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HUMAN PERFORMANCE AND LIMITATIONS

CHAPTER 14 – VISUAL ILLUSIONS

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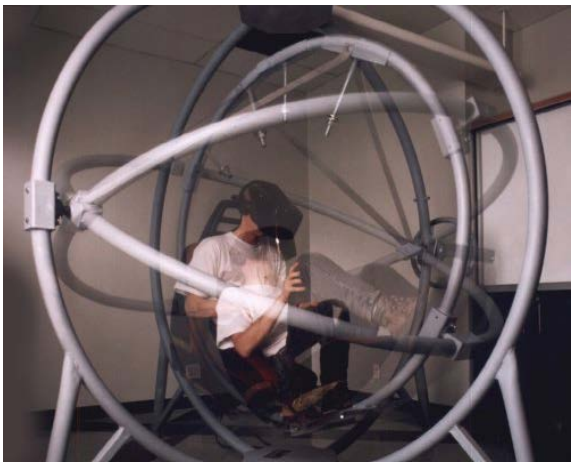
FAULTY SENSORY INPUTS (ILLUSIONS)

14.1 Introduction



Orientation or equilibrium involves an individual's accurate perception of their position, attitude and motion relative to the earth.

In the human body all the senses, with the possible exception of taste and smell, contribute to our perception of orientation. The sensory inputs that provide orientation all act simultaneously. Orientation is achieved through a continuous “loop” of sensation and feedback. The sensory inputs that provide orientation and **equilibrium** are the visual (80%), vestibular (10%) and proprioceptive systems (10%).

Sensory illusion is a false perception of reality caused by the conflict of orientation information from one or more mechanisms of the equilibrium. Sensory illusions are a major cause of spatial disorientation.

14.2 Spatial Disorientation

Spatial disorientation is the inability to determine one's position, attitude and motion relative to the surface of the earth or other significant objects (i.e. trees, poles or buildings).

This disorientation manifests in physiological (physical) and psychological illusions.

14.2.1 Visual Illusions

Vision is overwhelmingly the most important bodily sense for orientation. During flight, 80% of orientation is dependent on the visual sense. When the visual system is functioning normally, the vestibular and proprioceptive systems complement the visual system providing us our optimum orientation or situational awareness. During flight, in the absence of the visual system, the vestibular and proprioceptive system can be unreliable.

Orientation by vision requires perception, recognition, and identification. In other words, a person must determine their position by understanding where other objects are in relation to themselves.

Visual illusions may occur when visual cues are reduced by clouds, night, and/or other obscurities to vision.

A pilot, operating in an environment which provides limited *visual* cues, (i.e. full or partial IMC, or at night), is subjected to a certain amount of stress. He will sometimes perceive what he wishes to perceive. This may also be termed **confirmation bias,** or **false hypothesis**. It is the tendency to accept information that confirms the perception and to ignore or discount information in conflict with it.

14.2.1.1 Environmental (aerial) perspective

Objects seen in less detail are perceived to be further away than clearly visible objects. If haze is present in the atmosphere, less detail is visible and therefore the distance may be overestimated. If two aircraft are at the same distance away from an observer but their sizes differ, the larger one that can be seen in more detail will normally be judged to be closer.

14.2.1.2 False Horizon

The false horizon illusion occurs when the aviator confuses cloud formations with the horizon or the ground. This illusion occurs when an aviator subconsciously chooses the only reference point available for orientation.

A sloping cloud deck may be difficult to perceive as anything but horizontal if it extends for any great distance in the pilot's peripheral vision.

An aviator may perceive the cloudbank below to be horizontal although it may not be horizontal to the ground, thus flying the aircraft in a banked attitude.

This condition is often insidious and goes undetected until the aviator recognizes it and transitions to the instruments and corrects appropriately.

This illusion can also occur if an aviator looks outside after having given prolonged attention to a task inside the cockpit. The confusion may result in the aviator placing the aircraft parallel to the cloudbank.

14.2.1.3 Fascination or Fixation

Fascination or fixation occurs when aircrew members ignore orientation cues and focus their attention on their object or goal.

Target fixation, commonly referred to as target hypnosis, occurs when an aircrew member ignores orientation cues and focuses their attention on their object or goal.

> **Example** An attack pilot on a gunnery range becomes so intent on hitting the target, he forgets to fly the aircraft, resulting in the aircraft striking the ground, the target, or the shrapnel created by hitting the target.

