See and **Avoid**

Limitations of this Principle

Even when pilots are vigilant about looking out, there is no guarantee that other aircraft will be seen. Human factors at various stages in the process can reduce the chance that a threat aircraft will be seen and successfully avoided. These human factors are not errors, or signs of poor airmanship. They are limitations of the human visual and information processing system that are present, to varying degrees, in all pilots.

Seeing and avoiding involves a number of steps. First, you must look outside the aircraft. Second, search the available visual field and detect objects of interest, most likely in peripheral vision. Next, an object must be looked at directly to be identified as an aircraft. If it is thought to be a collision threat, a decision must be made on what evasive action to take. Finally, you must make the necessary control movements and allow the aircraft to respond.

Workload

Many tasks require the pilot to direct attention inside the aircraft.

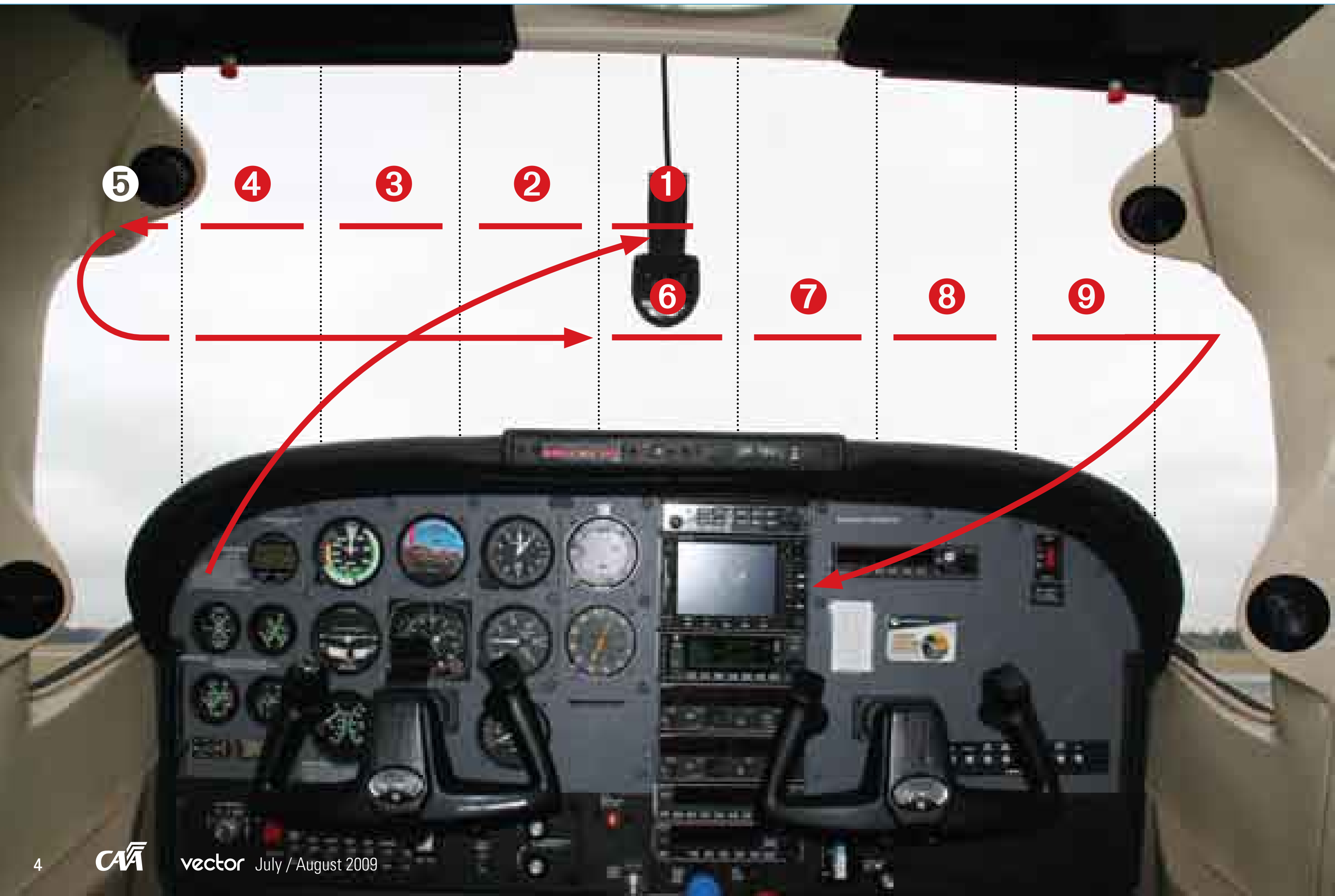
Cockpit workload is likely to be high near airports, where traffic is most dense, and where an outside scan is particularly crucial. Most of these cockpit tasks are essential; however some of the workload is less critical and could be performed at other times.

