

Human Performance & Limitations · Module E — The Senses

The Limits of Sight

Chapter 12 — Where vision fails the pilot: night vision and dark adaptation, the blind spot, protecting the eyes, refractive defects, colour vision and colour blindness, and how speed steals reaction time.

BOOK

Human Performance & Limitations

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EXAM

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CHAPTER

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Plate 12.0 — The eye is a superb instrument in daylight — and a treacherous one in the dark, at speed, and against glare.

§ 31

LIMITATIONS OF THE VISUAL SYSTEM

31.1 Night Vision & Dark Adaptation — the critical 7 vs 30 minutes

DGCA-QUOTED DEFINITION

Adaptation is the adjustment of the eyes to high or low levels of illumination.

The time required for:

- **Complete adaptation for HIGH levels of illumination is 10 seconds**, and
- **For full DARK adaptation, 30 minutes**.

WHY PILOTS CARE — DGCA-QUOTED

When **passing from bright ambient surroundings into the dark**, visual capacity is severely reduced until the eyes have adapted to the dark. It is **especially important for pilots to allow sufficient time for dark adaptation to take place before flying at night**.

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CONES VS RODS — THE TWO-STAGE DARK ADAPTATION

Dark adaptation takes time:

- About **7 minutes** for the CONES,
- And **30 minutes** for the RODS.

10s Bright-light adaptation (dark → bright)

