late. We've all heard news reports of aircraft engine noise low overhead, often for long periods before the actual crash.

All of which adds up the unsurprising conclusion that most, if not all, pilots who do go on too far under cloud have no idea how low they are actually flying until they hit something—or wind up in the "soup" itself, blind in cloud. The destination obsession affecting their decision making and distorting their judgment must have been very powerful indeed. Moreover, there is one more influence: *visual illusion.*

Many aircraft that have crashed under cloud into rising terrain having stalled while under full power. With the limited field of view, there is a tendency to use the ground as reference for level flight. The closer you get to the ground without a strong nose attitude vs. horizon reference, the more prone will you be to seeing the fuselage being parallel to the earth's surface as an indication of level flight. As the slope increases, therefore, so will the climb angle, until the inevitable stall.

It's the same phenomenon as not being able to judge height, anymore—too few visual clues available to make a correct assessment. The further you go pressing on, the less you'll appreciate just how close you are to the cloud and the tree tops. But, of course, you should never have got there in the first place. Unfortunately pilots do.



Figure 12-46 Rising terrain—false horizontal.

Personality and Matters of Choice

One of our defences against being discomforted by situations like these is the confidence that, "It won't happen to me." On the other hand, most of us do know people who we would rate as more-likely-than-most to do such a thing. Thus, the idea that some types are more prone to taking higher risks than others is not especially controversial. The sort or type of person is usually defined by a hazardous attitude.

Five Hazardous Attitudes

The FAA defines five types of hazardous mental attitudes for pilots. They include:

- *antiauthority (don't tell me!).* People who don't like others to tell them what to do are often resentful of wise advice and prone to disregarding the rules. *The antidote to antiauthority is: Follow the rules; they are usually right;*
- *impulsivity (do something, quickly!).* People who don't stop to think before they act are impulsive. They often do the first thing that comes to mind. *The antidote is: Not so fast. Think first;*
- *invulnerability (it won't happen to me).* We all know accidents happen, but some feel it could never happen to them. They are far more likely to take chances and risks. *The antidote is: It could happen to me;*
- *macho (I can do it).* Now, here's a person with something to prove and he or she will probably take risks to show off. *The antidote is: Taking chances is foolish;* and
- *resignation (what's the use?).* Resigned pilots figure that the flight went well because they were lucky. If the flight goes poorly, however, it isn't their fault, there's nothing they can, or will do to change things. *The antidote to this attitude is: I'm not helpless. I can make a difference.*

Formal Decision-Making Processes

You can learn to make better decisions by itemizing the correct decision-making process:

1. identify the decision to be made or problem to be solved;
2. collect relevant information;
3. generate alternatives;
4. analyze alternatives;
5. decide the most acceptable alternative;
6. action the alternative; and
7. monitor the outcome: if satisfactory, proceed; if not, repeat steps 2–7.

Pilots must assess the risks involved in any flight. Good judgment and decision-making skills can be learned.

While this may seem to be time consuming, it gives structure and method to the process and ensures no jumping to conclusions. Most airlines use these steps in crew resource management (CRM), decision making and training. It is a valid way to make decisions and to check if your normal process covers all options. But there is another important element: how much time you have to make the decision.

The other problem is not making a decision, i.e. deferring the decision until it is too late. You are forced into a situation where there is no decision to make. You are then committed with no escape route.

There is a well-known model for decision making based on the mnemonic DECIDE. This model implies the decision is a reaction to circumstances, a situation or a change in events. A better way to make decisions is to anticipate—to be *pro*active rather than *re*active. Have the decision made before it is needed—on standby—like you practice emergency procedures so you can anticipate a decision point and have most of the work done.

D Detect a change.

E Estimate the need to react.

C Choose an outcome.

I Identify actions.

D Do the necessary action.

E Evaluate the effect.



Figure 12-47
In-flight decisions must be decisive.

Crises? Decisions should ideally not be made under duress—in a crisis situation. They should be made under controlled conditions and be stored—ready for use. A different model is based on the mnemonic ACTION:

- **A** Anticipate and assess the possible scenarios.
- **C** Consider actions and outcomes.
- **T** Time—if available, immediate decision or nominate decision point (go/no-go point) and criteria.
- **I** Implement decision—make a control input, transmission etc.
- **O** Observe the result and correct—fine tune.
- **N** Nominate the next milestone, decision point or potential hazard.

Many problems are due to no decision or a delayed decision. Decisions are easy to defer. Deferring decisions is only acceptable if a nominated decision point is made and adhered to.

Assembling What-If's

Sesame Street (Envisioning Outcomes)

A fabulous episode of Sesame Street involved a child who was encouraged to imagine outcomes before crossing the road:

- what if I run onto the road without warning . . . ?
- what if I run out in front of a school bus . . . ?
- what if I run across the road and trip . . . ?
- what if I cross without looking in both directions . . . ?

This is exactly the what-if attitude a pilot needs to develop.

Choosing the Best Option

Priorities

The first priority must surely be to arrive safely, but we often neglect that or compromise it for "must arrive today," "must get to a meeting on time," "must land before dark," "haven't time to top off the tanks, complete a fuel check, complete an engine run-up check," etc.