In addition, pilots flying aircraft with advanced glass cockpits can find they spend more time 'heads-down', as they interact with the technology at their disposal, and less time looking out as they would in less advanced aircraft.

Don't let cockpit workload and modern technology reduce the time you should spend in traffic scans.

Obstructions

Most cockpit windscreen configurations severely limit the field of view available to the pilot. Visibility is



most restricted on the side of the aircraft furthest away from the pilot. Obstructions include window-posts, bug splatter, sun visors, wings, and front seat occupants. The instrument panel itself may obstruct vision if the pilot's head is significantly lower than the standard eye position specified by the aircraft designers.

An obstruction wider than the distance between the eyes, such as window-posts, will not only mask some of the view completely, but will make other areas visible to only one eye. A window-post can also act as a focal trap for the eyes. The presence of objects around 50 cm away can result in the eye being involuntarily trapped at that focal length, making it difficult to see distant objects.

Limitations of the Visual Scan

Accommodation is the process of focussing on an object. The human eye is brought into focus by muscle movements that change the shape of the eye's lens. Visual scanning involves moving the eyes in order to bring successive areas of the visual field onto the small area of sharp vision in the centre of the eye.

Pilot scans are often unsystematic. Areas of sky near the edges of wind-screens are generally scanned less than the sky in the centre, and the scan may be in chunks that are too large, leaving large areas of unsearched space between fixation points. A thorough and systematic search is not a perfect solution, however, as in most cases it would take an impractical amount of time.

FAA Advisory Circular 90-48 C recommends scanning the entire visual field with eye movements of 10 degrees or less. They estimate that around one second is required at each fixation. So to scan an area 180 degrees horizontal and 30 degrees vertical could take 54 fixations, so 54 seconds. However, the speed at which our eyes can accommodate to an object, and the degree of accommodation, degrades with age. Only a young person can accommodate to a stimulus in one second. The average pilot probably takes several seconds to accommodate to a distant object. This can also be affected by fatigue. So in reality, the scene would have changed before the pilot had finished the scan.

A big part of the answer is using a practical scanning technique – one that doesn't take too long to complete, but still gives you a good chance of seeing conflicting traffic. By fixating every 20 degrees, it should be possible to detect any contrasting or moving object in each visual block. Across the total scan area, this involves 9 to 12 blocks, each requiring one to two seconds for accommodation.

Here are two scans that have proved themselves. One method is to start at the far left of the windscreen and make a methodical sweep to the right, pausing in each block to focus. The other is to start in the centre, moving progressively to the left, then swinging quickly back to the centre and repeating the scan to the right. Look out the side windows before beginning the scan cycle again.

Scanning 10 degrees up and down horizontally is also a good idea, and allows you to spot any aircraft below and climbing, or above and descending.

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In high-wing aircraft there is a considerable blind spot created by the lower wing when in a turn.

To partially overcome this problem, you should lean forward to look through the side of the curved windscreen. Move both your head and upper body for a better view.

In the circuit, a systematic lookout before turns is crucial. This is due to the potentially large number of aircraft in close proximity to each other, and the high workload. Start your scan by looking in the direction opposite to the turn as far as the cockpit vision allows. Then move your eyes to scan in the direction of the intended turn, finally raising/lowering the wing to give you a view above and below. Once this scan is complete, a turn can be initiated.

On descent and climb-out, make gentle 'S' turns to ensure no-one is in the way.

On final do not fixate on the touchdown point. Look in front and behind this point for other traffic.

Limitations of Vision

The eye has a built-in blind spot at the point where the optic nerve exits the eyeball. Under the normal conditions of binocular vision the blind spot is not a problem as the area of the visual field falling on the blind spot will still be visible to the other eye. However, if the view from one eye is obstructed, then objects in the blind spot of the remaining eye will be invisible. You can compensate for this by moving your head and upper body during your lookout.

Acuity, or sharpness of vision, varies across the visual field. In daylight, acuity is greatest at the centre (fovea), in low light it is fairly equal across the whole retina, and at night it is greatest in the periphery. There are times when an approaching aircraft will be too small to be seen because it is below the eye's threshold of acuity. Peripheral acuity can be reduced by factors such as vibration, fatigue, and hypoxia.

Empty field myopia occurs in the absence of visual cues, causing the eye to focus at a relatively short distance. In an empty field such as blue sky, the eye will automatically focus at around 56 cm. It therefore requires an effort to focus at greater distances. To combat this, look for a cloud or distant terrain to focus on.

