Federal Aviation
Administration

PILOT VISION

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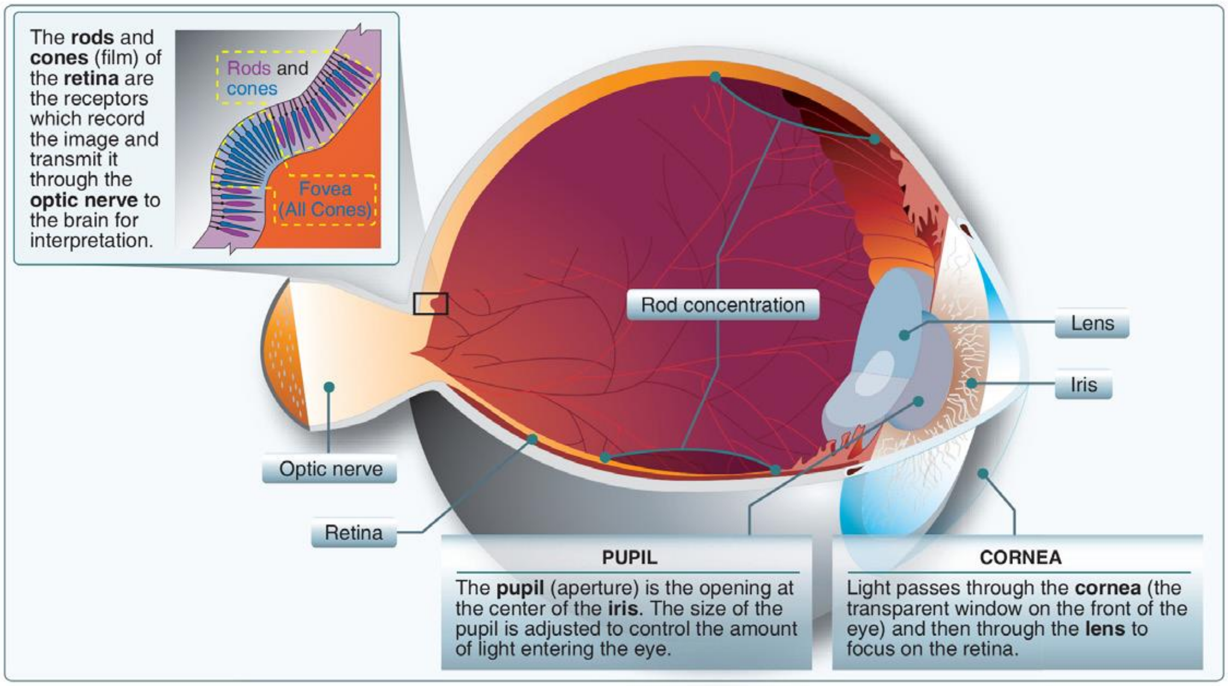
Vision is a pilot's most important sense to obtain reference information during flight. Most pilots are familiar with the optical aspects of the eye. Before we start flying, we know whether we have normal uncorrected vision, are farsighted or nearsighted, or have other visual problems. Most of us who have prescription lenses, contacts, or eyeglasses have learned to carry an extra set of glasses with us as a backup when we fly; however, vision in flight is far more than a lesson in optics.Seeing involves the transmission of light energy (images) from the exterior surface of the cornea to the interior surface of the retina (inside the eye) and the transference of these signals to the brain.



The Anatomy of the Eye

Light from an object enters the eye through the cornea and then continues through the pupil.

The opening (dilation) and closing (constriction) of the pupil is controlled by the iris, which is the colored part of the eye. The function of the pupil is similar to that of the diaphragm of a photographic camera: to control the amount of light.

The lens is located behind the pupil and its function is to focus light on the surface of the retina.

The retina is the inner layer of the eyeball that contains photosensitive cells called rods and cones. The function of the retina is similar to that of the film in a photographic camera: to record an image.

The cones are located in higher concentrations than rods in the central area of the retina known as the macula, which measures about 4.5 mm in diameter. The exact center of the macula has a very small depression called the fovea, which contains cones only. The cones are used for day or high-intensity light vision. They are involved with central vision to detect detail, perceive color, and identify far-away objects.