7_{min} Cones — partial dark adaptation

30_{min} Rods — FULL dark adaptation

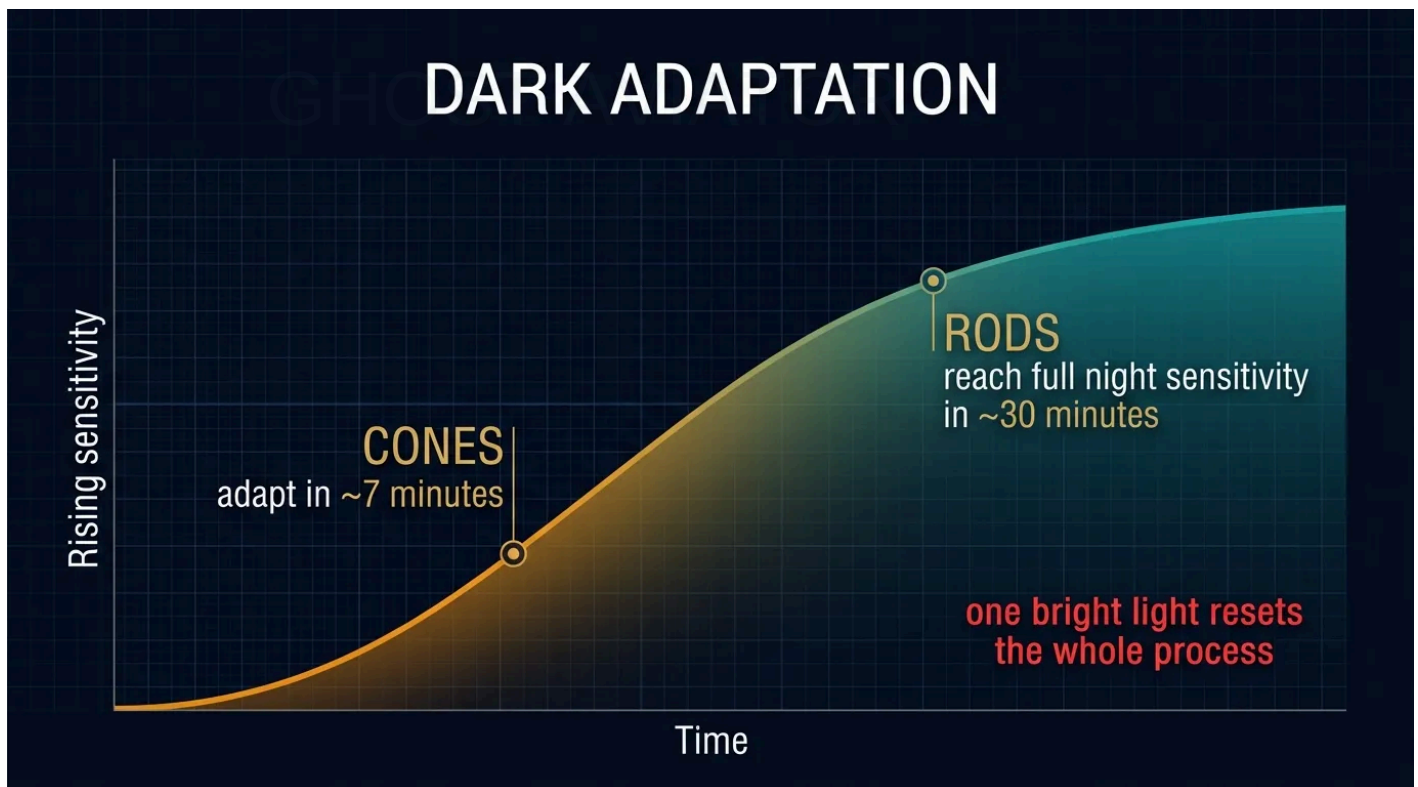


Figure 12.1 — Dark adaptation: cones adapt in ~7 minutes, but full rod (night) sensitivity takes ~30 minutes — and one bright light resets it.

31.2 Vision Under Dim & Bright Illumination

DGCA-QUOTED

Under conditions of **dim illumination**, **small print and colors on aeronautical charts and aircraft instruments become unreadable unless adequate cockpit lighting is available**. Moreover, another aircraft must be much closer to be seen **unless its navigation lights are on**.

In darkness, vision becomes more sensitive to light, a process called **dark adaptation**. Although exposure to **total darkness for at least 30 minutes is required for complete dark adaptation**, a pilot can achieve a **moderate degree of dark adaptation within 20 minutes under dim red cockpit lighting**.

WHY RED LIGHT — AND WHEN NOT TO USE IT (DGCA-QUOTED)

Since red light severely distorts colors, especially on aeronautical charts, and can cause serious difficulty in focusing the eyes on objects inside the aircraft, its use is advisable **ONLY** where optimum outside night vision capability is necessary.

Even so, white cockpit lighting must be available when needed for map and instrument reading, especially under IFR conditions.

DGCA-QUOTED — DARK-ADAPTATION KILLERS

Dark adaptation is impaired by:

- Exposure to cabin pressure altitudes above 5,000 feet,
- Carbon monoxide inhaled in smoking and from exhaust fumes,
- Deficiency of Vitamin A in the diet, and
- By prolonged exposure to bright sunlight.

DGCA-QUOTED — THE "CLOSE ONE EYE" PRESERVATION TRICK

Since any degree of dark adaptation is lost within a few seconds of viewing a bright light, a pilot should close one eye when using a light to preserve some degree of night vision.

31.3 Off-Centre Viewing — "Look 15–20° to the Side"

DGCA-QUOTED — THE NIGHT-VISION TECHNIQUE

Look to the side (**15 - 20 deg**) of the object.

WHY OFF-CENTRE VIEWING WORKS AT NIGHT

The fovea has **no rods** — and therefore **no night vision**. When you stare *directly* at a dim object at night, its image falls on the fovea, where there are zero rods → you cannot see it. By looking **15–20° to the side**, you place the image on the **rod-rich peripheral retina** where night vision is sharpest.

Counterintuitive but vital: at night, the way to see something is NOT to look at it. This is taught in night-VFR training as "**off-centre / scan viewing**".