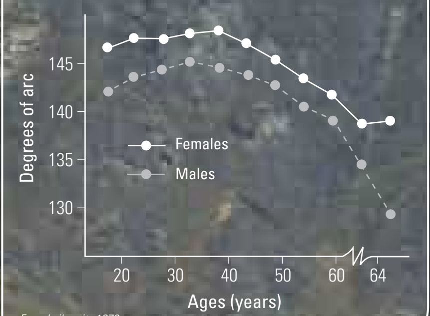
The average person has a field of vision of around 190 degrees, although it varies from person to person, and is generally greater for females than males. The field of vision begins to contract after age 35. In males, this reduction accelerates markedly after 55.

In addition to the natural reduction caused by age, a number of physical and psychological conditions can cause the effective field of vision to contract even further.

A comfortable and alert pilot may be able to easily detect objects in the corner of the eye, but the imposition of a moderate workload, fatigue, or stress, will induce tunnel vision. It is as though busy pilots are unknowingly wearing blinkers. This has also been observed under conditions of hypoxia and adverse thermal conditions.

The limited mental processing capacity of the human can present problems when they need to do two things at once. An additional task, even an unstressful one, such as radio work, performed during a traffic scan can reduce the effectiveness of the search by reducing the pilot's eye movements and effectively narrowing the field of view. Experiments conducted by NASA indicated that a concurrent task could reduce pilot eye movement by up to 60 percent. The key is to carefully prioritise your tasks.

Right eye visual field for males and females



From Leibowitz 1973

Contrast between the colour of the terrain and the aircraft helps to identify this as a target.

Direct glare from the sun and veiling glare reflected from windscreens can effectively mask some areas of the view. Direct glare is a particular problem when it occurs close to the target object. When the glare source is 5 degrees from the line of sight, visual effectiveness is reduced by 84 percent. A good pair of sunglasses will help combat this.

Traffic Characteristics

Atmospheric Effects

Contrast is the difference between the brightness of a target and the brightness of its background. A dark aircraft will be seen best against a light background and vice versa. Contrast is reduced when the small particles in haze or fog scatter light. Not only is some light scattered away from the pilot, but some light from the aircraft is scattered so that it appears to originate from the background, while light from the background is scattered onto the eye's image of the aircraft.

Contour Interaction

Complex backgrounds such as ground features, or clouds, hamper the identification of aircraft due to contour interaction. This occurs when background contours interact with the form of the aircraft, producing a less distinct image. Camouflage works because it breaks up contours and increases interaction. In order to see an aircraft, the pilot must detect the contour between the aircraft and its background.

Lack of Relative Motion

If two aircraft are converging on the point of impact on straight flightpaths at constant speeds, then the bearing of each aircraft from the other will remain constant up to the point of collision. From each pilot's point of view, the converging aircraft will grow in size, but remain fixed at a particular point on his or her windscreen. The human visual system is better at detecting moving targets than stationary targets, yet in most cases, an aircraft on a collision course appears as a stationary target in the pilot's visual field.

Effectiveness of Lights

The visibility of a light largely depends on the luminance of the background. Typical daylight illumination is generally sufficient to overwhelm even powerful strobes. In theory, to be visible at three nautical miles on a very dark day, a strobe light must have an effective intensity of around 5000 candelas. In full daylight, the strobe must have an effective intensity greater than 100,000 candelas. Most existing aircraft strobes have effective intensities of between 100 and 400 candelas. While strobes are not likely to be helpful against bright sky backgrounds, they may make aircraft more visible against terrain or in conditions of low light.

Evasive Action

Even when an approaching aircraft has been sighted there is no guarantee that evasive action will be successful. It takes a significant amount of time to recognise and respond to a collision threat and an inappropriate evasive manoeuvre may increase rather than decrease the chance of a collision.

The total time to recognise an approaching aircraft, recognise a collision course, decide on action, execute the control movement, and allow the aircraft to respond, is estimated to be around 12.5 seconds. The reaction time for older or less experienced pilots is likely to be greater than 12.5 seconds.

Summary

Many limitations of see-and-avoid are associated with the physical limits of human perception, however there is some scope to improve the effectiveness of see-and-avoid.

- Use a practical scanning technique and accommodate to an appropriate distance when searching for traffic.
- Keep the windscreen, windows, and top of the instrument panel clean and clear of obstructions.
- When cleaning windows, wipe in a vertical motion to reduce false horizons.
- Minimize head down time by having charts folded properly, and don't be distracted by technology in the cockpit.
- Navigation and anti-collision lights should be used at all times.
- Make accurate position reports and listen to other position reports to paint a situational picture.
- Turn your transponder to Mode C (or Mode A).
- Scan constantly – 90 percent outside the aircraft, 10 percent inside the aircraft.

The information in this article comes from a report by the Australian Transport Safety Bureau (ATSB) and an article in *Flight Safety Australia.* ■