The rods are located mainly in the periphery of the retina—an area that is about 10,000 times more sensitive to light than the fovea. Rods are used for low light intensity or night vision and are involved with peripheral vision to detect position references, including objects (fixed and moving) in shades of gray, but cannot be used to detect detail or to perceive color.

Light energy (an image) enters the eyes and is transformed by the cones and rods into electrical signals that are carried by the optic nerve to the posterior area of the brain (occipital lobes). This part of the brain interprets the electrical signals and creates a mental image of the actual object that was seen by the person.

The Anatomical Blind Spot

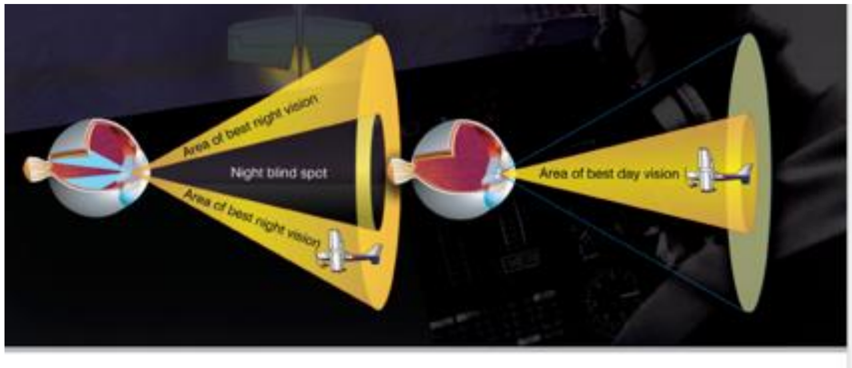
The area where the optic nerve connects to the retina in the back of each eye is known as the optic disk. There is a total absence of cones and rods in this area, and consequently, each eye is completely blind in this spot. Under normal binocular vision conditions this is not a problem because an object cannot be in the blind spot of both eyes at the same time. On the other hand, where the field of vision of one eye is obstructed by an object (windshield post), a visual target (another aircraft) could fall in the blind spot of the other eye and remain undetected.

The Night Blind Spot

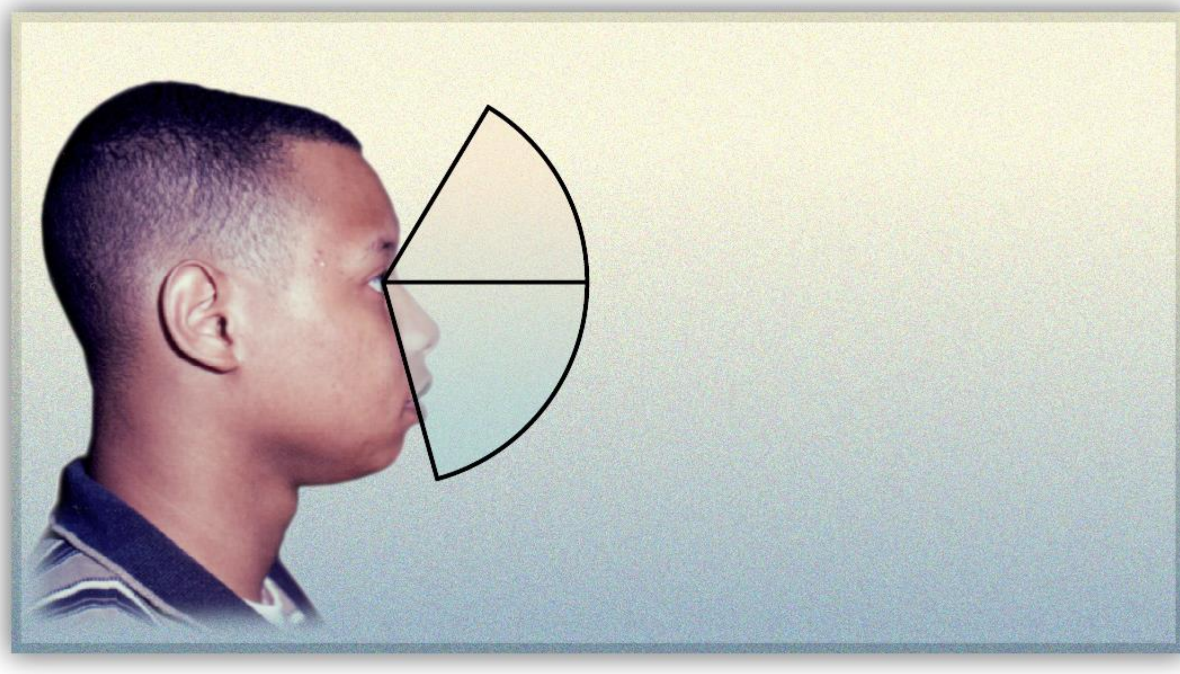
The "Night Blind Spot" appears under conditions of low ambient illumination due to the absence of rods in the fovea and involves an area 5 to 10 degrees wide in the center of the visual field. Therefore, if an object is viewed directly at night, it may go undetected or it may fade away after initial detection due to the night blind spot.