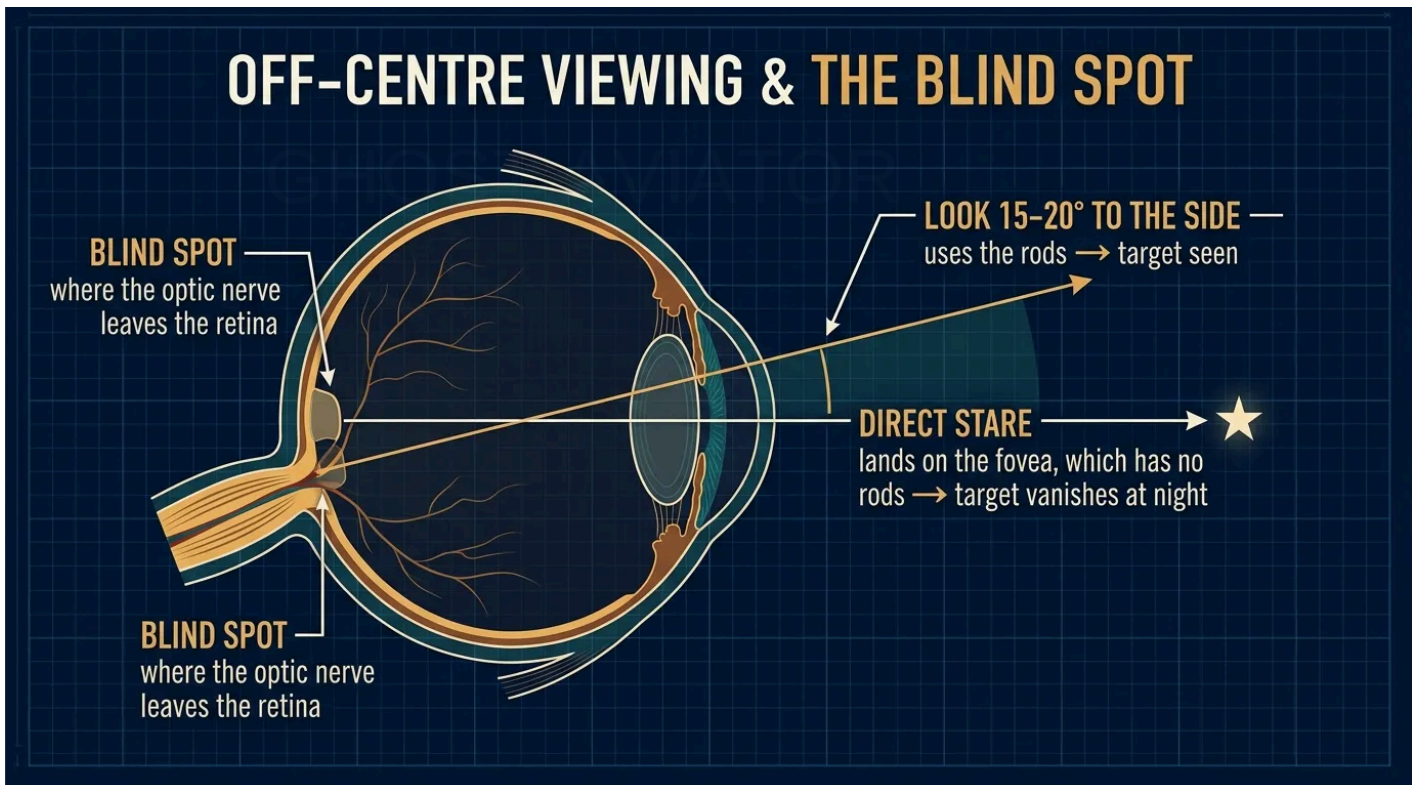


Figure 12.2 — Off-centre viewing: at night look 15–20° to the side, because a direct stare lands the target on the rod-free fovea.

31.4 The Blind Spot

DGCA-QUOTED

The **blind spot** is point on the retina where the optic nerve enters the eyeball. Here the retina has **no covering of light-detecting cells**.

WHY THIS MATTERS FOR SEE-AND-AVOID

If the eye remains **looking straight ahead**, it is possible for a **closing aircraft to remain in the blind spot until a very short time before impact**. To lessen the danger of collision, pilots are taught to **carry out a SYSTEMATIC LOOK OUT at all times**.

With both eyes open, the blind spot of one eye is covered by the other eye. But **be aware of obstructions to your visual field** such as passengers or canopy structures.