Fascination may occur during the accomplishment of simple tasks within the cockpit. Crewmembers may become so engrossed with a problem or task that they fail to properly scan outside the aircraft.

Other types of fascination are associated with wheels-up landings, rigid fixation on the lead aircraft during formation flight, and over concentration on one instrument during instrument flight.

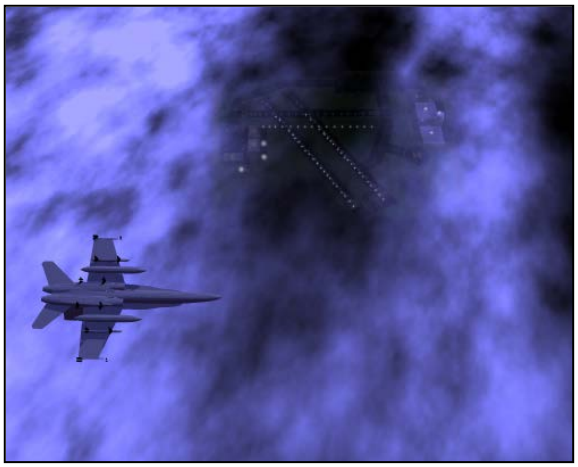
14.2.1.4 Flicker Vertigo

Flicker vertigo is technically not an illusion; however, as most people are aware from personal experience, viewing a flickering light can be both distracting and annoying.

- Flicker vertigo may be created by helicopter rotors blades or airplane propellers interrupting direct sunlight at a rate of 4 to 20 cycles per second (Hz).
- Other sources include such things as anti-collision strobe lights flashing, especially while in the clouds. One should also be aware that photic stimuli at certain frequencies could produce seizures in those rare individuals who are susceptible to flicker-induced epilepsy.

Note: Vertigo is a sensation of spinning or dizziness. Aircrew members often misuse the term vertigo as a generic term to represent all forms of spatial disorientation that they may experience.

14.2.1.5 Ground Lights

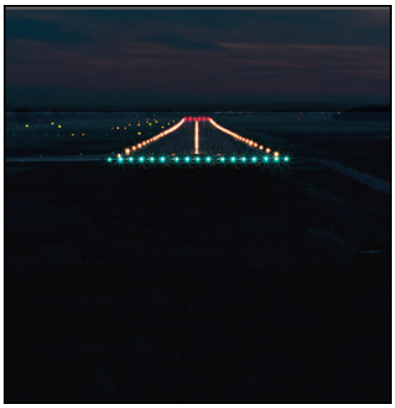


Confusion with ground lights occurs when an aviator, mistakes ground lights for stars. This illusion prompts the aviator to place the aircraft in an unusual attitude to keep the misperceived ground lights above them.

Isolated ground lights can appear as stars and this could lead to the illusion that the aircraft is in a nose high or one wing low attitude.

When no stars are visible due to overcast conditions, dark areas of terrain can blend with the dark overcast to create the illusion that the unlit terrain is part of the sky. This illusion can be avoided by referencing the flight instruments and establishing of a true horizon and attitude.

Many pilots, especially in unfamiliar areas, have mistaken lights along a straight road as approach, or runway lights. There have been many cases of a pilot lining up on ‘finals’ for a highway.



Flying to a runway with very bright lights will give the impression that you are close to the runway, resulting in flying a low approach.

Less Distance!

Flying to a runway with dim lights, for example when atmospheric conditions are poor (hazy of fog), will give the impression that you are far from the runway, resulting in flying a high approach with the associated risk of landing deep. This is not good if the runway is short.

Judging the flare will also be affected by ground lights, bright light will make the pilot under estimate his height, causing him to flare too early and dim lights will cause him to over estimate his height, causing him to flare too late or not at all.

14.2.1.6 Relative Motion

Relative motion is the falsely perceived self-motion in relation to the motion of another object.

> **Example:** You are sitting in a car stopped at a traffic light and unconsciously reduce your scan outside the vehicle. Your peripheral (ambient) vision detects the motion of another car pulling up alongside your car. You perceive the forward motion of the car beside you as the rearward motion of your own vehicle. Alarmed, you slam on the brakes.

The relative motion illusion can also occur during formation flight. The forward, aft, up, or down movement of a lead or trailing aircraft may be misinterpreted as movement of your own aircraft in the opposite direction.

The relative motion illusion can also occur to helicopter pilots hovering over water or tall grass. The rotor wash creates a continual waving motion, which makes it difficult to maintain a stationary hover point.

Example: Flying an approach through driving rain will give the illusion of excessive speed. This might cause the pilot to reduce his speed to below safe limits.