The Fovea

The fovea is the small depression located in the exact center of the macula, which contains a high concentration of cones but no rods, and this is where our vision is most sharp. While the normal field of vision for each eye is about 135 degrees vertically and about 160 degrees horizontally, only the fovea has the ability to perceive and send clear, sharply focused visual images to the brain.



This foveal field of vision represents a small conical area of only about 1 degree. To fully appreciate how small a one-degree field is, and to demonstrate foveal field, take a quarter from your pocket and tape it to a flat piece of glass, such as a window. Now back off 4 1/2 feet from the mounted quarter and close one eye. The area of your field of view covered by the quarter is a one-degree field, similar to your foveal vision.We know that you can see a lot more than just that one-degree cone, but do you know how little detail you see outside of that foveal cone? For example, outside of a ten-degree cone, concentric to the foveal one-degree cone, you see only about one-tenth of what you can see within the foveal field. In terms of an oncoming aircraft, if you are capable of seeing an aircraft within a pilot foveal field at 5,000 feet away, with peripheral vision you would detect it at 500 feet. That is why, when you were learning to fly, your instructor always told you to “put your head on a swivel,” to keep your eyes scanning the wide expanse of space in front of your aircraft.

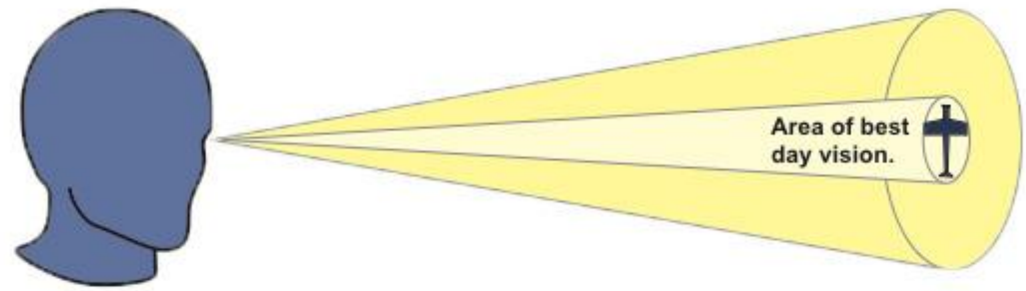


Types of Vision

Photopic Vision. During daytime or high intensity artificial illumination conditions, the eyes rely on central vision (foveal cones) to perceive and interpret sharp images and color of objects.

Mesopic Vision. Occurs at dawn, dusk, or under full moonlight levels and is characterized by decreasing visual acuity and color vision. Under these conditions, a combination of central (foveal cones) and peripheral (rods) vision is required to maintain appropriate visual performance.

Scotopic Vision. During nighttime, partial moonlight, or low intensity artificial illumination conditions, central vision (foveal cones) becomes ineffective to maintain visual acuity and color perception. Under these conditions, if you look directly at an object for more than a few seconds, the image of the object fades away completely (night blind spot). Peripheral vision (off center scanning) provides the only means of seeing very dim objects in the dark.

