SUBCOURSE
AV0593

EDITION
6

U.S. ARMY AVIATION CENTER

Aviation Medicine

THIS SUBCOURSE HAS BEEN REVIEWED FOR
OPERATIONS SECURITY CONSIDERATIONS.

THE ARMY INSTITUTE FOR PROFESSIONAL DEVELOPMENT
ARMY CORRESPONDENCE COURSE PROGRAM

AIPD
READINESS/PROFESSIONALISM THRU GROWTH

UNITED STATES ARMY CORRESPONDENCE COURSE

AVIATION SUBCOURSE 593

AVIATION MEDICINE

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LESSON 4. SPATIAL DISORIENTATION

<u>INTRODUCTION</u>

Aviation medicine and vision are integral to any aviation safety program. Understanding the requirements and capabilities of the aviation medicine program will enhance safety training and safety performance. Under-standing the capabilities and limitations of night vision, perceptual limitations and spatial disorientation will also facilitate aviation unit safety and safety training.

<u>Supplementary training material to be provided</u>--none.

<u>Material to be provided by the student</u>--none.

<u>Material to be provided by the unit or supervisor</u>--none.

<u>Supervision required</u>--none.

Seven credit hours are awarded for successful completion of this subcourse. Successful completion requires a grade of at least 70 percent on the examination.

LESSON 1. AVIATION MEDICINE PROGRAM

TASK: To evaluate an aviation medicine program recognizing the duties and responsibilities of the flight surgeon and medical restrictions to flight.

OBJECTIVES: You will know the aims of the aviation medicine program, the functions of the flight surgeon and be able to list the factors that require flight restriction.

CONDITION: You may use the text and references to complete the review exercise.

STANDARD: You must answer correctly at least 8 of 10 review exercise questions.

REFERENCES: AR 40-5 (Sep 84)(with changes), AR 40-8 (Aug 76), AR 385-95 (Dec 82)(with changes), U.S. Army Safety Center Publication, Aeromedical Aspects of Aviation Safety (Jun 80).

LESSON TEXT

1. GENERAL

Man and his environment are stable with respect to each other. The human animal, as we know him, has evolved over thousands of years to become an efficiently functioning organism under the conditions as present on the surface of the earth (gravity and atmospheric pressure). However, man has been released from the bonds of earth by flight and is traveling into space and even to the moon. While aircraft and aircraft systems have steadily improved, the human body and mind have remained essentially unchanged with little change expected during the next several centuries. This leaves us with an aviation subsystem (man) that possesses known limitations around which aircraft must be designed and operated. Since the human operator is an integral subsystem, it becomes obvious that the individual deserves the same care and attention as other subsystems. If a few basic rules and guidelines are disregarded an accident can occur. This is not to say that the individual is always responsible, but man is frequently the weak link in the man-machine relationship.

a. Aviation Medicine Program Requirements. The requirements for the procurement (initial entry physical qualification), inspection (annual physical examination), maintenance (physiologic and physical fitness training) and repair (clinical care) of aircrew members are established by AR 40-5. The aviation medicine program is a vital part of the Army aviation safety program and is designed to reduce the number of accidents resulting from human error. This program is also designed to minimize injury and illness due to an aviation environment.

b. Aviation Medicine Program Aim. The specific aim of the program is to promote health and safety through preventive practices. These practices include physical examinations; clinical care; hygiene and physical fitness; education and training of aircrew members; and inspection of the living and working environment of aviation personnel.

2. FLIGHT SURGEON ROLES

Most aircrew members view the flight surgeon only as the person to whom they go when they are sick or need a flight physical. However, the duties of the flight surgeon are more complex and demanding. In any week a flight surgeon may be required to perform in one or all of the following capacities.

a. Perform Physical Examinations. All soldiers receiving proficiency pay for flight must be given physical examinations.

(1) Initial flying physicals: Before a soldier can be trained as an Army aviator or perform duties as crew member on an Army aircraft he must be given an initial physical. During this physical the flight surgeon must determine if the soldier meets the physical requirements for flying duty and if he is able to cope with the psychological stress of flight.

(2) Annual flying physicals: All Army aviators and flight crew members must be given annual physicals. During this physical the flight surgeon must ensure the crew member is physically and emotionally able to continue his duties.

(3) Post-mishap physicals: All crew members aboard an aircraft at the time of an accident mishap must be given a physical before being allowed to continue flying duties.

b. Provide Medical Care to Include Prevention and Treatment of Illness.

(1) Crew member sick call: The flight surgeon will be available to diagnose and treat all crew members suffering from illness or injury.

(2) Family practice: The flight surgeon may, as part of a hospital staff, be required to perform services in family practice or other hospital clinics.

c. Act as an Advisor to the Commander. The flight surgeon will act as a consultant to aviation unit commanders on individual and unit health problems that could compromise flying safety. He will also maintain liaison with the command to implement the aviation medicine program.

d. <u>Act as a Board Member</u>.

(1) <u>Accident investigation boards</u>: A flight surgeon is a required member of accident investigation boards. He will make recommendations to improve the human factors compatibility, crashworthiness and survival features of the aircraft. These recommendations will be based upon the accident investigation or from observations made while performing other aeromedical functions.

(2) <u>Flying evaluation boards</u>.

(3) <u>Unit safety council</u>.

e. <u>Supervision</u>. Supervise the fitting and use of safety equipment for aviation personnel and monitor the survival and physiological training of aviation crew members.

f. <u>Safety Meetings and Training</u>. Participate in unit safety meetings and training to educate crew members on the aeromedical aspects of flight.

g. <u>Flying</u>. Fly as a crew member to observe flight operations and to monitor the interactions of other crew members, aircraft and environment.

h. <u>Unit Preaccident Plan</u>. Ensure the medical portion of the unit preaccident plan is adequate.

i. <u>Monitoring</u>. Monitor the physical and mental well-being of aviation personnel, including drug or alcohol abuse and self-medication problems.

j. <u>Records</u>. Maintain aviation medical records.

k. <u>Assistance</u>. Assist in and advise on hearing and eyesight conservation programs.

3. FLYING RESTRICTIONS

Flight crew members must be in top physical and psychological condition to perform their duties. Physical fitness may be affected by a variety of outside factors (for example, medications), some of which may not be noticeable in nonflying activities, that may impact considerably on their flying safety. Flight crew members partaking of any substance or medical procedure likely to provoke an adverse systemic reaction will, by regulation (AR 40-8), be restricted from flying duties until declared fit by a flight surgeon. The flight surgeon on his own does not have the authority to ground an aviator (the aviator must be grounded by the commander). However, the flight surgeon will inform the commander of the required restrictions from flight based on the individual's physical condition or any medication that is being taken.

a. Flight Safety Requirements. Flight safety requires that the medical treatment of all crew members be under the supervision of a flight surgeon who is aware of the effects of medication on flying duties.

b. Crew member Requirements. Crew members are required by regulation to inform their flight surgeon when they have participated in activities or received treatment which may require the imposition of a flying restriction.

c. Medical Restrictions. Appropriate medical restrictions from flying will be made under the following conditions.

(1) Administration of drugs: Flight crew members who are taking a drug which has a systemic effect will be restricted from flying duties until convalescence or rehabilitation is complete. This does not mean that crew members are prohibited from being prescribed medication after aeromedical evaluation by appropriate medical authority. Drugs and medication will be dispensed by or with the consent of a qualified flight surgeon. Individuals receiving medication or drugs will be restricted flying duties as listed.

(a) Alcohol. Individuals using alcohol will be restricted from flight for 12 hours after their last drink or until no residual effects (hangover) remain.

(b) Antihistamines and barbiturate. Individuals using antihistamines or barbiturates will be restricted from flight starting with use and for a period of 24 hours from the time usage is discontinued. This time period may be extended until side effects are no longer present.

(c) Mood altering and tranquilizing drugs. Individuals using these drugs will be restricted from flight during use and for a period of four weeks following discontinuance of use.

(2) Immunizations: Medical restriction from flying will be for a minimum of 12 hours following all immunizations (except smallpox) or for the duration of systemic or severe local reaction(s), whichever is longer.

(3) Blood donation: Blood donations (200cc or more) require a restriction from flight for a period of 72 hours from the time of donation.

(4) Decompression: Crew members will be restricted from flying duties when symptoms or reactions occur during or following decompression. If symptoms from decompression are present the crew member will be restricted until evaluated and released by a flight surgeon. Crew members engaging in low-pressure altitude chamber flights (regardless of altitude reached) will be restricted from flying for 12 hours following decompression.

(a) Decompression sickness. The incidence of decompression sickness during flight is considerably higher after exposure to an environment (scuba diving) with higher than standard atmospheric pressure.

(b) Scuba diving or compressed air dives. Crew members will not perform flying duties for a period of 24 hours following scuba diving or compressed air dives. If operational requirements dictate, personnel may fly during this period provided no symptoms have developed and they are cleared by a flight surgeon to perform flying duties.

d. Other Conditions or Situations Causing Restriction. Other conditions or situations that may be cause for restriction or may limit flight duties include the use of tobacco, strenuous sporting activities and corrective lenses for vision.

(1) Tobacco smoking: Crew members are discouraged from smoking at all times, but those who do smoke should be warned of the special effects smoking has on vision and flying at altitude. Smoking degrades the ability of the eyes to adjust to reduced lighting (such as at night). Smoking also increases the level of carbon monoxide in the blood which will compound the hypoxic effect of flying at altitude. For example, the average cigarette smoker will experience hypoxic effects equivalent to adding 5,000 feet to his actual flight altitude.

(2) Strenuous sporting activities: The effects of strenuous physical activity should be considered when assigning (or restricting) flight duties immediately following physical activity. It should be remembered that what may not be strenuous to some individuals may be strenuous to others.

(3) Corrective lenses for vision: Personnel requiring corrective lenses to achieve 20/20 vision shall be restricted from flying duties unless they are using the prescribed lenses. Contact lenses will not be worn by crew members.

4. MEDICAL SUBJECTS FOR SAFETY MEETINGS

As part of the aviation medicine program the flight surgeon is not only required to monitor but also to conduct certain types of training. Aeromedical subjects that would be of value to aviation units that should be presented by the flight surgeon include the following:

a. Aviation Accidents in Which Human Factors Were Involved.

b. Proper Fitting and Use of Safety Clothing and Equipment.

c. Physiological Problems of Night Flight.

d. Perceptual Limitations.

e. Spatial Disorientation.

f. Physical Fitness and Aircrew Performance.

g. Crew Endurance Limitations.

h. Medical Aspects of Drug and Alcohol Abuse.

i. Other Subjects. Other subjects the flight surgeon, commander or aviation safety officer feel would enhance the safety training of the unit.

REVIEW EXERCISE

REQUIREMENT: Complete the following by selecting the correct answers.

1. The aviation medicine program is designed to reduce the number of accidents resulting from human error with the specific aim of

A. grounding aviators who are not physically qualified.
B. promoting health and safety through preventive practices.
C. training aviation personnel in all aspects of the aviation medicine program.
D. ensuring regulatory restrictions from flight are enforced whenever medicine is prescribed.

2. In addition to conducting required flight physicals, a flight surgeon

A. reviews the flight records of all aviation personnel.
B. must be present at all aviation unit safety meetings.
C. can restrict an aviator from flight when he prescribes medication.
D. is a required member of aviation accident investigation boards.

3. A flight surgeon is not required to

A. fly as a crew member.
B. monitor the mental well-being of aviation personnel.
C. participate as a member of aviation unit safety survey teams.
D. ensure the medical portion of the unit preaccident plan is adequate.

4. After donating blood, a crew member should be restricted from flight for a period of

A. 24 hours.
B. 48 hours.
C. 72 hours.
D. 96 hours.

5. Treatment, administered by a doctor (not a flight surgeon), that may require the imposition of a flying restriction must be reported to a flight surgeon by the

A. unit commander.
B. unit safety officer.
C. individual crew member.
D. clerk handling the crew member's medical records.

6. Strenuous sporting activities

   A. should be considered in assigning flight duties.
   B. are considered to have the same effect on everyone.
   C. should be restricted to nonflying members of the unit.
   D. are always considered justification for restricting flight duties.

7. Contact lenses may

   A. be worn by aviators.
   B. not be worn by crew members.
   C. be worn by crew members other than pilots.
   D. be worn except during the hours of darkness.

8. A safety class concerning aviation accidents in which human factors were involved should be taught by the

   A. flight surgeon.
   B. safety officer.
   C. operations officer.
   D. maintenance officer.

9. The person with the authority to restrict the flight duties for medical reasons is the

   A. flight surgeon.
   B. unit commander.
   C. operations officer.
   D. flight section leader.

10. A crew member who has a systemic reaction to a medical procedure will be restricted from flying duties

   A. for 24 hours.
   B. until cleared by the commander.
   C. until the reaction no longer exists.
   D. until declared fit by a flight surgeon.

REVIEW EXERCISE SOLUTIONS

1. B. (paragraph 1b)
2. D. (paragraph 2d(1))
3. C. (paragraphs 2g, h, and i)
4. C. (paragraph 3c(3))
5. C. (paragraph 3b)
6. A. (paragraph 3d(2))
7. B. (paragraph 3d(3))
8. A. (paragraph 4a)
9. B. (paragraph 3, introduction)
10. D. (paragraph 3, introduction)

LESSON 2. NIGHT VISION IN AVIATION

TASK: To incorporate night vision capabilities and limitations into the aviation medicine program and the unit safety program.

OBJECTIVE: You will be familiar with the structure, anatomy and physiology of the eye; night viewing conditions and techniques; and the hazards associated with night vision.

CONDITION: You may use the lesson text and reference to complete the review exercise.

STANDARD: You must correctly answer at least 8 of 10 review exercise questions.

REFERENCE: FM 1-301 (Mar 83).

LESSON TEXT

1. GENERAL

There are three types of vision, each type requiring a different sensory stimulus or ambient lighting condition, Photopic vision is experienced during daylight hours or when a high level of artificial illumination exists. Mesopic vision is experienced at dawn, dusk and during periods when the level of light is equivalent-to that of full moonlight. Scotopic vision is experienced when low levels of light exist. In order to understand the capabilities and limitations resulting from resopic and scotopic vision it is necessary to understand the structure, anatomy and physiology of the eye. Before flying in conditions of low illumination you should also understand the hazards to night vision and what can be done to prepare for flights made under those conditions.

2. EYE STRUCTURE

The structure of the eye (Figure 1) can be compared to the structure of a camera. The hard, white, outer coat of the eye (sclera) serves the same purpose as the camera case. The cornea and the thin protective layer covering the cornea (conjunctiva) compare to filters used to protect the camera lens from outside elements. The iris and pupil can be compared to the camera aperture and the eye lens is the same as the camera lens. Finally, the retina can be compared to the film of the camera where the image is projected before being sent to the brain for interpretation (film developing). In order to get a clear picture, the eye (camera) must be in focus. The eve accomplishes this by the use of muscles to extend and contract the eyeball to achieve the proper focal distance. Unlike a camera, out-of-focus pictures from the eye can be the result of four different problems.