While taxing in fog the sensation might be that the aircraft is speeding, this sensation can so strong that the crew might slow the aircraft to a standstill while believing they are still moving.

Taxing into the parking bay while an adjacent aircraft is being pushed back can give the impression that your aircraft has accelerated. This can result in instinctive braking.

14.2.1.7 Altered Planes of Reference

Inaccurate sense of altitude, attitude, or flight path position in relation to an object very great in size so that the object becomes the new plane of reference rather than the correct plane of reference; the horizon.

A pilot approaching a line of mountains may feel the need to climb although his/her altitude is adequate. This is because the horizon, which helps the pilot maintain orientation, is subconsciously moved to the top of the ridgeline. Without an adequate horizon, the brain attempts to fix a new horizon.

Conversely, an aircraft entering a valley, which contains a slowly increasing up-slope condition, may become trapped because the slope may quickly increase and exceed the aircraft's ability to climb above the hill, causing the aircraft to crash into the surrounding hills.

When flying next to large cloud formations, the eyes may interpret the cloud formations as a horizon. The tendency would be to tilt away from the clouds.

14.2.1.8 Structural Illusions

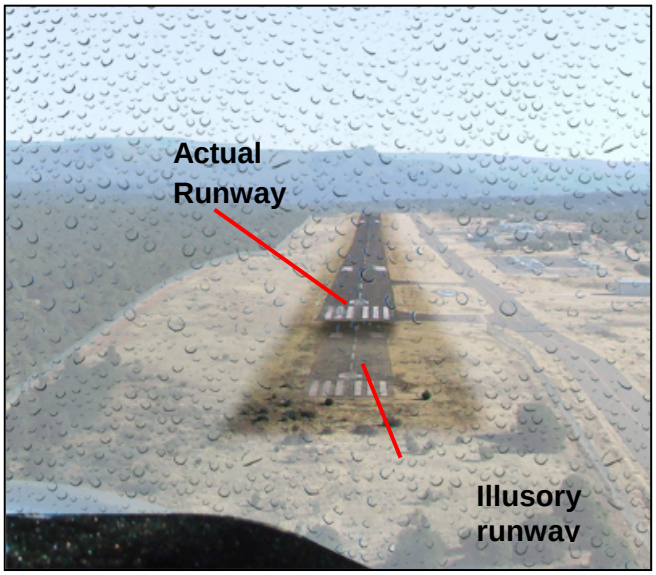
Structural illusions are caused by heat waves, rain, snow, sleet or other visual obscurants.

A straight line may appear curved when viewed through heat waves.

With water on the windscreen the pilot will have the impression that the runway moved lower and closer to the aircraft.

Without water the image through the windscreen appear at the correct position. There is only minor refraction of light.

With water on the windscreen the refraction is much more and the runway appears to move lower and further away to the aircraft.



14.2.1.9 Height-Depth Perception Illusion

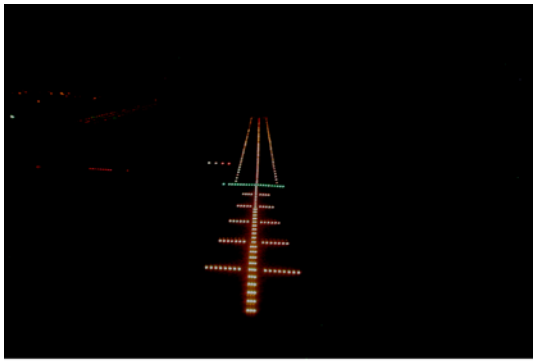
Due to a lack of sufficient visual cues, the aircrew member will experience the illusion that they are higher above the terrain than they actually are.

Flying over an area devoid of visual references, such as desert, snow, or water will deprive the pilot of his perception of height.

Flight in an area where visibility is restricted by fog, smoke, or haze produces the same illusion.

14.2.1.10 Black Hole Illusion

An approach at night, with cloud obscuring the stars and the horizon, over water or featureless terrain into a brightly-lit runway creates the illusion that the aircraft is high. This may result in a low approach and an undershoot situation where the aircraft impacts the ground or water well short of the runway.



14.2.1.11 The Size-Distance Illusion

A false perception of distance from an object or the ground, created when a pilot misinterprets an unfamiliar object's size to be the same as an object he/she is normally accustomed to viewing.

An aircraft hovering close by with its dim position lights on may appear to be farther away than when viewed at the same distance with its lights on bright.

