Your Most Important Soaring Instrument – Your Eyes

By David M Wilson

Your most important soaring instrument in the cockpit is not a variometer, or a final glide computer. It is your eyes!

Yes you do need your eyes to read the instruments. However our eyes are far more important than that.

A soaring pilot needs to see wedge tailed eagles, willy willy cores, wisps of newly forming cumulus clouds, other gliders marking thermals, pick out ground features marking potential sources of thermals. These essential clues are often the difference between an outlanding and getting home, or between just competing in a race and getting home first. You need to see those things from several km away if you are to adjust your flight path to meet them.

If you are near the ground, you need keen eyesight to read the features of potential landing paddocks, find potential hazards such as single wire earth return power lines, rocks, stumps, star pickets, tall crops, slopes and gullies. You need to be able to see this detail from about 1 km away.

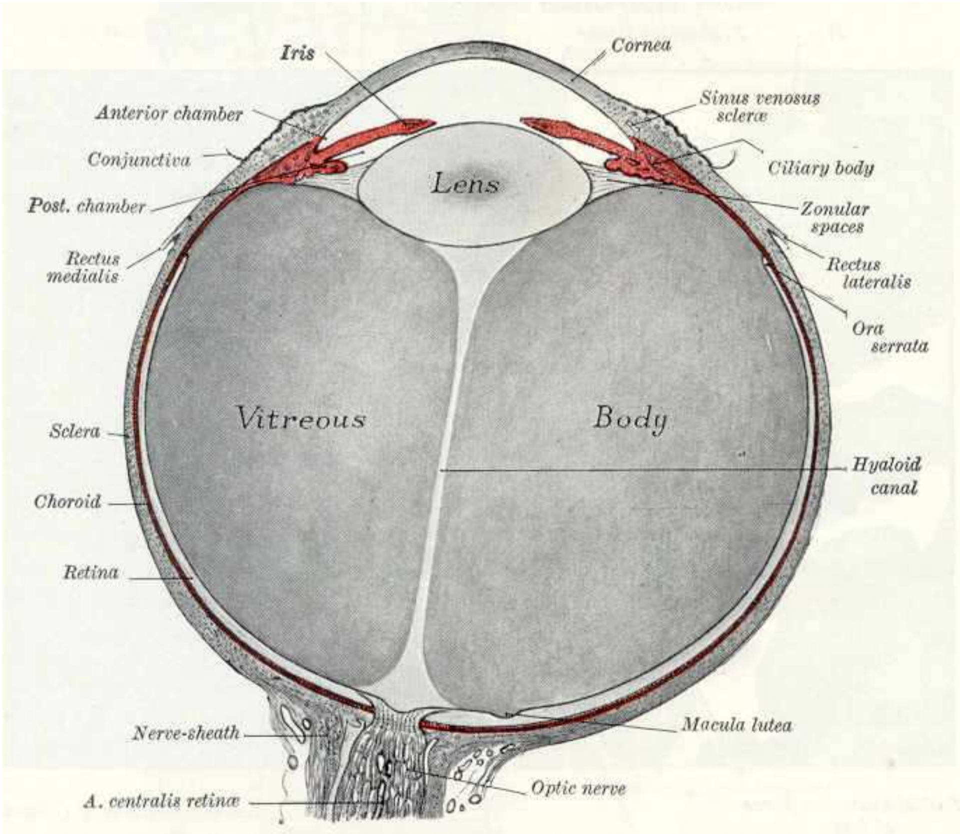
All pilots, even those with an engine to sustain their flight, need their eyes to work overtime to maintain a good lookout to avoid mid air collisions. The excellent article by John Buchanan (Australian Gliding and Sky Sailor – April 1999) described the techniques you should use to scan the sky. These techniques are critically dependent on the performance of your eyes.

Fortunately, we are blessed with two eyes, both connected to a powerful multi-tasking computer with excellent built-in image processing capability.