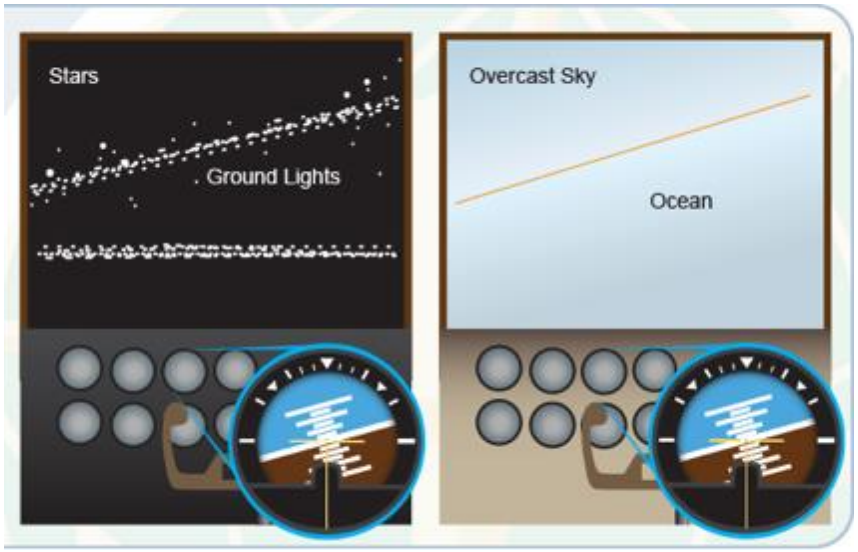


Factors Affecting Vision

The greater the object size, ambient illumination, contrast, viewing time, and atmospheric clarity, the better the visibility of such an object.

During the day, objects can be identified easier at a great distance with good detail resolution. At night, the identification range of dim objects is limited and the detail resolution is poor.

Surface references or the horizon may become obscured by smoke, fog, smog, haze, dust, ice particles, or other phenomena, although visibility may be above Visual Flight Rule (VFR) minimums. This is especially true at airports located adjacent to large bodies of water or sparsely populated areas where few, if any, surface references are available. Lack of horizon or surface reference is common on over-water flights, at night, and in low-visibility conditions.



Flying at night under clear skies with ground lights below can result in situations where it is difficult to distinguish the ground lights from the stars. A similar problem is encountered during certain daylight operations over large bodies of water. Various atmospheric and water conditions can create a visual scene with no discernible horizon.

Excessive ambient illumination, especially from light reflected off the canopy, surfaces inside the aircraft, clouds, water, snow, and desert terrain can produce glare that may cause uncomfortable squinting, eye tearing, and even temporary blindness.

Presence of uncorrected refractive eye disorders such as myopia (nearsightedness–impaired focusing of distant objects), hyperopia (farsightedness–impaired focusing of near objects), astigmatism (impaired focusing of objects in different meridians), or presbyopia (impaired focusing of near objects).

Self-imposed stresses such as self-medication, alcohol consumption (including hangover effects), tobacco use (including withdrawal), hypoglycemia, and sleep deprivation/fatigue can seriously impair your vision.

Inflight exposure to low barometric pressure without the use of supplemental oxygen (above 10,000 ft during the day and above 5,000 ft at night) can result in hypoxia, which impairs visual performance.

Other factors that may have an adverse effect on visual performance include windscreen haze, improper illumination of the cockpit and/or instruments, scratched and/or dirty instrumentation, use of cockpit red lighting, inadequate cockpit environmental control (temperature and humidity), inappropriate sunglasses and/or prescription glasses/contact lenses, and sustained visual workload during flight.

Due to the effects of carbon monoxide on the blood, smokers may experience a physiological altitude that is much higher than actual altitude. The smoker is thus more susceptible to hypoxia at lower altitudes than the nonsmoker.