This illusion also occurs if the visual cues, such as trees, are of a different size than expected; e.g. small trees in a particular geographical area have the same shape and contrast as the tall trees in another area. The pilot may fly his aircraft dangerously low, thinking that he is further away from the ground.

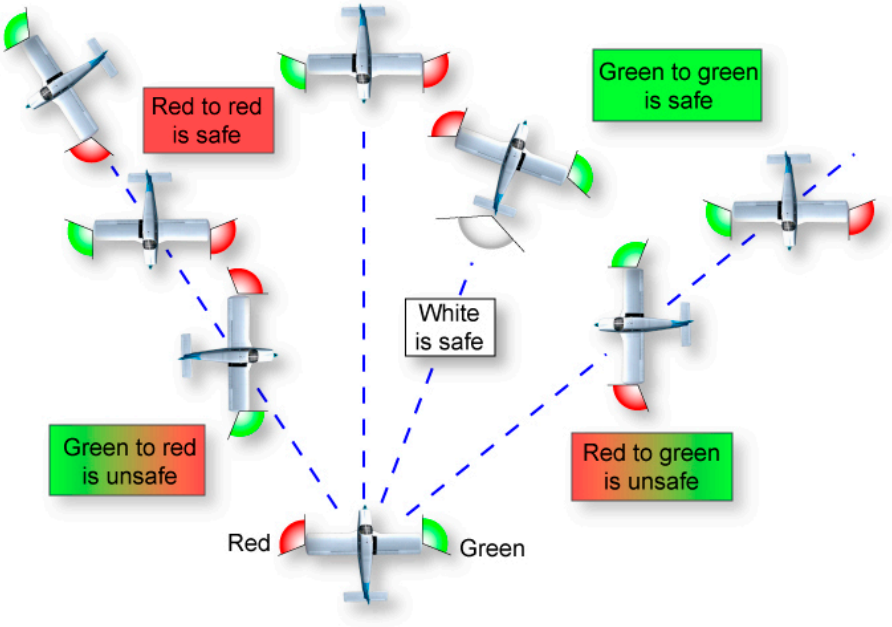
14.2.2 Autokinesis

The autokinetic illusion results when a static light appears to move when it is stared at for several seconds. Uncontrolled eye movement may possibly cause the illusion of movement as the eye attempts to find some other visual reference points.

The cure is to maintain a normal varying scan pattern.

14.2.2.1 Reversible Perspective

At night, an aircraft may appear to be going away when it is actually approaching. This illusion is often experienced when an aircrew member observes an aircraft flying a parallel course. To determine the direction of flight, the aircrew member should observe the position of the aircraft lights (red, right, return).