It is likely, although I am not aware of any study to prove it, that the eyesight of soaring pilots is much better than the average of the population as a whole, because those with poor eyesight will gravitate to sports where the deficiencies in their eyesight are less significant. However I am sure that even amongst our ranks, not all of us have perfect vision. By writing this article, I hope to perhaps persuade some of the 30% or so of you who are unaware that you have less than perfect vision to do something about improving the ability to use your eyes when flying. I hope that this will improve your safety as well as the safety of others who fly in your vicinity. It should also improve your soaring performance.

How The Eye Works

Today, we have developed a close approximation to the eye in the modern digital camera. Since most people are familiar with a camera, I will frequently refer to the camera analogy to explain how the eye works. The eye (or at least the computer behind it) even has high-powered features seen only on expensive cameras, such as digital anti shake imaging, auto focusing, and auto exposure control.



The eye in horizontal cross-section (After Gray's anatomy)

The eyeball is roughly spherical, and normally about 23 mm diameter. Its axis is capable of being pointed in different directions by a group of muscles called the orbital muscles. The brain automatically directs the muscles of the two eyes so that both eyes point to the same object at once.

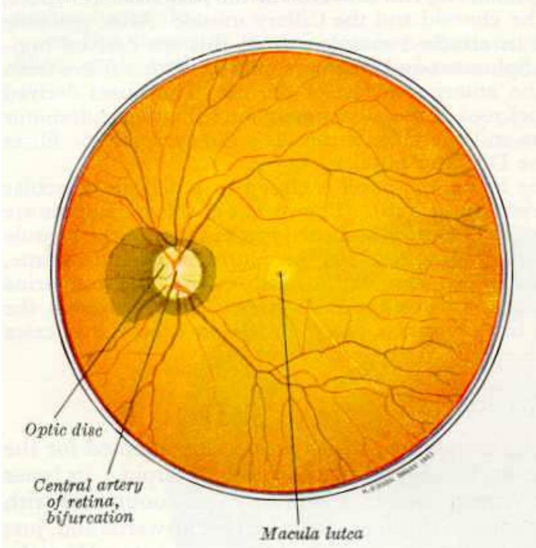
Retina

The light sensing part of the eye is called the retina, which covers the back and wraps around the sides of the eyeball, unlike the camera, which has light sensing only on a plane at the back. The wrap around of the retina gives the eye a very wide angle of view, so that when you are looking straight ahead, the eye can sense movement and shapes out to the side 90^o from where you look. In the vertical plane, the eye has wide-angle vision below to about 80^o, but upwards only to about 45^o above the direction the eye is pointing. If you wear a baseball cap, the upward vision will be dramatically reduced. If you must wear such a cap when flying, copy Lleyton Hewitt, and reverse it.

There are two different kinds of cells in the retina that react to light. The rods react to relatively low light intensity, and do not detect colour. The cones need a higher light intensity, and differentiate between different colours.

On the axis of the eyeball at the back there is a small region called the macula lutea.. In camera terms, this region has a very high number of pixels per sq mm, and about 20% of the optic nerve fibres terminate in this small region. In the centre of this region is an even smaller area called the fovea, in which the cones are found very tightly spaced, and there are almost no rods. In that area, each light-sensing cell is connected to one nerve. The fovea is only about 1.5 mm diameter. This is the part of the retina on which the image of what you are looking directly at will focus, and in that region, you should be able to resolve fine details such as reading fine print, or detecting what sort of crop is in the paddock below. The visual field accessed in fine detail is only about 2^{o} wide! For the rest of the retina, there are both rods and cones, and each nerve fibre branches to integrate the signals from a number of adjacent cells, so that the resolution power is much lower.

FIG. 1020.—The macula lutea, the optic disc and the retinal blood-vessels of the left eye as seen on ophthalmoscopic examination.