Focusing

The natural ability to focus your eyes is critical to flight safety. It is important to know that normal eyes may require several seconds to refocus when switching views between near (reading charts), intermediate (monitoring instruments), and distant objects (looking for traffic or external visual references).If dark-adapted eyes are exposed to a bright light source (searchlights, landing lights, flares, etc.) for a period in excess of 1 second, night vision is temporarily impaired: Exposure to aircraft anti-collision lights does not impair night vision adaptation because the intermittent flashes have a very short duration (less than 1 second

Visual Scanning

The probability of spotting a potential collision threat increases with the time spent looking outside, but certain techniques may be used to increase the effectiveness of the scan time. Effective scanning is accomplished with a series of short, regularly-spaced eye movements that bring successive areas of the sky into the central visual field. Each movement should not exceed 10 degrees, and each area should be observed for at least 1 second to enable detection. Although horizontal eye movements seem preferred by most pilots, each pilot should develop a scanning pattern that is most comfortable and adhere to it to assure optimum scanning. The human eyes tend to focus somewhere, even in a featureless sky. If there is nothing specific on which to focus, your eyes revert to a relaxed intermediate focal distance (10 to 30 feet). This means that you are looking without actually seeing anything, which is dangerous. In order to be most effective, the pilot should shift glances and refocus at intervals. Shifting the area of focus, at regular intervals, between the instrument panel and then refocusing outside of the aircraft helps to alleviate this problem. [See FAA-H-8083-3B and AC 90-48, Pilots' Role in Collision Avoidance.]

Vision Pathophysiology

Cataracts:

A cataract is a painless, progressive condition where the lens becomes progressively opaque interfering with vision first noted at night and with reading fine print. Most cases occur in people over 60 but can occur in younger patients with diabetes mellitus, chronic use of cortisone, or with a history of eye trauma. Surgical correction involves implanting a synthetic intraocular lens, either monofocal or multifocal. Untreated cataracts were a factor in a fatal accident in 2013. The FAA permits pilots to fly with early cataracts with regular eye examinations and post surgically with monofocal lenses when they meet vision standards without complications. Multifocal lenses require a brief waiting period. The visual effects of cataracts can be successfully treated with a 90% improvement in visual function for most patients. Regardless of vision correction to 20/20, cataracts pose a significant risk to flight safety.