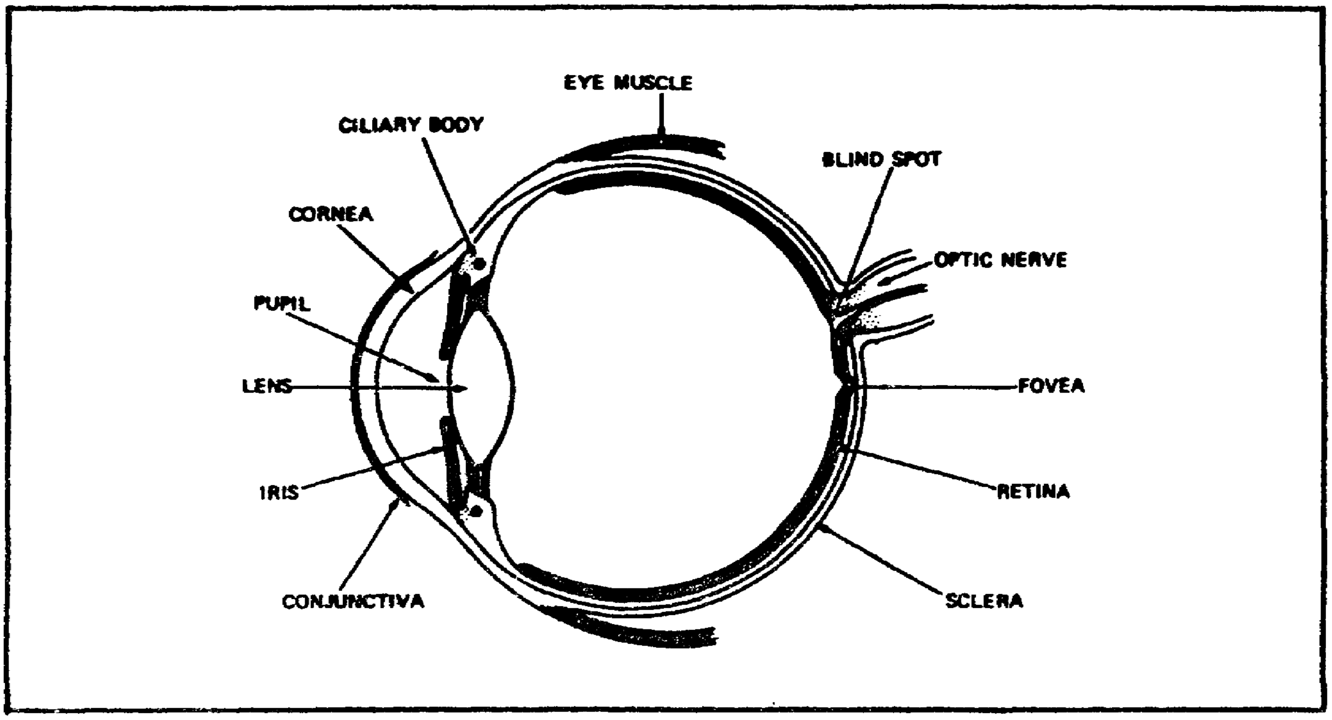


Figure 1. Eye structure.

a. Myopia. This out-of-focus condition results when the eye is unable to contract to the required focal length for a clear picture (Figure 2) and is commonly referred to as nearsightedness.

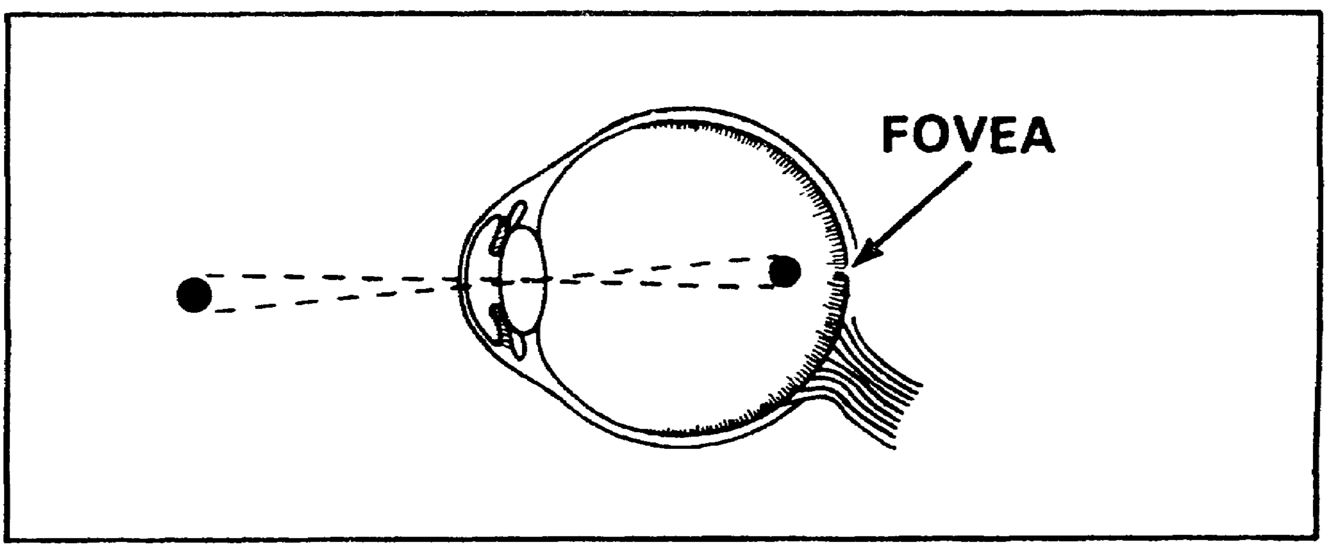


Figure 2. Myopia.

b. Hyperopia. This out-of-focus condition results when the eye is unable to extend to the required focal length for a clear picture (Figure 3) and is commonly referred to as farsightedness.

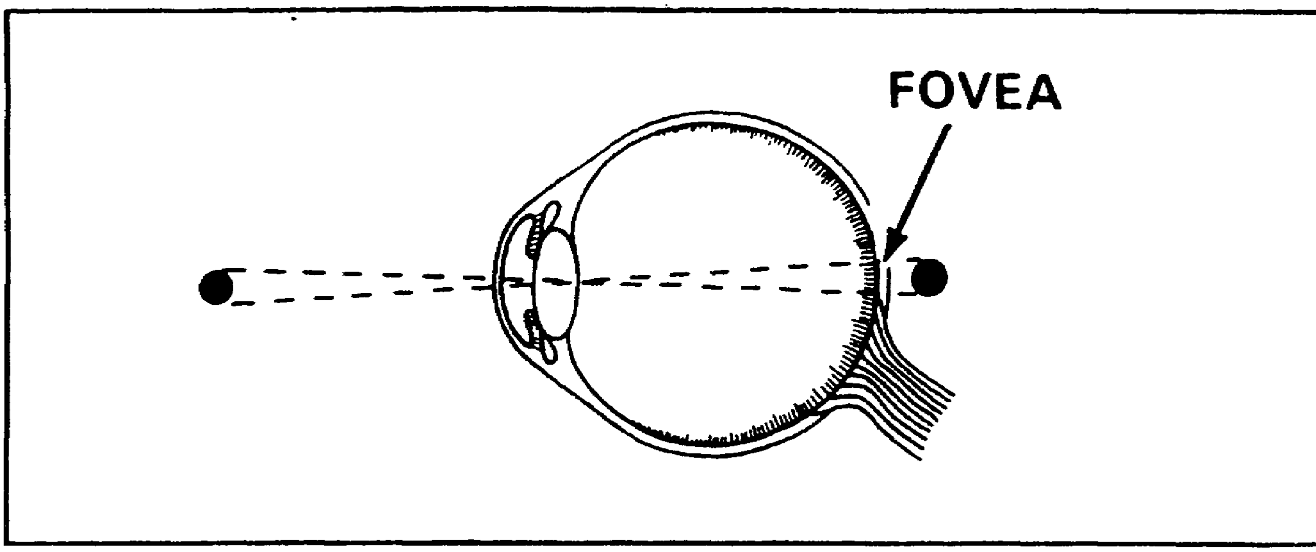


Figure 3. Hyperopia.

c. Astigmatism. Basically, astigmatism is the inability to simultaneously focus different meridians. If, for example, the individual focuses on power poles (vertical reference), the wires (horizontal reference) will be out of focus (Figure 4).

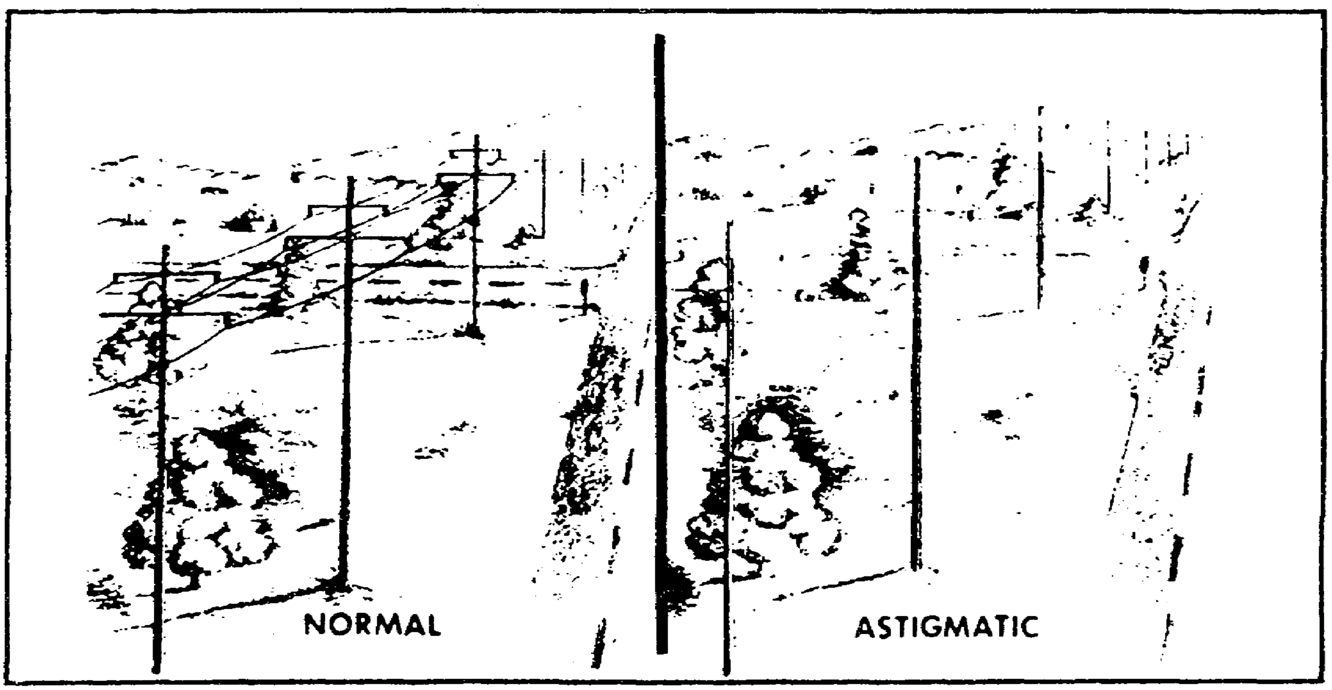


Figure 4. Astigmatism.

d. Presbyopia. Presbyopia is the inability to accommodate and focus on near objects. It is a normal aging process where the ability to accommodate for near objects is reduced gradually, beginning in the early teens. At approximately 40 years of age, the eyes are unable to focus at the normal reading distance and reading glasses are needed to assist in focusing. Additionally, any reduction in illumination interferes with depth of focus and accommodation ability.

3. EYE ANATOMY AND PHYSIOLOGY

The retina (camera film) contains both retinal rods (rods) and cell cones (cones). The cones are used principally for vision during periods of high illumination (daylight) and the rods are used principally for vision during periods of low illumination. The differing eye characteristics between day vision and night vision are due in part to the distribution of the rods and cones. Notice in Figure 5 that the center of the retina, the fovea centralis (fovea), contains only cones. The concentration of cones decreases and the concentration of rods increases as you move to the peripheries of the retina which are almost totally rods. Also notice that at the point the optic nerve enters the eye (optic disc) there are neither rods nor cones. This optic disc creates a day blind spot which is compensated for by the fact that we have two eyes with overlapping fields of view. However, the fact that we have two eyes does not compensate for the night blind spot that is created by the fovea which has only cones and no rods.

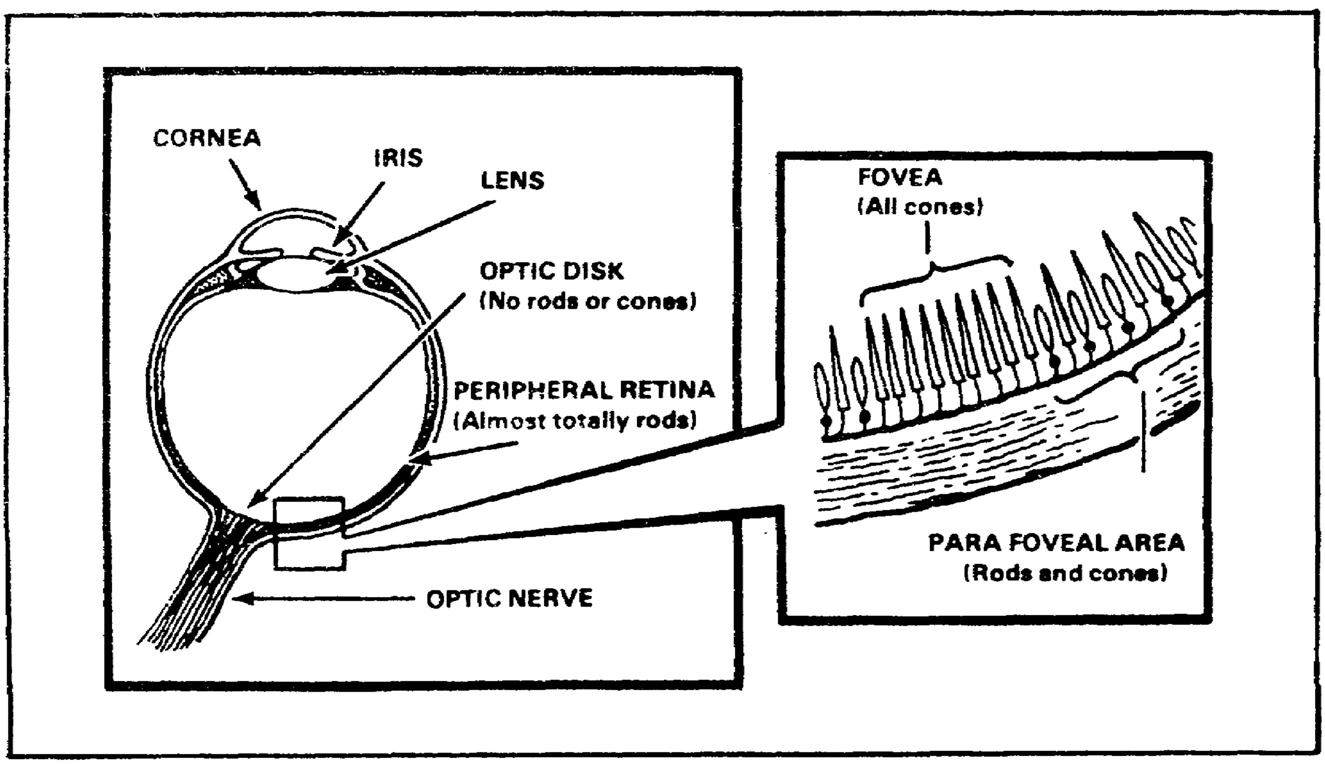


Figure 5. Anatomy of the eye.

a. Photopic Vision. During periods of sunlight or high illumination we find the aperture of the eye (pupil) closing to accommodate the brightness. Discriminations during these periods require only the use of cones. Since the focal point on the retina is the fovea, this set of conditions gives a clear, crisp picture with good color discrimination and depth of view (depth perception).

b. Mesopic Vision. During periods of reduced illumination the pupil opens to accommodate the reduction in illumination. Discriminations during these periods require the use of both rods and cones. The focal point on the retina is still the fovea, but since the discrimination must be made on the periphery of the fovea, the picture transmitted to the brain will be different. Pictures will not be as sharp and colors will change.

c. Scotopic Vision. During periods of darkness or low illumination the pupil is completely open to accommodate the low illumination. Discriminations during these periods require the use of rods only. During these periods you will have a central vision blind spot (Figure 6), be unable to distinguish the color of objects and peripheral vision will be the only means of seeing very dim objects.