Optic Nerve and arteries affecting the image.
(After Gray's Anatomy)

The optic nerve pierces the retina in a spot about 6 mm diameter, a little to the nose side of the macula lutea. In this region there are no light sensing cells, so that using only the right eye, there is a blind spot in the field of view at about 15^{o} to the right of straight ahead. This blind spot is quite large enough to hide an oncoming glider or power plane when scanning with one eye. For the left eye, the blind spot is about 15^{o} to the left of straight ahead.

Fortunately, the blind spots in our eyes do not overlap. The brain's image processing software seamlessly merges the images seen by the two eyes, so that normally all areas in the field of view are covered by light detecting cells in one eye or the other.

Body of the Eye

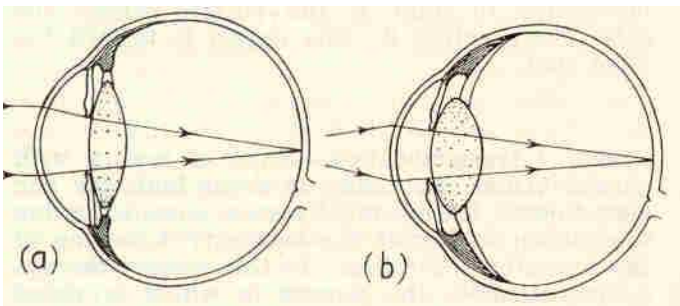
The body of the eye consists of a transparent jelly like substance with a refractive index not very different from water. The space between the lens and the cornea is filled with a transparent fluid.

The Lens

The lens shown in the diagram is actually only a part of the lens system of the eye, since most of the refraction of light occurs at the front spherical surface of the cornea. The lens in the eye would, on its own, have a focal length far longer than the 23 mm required to focus distant objects on the retina.

Whereas in a camera the accommodation of different distances of the object is achieved by moving the lens closer or further from the film plane, in the eye, focusing is achieved by varying the shape of the lens. In a perfect eye, totally relaxed, the combination of the curvature of the cornea and the natural shape of the lens suspended inside will focus a distant object onto the retina in the region of the macula lutea. An eye with perfect focus on the retina when relaxed is called emmetropic.

The lens consists of transparent fibrous tissue, with a different refractive index to the liquid in front and the jelly-like substance behind. The lens is suspended by a great number of fine fibres called the ciliary fibres, which are normally in tension so that they hold the lens precisely in position, and also hold the lens in a stretched out or flattened state. The lens has natural elasticity, and the curvature of the front and back surfaces changes if the ciliary muscle operates. Contraction of the ciliary muscle compresses the ring of fibrous material holding the outer end of the ciliary fibres, reducing the tension in those fibres and allowing the lens to adopt a more rounded shape. This is the way the eye focuses on near objects, such as when reading. In a very young person, the accommodating power available is about 10 dioptres, so that an emmetropic eye can focus on an object as close as about 100 mm from the nose. As people get older, the lens becomes less elastic, so that by the age of about 45 to 55 years, most people with normal eyes cannot focus objects closer than the length of their arms, and they find they need glasses for reading.



The Eye relaxed (a) and focusing on a close object (b)

Focusing is almost automatic, although one can voluntarily contract the ciliary muscles with a bit of practice.

Exposure Control

In a camera, the exposure is controlled by a combination of the size of the aperture and the length of time the shutter is opened. The aperture is formed by a diaphragm which can change the diameter of a small hole through which the light must pass. In bright light conditions, photographers can use a smaller aperture, which results in a greater latitude in the focusing (more depth of focus).

Adjusting the exposure time does not happen in an eye, although we can blink if the light is too bright.

The eye's aperture is the pupil, the black hole in the centre of the iris. The iris is the coloured part of the eye, and is an opaque diaphragm of contractile tissue. In bright light, the muscle fibres of the iris contract, reducing the pupil to a minimum of about 2 mm diameter (equivalent to about f/16). In very dull light, the iris relaxes and allows the pupil to expand up to about 6 mm diameter (equivalent to about f/5). Adjustment of the size of the pupil is automatic and involuntary.