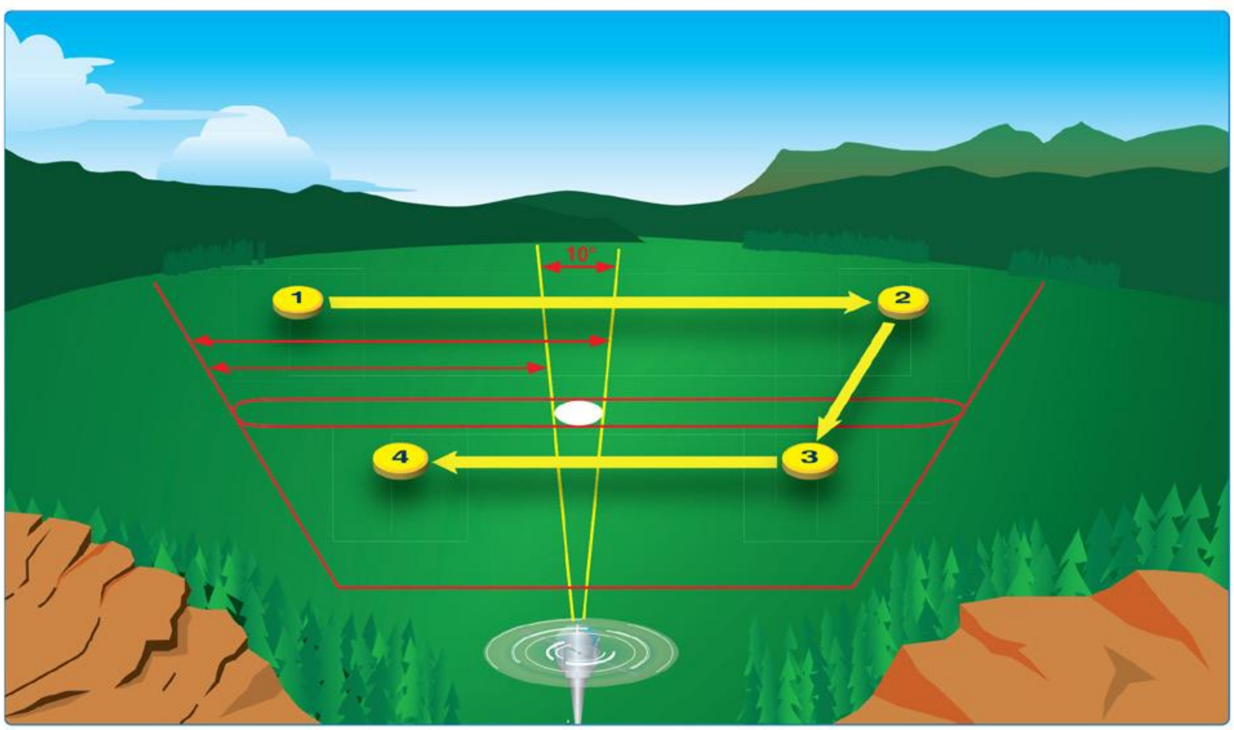


Figure 13-5. *Scanning pattern.*

Untreated cataracts were a factor in a fatal accident in 2013. As a cataract progresses, it can cause vision disturbances such as glare, halos, starbursts, and loss of contrast sensitivity in dark or dusk conditions making it difficult for a pilot to land.

Glaucoma:

Glaucoma can be defined as optic nerve damage resulting from an increase in intraocular pressure affecting the ability of axons of the retinal ganglion cells to effectively carry visual information to the brain.The specific type of glaucoma, stability on acceptable medications, evidence of visual field defects, and adequate control of intraocular pressures are factors that influence the ability to fly with this condition. Ocular Hypertension or

Glaucoma Suspect that is monitored and stable or previous history of Narrow Angle/Angle Closure Glaucoma which has been treated with iridectomy /iridotomy (surgical or laser) and is currently stable may be certified for flying. Symptoms of severe pain, nausea, transitory loss of accommodative power, blurred vision, halos, epiphora (excessive watering of the eye), or iridoparesis (swelling of the iris of the eye) characteristic of primary or secondary narrow angle glaucoma are not acceptable for flying. There must be an absence of side effects and unreliable visual fields or other defects, and intraocular pressure must be 23 mm Hg or less in both eyes to be certified by the FAA.

Heterophoria:

Heterophoria relates to an improper fixation of the visual axis, resulting in misalignment of the eyes. When the ability to maintain binocular fusion through vergence is exceeded,
phoria results. A pilot who has such a condition could progress to seeing double (tropia) should they be exposed to hypoxia or certain medications.One prism diopter of hyperphoria, six prism diopters of esophoria, and six prism diopters of exophoria represent FAA phoria (deviation of the eye) standards that may not be exceeded.

Color Vision

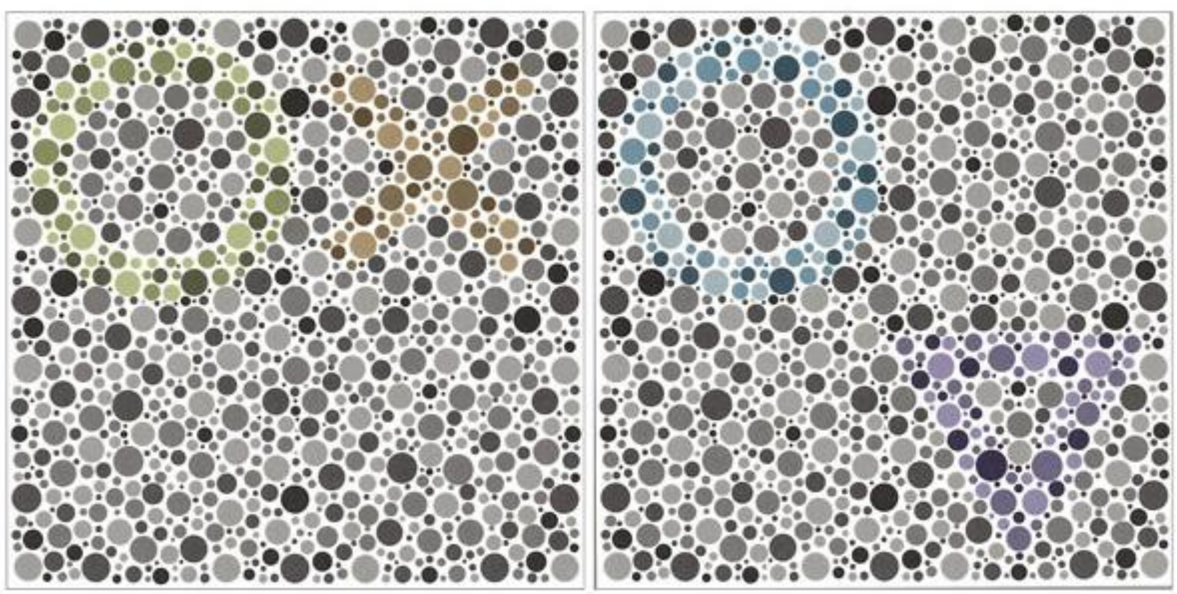
Color perception is critical to safe flight for several reasons. Within the flight environment many types of information are conveyed using color.