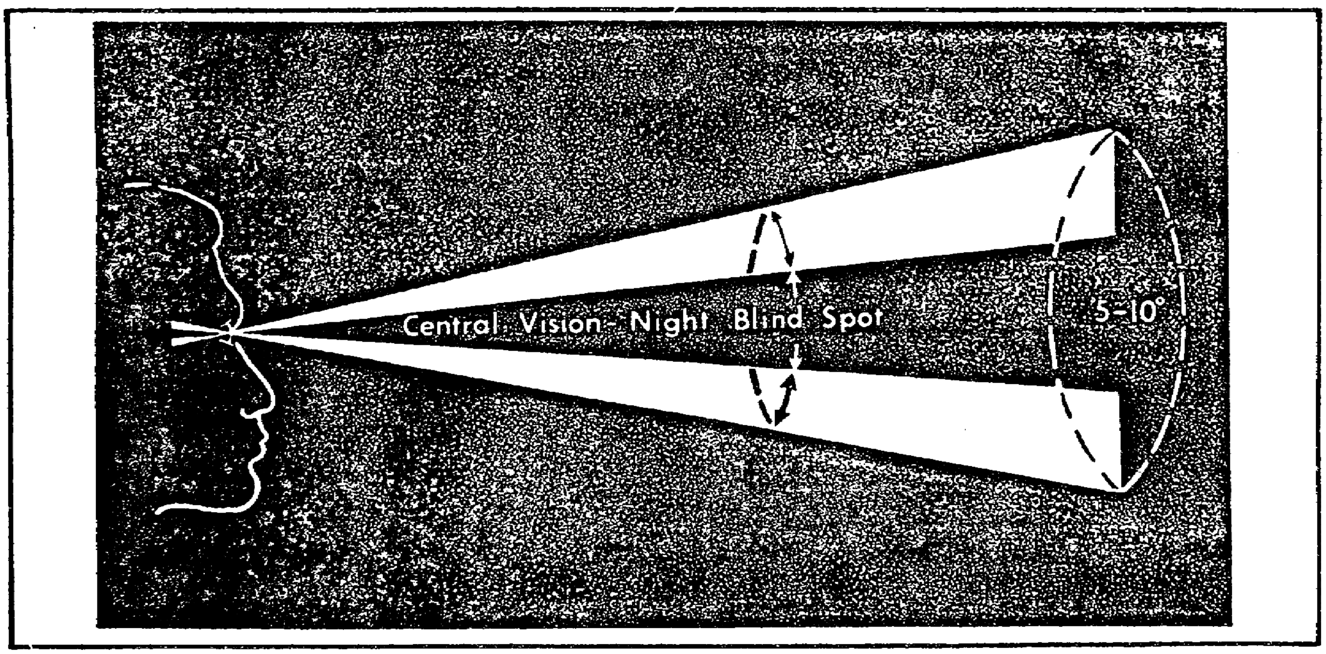


Figure 6. Night blind spot.

4. NIGHT VISION LIMITATIONS AND CAPABILITIES

There are four limitations to vision created by reductions in the amount of illumination. These are the existence of the night blind spot, the inability to detect objects while the eye is in motion, the degradation of depth perception and a reduction in visual acuity.

a. <u>Night Blind Spot</u>. The night blind spot can be experienced by looking at a distant object on a dark night. If you stare directly at the object it will disappear; however, if you look to the side of the object it will reappear. The blind spot is from 5 to 10 degrees in width and is centered in the field of vision (Figure 6). This means that as the distance to an object increases, the size of the blind spot will also increase. For example, at a distance of 3 feet an object the size of a screw can be lost in the blind spot, but at a distance of 3,000 feet an object the size of a large aircraft may be lost (Figure 7). To compensate for this blind spot a person must use a good scanning technique. Although the effectiveness of a technique varies with the individual, there is a suggested technique for an effective scan (Figure 8). This technique uses a pattern that goes from either the left to the right or from the right to the left, starting as far out as objects can be recognized and working inward toward yourself.

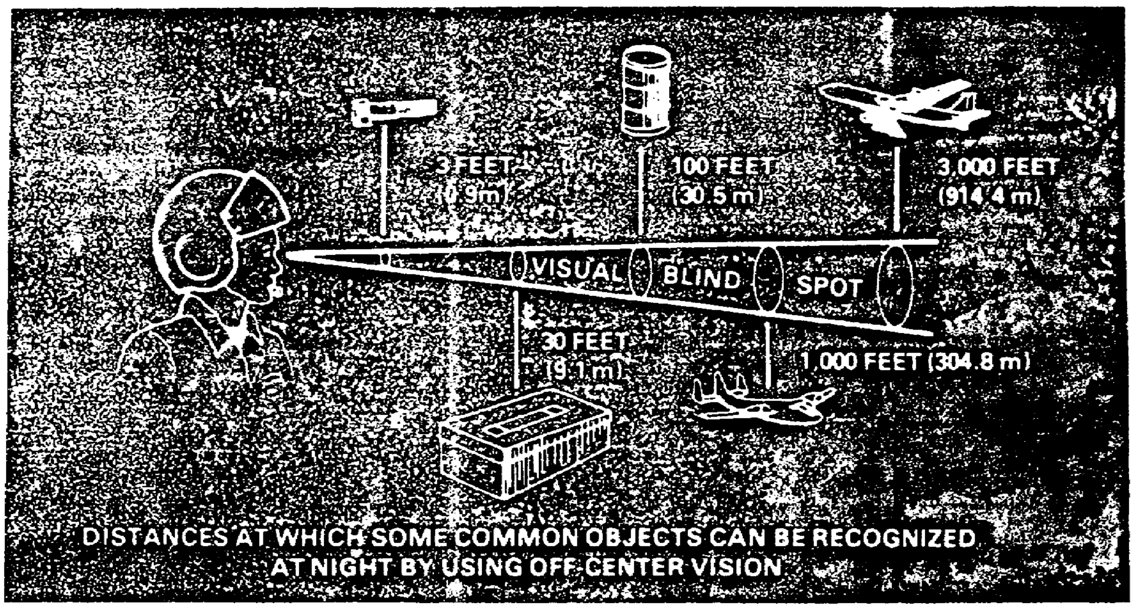


Figure 7. Effects of night blind spots.

b. <u>Motion of the Eye</u>. The light sensitive elements of the retina are unable to perceive images while the eye is in motion, therefore, a stop-turn method should be used. Each time the eye stop. you should concentrate on an area about 30 degrees in width. The length of the stop will depend on the clarity desired, but should be no longer than 2 to 3 seconds. When moving from one viewing point to the next, you should overlap the previous field of view by at least 10 degrees. Once an object has been detected, you can continue to track the object by using off-center vision by focusing 10 degrees right, left, above or below the object.

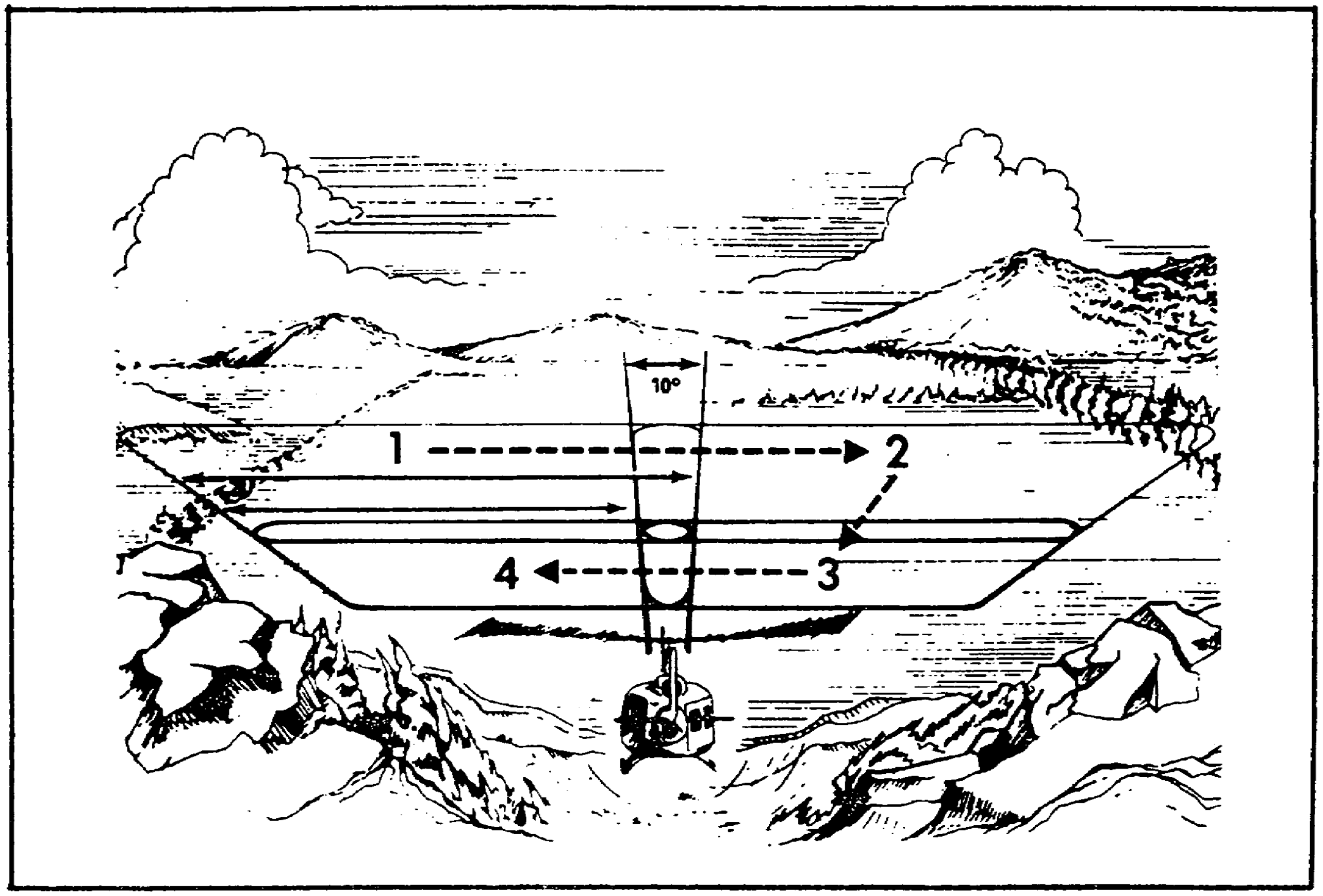


Figure 8. Scanning pattern.

c. Depth Perception. Periods of low illumination greatly reduce the ability of the eve to determine distances. Therefore, various cues must be used to estimate distances at night. These monocular cues are usually used at the subconscious level. Awareness of these cues by crew members may enable them to look for and use cues that they are not in the habit of using.

(1) Geometric perspective: The size and shape of an object changes depending on the distance and angle from which it is viewed. These apparent changes give a geometric perspective that is evaluated in three different ways.

(a) Linear perspective. Objects appear to converge over distance. Therefore, you estimate the distance to an object by comparing the apparent separation to the known separation. For example, if you know the distance between the navigation lights of an aircraft, you can estimate the distance to the aircraft by comparing their apparent separation distance to the known separation distance.

(b) Apparent foreshortening. The shape of an object tends to appear elliptical over distance. Therefore, you estimate the distance to an object by comparing its apparent shape to its known shape. For example, the greater the amount of detail you can recognize on an aircraft, the closer you are to the aircraft.

(c) Vertical position in the field of vision. Objects tend to be higher in the field of vision over distance. Therefore, you estimate the distance to an object by its position in the field of vision. For example, terrain features which are far away from the observer appear higher in the field of vision than terrain features closer to the observer.

(2) Motion parallax: Motion parallax is the apparent motion of stationary objects due to the motion of the observer. The speed with which the object moves or whether it is stationary is dependent upon the distance the observer is from the object. For example, fence posts close to the observer will appear to be moving rapidly, trees at a greater distance will appear to be moving more slowly, and mountains at even greater distances will appear stationary. This cue to depth perception is considered important because of its use during low-level flight.

(3) Retinal image size: The brain determines the distance to objects by interpreting the size of the image focused on the retina. The brain is able to determine the distance to an object by comparison of several different factors. Those factors include the known size of the object, increasing or decreasing size due to movement, terrestrial associations and overlapping of contours.

(a) Known size of objects. The nearer an object is to the observer the larger the retinal image is. By experience, the brain learns to estimate the distance of familiar objects from the size of their retinal image. A structure will subtend a specific angle on the retina based on the distance from the observer. If the angle is small the observer knows the distance is great. To do this the observer must know the size of the object and have prior visual experience with it.

(b) Increasing and decreasing sizes of objects. If the retinal image size increases, the object is becoming closer to the observer. If the size decreases, the object is becoming farther from the observer. However, if the size is constant, the object has remained a fixed distance from the observer.

(c) Terrestrial associations. Comparing an object of unknown size to an object of known size may be helpful in determining the relative size of the unknown object and its apparent distance from the observer. Ordinarily, the objects to be compared are judged to be at approximately the same distance from the observer (Figure 9). For example, if you see an aircraft (known size) in the vicinity of an airport (unknown size and distance) you can judge the aircraft to be in the traffic pattern and that the airfield is at approximately the same distance (determined from the known size of the aircraft).

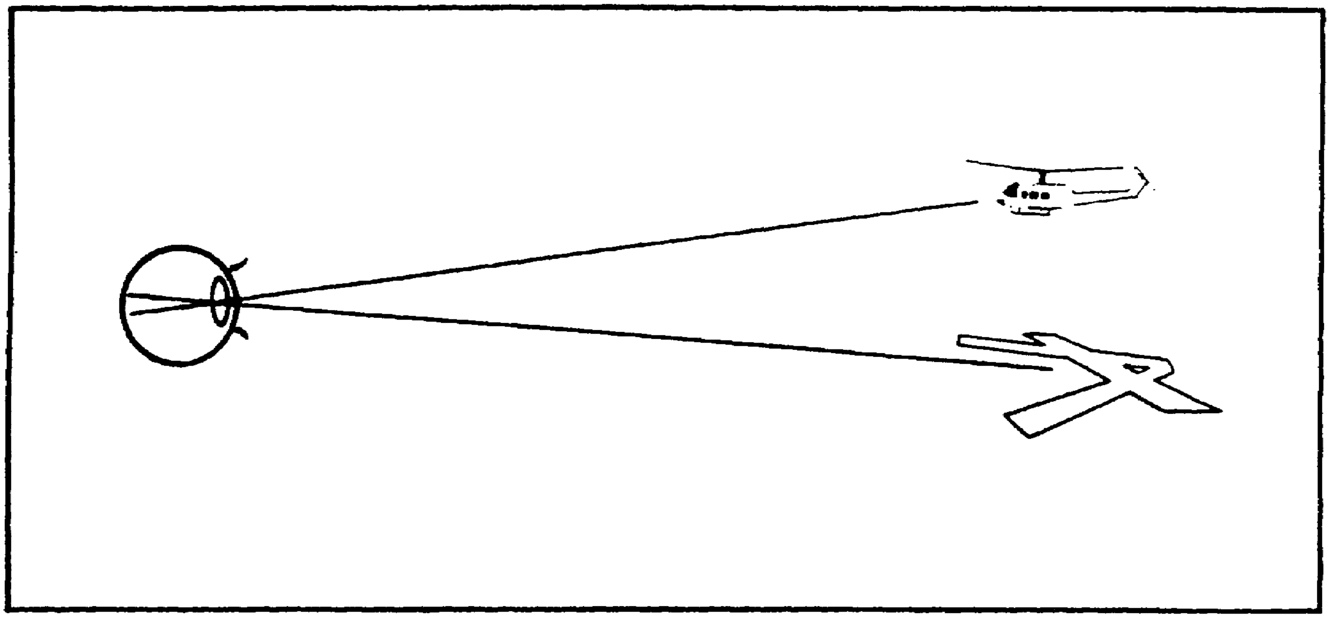


Figure 9. Terrestrial associations.

(d) Overlapping of contours. When one object appears to overlap another, the object seeming to be overlapped is farther away. In other words, any object concealed by another object is determined to be behind the object seen clearly (Figure 10).