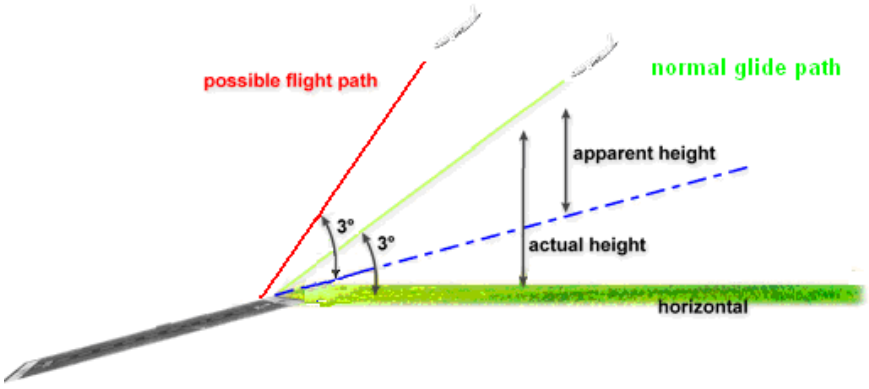
14.3 Landing Illusions

14.3.1 Runway slope illusion

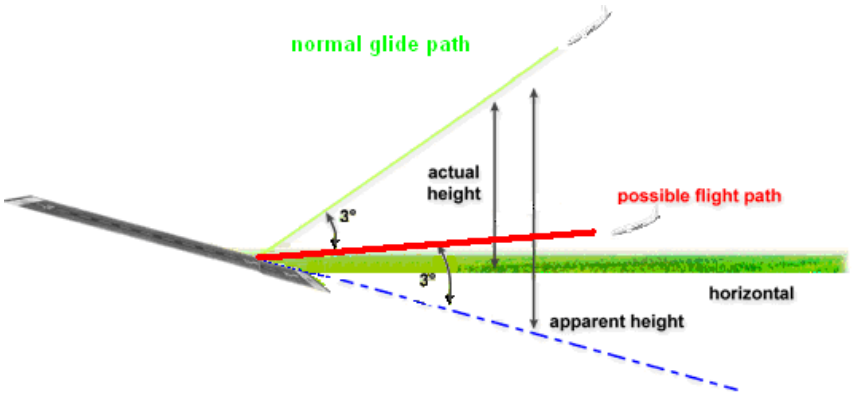
In early training we are conditioned to store a mental model of the shape of a flat runway as it appears on a normal 3° approach path. However, if we select this model for a sloping runway we have an illusion producing inappropriate actions.

When approaching a sloped runway, the tendency is to position the aeroplane so the runway appears as it would for a normal, flat runway. On a runway that slopes uphill, this produces a dangerously low approach. For a downhill runway it produces a high approach with the possibility of overshooting the runway.

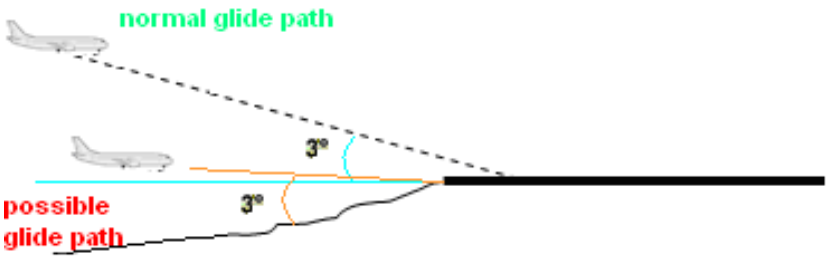
- **Runway sloping down**



- **Runway sloping up**



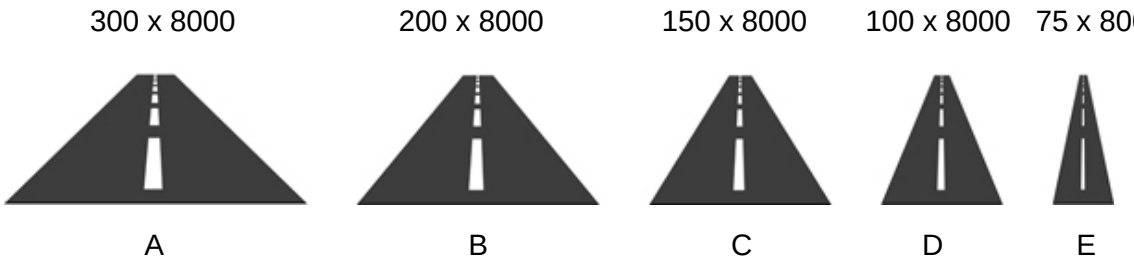
- **Terrain sloping down from the threshold**



Runway width produces a stored mental model related to the angle between our eyes and the edges of the runway during the flare. If we use a runway of different width (e.g. after operating at Parafield, the first time we land at Adelaide or Mildura), this can induce an illusion of being too low over the threshold, with a resulting high flare and a consequent 'heavy' landing. The converse will happen with a narrower than usual runway.

14.3.2 Runway width illusion

A pilot may falsely perceive an unfamiliar landing zone to be the same size as to which he is used to landing. E.g. a pilot who is used to landing at an airfield with a large runway 200 feet wide and 5 000 feet long, may fly too low if making the same approach to a small airstrip of 100 feet wide, 2 000 feet long.



Schematic outlines of the projected images of five different runways of the same length but different widths, seen from the same approach point.

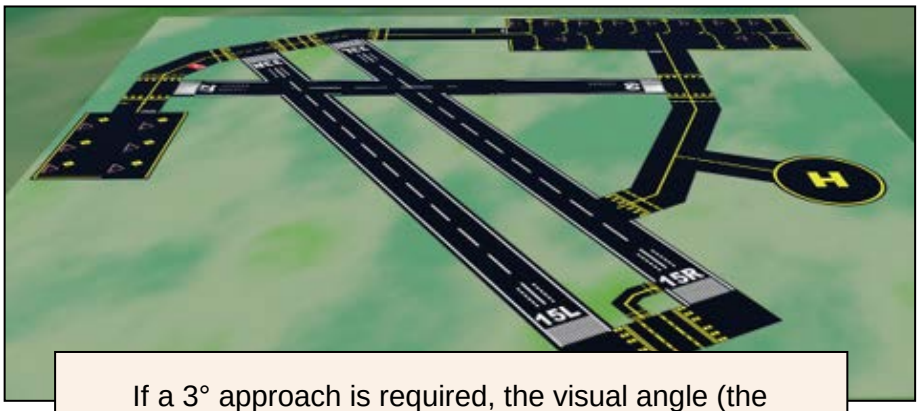
(Adapted from H.W. Jertens and M.F. Lewis (1982). Aviation Space and Environmental Medicine, 53, 464.)