31.5 Empty Visual Field (Empty Field Myopia)

DGCA-QUOTED

In the **absence of anything to focus on** (that is when your visual field is empty), the **natural focus point of the eye is, on average, at a distance of between 1 and 2 meters in front of the eye**.

Pilots should **minimize the risks associated with empty visual field by periodically and deliberately focusing on objects, both close and at a distance**.

THE DANGER — "EMPTY FIELD MYOPIA"

At high altitude with a clear blue sky and no clouds, your eye relaxes to its **resting focal length of 1-2 m** — well inside the cockpit. A distant aircraft becomes **blurry and easy to miss**. Mitigation: deliberately re-focus the eyes by looking at the wingtip, then at the horizon, then at a distant ground feature. This pumps the ciliary muscles and breaks empty-field myopia.

31.6 Damage to the Visual System — UV at Altitude

DGCA-QUOTED

Very high light occurs at altitude. At altitude, light contains **more of the high energy blue and ultraviolet wavelengths than is experienced at sea level**. Over a long period, such light can cause **cumulative damage to the retina and lens of the eye**. However, **most harmful wavelengths are filtered out by the cockpit windows**.

31.7 Vibrations & Blurred Vision

DGCA-QUOTED

Vibrations can cause blurred vision. This is due to TUNED RESONANCE oscillations of the eyeballs.

*(Recall §25 — the eyeball's natural resonance is **30–40 Hz**. Aircraft vibration that hits that band → vision-blur. This is one of the most direct cross-links between Part 6 and Part 7.)*

Protection of the Visual System — Sunglasses

DGCA-QUOTED — FLASH-BLINDNESS PROTECTION IN THUNDERSTORMS

When flying through a thunderstorm with lightning you can protect yourself from FLASH BLINDNESS by:

- Turning up the intensity of cockpit lights,
- Looking inside the cockpit,
- Wearing sunglasses, and
- Using face blinds or face curtains when installed.

DGCA-QUOTED — WHAT GOOD SUNGLASSES MUST DO

The requirement of good sunglasses is to:

- Absorb at least **85 %** of visible light to eliminate glare without decreasing visual acuity,
- Absorb UV and IR radiation,
- Absorb all colors equally.

Make sure you avoid using cheap sunglasses. Light sensitive lenses (Photo chromatic) are also generally forbidden for use in flight.

DGCA-QUOTED — SUNGLASSES CHARACTERISTICS (THE "SIX" LIST)

Sunglasses should have the following characteristics:

1. Be impact resistant.
2. Have thin frames (minimum visual obstruction).
3. Be coated with poly carbonate for strength.
4. Be of good optical quality.
5. Have a luminescence transmittance of **10 - 15 %**.
6. Possess appropriate filtration characteristics.

SUNGLASS LIGHT ABSORPTION

≥ 85 %

SUNGLASS LUMINESCENCE
TRANSMITTANCE

10 - 15 %

PHOTOCHROMATIC LENSES

Forbidden in flight

FRAME COATING FOR STRENGTH

Polycarbonate

VISUAL DEFECTS

DGCA-QUOTED OPENING

The most common visual defects are caused by the distorted shape of the eyeball.

33.1 The Four Refractive Defects — Myopia, Hypermetropia, Presbyopia, Astigmatism

MYOPIA (Short-sightedness)

Myopia is more commonly known as **short-sightedness**. In a myopia eye, the **eyeball is LONGER than normal** causing the **image to fall in FRONT of the retina**.

Correction: A **CONCAVE lens** will correct Myopia by **bending the light from distant objects OUTWARDS before it hits the cornea**.

Normal pilot distance vision: "may be very approximately assessed as the ability to **read a car number plate at 40 meters**".

HYPERMETROPIA (Long-sightedness)

Hypermetropia is also known as **long-sightedness**, because **only objects at a distance can be seen clearly**.

Correction: A **CONVEX lens** will overcome Hypermetropia by **bending the light rays from near objects INWARDS before they meet the cornea**.