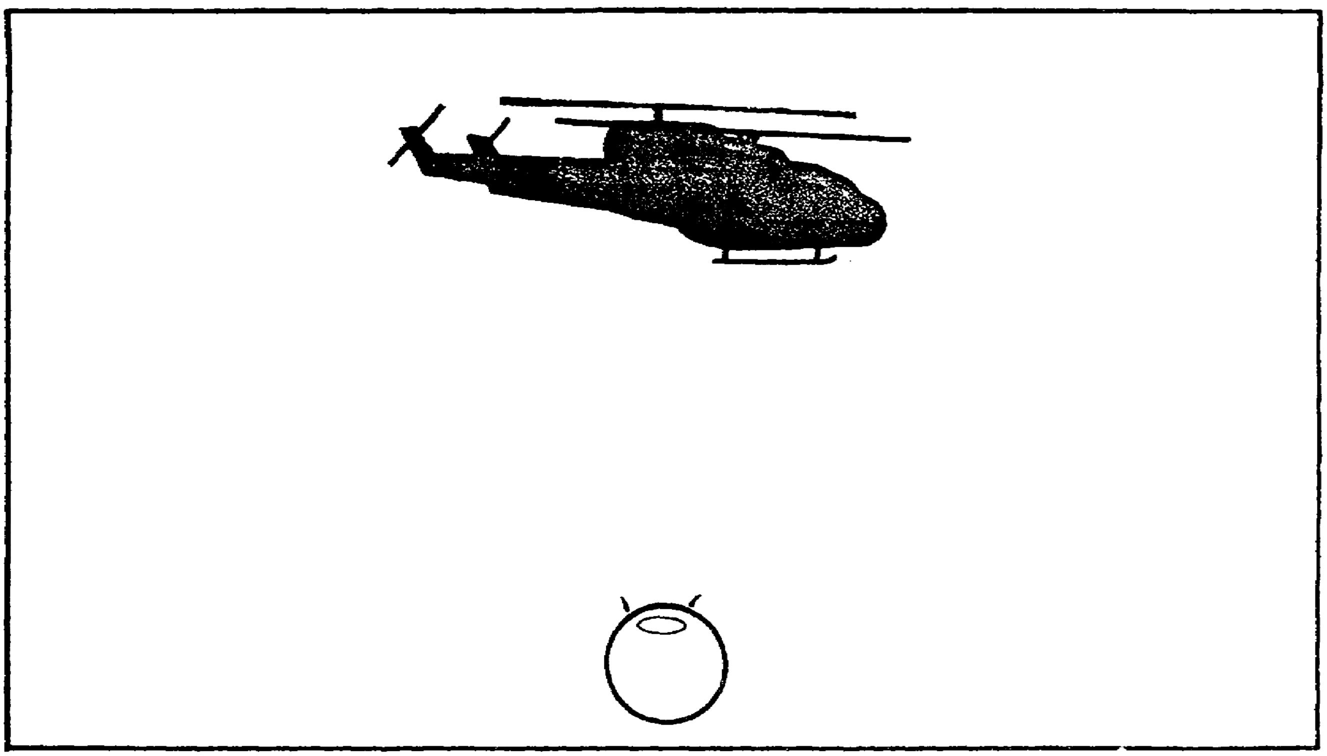


Figure 10. Overlapping contours.

(4) Aerial perspective: The clarity of an object and the shadow cast by the object are perceived by the brain and used as cues for estimating distance. The factors used to determine distance during periods of reduced illumination are loss of discrimination and light and shadows.

(a) Loss of discrimination. As you get farther from an object discrete details become less apparent. For example, a town at a great distance would appear as a single source of light, but as you approach it the individual light of each building is discernible.

(b) Light and shadows. Every object will cast a shadow if there is a source of light. The direction the shadow is cast depends on the position of the light source. If the shadow of an object is toward the observer, the object is closer than the light source (Figure 11).

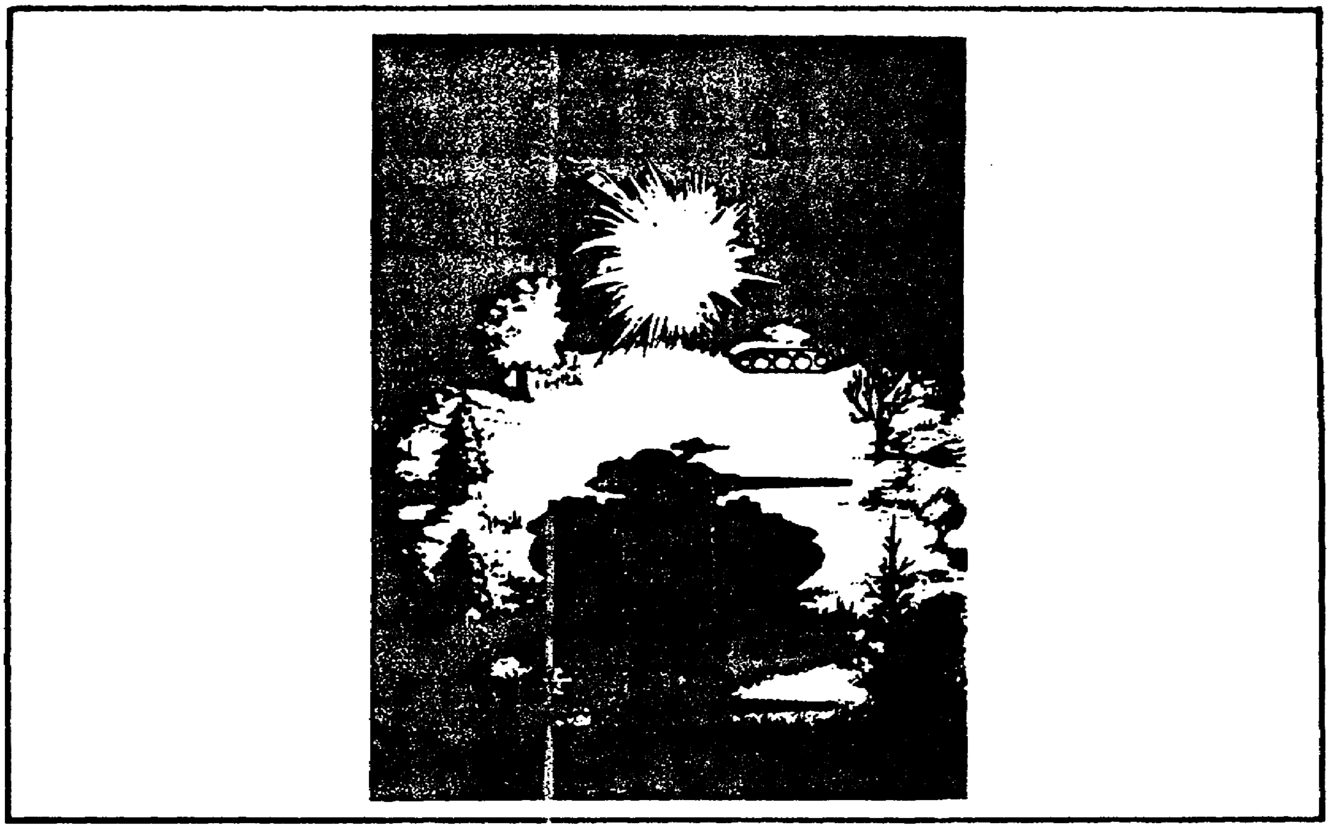


Figure 11. Light and shadows.

d. Visual Acuity. Visual acuity will be significantly reduced at night. Because of this limitation, objects must be identified by their shapes or silhouettes.

5. METEOROLOGICAL EFFECTS ON NIGHT VISION

There are meteorological conditions that will affect vision at night, therefore, changes in your ability to see may indicate the presence of adverse weather conditions. Reductions in the level of illumination will result from increasing cloud cover. Warning of impending cloud coverage or meteorological change at night can be observed by the change in the level of illumination.

a. Obscuration. The obscuration of the moon or stars indicates the formation of clouds; the greater the obscuration, the thicker the cloud cover.

b. Ambient Light. Varying levels of ambient light along the flight path indicate clouds are obscuring the source of light (moon or stars).

c. Halo. A halo effect around ground lights indicates moisture in the air and the possibility of fog formation.

6. HAZARDS TO NIGHT VISION

The effectiveness of the human eye is dependent on the amount of stress being experienced by the observer. The normal stresses of night flying will be compounded by many things. Additional stress is created by the use of drugs and alcohol, the level of exhaustion and dietary habits of the individual and the use of tobacco.

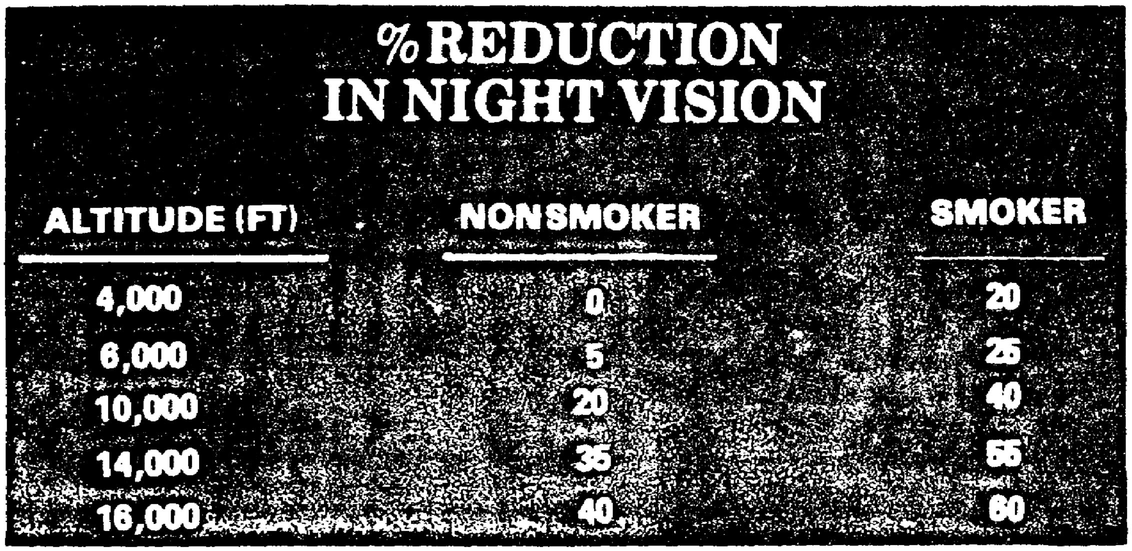
a. Drugs. Even over-the-counter medication can severely impair visual acuity both during the day and at night. Cold medicines can cause drowsiness and blurred vision and some appetite suppressants can cause nervousness and irritability. Therefore, a flight surgeon should be consulted before flying, especially at night, if these types of medication are being used.

b. Alcohol. The use of alcohol causes a loss of coordination and an impairment in judgment. Under the influence of alcohol a person may not use (or be able to use) proper vision techniques. Additionally, he may not be able to recognize or interpret properly the monocular cues required in determining distance. Therefore, the 12-hour rule for alcohol must be followed.

c. Exhaustion. As an observer tires, his reaction time and ability to concentrate begin to degrade. As the level of exhaustion increases, the individual may develop tunnel vision and tend to ignore peripheral conditions. For these reasons a crew endurance program must be adopted and enforced.

d. Hypoglycemia (Nutrition). A proper diet is essential for crew members who fly during periods of reduced illumination. Vitamin A is essential for the visual purple in retinal rods, which are in turn essential for night vision, therefore, a deficiency of Vitamin A will cause a problem. Vitamin A can be found in eggs, butter, cheese, liver, carrots and green vegetables. Vitamin deficiency is not the only problem; hunger itself can cause lapses in concentration that may be hazardous to night flight as well.

e. <u>Tobacco</u>. The use of tobacco causes increased levels of carbon monoxide in the blood and corresponding reductions in the ability of the eye to adjust to reduced illumination. A person who smokes an average of one pack of cigarettes per day will experience an 8- to 10-percent increase in the level of carbon monoxide in his blood. This increase corresponds to reductions in night vision at the different altitudes as shown in Figure 12.



% REDUCTION IN NIGHT VISION

ALTITUDE (FT)	NONSMOKER	SMOKER
4,000	0	20
6,000	5	25
10,000	20	40
14,000	35	55
16,000	40	60

Figure 12. Reductions in night vision from smoking.

7. PREPARING FOR NIGHT FLIGHT

There are several things that flight crew members can do to prepare themselves for flying at times of low illumination,

a. <u>Understanding</u>. Understanding the capabilities and limitations of the eye will reduce the normal levels of stress associated with flying at night.

b. <u>Avoiding</u>. Avoid imposing self-induced stress.

c. <u>Preparing</u>. Be prepared to use off-center viewing and effective scanning techniques during the flight.

d. <u>Adapting</u>. Allow the eyes to adapt to low-illumination conditions for a period of 30 to 45 minutes before flying.

e. <u>Staying Adapted</u>. Once the eyes are adapted to the reduced illumination avoid destruction of night vision by exposure to bright illumination.

REVIEW EXERCISE

REQUIREMENT: Complete the following by selecting the correct answers.

1. The type of vision used for seeing during periods of low illumination is

   A. mesopic vision.
   B. scotopic vision.
   C. photopic vision.
   D. presbyopic vision.

2. The inability of the eye to contract to a required focal length is called

   A. myopia.
   B. hyperopia.
   C. presbyopia.
   D. astigmatism.

3. Vision during periods of low illumination uses

   A. only the fovea.
   B. principally cell cones.
   C. principally retinal rods.
   D. an equal amount of retinal rods and cell cones.

4. The night blind spot

   A. is caused by the optic disc.
   B. increases in size with distance.
   C. cannot be eliminated (compensated for).
   D. is compensated for by the fact that we have two eyes.

5. Linear perspective is the appearance that objects

   A. converge over distance.
   B. tend to look elliptical over distance.
   C. have motion even though they are stationary.
   D. tend to be higher in the field of vision over distance.

6. A halo effect around ground lights indicates

   A. cloud cover.
   B. the light is moving.
   C. the light is stationary.
   D. moisture in the air and possible ground fog.

7. The <u>visual purple</u> in retinal rods require and adequate supply of vitamin

A. A.
B. C.
C. D.
D. E.

8. Preparations for night flight do <u>not</u> include

A. avoiding self-imposed stress.
B. reducing normal levels of stress.
C. allowing the eyes to adapt to reduced illumination conditions.
D. understanding the requirement to centrally focus on distant objects.

9. Normally, the eyes will become unable to focus at usual reading distances about the age of

A. 30.
B. 35.
C. 40.
D. 45.

10. Which of the following is <u>not</u> a limitation to vision created by reductions in the amount of illumination?

A. The reduction in visual acuity.
B. The existence of a night blind spot.
C. The degradation of depth perception.
D. The inability of the eye to detect moving objects.

REVIEW EXERCISE SOLUTIONS

1. B. (paragraphs 1 and 3c)
2. A. (paragraph 2a)
3. C. (paragraph 3, introduction)
4. B. (paragraph 4a)
5. A. (paragraph 4c(1)(a))
6. D. (paragraph 5c)
7. A. (paragraph 6d)
8. D. (paragraphs 7a, b, c, and d)
9. C. (paragraph 2d)
10. D. (paragraph 4, introduction)

LESSON 3. PERCEPTUAL LIMITATIONS

TASK: To incorporate the knowledge about the effects of visual perceptions and visual illusions into an aviation unit safety program.

OBJECTIVE: You will know the difference between perceptions and visual illusions, the effects of depth perception on flight, the effects of illusion on flight and how to overcome illusions.

CONDITION: You may use the lesson text and reference to complete the review exercise.

STANDARD: You must correctly answer 8 of 10 review exercise questions.

REFERENCES: FM 1-301 (Mar 83).

LESSON TEXT

1. GENERAL

Vision is man's strongest and most dependable sense of balance. Accurate perception of aircraft orientation necessary for adequate aircraft control is dependent primarily on correct interpretation of visual cues obtained from flight instruments. Vision is dependent upon varied cues; the more cues available, usually the more accurate our orientation. With only a few cues our perception can be false, resulting in what are commonly called visual illusions.

a. Perception. A perception is defined as an awareness acquired directly from any one of a person's senses (sight, hearing, smell, taste or feel).

b. Illusion. An illusion is defined as an erroneous perception of reality or a-misinterpretation of what is occurring.