14.4 Illusions during landing

Probably the most critical task that the pilot has to execute is the judgement required during the approach and landing phase of a flight.

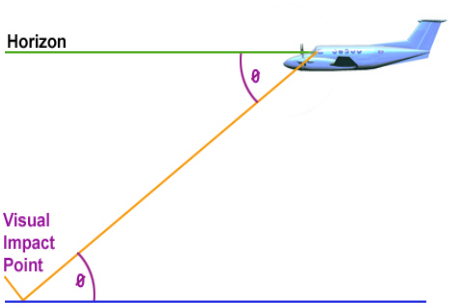
These tasks may be divided into three phases:

Phase 1: The initial judgement of an appropriate (e.g. 3°) glide slope



If a 3° approach is required, the visual angle (the angle between the horizon and the touchdown-point that is aimed for) must remain constant at 3° below the horizon.

Initial judgement of an appropriate glide slope may be facilitated by aids such as VASIS and PAPIS or by positioning the aircraft at predetermined heights above known ground features (especially when doing circuit flying), but sometimes judgements without such aids must be made.

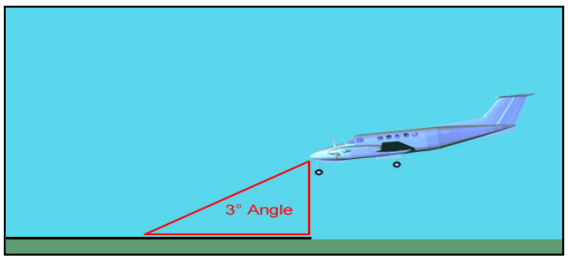


However, it is often true that the pilot making this judgement is prevented from seeing the horizon due to poor visibility or bad light (including night time). He/she may thus estimate the aircraft's position in such circumstances in a number of ways; e.g. by judging the angle by "extending the runway sides to the horizon" and by looking at texture gradients in the surrounding terrain.

These cues are accurate only if the terrain and runway are level. Runways on sloping terrain may produce incorrect estimates of horizon location, which in turn may result in an inaccurate approach slope judgement.

Phase 2: The maintenance of the glide slope during the approach

During visual glide slope maintenance, the pilot is required to aim for the visual impact point and to prevent the approach angle from varying.



He/she will know that the progress to the projected touchdown-point is correct, if all the textures "flow away" from that point. (As the aircraft gets closer to the ground, the size of everything increases.)

Phase 3: The ground proximity judgements before touchdown

In the final phase, the pilot may well be required to make height adjustments to ensure that the aircraft does not undershoot. It is important to bear in mind that with larger aircraft the undercarriage will touch down a considerable distance before the visual touchdown-point, if the approach is continued without any check or flare.

Cues such as:

- The texture of the ground and the speed at which the ground passes by can be used (increasing speed is produced by proximity); or in their absence (such as an approach at night or over water)
- Then the apparent size or width of the runway (as discussed earlier) can be used, bearing in mind the pitfalls that it may have.

14.5 Summary of illusions during approaches

The pilot will think he is high in the following situations:

Condition	Illusion	Flight deviation
The runway slope up from the threshold	Runway profile appears incorrect	Low approach
The terrain slopes up to the threshold	Perceived height to high	Low approach
The runway is narrower or longer than usual		Low approach
The approach is over featureless terrain or water	Perceived height to high	Low approach
The approach is black	Runway appears close	Low approach
The air is abnormally clear	Runway looks close	Low approach
The runway and approach lights are brighter	Runway looks close	Low approach, undershoot
There is heavy rain on the windscreen	Runway looks lower and closer	Low approach

The pilot will think he is low in the following situations:

Condition	Illusion	Flight deviation
The runway slopes down from the threshold	Runway profile appears incorrect	High approach
The terrain slopes down to the threshold	Perceived height to low	High, steep approach
The runway is shorter or wider than usual.		High approach
Runway and approach light less bright than usual	Runway looks far	High approach
Visibility is poor	Runway looks far	Delay the descent leading to a high approach