Note that choosing very dark sunglasses will be automatically compensated by the iris opening to let more light through. Since a larger aperture makes the eyes ability to focus worse, dark sunglasses have a detrimental effect on vision. This is particularly true for those persons with defects in their lens systems.

This is not to say we should avoid wearing sunglasses when flying. Properly chosen sunglasses eliminate glare (which is mostly polarized light), filter out the blue light reflected by dust particles within the air allowing the longer wave length light from more distant objects to be perceived, and most importantly, they protect the cornea and lens of the eye from the effects of ultra-violet light, which is known to be one cause of cataracts. However, avoid using very dark sunglasses, or those with a partially reflective mirror coating, which merely open the pupil and degrade your vision.

Image Processing

The way in which the brain can merge the images from the two eyes has already been mentioned.

The brain automatically detects if the image is not focused on the retinal plane, and will adjust the ciliary muscles to achieve the sharpest image possible in the Fovea. Furthermore, the brain has image enhancing software better than our most powerful computers. Provided that the brain sees something, it will try to improve the image. Amongst other techniques, it will compare adjacent frames taken of the same thing, and fill in the blurs.

If you watch some one reading a book, you can observe that the eye moves in a series of little jumps, pointing first at one point until the brain has absorbed the words which fell within the fovea, then moving very quickly to a new point to take in the next group of words. The eyes are used in this way for all sight, including scanning the sky. During the period while the eyes are actually moving, the brain switches off the image reception in the macula lutea region, though not in the remaining peripheral vision. It is as if the brain takes a series of still shots, perhaps a bit like the conventional movie camera which takes 24 frames a second. You cannot see things when scanning if you sweep your eyes over the area without pausing.

During the periods while the eye is stationary, and processing is occurring, the brain is programmed to detect any movement. Anything which moves relative to the rest of the picture, or changes brightness is detected, (in the whole field of view, not just in the small region covered by the fovea) and the brain will probably choose to direct the eyes at the point where movement was detected for the next frame, so as to see the detail. Objects which do not move relative to the background are quite likely to be missed, so if you are on a collision course with another aircraft, and both of you are moving in a straight line, you are likely to miss seeing it. Similarly, you are more likely to spot a circling glider when the sun glints on the wings than you are to see one which is flying straight.

Scanning while circling, when your course is not a straight line, is much more likely to detect other objects in the sky. Even so, you will not see every object every time you look. Fortunately, the brain is a multitasking computer, and we can learn to build in our head a 3-D picture of where the other object(s) are, and compute where they are likely to be next time you look for them. This skill is not one of the built in programs in the computer's system like the programs for vision.

Defects of the eye

In this article, I am not going to discuss colour blindness, since that deficiency is of little significance for pilots.

There are four common refractile defects which can be corrected by wearing prescription glasses. The defects range in severity from minor through to major. The major defects usually result in the person affected seeking help and getting glasses. However, more minor defects are not serious enough to prevent a person living a normal life, reading, driving a car, skiing, surfing, etc. Such persons may not even be aware that their eyes could be better, since their experience of the world from birth has been a little blurred, but isn't everyone the same?

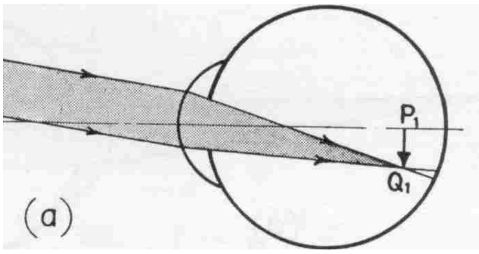
Presbyopia – Loss of accommodating power with age

Presbyopia is the loss of accommodating power that develops with age, so that you need glasses for reading. (It is also sometimes incorrectly called long sightedness, which is described below.) Most elderly people end up with glasses for this defect. If you cannot read the map in the cockpit or see the instruments, but have perfect distant vision, you would need either bi-focal or multifocal glasses in which the bottom section of the glasses lens has a magnifying effect, while the top part of the glasses is plain for looking at objects far away. For flying, we need to remember that such glasses reduce the amount of sky that one processes at each frame of the scan, since light coming through the reading part of the glasses will be out of focus. I have had glasses specially made with only a small section magnifying rather than the usual standard of 50% of the lens area.