2. PERCEPTIONS

Perceptions are based on the nature of the stimulus regardless of the sense used for interpreting the stimulus. Due to the predominant use of vision, sight will be the source of perceptions examined in depth.

a. Characteristics. There are several characteristics of the visual perceptions that must be considered for the safe operation of an aircraft.

(1) Threshold differences: The ability to visually perceive things is primarily based upon changes; therefore, the rate and the duration of

the change are important. Changes that take place slowly over a long period of time are not as readily perceived as changes that occur quickly.

(2) Fatigue: The fatigue associated with constantly or repeatedly viewing an object (stimuli) decreases the sensitivity of the eye to change.

(3) Contrast: The ability of the eye to detect change is dependent upon the differences (contrasts) of the stimuli. The greater the difference, the easier to perceive change. For example, it is easier to accurately perceive movement when flying over mountainous terrain with differing types of vegetation and contour than it is to perceive movement when flying over a desert with little or no contrast.

(4) Expectancy: People tend to see what they expect to see, especially when there is little contrast between what is seen and what is expected. For example, when navigating, a small lake may be perceived to be the larger lake you expected to find along the flight path.

b. Perceptual Conflict. Because the strength of a stimulus tends to dominate the entire visual perception, an object with a strong stimulus may prevent the viewer from perceiving an object with a weaker stimulus. For example, the presence of a large mountain may cause a failure to notice the small hill in front of it. There are two other areas which may create a perceptual conflict with which aviators must be familiar.

(1) Relative motion: Perceptions of movement are influenced by the distance to and the movement of the object being viewed. When flying in formation, a decrease in the speed of one aircraft may be perceived by the occupants of the second aircraft as an increase in their speed.

(2) Past Experience: If your past experience (stimulus) of an object is different than a new stimulus for the same object you may fail to recognize it under the new stimulus. For example, if your past experience has been that dirt roads are either brown or grey, you may fail to recognize a dirt road that is red in color.

c. Factors of a Visual Perception. There are two major factors effecting visual perception. They are visual acuity and depth perception.

(1) Visual acuity: Visual acuity is the ability to see clearly, sharply and precisely. The degree of acuity is dependent upon the type of vision used (peripheral and central). Peripheral vision is used extensively at night and has limitations as covered in Lesson 2. The perceptual limitations of central vision are time, accommodation and color.

(a) Time. The brain requires time to interpret what the eye transmits to it. An example would be a mirage in the desert. It takes time and reason for the brain to determine that a picture of a lake in the desert is just a mirage and does not actually exist even though the eye will continue to transmit pictures of the lake.

(b) Accommodation: It is necessary for both eyes to converge on an object to see it clearly. Therefore, the transition from focusing on a close object to a far object or from a far object to a near object takes time.

(c) Color: Color can both help and hinder visual perception. The contrast between some colors (black and white) can clarify the perception. However, the contrast between other colors may hinder visual perception (camouflage) or confuse visual perception (clashing of colors).

(2) Depth perception: Depth perception requires the use of numerous visual cues. The interpretation of these cues requires the use of central vision and good illumination. The binocular cues required for depth perception are accommodation and stereopsis. Monocular cues are also required for depth perception.

(a) Accommodation. Depth perception is determined at a subconscious level by the comparison of differences between the image size of an object projected on the retina and the known size of the object.

(b) Stereopsis. Each eye transmits a different picture to the brain. The difference in the angle of the two pictures is combined in the brain to form a 3-dimensional picture of what is being seen.

(c) Monocular cues. Monocular cues are those cues that can be perceived by the use of one eye. These cues were presented in Lesson 2 (interposition of objects, geometric perspective, motion parallax, retinal image, aerial perspective and shadows).

3. DEPTH PERCEPTION AND FLIGHT

Erroneous visual perceptions are experienced in most modes of flight, being most pronounced in autorotations.

a. Wider Than Normal Runway. When a pilot experiences this illusion his perception will be that he is lower than normal due to his relatively smaller visual reference angle to the sides of the runway at equivalent heights above the ground. He tends to pull pitch too soon which may result in a hard landing.

b. Narrower Than Normal Runway. Here, Just the opposite occurs. The pilot may perceive that he is higher than normal due to his relatively larger visual reference angle to the sides of the runway. This may cause him to pull pitch too late causing a faster than normal landing speed.

c. Upsloping Lane. The illusion that the runway is upsloping may make the pilot perceive himself lower than normal due to a shorter relative visual distance to a given touchdown point. This again may result in a premature deceleration and pitch pull and a hard landing.

d. Downsloping Lane. The most crucial perception based on a visual illusion is that of the downsloping runway. In this case the pilot would perceive himself higher than normal, causing a late deceleration and pitch pull which may result in hitting the tail stinger or tail boom.

4. OTHER ILLUSIONS AND FLIGHT

There are also several visual illusions that may be present in flight (especially during autorotational landings) that should be understood.

a. Sloping Threshold Terrain. The actual slope of the runway or the terrain surrounding the runway may cause visual illusions that may create problems for pilots.

(1) Upsloping runway: When making an approach to an upsloping runway, a normal approach angle will appear too steep. Flying the approach angle that appears normal could result in landing short of the desired touchdown point.

(2) Downsloping runway: If an approach is being made to a downsloping runway, a normal approach angle will appear to be too shallow. Flying an apparent normal approach angle may cause the landing to be beyond the desired touchdown point.

(3) Upsloping terrain: When the terrain surrounding the approach to a runway is upsloping, the aircraft will appear to be above a normal approach glide path. To compensate, the pilot should try to adjust his visual glide path to a point beyond the desired touchdown point.

(4) Downsloping terrain: If the terrain surrounding the approach to a runway is downsloping, the aircraft will appear to be below a normal approach glide path. If the aircraft flight path is changed because of this illusion the aircraft will land short of the desired touchdown point.

b. Visibility Restrictions. Atmospheric conditions such as smoke, dust, glare and darkness may confuse the sense of sight due to the fact that shadows will be less distinct or even absent. Under any of these conditions an observer may get the illusion that an object is farther than it really is. An important consideration for pilots is that these conditions may create an illusion that the altitude of the aircraft is higher than it actually is.

c. Runway Lighting. When approaches are made to lighted runways the intensity of the lights and variances in intensity of the lighting may create illusions of untrue situations.

(1) <u>Dim runway markers</u>: You should expect the illusion of being higher and farther away from the runway environment than you actually are.

(2) <u>Bright runway markers</u>: You should expect the illusion of being lower and closer from the runway environment than you actually are.

(3) <u>Differing intensities in runway markers</u>: Differing intensities of left and right markers will create an illusion that an aircraft is being banked when it is actually level.

(4) <u>The transition from low-intensity lighting to a runway illumination environment</u>: The transition from an environment of relatively low illumination (such as a large body of water) to an environment of comparatively high illumination (such as a lighted airfield in a large city) will also cause a visual illusion that differs from the actual situation. This illusion (called a black-hole approach) may cause an approach to be short of the desired point of landing because of the apparent closeness of the runway environment.

d. <u>Runway Characteristics</u>. Visual illusions, like visual perceptions, are dependent upon past experience; therefore, runway characteristics different from past experience may create a visual illustration.

(1) <u>Narrower than normal runway</u>: The distance to and the height above a narrower than normal runway will appear to be greater than they actually are.

(2) <u>Wider than normal runway</u>: The distance to and the height above a wider than normal runway will appear to be less than they actually are.

e. <u>Runway Contrast</u>. You must be alert for visual illusions whenever the color of the runway is similar to the surrounding terrain. The lack of contrasting colors may make distances and altitudes appear greater than they actually are. The following are some examples where the lack of color contrast may be a factor.

(1) <u>Snow</u>: The runway and terrain are covered with snow.

(2) <u>Reduced illumination</u>: An unlighted runway during periods of reduced illumination.

(3) <u>Intense illumination</u>: A concrete runway or sandy terrain during periods of intense illumination (especially if the runway is wet).

5. OVERCOMING ILLUSIONS

The keys to overcoming visual illusions are awareness of conditions under which illusions are apt to occur and good prior planning.

a. Awareness of Illusion Factors. You must have an awareness that visual illusions exist. Knowing what illusions are and when they are most likely to be experienced will enable the pilot to consciously modify his perception of what he visualizes.

b. Prior Planning. Good prior planning will refresh in the pilot's mind the illusions that may be created by the flight conditions and enhance his perceptual ability.

c. Rely on Instruments. Even under visual flight conditions a pilot should cross-check his instruments before altering the attitude of his aircraft based only on a perception. For example, if you perceive that the aircraft is banking, cross-check your instruments before changing the attitude of the aircraft to what you perceive to be a level attitude.

d. Don't Be Afraid to Make a Go-Around. Whenever you perceive something substantially different than expected, you should discontinue the approach. It is better to feel a little silly for making an unnecessary go-around than to risk an aircraft mishap.

REVIEW EXERCISE

REQUIREMENT: Complete the following by selecting the correct answers.

1. A perception is

   A. acquired from a single cue.
   B. a misinterpretation of what is occurring.
   C. acquired directly from any of a person's senses.
   D. always a true interpretation of what is really happening.

2. Visual perceptions are not based on a characteristic of

   A. fatigue.
   B. contrast.
   C. past experience.
   D. threshold differences,

3. Perceptual conflict may result from

   A. the acuity with which the object is seen.
   B. the relative motion of the object being viewed.
   C. a reduction in the ability to perceive distance.
   D. a lack of familiarity with the object being viewed.

4. Interpretation of the visual cues necessary for depth perception

   A. requires the use of central vision.
   B. requires the use of peripheral vision.
   C. is independent of the type of vision used.
   D. is independent of the level of illumination.

5. Erroneous visual perceptions are most pronounced

   A. in hovering.
   B. in autorotations.
   C. when making steep approaches.
   D. when making shallow approaches.

6. The most crucial of the erroneous perceptions is that of a

   A. wide runway.
   B. narrow runway.
   C. upsloping runway.
   D. downsloping runway.

7. If you are making an approach at night to a runway with dim markers you should expect an illusion of being

A. lower and closer than actual.
B. higher but closer than actual.
C. lower but farther away than actual.
D. higher and farther away than actual.

8. A visual illusion that you are higher and farther from a runway may be created if

A. the runway is covered with snow.
B. the runway markers are extremely bright.
C. the runway is wider than the one you normally use.
D. you are transitioning from an environment of low illumination to one of high illumination.

9. To overcome a visual illusion a pilot should not

A. be afraid to make a go-around.
B. continue the approach if he recognizes the effects of a visual illusion.
C. be aware of illusion factors because it will increase his level of anxiety.
D. rely on his instruments since this may cause him to get spatial disorientation.

10. Factors effecting the acuity of visual perception do <u>not</u> include

A. time.
B. color.
C. accommodation.
D. past experience.

REVIEW EXERCISE SOLUTIONS

1. C. (paragraph 1a)

2. C. (paragraphs 2a(1), (2) and (3))

3. B. (paragraph 2b(1))

4. A. (paragraph 2c(2))

5. B. (paragraph 3, introduction)

6. D. (paragraph 3d)

7. D. (paragraph 4c(1))

8. A. (paragraph 4e(1))

9. A. (paragraph 5d)

10. D. (paragraphs 2c(1)(a), (b) and (c))

LESSON 4. SPATIAL DISORIENTATION

TASK: To incorporate the understanding of spatial disorientation into the safety training of an aviation unit.

OBJECTIVES: You will be familiar with the body mechanisms that determine balance and motion; the common disorientations created by visual illusions, vestibular illusions and proprioceptive illusions; and what can be done to prevent and treat spatial disorientation.

CONDITION: You may use the text and reference to complete the review exercise.

STANDARD: You must correctly answer at least 8 of 10 review exercise questions.

REFERENCE: FM 1-301 (Mar 83).

LESSON TEXT

1. GENERAL

Standing still is easy. You know you are standing still because all your senses indicate you are standing still. Start moving and a whole new set of sensations come into play. You can see that you are moving and other body senses detect movement. Still there is no problem, thousands of years of evolution have adapted man's senses to deal with movement (up to 8 miles per hour). In the last century man has created machines that allow him to move faster and into environments never before experienced. Man's bodily senses, however, have not adjusted to the faster speeds or the differing environments created by losing visual contact with an earthly reference. Our bodies were never intended to be able to detect climbing and descending turns or to be able to tell the difference between standing still and moving without earthly reference. Therefore, anytime (regardless whether it is the first or the hundredth time) a person operates in an environment where he cannot correctly perceive his position, attitude or movement with respect to the earth he is spatially disoriented.

a. Adapting to Earthly Referenced Senses. How do we adapt our 5 to 8 miles per hour earthly referenced senses to new environments? We do not. Instead, we learn our limitations and we learn how to deal with them. We learn to trust artificial senses (aircraft instruments) and to disregard our natural senses when operating in alien environments.

b. Dealing With Spatial Disorientation. The only way to deal with spatial disorientation (equilibrium limitations) problems is through education. Therefore, you must know the bodily mechanisms used to determine equilibrium (balance) and how they are affected by a flight environment.

2. MECHANISMS OF EQUILIBRIUM

The mechanisms of equilibrium are vision, vestibular apparatus and the proprioceptive system. The mechanism of vision (perception, illusion and night vision) has been detailed in Lessons 2 and 3, hence, only the vestibular and proprioceptive mechanisms will be covered here.

a. Vestibular Apparatus. The inner ear contains the vestibular apparatus which is the body's motion and gravity detecting sense organ. It is located in the temporal bone on each side of the head. Each vestibular apparatus consists of two distinct structures (otolith organs and the semicircular canal which contains the otolith organs) as shown in Figure 13. Both the otolith organs and the semicircular canal will sense changes in aircraft performance. The otolith organs will sense changes in linear acceleration or gravity and the semicircular canals of the inner ear will sense changes in angular acceleration.

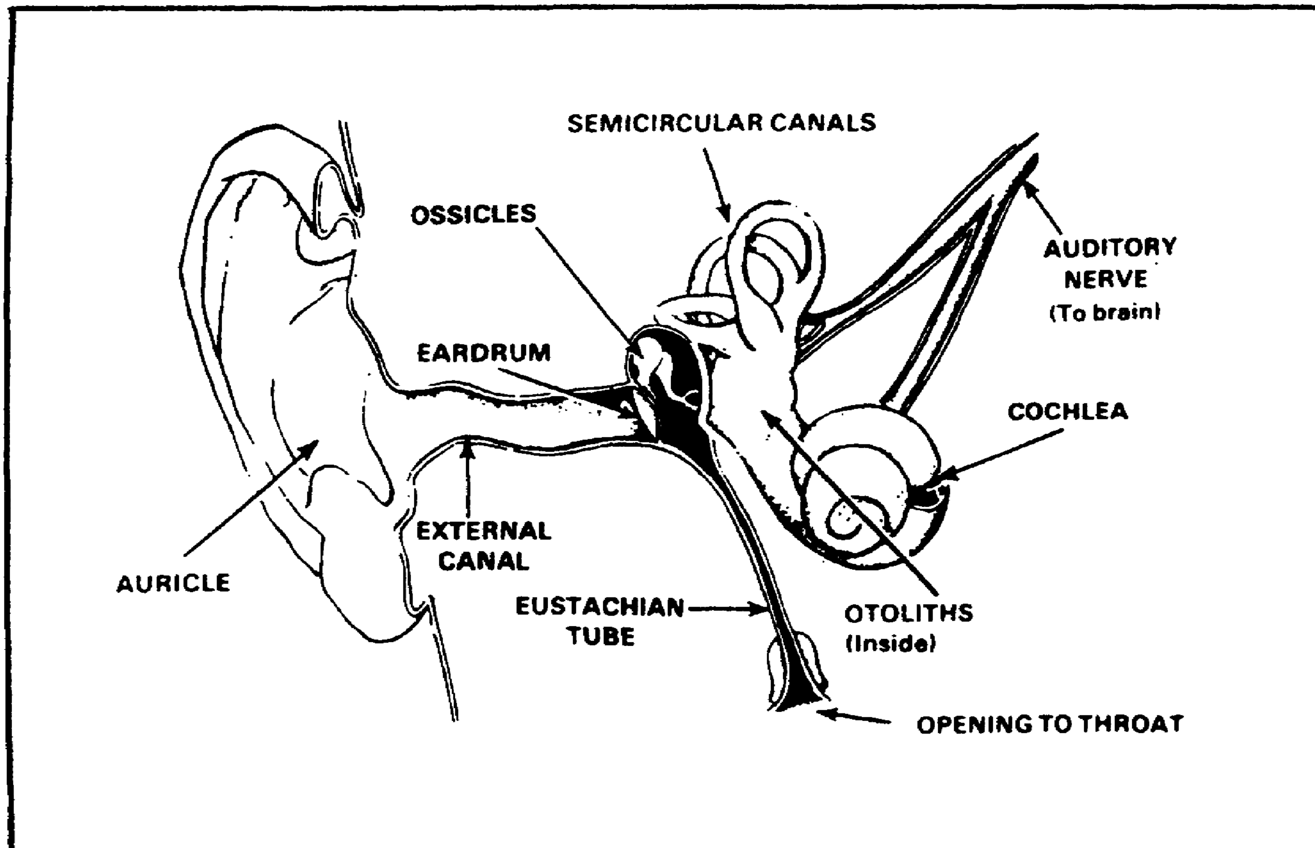


Figure 13. Vestibular apparatus of the inner ear.