Bets and Betters

We endlessly evaluate bad decisions but what about some examples of good decisions? It is better to spend a cold night in a sleeping bag in a tent under the wing of the airplane than flying into deteriorating weather and impacting terrain. It is better to arrive late, even the next day or next week, than not at all.

If you have to be there, have an alternative plan: "I will leave early enough so that if the weather deteriorates over the mountains, I can land at . . . and take the bus and pick up the airplane on the way home."

It's better to accept the rebuke, criticism and complaints of a passenger or employer by refusing to overload the airplane or exceed the CG limits than crash on takeoff. Saying "I told you so" is no consolation in the eddying seconds of the flight as you

inevitably impact the trees. (Incidentally, they expect you to protect them from themselves.) It is better to land and leave your family safely on the ground rather than risk injuring all of them because you have to get to a business meeting. But then shouldn't you also stay on the ground with them? It is better to pay several hundred dollars for taxis and hotel rooms at an unplanned stop than miss your daughter's wedding and have them attend your hospital bed instead. It is better to be called a chicken than to be decimated and burned in the wreck of an airplane that stalled and spun trying to attempt a low pass after takeoff. It is better to go around and accept the extra time and expense than land when the runway is occupied or when your threshold speed is too high. You bet!

On Def Ears

Two common situations lead to dangerous situations. They are:

- deference; and
- deferral.

Deference is when you relinquish the decision to someone or allow their views to dominate such as when you avoid discussion and possible conflict, or when you want to please by saying what they want to hear or doing what they want to do despite your inner feelings that this option is perhaps risky. Deferral is avoiding making a decision—until later perhaps until its too late. This is the reason you have to set your own milestones, gates and go/no-go points and stick to them.

Choosing When to Implement a Decision

As important as the decision is the timing (when to implement it). But when is the right time?

- Immediately?
- Before sunset?
- Before reaching the point of no return (PNR)?
- Before becoming fatigued?
- Before becoming stressed due to weather or terrain?



Figure 12-48
Go or no go.

Mostly a decision is needed now. But there are some occasions when a gate or milestone can be set. For example:

- I will proceed until the PNR, but at that point, if I have any doubts about the weather at the destination, I will turn back. (The decision is already made and the criteria set. The decision point is also set—it is non-negotiable);
- I will maintain minimums until overhead the airfield and if I cannot see the runway lights I will divert to the alternate. (I will not descend);
- I will continue while I can maintain safe terrain clearance. I have a defined horizon and I have at least a 500-foot vertical separation from cloud. If I lose the horizon, if I feel squeezed between ground and cloud, I will immediately turn right (least risk); and
- I will continue until an intermediate landing point and if I do not reach there by a certain time, which guarantees I will reach the ultimate destination by sunset, I will land.

Review 12
The Human in the Cockpit

Am I Fit to Fly?

1. You have consumed a small amount of alcohol. You should not fly for at least how many hours?
2. What is Hypothermia?
3. The FAA prescribes a method for evaluating risk and reducing stress. What is it?
4. List at least two ways you can keep your stress levels down when planning a flight or during a flight.

Respiration

5. What is hypoxia?
6. What is hyperventilation?
7. What effect does hyperventilation have on the body?
8. What is the main cause of hyperventilation?
9. Name a common symptom of hyperventilation.
10. Why is a faulty exhaust system potentially dangerous?
11. Susceptibility to carbon monoxide poisoning increases as:
    - **a.** air pressure increases.
    - **b.** altitude decreases.
    - **c.** altitude increases.

Balance

12. What is spatial disorientation?
13. What should you rely on in order to interpret airplane attitude in poor visibility conditions?
14. To best overcome the effects of spatial disorientation, a pilot should:
    - **a.** rely on body sensations.
    - **b.** increase the breathing rate.
    - **c.** rely on aircraft instrument indications.

Vision

15. The retina contains rods and cones. Describe where each are located in the eye.
16. True or false? Cones are most effective at night.
17. Are rods color-sensitive?
18. What is your peripheral vision provided by?
19. What is the most effective method of scanning for other aircraft in daylight?
20. True or false? In daylight, other aircraft are most clearly seen in your central vision.
21. Another aircraft remains in view in the same position in your windshield. Is there a possibility that you are on a collision course?
22. True or false? At night, other aircraft are most clearly seen in your central vision.
23. The most effective method of scanning for other aircraft for collision avoidance during nighttime hours is to use:
    - **a.** regularly spaced concentration on the 3, 9, and 12 o'clock positions.
    - **b.** a series of short, regularly spaced eye movements to search each 30° sector.
    - **c.** peripheral vision by slowly scanning small sectors and utilizing off-center viewing.
24. How can you determine if another aircraft is on a collision course with your aircraft?
25. Is it possible for other objects to be closer than they appear to be in hazy conditions?
26. If you are exposed to bright lights prior to flight, how long is it recommended you wait before undertaking a night flight?
27. During a night flight, you observe a steady red light and a flashing red light ahead and at the same altitude. What is the general direction of movement of the other aircraft?
28. What illusion can an upward sloping runway give?
29. What illusion can a narrow runway give?

Answers are given on page 652.