(Eyeball is shorter than normal — image would form behind the retina. Convex lens converges the rays earlier.)

PRESBYOPIA

Presbyopia is the **inability of the lens to change its shape to accommodate adequately**, to focus as an image from a near object onto the retina.

This condition normally arises in people **between the ages of 40 and 50**. It is a **form of long-sightedness** and is **corrected using a CONVEX lens**.

(This is why pilots at middle age often need bi-focals — see §29.5.)

ASTIGMATISM

Astigmatism is caused by a **misshapen or oblong cornea**. For a person with astigmatism **objects will appear irregularly shaped**.

(Corrected with a cylindrical lens that compensates for the corneal irregularity.)

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REFRACTIVE ERRORS

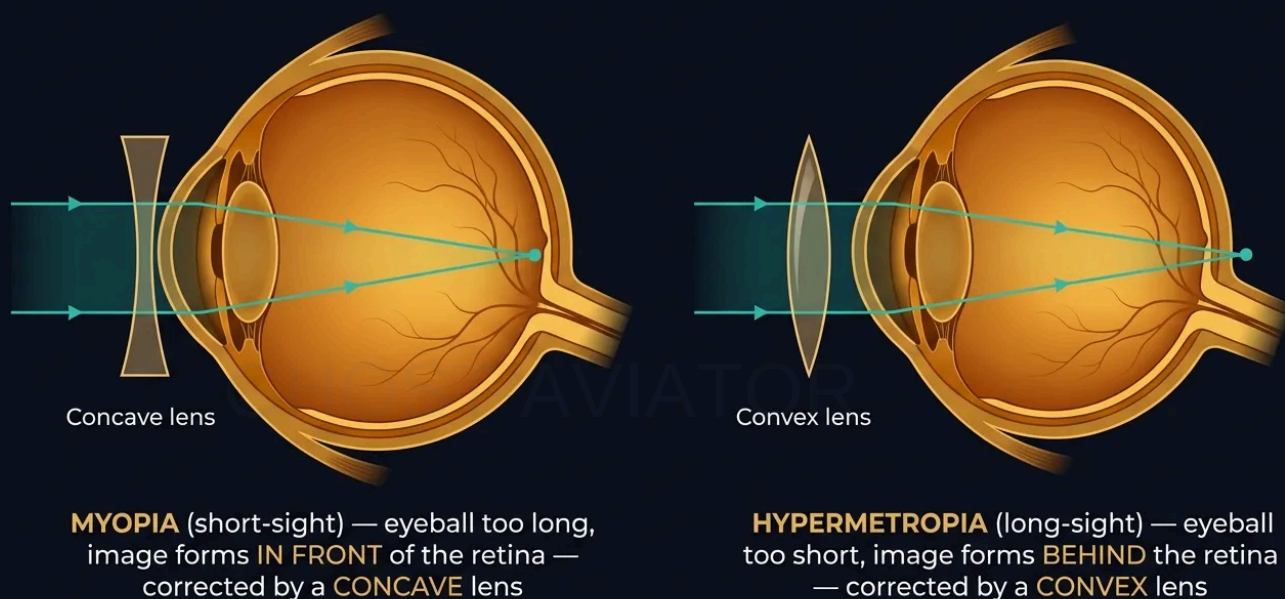


Figure 12.3 — Refractive errors: myopia (eyeball too long, corrected by a concave lens) and hypermetropia (too short, convex lens).

Refractive Defects — Memory Table

Defect	Common Name	Mechanism	Correction
Myopia	Short-sightedness	Eyeball longer → image in front of retina	Concave lens
Hypermetropia	Long-sightedness	Eyeball shorter → image behind retina (only distance clear)	Convex lens
Presbyopia	Age-related (40–50 yrs)	Lens can't change shape — accommodation fails	Convex lens (often bi-focal)
Astigmatism	—	Misshapen / oblong cornea — objects irregular	Cylindrical lens

33.2 Wearing of Corrective Spectacles by Pilots

DGCA-QUOTED RULE

Pilots who wear corrective spectacles or contact lenses, for whatever reason, must carry a **SPARE PAIR** at all times when they are exercising the privileges of their license.