(1) The otolith organs: The otolith organs are small sacs located in the vestibule. The sensory hairs project from each macula into an overlying gelatinous membrane (the cupula) containing chalk-like crystals called otoliths (Figure 14). These organs normally respond to gravity and changes in head position relative to the gravitational force. Changes in the gravitational force cause the otolithic membrane to shift position on the macula, thus bending the sensory hairs and signaling the change in head position.

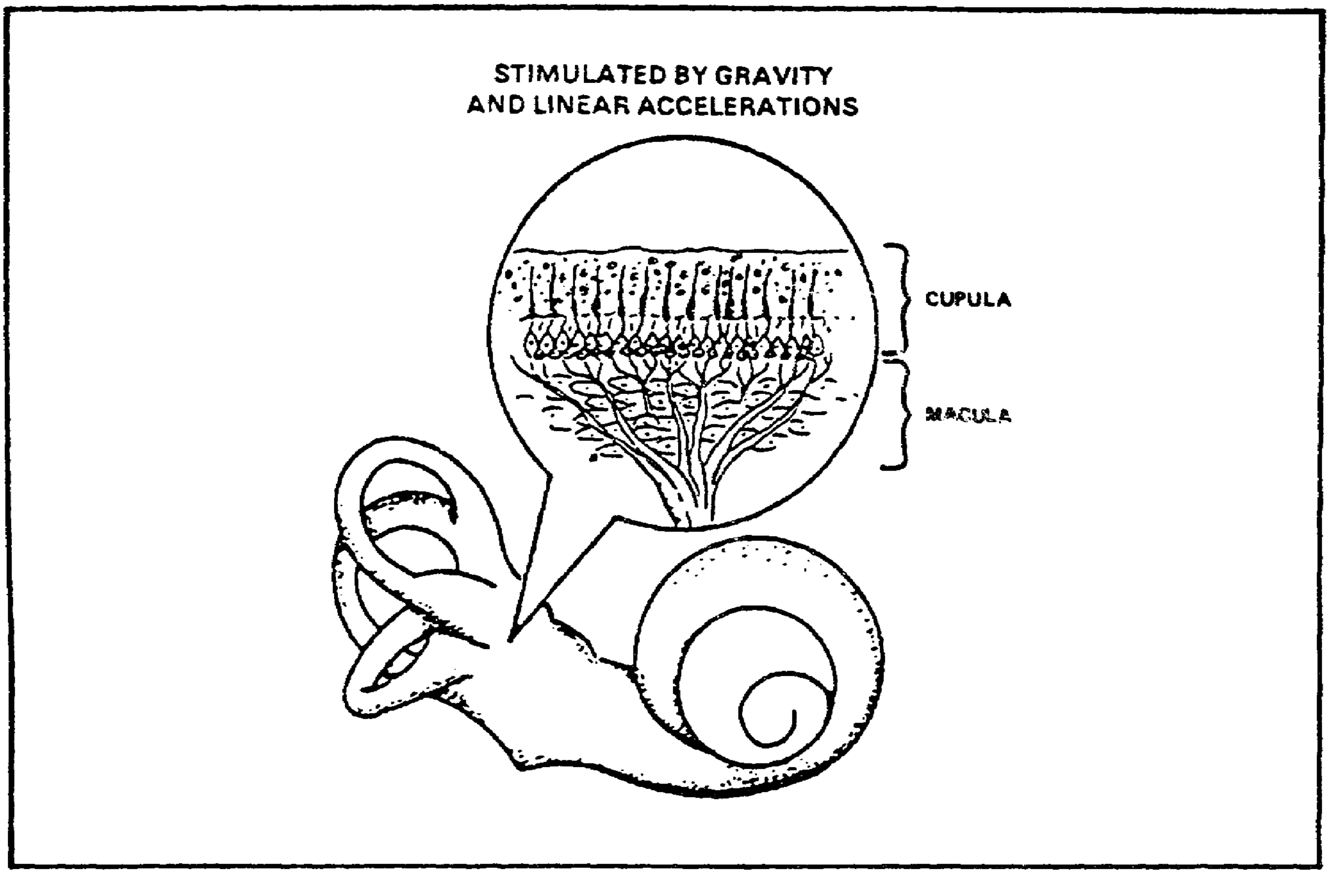


Figure 14. Otolith organs of the inner ear.

(a) Resting frequency. When the head is upright, a resting frequency of nerve impulses is generated by the hair cells.

(b) Altering resting frequency. When the head is tilted, the resting frequency is altered to inform the brain of the new position of the head relative to the vertical.

(c) Linear accelerations. Linear accelerations also stimulate the otolith organs since inertial forces resulting from linear accelerations (Figure 15) cannot be distinguished from gravitational forces. A forward acceleration, for example, results in a backward displacement of the otolith membranes which can create the illusion of backward tilt of the head when adequate visual reference is not available.

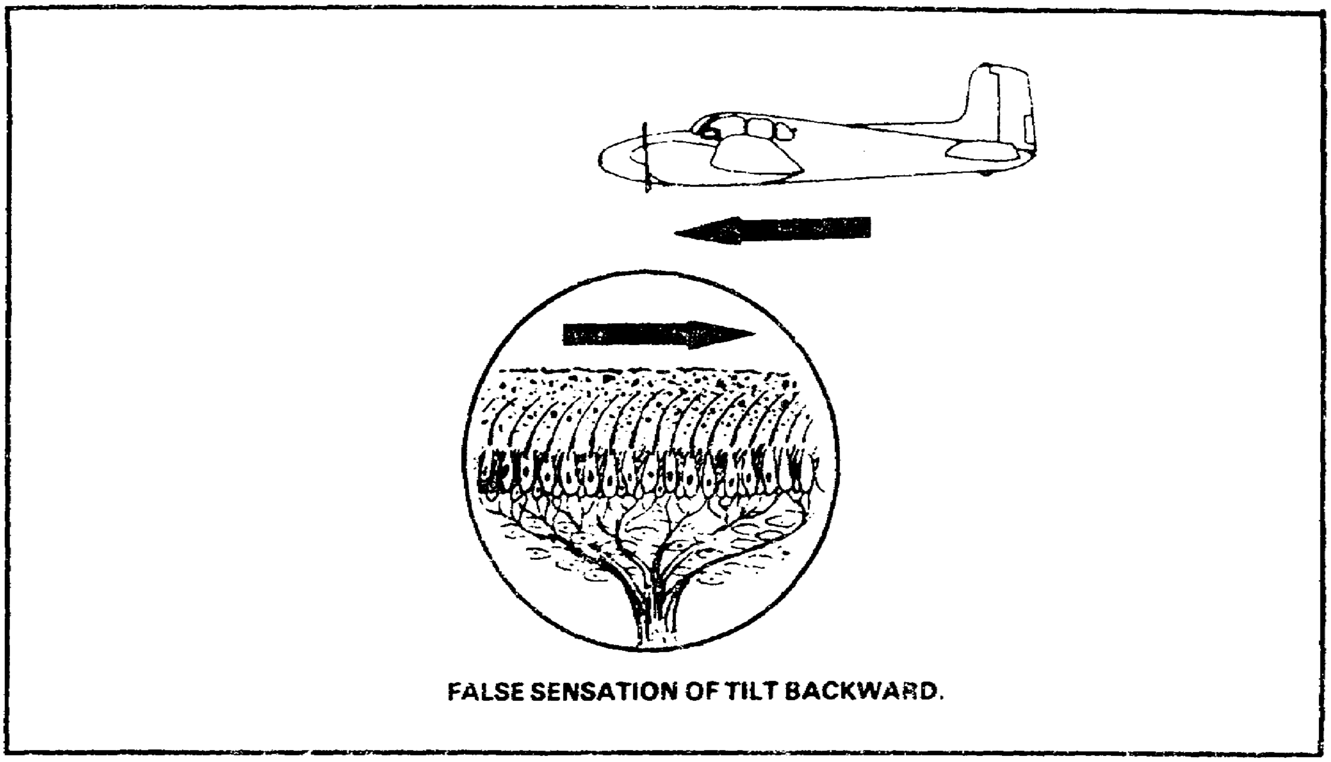


Figure 15. Sensations from linear accelerations.

(2) The semicircular canals. The semicircular canals of the inner ear, in sensing changes in angular acceleration, will react to any changes in pitch, roll or yaw attitude of the head (Figure 16). These canals are situated in three planes perpendicular to each other. They are filled with a fluid called endolymph which is put into motion by the inertial torque resulting from angular acceleration in the plane of a canal. Motion of the fluid exerts a force upon a gelatinous structure called the cupula located in the canal. This movement stimulates the vestibular nerve which transmits an impulse to the brain that is interpreted as rotation of the head.

(a) No movement of endolymph. When no acceleration takes place there is no movement of endolymph and the sense of no turn is interpreted.

(b) Movement of endolymph. When the canal is put into motion by angular acceleration the endolymph movement within the canal lags behind the acceleration and contacts the canal wall opposite the direction of acceleration. For example, if the acceleration is due to a turn to the left the endolymph motion will be against the right wall of the canal. The brain will then interpret the impulse created by this endolymph movement as motion or a turn to the left.

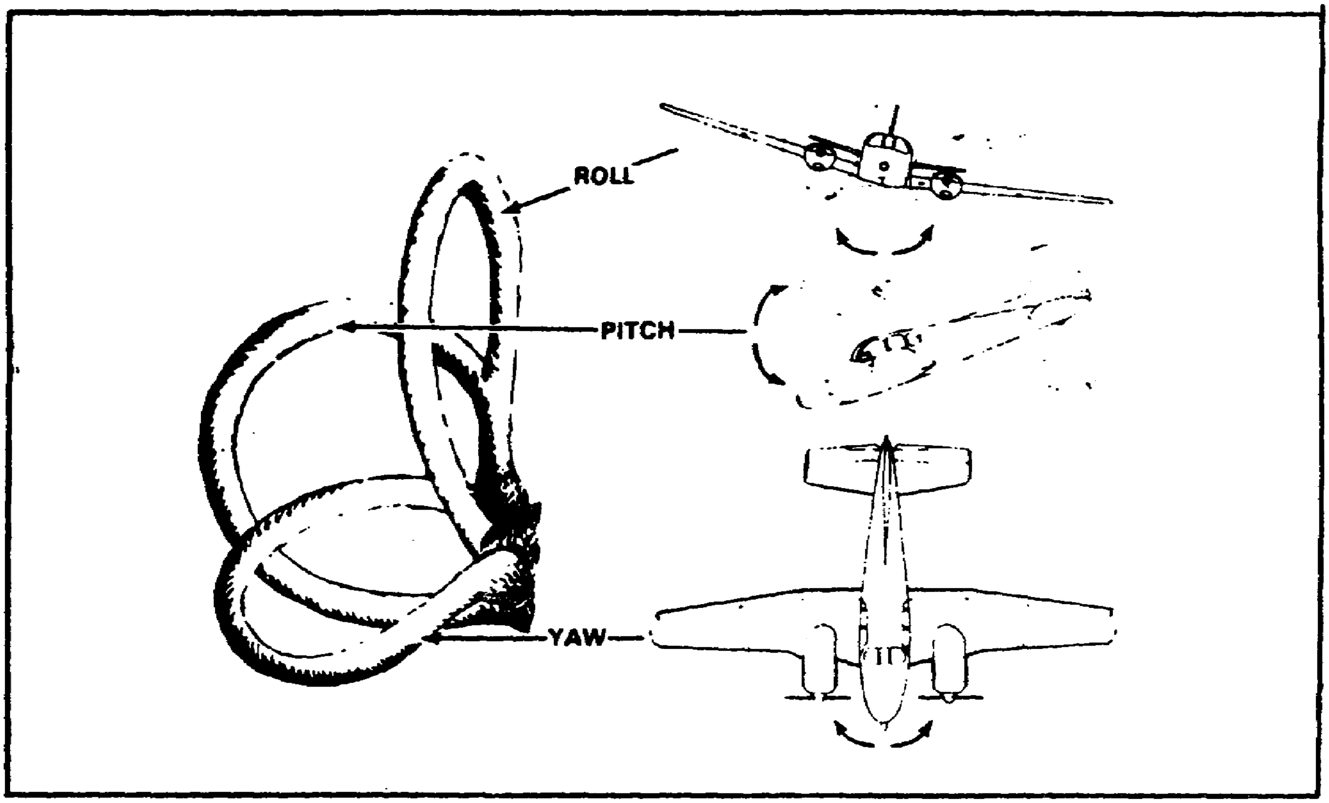


Figure 16. Reactions of the semicircular canals.

(c) Endolymph movement ceases. If the turn continues for several seconds the motion of the endolymph catches up with the motion of the canal and pressure will no longer be placed on the opposite canal wall. In this case an illusion of no turn will be created when the brain interprets the impulse resulting when endolymph motion is no longer being sensed.

(d) Angular acceleration. When an angular acceleration (rotation) is slowed or stopped, especially after a turn of long duration, the endolymph will continue to move for a short period of time. This continued movement will place pressure on the opposite canal wall and create an illusion of turning in a direction opposite that of the original turn.

b. Proprioceptive System. This system involves the sensations resulting primarily from pressures on joints, muscles and skin. To a lesser degree, sensations resulting from the change in position of internal organs are also part of the system. The proprioceptive system is intimately associated with the vestibular system and the visual system (to a lesser degree). Since a pilot is seated during flight, the forces acting on his body are such that, with training and experience, distinct aircraft movements can be sensed by pressures on his body from the aircraft seat.