Human color perception is the result of three types of cones that contain variations of the photopigment photopsin that are sensitive to long, medium, and short wavelengths. The cones are most sensitive to approximately 565nm (red), 545nm (green), and 440nm (blue), respectively.

Six to eight percent of males have some degree of genetically programmed color blindness.

There are many degrees of color vision deficiency, including perception, that are skewed but largely trichromatic. Some individuals are "weak," or anomalous, in detecting certain colors, while others have dichromatic vision and only have two cone types.

An applicant can be tested with a number of different color vision tests: the FAA recommends Richmond HRR (Hardy Rand and Rittler) pseudoisochromatic plates based on the ability to test for both Red-Green and Blue-Yellow color deficiency.



Richmond HRR pseudoisochromatic plates can test for Blue – Yellow color deficiency (tritanopia)

Monocular Vision

A pilot with one eye (monocular), or with effective visual acuity equivalent to monocular (**i.e., best corrected distant visual acuity in the poorer eye is no better than 20/200**), may be considered for medical certification through special issuance with a satisfactory adaption period, complete evaluation by an eye specialist, satisfactory visual acuity corrected to 20/20 or better by lenses of no greater power than ±3.5 diopters spherical equivalent, and by passing an FAA medical flight test (MFT).

A Word about Contact Lenses

Monovision contact lenses (one contact lens for distant vision and the other lens for near vision) make the pilot alternate his/her vision; that is, a person uses one eye at a time, suppressing the other, and consequently impairs binocular vision and depth perception. These lenses are not acceptable for piloting an aircraft.

The Eyes Have It

Good near, intermediate, and distant visual acuity is vital because:

Distant vision is required for VFR operations including take-off, attitude control, navigation, and landing.

Distant vision is especially important in avoiding midair collisions.

Near vision is required for checking charts, maps, frequency settings, etc.

Near and intermediate vision are required for checking aircraft instruments.

Pilots are encouraged to learn about their own visual strengths and weaknesses. Changes in vision may occur imperceptibly or very rapidly. Any change in range of visual acuity at near, intermediate, and distant points should be brought to the attention of a licensed physician or Aviation Medical Examiner (AME). An extra pair of corrective lenses or glasses should be carried when flying. Always remember vision is a pilot's most important sense.

See and Be Seen:

Outside of a 10° cone, visual acuity drops 90%.

Pilots are 5 times more likely to have a midair collision with an aircraft flying in the same direction than with one flying in the opposite direction.

Avoid self-imposed stresses such as self-medication, alcohol consumption, smoking, hypoglycemia, sleep deprivation, and fatigue.

Do not use monovision contact lenses while flying an aircraft.

Use supplemental oxygen during night flights above 5,000 ft MSL and daytime flights above 10,000 ft MSL.

Any pilot can experience visual illusions–rely on instruments to confirm visual perceptions during flight.

Some images used from The Federal Aviation Administration. Helicopter Flying Handbook. Oklahoma City, Ok: US Department of Transportation; 2012; 13-1. Publication FAA-H-8083.
Available at:
https://www.faa.gov/regulations_policies/handbooks_manuals/aviation/helicopter_flying_handbook/
. Accessed September 28, 2017.

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