33.3 Glaucoma

GLAUCOMA — DGCA-QUOTED (THE MOST AVIATION-MEDICALLY IMPORTANT VISUAL DEFECT)

Glaucoma is characterized by:

- **Progressive narrowing of the visual field,**
- **Insidious onset and concealed progression,**
- **An increase in intra-ocular pressure.**

Glaucoma can lead to total blindness and undetected reduction of the visual field. It reduces visual acuity in its final stage.

WHY GLAUCOMA IS SCREENED AT EVERY PILOT MEDICAL

The word "**insidious**" + "**concealed**" + "**undetected reduction of visual field**" is what makes glaucoma so dangerous to aviation. A pilot may be losing peripheral vision over months or years and not realise it — until a critical traffic conflict or runway-incursion-detection failure exposes it. **Intra-ocular pressure (IOP) measurement (tonometry) is part of every routine Class-1 / Class-2 DGCA medical** precisely to catch glaucoma early.

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Colour Vision

DGCA-QUOTED

Good color vision is essential for pilots because of the use of color associated with the items listed below.

Why pilots need good colour vision — DGCA-listed items

#	Item	Operational use of colour
1	Navigation light of aircraft	Red (left wingtip) · Green (right) · White (tail) — defines aircraft direction at night.
2	Runways and airfields	White runway edge lights · red runway end · green threshold · PAPI (white/red) glide-path.
3	Ground obstructions	Red obstruction lights on towers · obstacle markings.
4	Cockpit displays and instruments	Red = warning · amber = caution · green = normal · cyan = sky · brown = ground (PFD).
5	Maps and charts	VFR/IFR charts use colour-coded airspace, terrain, MSA values.
6	Emergency flares	Distress flares — red = distress · white = signalling.
7	Light signals	ATC light-signal codes (steady green = clear to land · red flashing = airport unsafe, etc.)

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COLOUR BLINDNESS — THE ISHIHARA TEST



a colour-deficient eye cannot read the hidden number

Figure 12.4 — Colour blindness is screened with Ishihara plates: a number hidden in coloured dots that a colour-deficient eye cannot read.

DGCA-QUOTED DEFINITION

Color blindness or, more accurately, color-defective vision, is caused by a defect in the structure of the color-sensitive cones in the retina.

WHY THIS CONNECTS DIRECTLY TO §29.2

Recall from Part 7 that **cones are the colour-sensitive photoreceptors** packed into the fovea — about **6 million** of them. If their *structure* is defective (most commonly a missing or weak red, green, or blue pigment), the brain cannot distinguish between certain colours. This is most commonly genetic (sex-linked recessive — far more common in males) and is non-treatable.

DGCA-MEDICAL IMPLICATION

Colour-defective vision (red-green most commonly) is screened at every DGCA Class-1 / Class-2 medical using the **Ishihara colour plates**. Significant deficiency can disqualify a candidate, or restrict the licence to "day-VFR only" because of the night colour-signal interpretation problem (nav lights, PAPI, ATC light signals all rely on red/green discrimination).