3. SPATIAL DISORIENTATION AND VISUAL ILLUSIONS

Although the visual system is not the most reliable of the senses, there are illusions which can result from misinterpreting what is seen. Even with references outside the cockpit and the instrumentation inside, pilots must be careful to interpret visual information correctly and understand that what is being seen is not always what is actually happening.

a. Relative Motion. This illusion is often encountered in formation flights where a pilot sees the motion of another aircraft and interprets it as motion of his own. Another area where this can occur is hovering a helicopter over tall grass and interpreting the wave action of the grass (due to the rotor wash) as aircraft movement.

b. Confusion of Ground Lights. Many pilots have put their aircraft into very unusual attitudes to keep ground lights above them, having mistaken them for stars. Less frequent, but just as dangerous, are the illusions caused by certain patterns of ground lights imagined to be things they are not. Some pilots have interpreted lights along a seashore to be the horizon and come dangerously close to the ocean while thinking they were flying straight and level. Aviators have also confused certain geometric patterns of ground lights (such as a moving train) with runway and approach lights, again causing a dangerous situation.

c. False Vertical and Horizontal Cues. Cloud formations may be confused with the horizon or ground (Figure 17). Momentary confusion may result when an individual looks for outside reference after prolonged attention inside the cockpit.

d. Structural Illusions. Structural illusions are caused by heat waves, rain, snow, sleet or other obscurants to vision. For example, a straight line may appear curved when seen through the heat wave from a desert, or a wing tip light may appear as a double light or in a different location when viewed through a rain shower.

e. Autokinetic Illusions. Autokinetic illusion (autokinesis) is the illusory phenomenon of movement exhibited by a static light when stared at for a long enough period of time. The cause is not known but appears to be due to the uncontrolled movement of the eye in attempting to find another reference point in the field of vision. Autokinesis is not exclusively limited to periods of darkness. It can occur whenever a small, bright, still object is stared at against a dull, dark, still object in a light, structureless environment.

f. Flicker Vertigo. A great deal of time and research have been devoted to the study of flicker vertigo. Light flickering at a rate of between 4 and 20 cycles per second can produce unpleasant and dangerous reactions. Fatigue, frustration and boredom tend to increase the severity of these reactions and, although not a serious problem in Army aviation,

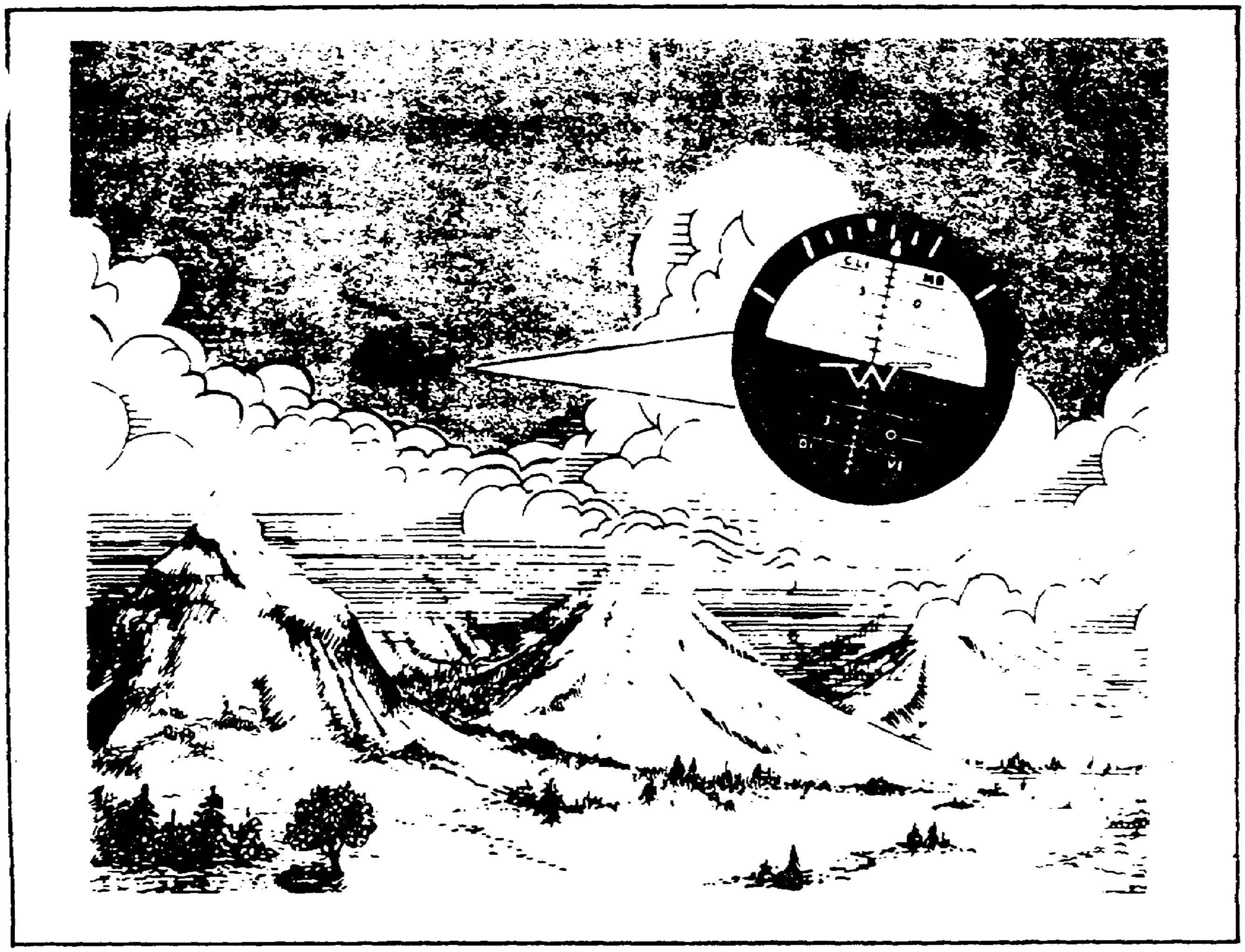


Figure 17. Confusion of a cloud bank with the horizon.

its potential must be recognized. The problem can be caused by the flickering of sunlight through turning rotors or propellers or perhaps even the reflection of a rotating beacon off a cloud.

g. Fixation. Fixation is said to occur when a pilot ignores orientation cues while focusing his attention on another object. Target hypnosis is a common type of fixation. The pilot becomes so intent upon hitting a target that the pull-up is delayed so long the aircraft hits the ground.

4. SPATIAL DISORIENTATION AND VESTIBULAR ILLUSIONS

In flight, the vestibular apparatus may allow certain movements to remain unperceived while creating the illusion of movements that do not really exist. A pilot who does not correctly perceive his position, attitude and motion relative to the earth is spatially disoriented. Obviously, he is not expected to rely on first-hand perceptions under all conditions, but has instruments to keep him spatially oriented under those conditions where false perceptions may be experienced.

a. The Leans. The most common form of spatial disorientation is the leans. According to Mulder's law, any constant angular motion slower than 2.5 degrees per second will not be perceived. Since a constant angular motion is a function of both the rate of angular acceleration and the time over which the acceleration is applied, there are several situations where angular motion may not be perceived.

(1) High rates of angular acceleration over a relatively short period of time: An example would be the motion of an aircraft rotating on its roll axis with an acceleration of 8 degrees per second per second for a quarter of a second. The constant angular motion in this case would be 2 degrees per second (8 X 0.25 = 2), which is below the 2.5 degrees per second rate required for perception.

(2) Slow rates of angular acceleration over a longer period of time: For example, the motion of an aircraft rotating on its roll axis with an acceleration of a quarter of a degree per second per second for a period of 8 seconds. Here the constant angular motion of the aircraft would again be 2 degrees per second (0.25 X 8 = 2) and would go unperceived. If either of these conditions recur over time, considerable angles of bank could be achieved without perception. Once this unperceived bank is detected by reference to attitude instruments the pilot will apply control pressure to correct the attitude. If the correction is accomplished with a constant angular motion faster than 2.5 degrees per second the pilot will perceive the motion in the direction of correction. Since only the corrective motion has been perceived, when the aircraft Is returned to level flight (instrument indication), the pilot will sense himself in a bank equal to the amount of correction. Even though the pilot believes his instruments, he will be compelled to align his body with the perceived vertical and actually lean in the direction of the original (subthreshold) roll as depicted in Figure 18).

(3) Slow angular correction (acceleration in the opposite direction to rapid angular acceleration): The leans can be generated in the opposite way as well. If an aircraft is rolled in one direction with a perceivable rate of motion (suprathreshold), and the pilot corrects the change in attitude very slowly and smoothly (subthreshold), the leans may result. The fact that only one of the motions has been perceived will again cause the pilot (who believes his instruments) to align his body with the perceived vertical and lean in the direction opposite the original roll.

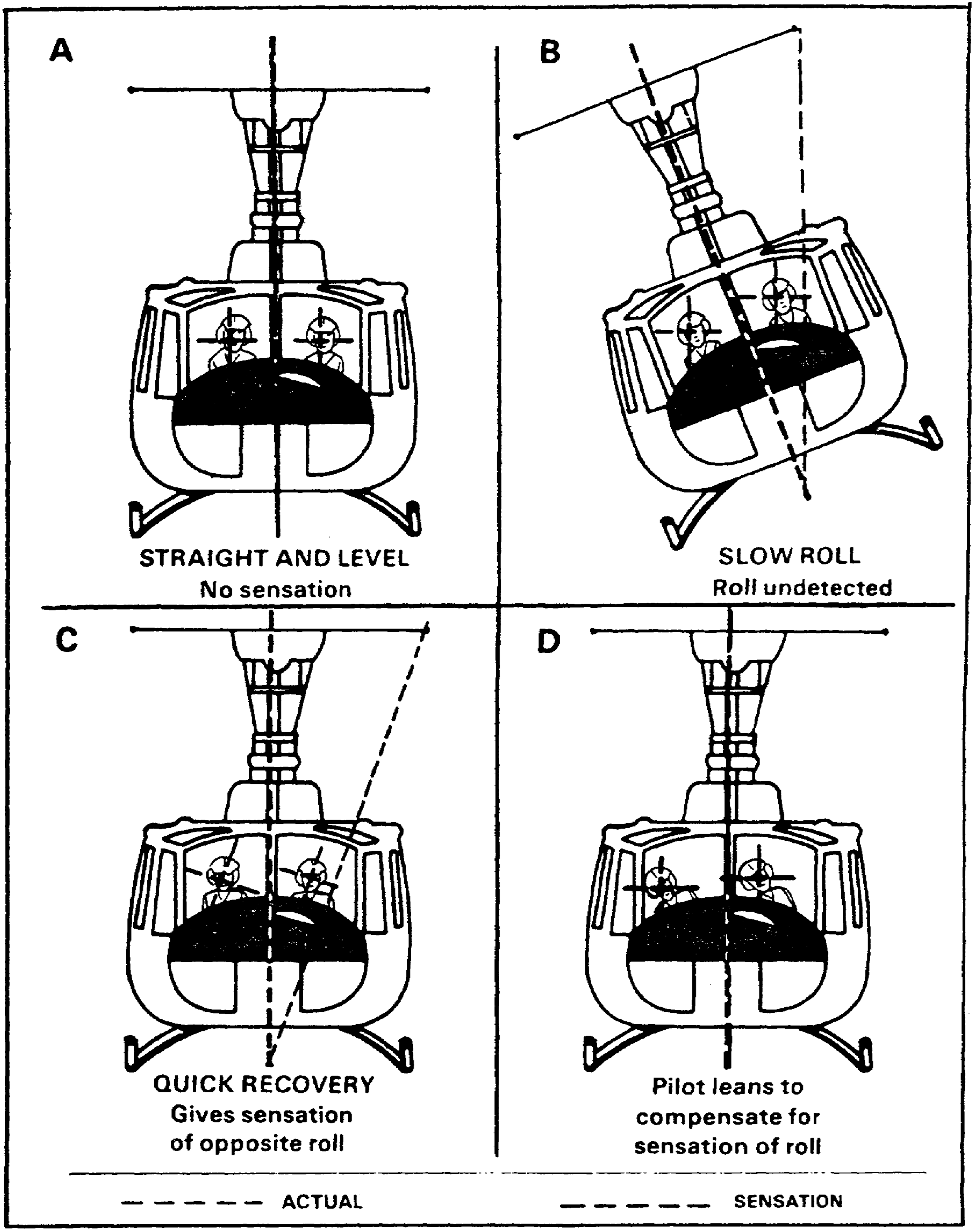


Figure 18. The <u>leans</u>.

(4) Other factors affecting the ability to perceive angular motion: The threshold of perception of angular acceleration is raised considerably by vibrations, noise, inattention and anxiety. It is, therefore, highly probable that angular accelerations of much greater magnitude than specified by Mulder's law can go unperceived under actual flight conditions. It is also probable that the threshold for a given individual fluctuates according to the individual's need for vestibular information. If, for example, a pilot is jarred into a state of anxiety about his attitude by unusual turbulence, he will probably reflexively lower his vestibular threshold. In doing this, he is increasing the likelihood that he will generate false impressions about his actual attitude and increase the change of the leans.

b. Graveyard Spin. The semicircular canals monitor angular acceleration to give angular velocity information. They do not perceive angular velocity per se. When a pilot gets into a spin he undergoes an initial angular acceleration and perceives the angular motion of the spin for a short time following the initiation of the angular acceleration. After this time (15 to 20 seconds), the fluid in the semicircular canals catches up with the motion giving a perception of discontinuation of motion even though motion still exists. In other words, the semicircular canals have equilibrated with the rotating motion and no motion is perceived. If the pilot then makes the proper control maneuver to stop the spin, he will undergo an angular deceleration which will be monitored by his semicircular canals. The central nervous system will interpret this sensation as representing a spin in the opposite direction, even though his instruments are telling him that he is not spinning. If deprived of external visual reference, he will be tempted to make a control correction that spins him in the direction of the original angular motion.

c. Graveyard Spiral. The graveyard spiral is similar to the graveyard spin in that the semicircular canals equilibrate to a constant angular velocity and persisting rotary motion goes unperceived. In the graveyard spiral, however, the angular velocity is in the form of a coordinated, banked turn rather than a spin. If a pilot remains in a constant rate, coordinated turn long enough for his semicircular canal to equilibrate, he will lose the sensation of turning. If a loss of altitude results from the decrease in lift due to the bank, the novice pilot may try to correct the condition by pulling back on the stick or adding power. These maneuvers only tend to tighten the spiral. Unless he first corrects the bank attitude he will never recover with power or pitch. Once the spiral has started the pilot will suffer an illusion of turning in the opposite direction if he corrects the aircraft to straight and level. Under these conditions he would not be likely to take the appropriate correction action and would probably continue tightening the spiral until he either regained good outside reference or hit the ground.

d. Coriolis Effect. During the mid-1950's, both the Air Force and the Navy experienced a rash of fatal accidents involving single-seat aircraft. Most of these accidents resulted from a high-speed dive that was initiated when the pilots were changing radio frequencies. All of these accidents had a similar pattern of events.

(1) <u>Pattern of events</u>:

(a) <u>Aircraft</u>. The aircraft were jet fighters or intercepters.

(b) <u>Pilots</u>. The pilots were young and inexperienced.

(c) <u>Procedures</u>. The accidents usually occurred when landing, in the approach pattern or in a procedural turn.

(d) <u>Altitude</u>. The altitude was relatively low, usually less than 2,000 feet.

(e) <u>Environment</u>. Instrument weather conditions with minimum visibility or darkness prevailed.

(f) <u>Diversions</u>. The pilot was requested to change radio channels or modes.

(g) <u>Position</u>. Almost immediately thereafter, the aircraft struck the ground at a terrific velocity and oftentimes in a near vertical or inverted position.

(2) <u>Accident investigation findings</u>: During accident investigations it was noted that the radio channel selector was set far to the rear of the console. This required the pilot to turn his head down and to the right while flying in a banked turn. By this maneuver, the pilot not only lost monitorship of his instruments but placed himself in an optimum position to experience the most deadly of all spatial disorientations (the coriolis effect).

(3) <u>Vestibular coriolis effect</u>: The vestibular coriolis effect results when one set of semicircular canals has equilibrated to a constant angular velocity and a head motion is made in a plane other than the plane of constant angular movement. When a second set of canals (out of the plane of rotation and unstimulated by the rotation) is rotated into the plane of constant movement, an angular acceleration is imposed on them. Simultaneously, an angular deceleration is imposed upon the first set of canals as it is rotated out of the plane of motion. This activation of movement of endolymph in two canals also induces movement in the third canal, resulting in a perception of motion in a plane in which no real motion exists.

(a) <u>Head movement forward and downward</u>. A pilot yawing in a clockwise direction at a constant velocity, pitches his head forward and downward. This head movement places the vertical canal in a horizontal plane, subjecting it to clockwise acceleration. It also causes the horizontal canal to move to a vertical position, subjecting it to a deceleration. This multiple stimuli will result in the false perception of rolling in a clockwise direction.