Short Sight and Long Sight

These conditions involve the lens not focusing properly on the retina when the ciliary muscles are relaxed. About 25% of the population have one of these defects sufficiently severely that an optometrist would prescribe glasses for normal living. About another 40% have less severe defects, which do not affect normal living, but which would affect safety and soaring ability in pilots. These defects can be present from birth, and can become more common with age.

Shortsightedness or Myopia



In a myopic eye, light from a distant object focuses in front of the retinal plane when the eye muscles are at rest. Contracting the ciliary muscles moves the image even further away from the retina, so that for such persons, distant objects are always blurred (see exception mentioned below). Myopic eyes can focus on close objects.

Those of you who are experienced photographers will know that a camera has a "depth of field". An object being photographed will not come out blurred in the photo if it is within a range of distances, either side of the nominal point on which the lens is focused. The depth of field depends on the size of the aperture (F stop), and in a bright light (f/16), when focused on say 5 m, all objects from 2.5m to infinity will be in acceptable focus. In a duller light (f/8), the depth of field might be reduced so that only objects between 4m to 10m are acceptably clear. When a person with only mild myopia is in broad daylight, so that their pupils are contracted to a small aperture, this depth of field may be enough that distant objects will not be blurred, even though their eyes focus on 5 m distance when the ciliary muscle is totally relaxed.. Putting on dark glasses without optical correction will blur the distant objects for these persons.

Shortsightedness is corrected by fitting a concave lens of the required power in front of the eye.

Long-sightedness or Hypermetropia

In a hypermetropic eye with the ciliary muscles relaxed, the image forms behind the retinal plane.

In this case, tensing the ciliary muscles slightly will provide a correction, so that such a person can focus on distant objects by using up some of their accommodating power. The depth of field can also help persons with hypermetropic eyes in bright light.

An optometrist would not normally prescribe glasses for hypermetropic eyes unless the condition was severe, since a person can live a normal life using their accommodating power to correct for the defect. They might prescribe glasses for reading only. As such persons get older, their accommodating power is reduced, and they need glasses for reading sooner than those with emmetropic eyes or myopic eyes.

When you scan the blue sky, there is nothing in the background on which the eye can focus, so it will automatically relax. Hypermetropic eyes can easily miss objects while scanning above the horizon because the eye has relaxed and the distant objects are blurred to the extent that wedge tailed eagles, other gliders and power planes in the distance are not detected.

Some people have advocated that you can fix this by looking at something on the ground first, and then doing the scan. This is unlikely to work because the relaxation of the eye when one looks at the blank sky is automatic and rapid.

Obtaining convex glasses with the appropriate power is the correct way to overcome this deficiency.

Astigmatism

The fourth type of defect of the lens system causing blurred vision is not able to be improved by movement of the ciliary muscles.

In a perfect eye, the surface of the cornea and the front and back surfaces of the lens are all spherical – at least in the area used to focus on the macula lutea. In an astigmatic eye, one or more of the surfaces is not spherical, usually having a different radius of curvature in the horizontal section compared with the vertical, or possibly at some angle to those directions.

For such a person, the light refracted from the sides of the eye will focus on a different plane to the light impinging on the eye above and below the centre. Everything appears blurred, at all distances, although if such a person looks at a diagram with radial lines, lines in one direction may appear sharp.

To correct for this defect with glasses, the glasses need to be non spherical, and shaped specifically to correct the defect in the eyes lens system.