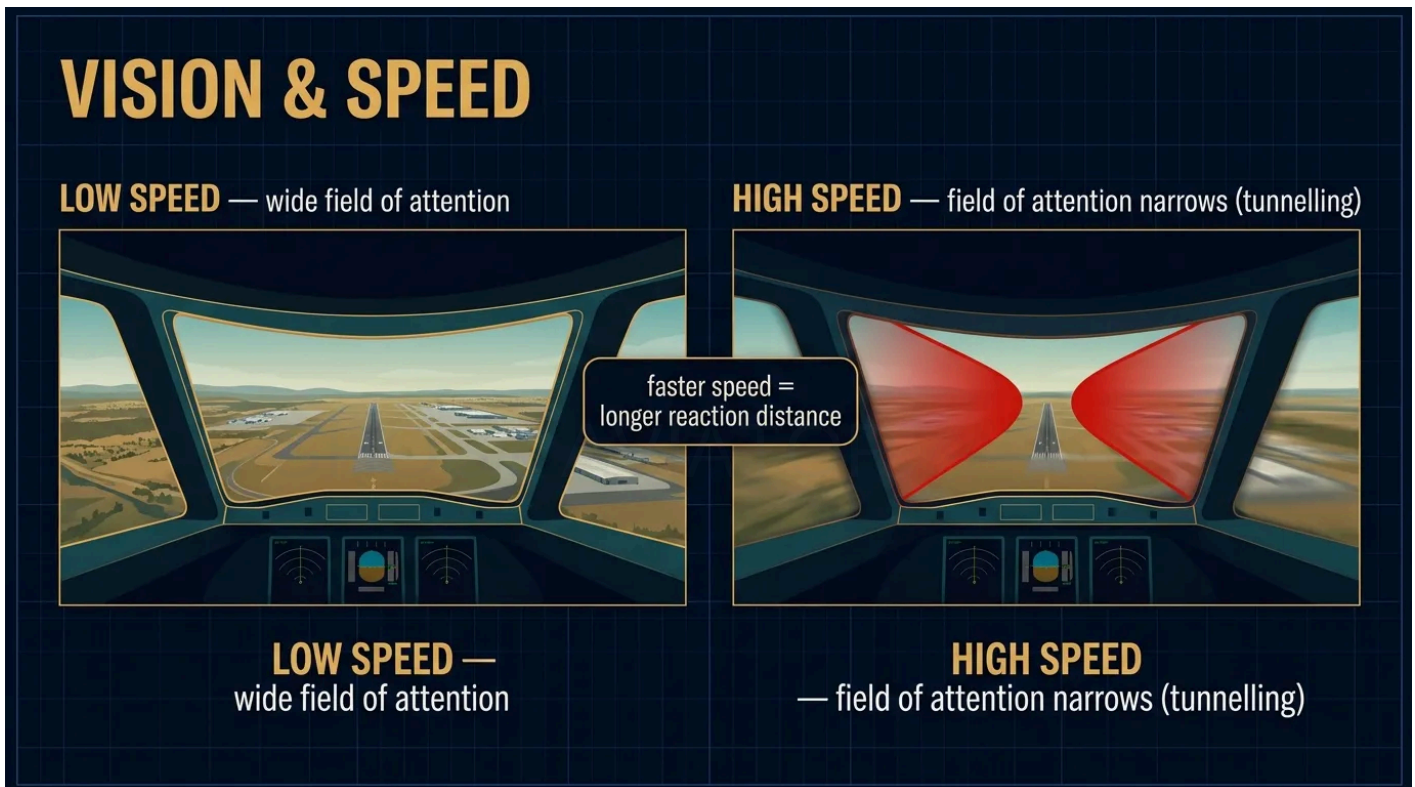


Figure 12.5 — Vision and speed: as speed rises the field of attention narrows and reaction distance grows.

DGCA-QUOTED

Reaction time depends on the closing relative speed of two aircraft. If one of the aircraft were to be a fast jet, the closing speed would be much higher.

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WHY THIS MATTERS OPERATIONALLY — SEE-AND-AVOID LIMITATIONS

At a closing speed of **1,000 kt** (two fighters head-on, each at 500 kt), aircraft cover roughly **0.5 nm per second**. The human eye + brain typically needs:

- ~ **0.1 s** to detect a moving target
- ~ **1 s** to recognise it as another aircraft
- ~ **1 s** to decide on an evasive action
- ~ **4 s** for the controls + airframe to respond

That's **≈ 6 seconds** from "first photon hitting the retina" to "aircraft actually moving out of the way" — at 1,000 kt closing, the other aircraft has already covered **~ 3 nm**. The pilot must therefore detect the conflict at a range that allows for these reaction-time bites; this is why **systematic scan**, **traffic alerts**, and **TCAS** exist.

◆ END OF CHAPTER 12 ◆

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