(b) Rolling head onto left shoulder. Assume the pilot is in a pitching attitude at a constant velocity and rolls his head onto his left shoulder. Here he will experience a false sensation of yaw in addition to the sensations induced by the true movements of his head and the aircraft.

e. Oculogravic Effect. The body is not equipped with sensors capable of informing the brain of all the different linear accelerations acting upon it. Instead, utricles and saccules transmit composite information of the direction, magnitude and resultant vector. The false sensations that we get because the otolith organs are unable to distinguish between the earth's gravity and other superimposed linear accelerations are called the oculogravic effects.

(1) Sensation of down: In 1820, it was discovered that a person on a merry-go-round tended to lean to the center of the rotation to bring the long axis of the body in line with a perceived vertical. This is explained by the increased stimulation of the nervous epithelium within the otolith organs resulting from both the increased magnitude and direction of the force vector. This stimulation from centrifugal force gives the sensation that down is to the outside. Simultaneously, as the individual begins to align with the newly perceived vertical the illusion is intensified. Carried to the extreme, as the rate of spin becomes great enough to exceed the force of gravity, the perceived vertical would be 90 degrees from the actual vertical.

(2) Sensation of nose-high attitude: During World War II, in reporting on a series of night takeoff accidents, the Royal Air Force found that forward acceleration caused the sensation of a nose-high attitude. Pilots who were actually flying level or in a gentle climb would nose the aircraft over and crash. The mechanism at work here is the same as the merry-go-round illusion.

(3) Perceived nose-up attitude: Night takeoff accidents usually occur as the pilot accelerates the aircraft forward at the rate of 32 feet per second per second. Here a I G inertial vector pulls the otolith membranes to the rear. The 1 G gravity vector which is always present will combine with the 1 G inertial force to create a 1.4 G resultant force vector pointing diagonally to the rear and down (Figure 19). The pilot perceives up to be in the opposite direction to the resultant force vector and when the aircraft is level will feel the nose is pitched up at an angle of 45 degrees. By correcting for this perceived nose-up attitude he pushes the aircraft into the ground at an angle of 45 degrees. Oculogravic effects are not experienced if adequate outside references are available; however, bad weather and darkness make a pilot considerably more susceptible to them.

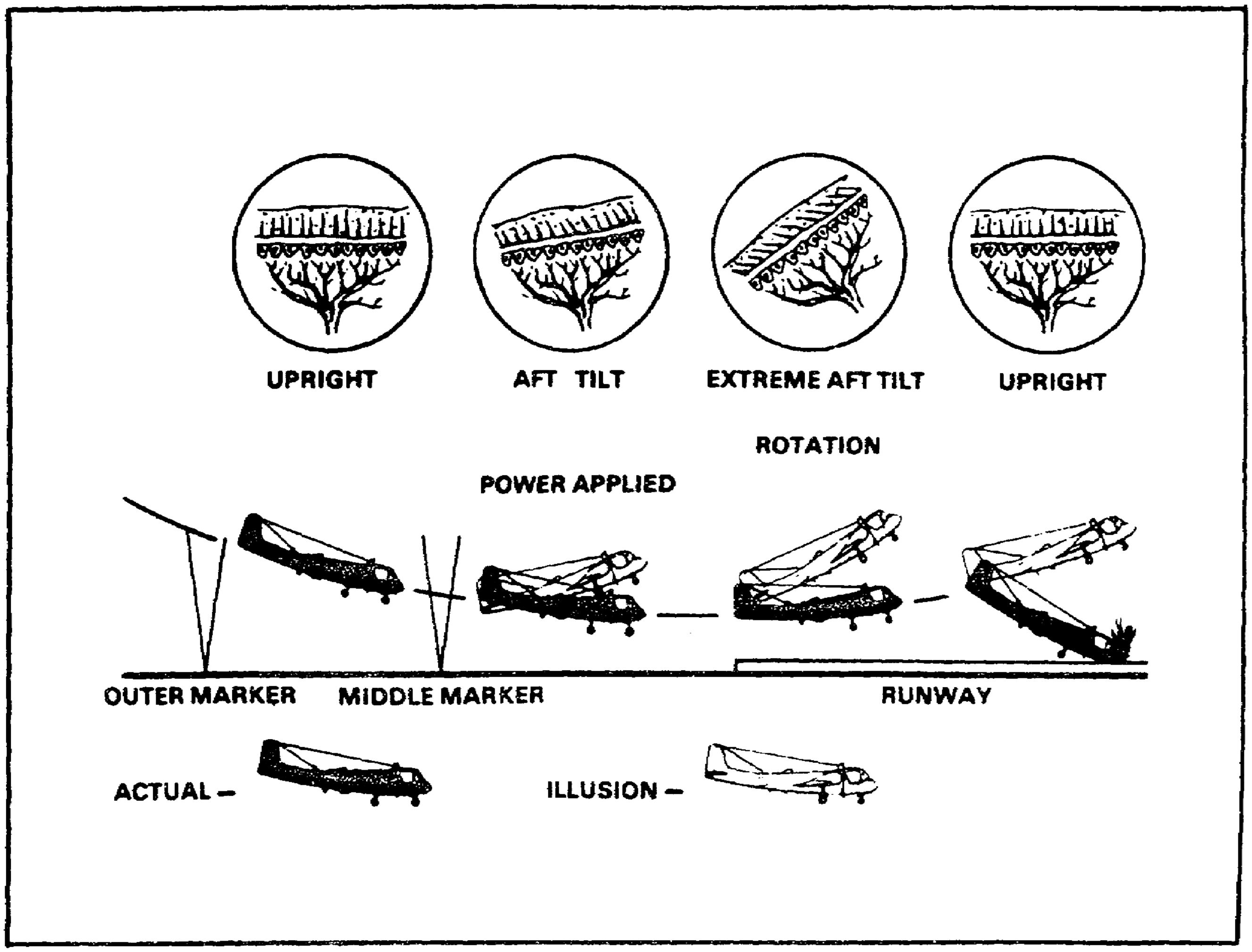


Figure 19. The oculogravic effect.

(4) <u>Illusion of nose-down attitude</u>: It is probable that the illusion of a nose-down attitude occurs during decelerations caused by extending speed brakes or otherwise reducing forward velocity. If this is true, the illusion has not yet been reported as causing an operational hazard.

f. <u>Inverted and Elevator Illusions</u>. Several variations of the oculogravic effect occur to include the inverted and the elevator illusions. Both of these are based on the same mechanism as described for the oculogravic effect.

(1) <u>Inverted illusion</u>: The inverted illusion variation occurs during the pushover from a climb into level flight. Under these circumstances, the centripetal and tangential acceleration acting upon the aircraft yield an inertial vector which, when combined with the gravitational vector, create a resultant vector that is rearward and

upward relative to the pilot. This gives the pilot the sensation that he is tilting over backward until he is inverted. To try to correct this illusory attitude, he is likely to push the nose of the aircraft abruptly downward, thus intensifying the illusion. This illusion is especially dangerous because some aircraft cannot be safely recovered once a nose-down, negative angle-of-attack attitude is entered.

(2) Elevator illusion: The otolith organs can monitor changes in the length of the gravity vector as well as changes in its direction. The elevator illusion results when the utricle and saccule respond to changes in the length of the gravity vector. An increase in the length of the applied gravity vector (as during an acceleration in an upward direction) results in the compensatory downward tracking eye movement. This tracking eye movement results as the body tries, through the vestibular ocular reflex, to maintain visual fixation on the environment during upward acceleration. Since the instrument panel, situated directly in front of the pilot, does not move relative to him while his eyes are tracking downward, the pilot will see the instrument panel (hence the nose of the aircraft) rise.

g. Oculogyral Illusion. The term oculogyral illusion has been used to describe the apparent relative motion of an object in front of a person when both the person and the object are subject to angular acceleration. For example, in the dark, if a pilot fixes his eyes on a light which rotates as the pilot is turning, the light will appear to move in the direction the pilot is turning. When the pilot stops his turn, the light will move rapidly in the direction opposite his rotation in a series of jerks and may appear to be displaced as much as 60 degrees from its actual position.

5. SPATIAL DISORIENTATION AND PROPRIOCEPTIVE ILLUSIONS

Proprioceptive illusions as a pure entity probably do not occur. They are intimately associated with the vestibular system and to a lesser degree with the visual system. The proprioceptive information input to the brain may also lead to a false perception of the true vertical (Figure 20). During turns, banks, climbs and descending maneuvers, proprioceptive information is fed into the central nervous system. A properly executed turn vectors gravity and centrifugal force through the vertical axis of the aircraft. In the absence of visual reference the only sensation experienced by the body is an awareness of being pressed firmly into the seat. This sensation is normally associated with a climb and may be falsely interpreted by the pilot as such. Recovering from turns lightens the pressure on the seat creating the illusion of descending and may cause the pilot to pull back on the stick and reduce his airspeed.

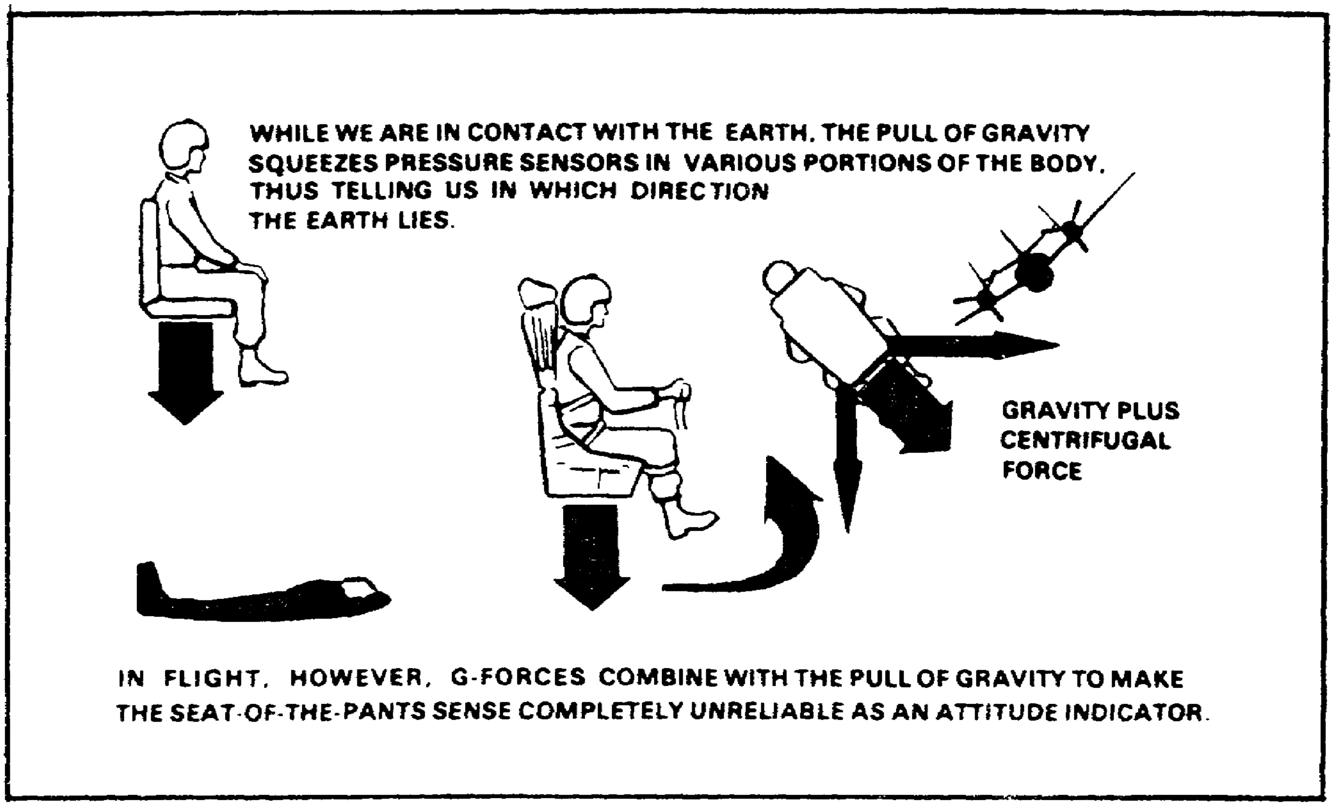


Figure 20. Proprioceptive illusions.

6. PREVENTION OF SPATIAL DISORIENTATION

There is no such thing as total prevention of spatial disorientation. However, the best prevention is understanding that the misleading sensations which come from our sensory apparatus are predictable. They can happen to anyone since they are due to the normal functions and limitations of our sense of balance. Awareness of this potential hazard means that the pilot who experiences these sensations must understand their significance and how to overcome them.

a. <u>Reference Points</u>. Never fly without visual reference points. These can be either a visual horizon or an artificial horizon provided by instruments.

b. <u>Instruments</u>. Trust your instruments.

c. <u>Lights</u>. Never stare at lights.

d. <u>Conditions to Avoid</u>. Avoid fatigue, smoking, hypoglycemia (deficiency of sugar in the blood), hypoxia and anxiety. These conditions ill aggravate all illusions.

7. TREATMENT OF SPATIAL DISORIENTATION

Every pilot should understand that spatial disorientation can easily occur in an aviation environment. If a pilot should experience spatial disorientation there are several things that he can do to regain his sense of equilibrium.

a. Get on the instruments and develop a good cross-check.

b. Do not attempt to fly by using both inside (instrument) and outside references at the same time.

c. Delay intuitive actions long enough to check instruments or outside references.

d. Transfer control if there are two pilots in the aircraft. Seldom will two pilots experience disorientation at the same time.

REVIEW EXERCISE

REQUIREMENT: Complete the following by selecting the correct answers.

1. A person will be spatially disoriented

   A. whenever he operates in an alien environment.
   B. when he is forced to rely on artificial senses (instruments).
   C. only the first few times he experiences an alien environment.
   D. every time he cannot correctly perceive his attitude with respect to the earth.

2. The mechanisms of equilibrium do not include

   A. vision.
   B. the sense of balance.
   C. vestibular apparatus.
   D. the proprioceptive system.

3. The otolith organs of the vestibular apparatus are stimulated by

   A. linear accelerations.
   B. angular accelerations.
   C. continuous linear motion.
   D. continuous angular motion.

4. Flicker vertigo may be caused by light that is flickering at a rate of

   A. 10 cycles per minute.
   B. 15 cycles per second.
   C. 20 cycles per minute.
   D. 25 cycles per second.

5. The most common form of spatial disorientation is

   A. leans.
   B. autokinesis.
   C. elevator illusion.
   D. oculogyral illusion.

6. The threshold of perceiving angular motion is not raised by

   A. anxiety.
   B. vibrations.
   C. inattention.
   D. past experience.

7. Spatial disorientation resulting from one set of semicircular canals being equilibrated to a constant angular velocity followed by a head movement in a different plane is called the

A. <u>leans</u>.
B. graveyard spin.
C. coriolis effect.
D. oculogravic effect.

8. By themselves, proprioceptive illusions

A. occur frequently.
B. probably do not occur.
C. may lead to a false perception of the true horizontal.
D. may lead to a false perception of true linear acceleration.

9. Although spatial disorientation <u>cannot</u> totally be prevented, you can reduce the chance of disorientation by

A. delaying intuitive actions.
B. focusing your attention on a single object.
C. simultaneous reference to instruments and outside conditions.
D. avoiding fatigue, smoking, hypoglycemia, hypoxia and anxiety.

10. If a pilot experiences spatial disorientation he should <u>not</u>

A. delay intuitive actions.
B. attempt to cross-check all aircraft instruments.
C. attempt to fly using both inside and outside references.
D. transfer control because copilot will also be disoriented.

REVIEW EXERCISE SOLUTIONS

1. D. (paragraph 1, introduction)
2. B. (paragraph 2, introduction)
3. A. (paragraph 2a(1)(c))
4. B. (paragraph 3f)
5. A. (paragraph 4a)
6. D. (paragraph 4a(4))
7. C. (paragraph 4d(3))
8. B. (paragraph 6d)
9. D. (paragraph 6d)
10. C. (paragraph 7b)