Eye Tests

Standard eye tests involving reading a chart on the wall of the doctors office from about 2m away do not test whether the eyes are focused on infinity when resting. A mildly shortsighted person would be able to read the chart at that distance. A person with hypermetropia would be able to focus on the chart by use of their ciliary muscles.

An optometrist will test the eye by putting test lenses of different power in front of the eye while the subject is looking at a distant chart. By shining a light into the lens while the eye is relaxed, and observing the light reflected off the retina, they can determine whether the eye is myopic or hypermetropic. The optometrist can put drops in the eye, causing the eye muscles (both the ciliary muscles and the muscles of the iris) to relax. This is of great help to properly identify hypermetropia. Normally an optometrist or ophthalmologist would pass as normal eyes which are mildly hypermetropic, but with sufficient accommodating power for the person to live a normal life. You need to tell the person testing your eyes that you are a pilot and ask them to take extra care in measuring your eyesight, and, if necessary, prescribe lenses to achieve emmetropic corrected eyesight. Unless the tester is briefed, it is likely that the focus of the testing will be on ensuring ability to read.

Diseases of the eye affecting vision.

Space does not permit much discussion on diseases of the eye, and I do not claim any expertise. However some diseases cause effects that should be mentioned.

Opacity of the lens – Cataracts

If the lens loses its normally transparency, the result is blindness. This usually affects the elderly, and is known to be aggravated by smoking. Damage to the lens is also caused by prolonged exposure to ultraviolet radiation. In cases of partial opacity, the effect is a bit like looking though a pair of glasses that are very dirty or spotty.

Retinal blind spots from burns.

It is possible to damage a spot on the fovea by looking at very bright object like the sun. This can cause a permanent scar on a small spot on the fovea, and if you used both eyes, both would be scarred so that the brain's image processor could not overcome the blind spot. The result would be a small spot that annoyingly obscured the point you were looking at. In time the brain may learn to compensate by pointing the eyes so that a different part of the fovea becomes the central spot.

Macular degeneration

Macular degeneration is a term used to describe a condition where the whole area of the macula lutea loses its ability to see, while the rest of the retina continues to function. The eyes lose their ability to see fine details, and vision appears to have a black area over the central area of the field of view. The causes of macular degeneration are not fully understood, but one known cause is diabetes. Once again, smoking and old age are definitely things to avoid.

Retinal Detachment

Part of the retina of an eye can become detached from the layers beneath it, so that connection between the light detecting cells and the nerves is lost. This results in a blind area in the field of view of that eye. The size and location of the blind patch depends on the size of the detached retinal area. It may affect the central macula lutea, or only part of the peripheral vision. The condition can occur spontaneously, or may be induced by trauma such as a blow to the head.

Glaucoma

Glaucoma is a build up of internal pressure in the fluids of the eye. The pressure does not cause immediate loss of vision, but the pressure damages the cells in the retina, and if untreated, permanent loss of all vision will eventually occur.

Ophthalmologists and optometrists will look for these diseases during any eye examination.

Can you test your own eyes

It is quite instructive to get together a group of your friends (preferably at least half a dozen) in bright daylight on a straight stretch of road. Choose some distant sign like a street name or number-plate on a parked car, too far away to read clearly at that distance, and all walk towards the sign, each person stopping when they can clearly read the writing. You will be surprised by the differences in the ability of people to see distant objects clearly. Such a test will not detect the condition of mild or moderate hypermetropia, but will show quite a lot of people that their vision could be improved.

Conclusion

Your eyes are critical for your safety when flying, and you depend on them to pick up the visual clues to help find thermals to stay airborne, to avoid midair collisions, and to choose a safe place to land when the thermals stop.

Knowing how the eyes work and understanding the brain's image processing program should help you improve your ability to scan the sky, and see critical things.

My main message is to get your eyes tested and use glasses for flying if your eyes do not focus on infinity when at rest.

Good soaring and safe flying.