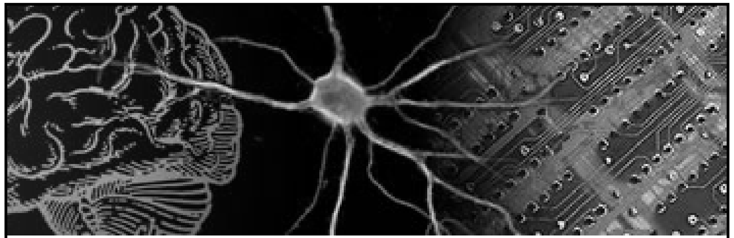


PSYC305

Applied Cognition & Neuroscience

Mātai hinengaro whaipainga

Lecture 8: Aviation and Aerospace Visual Function and Performance

Vision obviously plays an important part in aviation and aerospace (e.g., cockpit design; colour perception; depth perception; motion perception etc., etc).

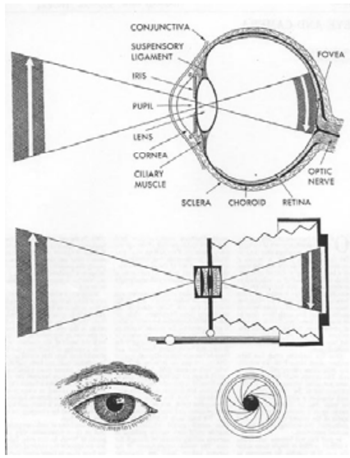
Lecture 8: Aviation and Aerospace Visual Function and Performance

© Assoc Prof. John Perrone
Psychology Dept.
The University of Waikato

Topics :

1. Eyes (Wald reading).
2. Chromatic-aberration (see Wald article)
3. Visual slant perception
4. Approach and landing errors in aviation

1. Eyes

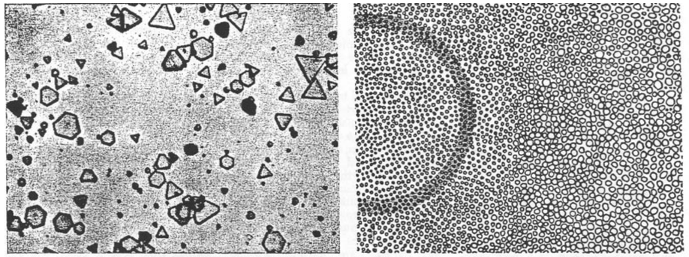


Optical similarities of eye and camera

Figure from Wald article

Eye and Camera, Ch 10. From Readings from Scientific American: Perception: Mechanisms and Models 1972. (W.H. Freeman and Company San Francisco).

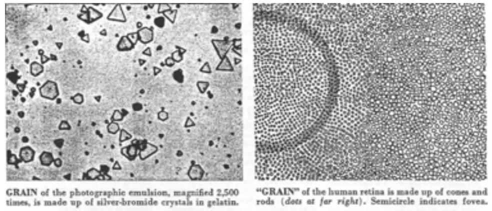
You should know all the main parts of the eye. (if not, see Goldstein textbook from PSYC226)



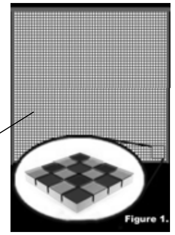
GRAIN of the photographic emulsion, magnified 2,500 times, is made up of silver-bromide crystals in gelatin.

"GRAIN" of the human retina is made up of cones and rods (*dots at far right*). Semicircle indicates fovea.

'The retina of the eye is grainy just as is photographic film'
Wald, p 96.



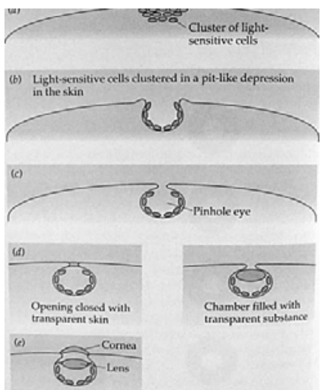
Digital cameras. Include more processing of images (like retina?)



CCD cell (Charge Coupled Display) array

There are many different ways that an 'eye' can capture light. We have evolved one particular design that uses a lens.

Light



Steps in the evolution of Single-Chambered eyes with a lens

From: *Biological Psychology*
Rosenzweigm Leiman
& Breedlove.

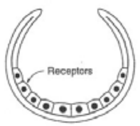


Figure 2.53
Open eye cup consisting of light-sensitive receptors in an open cup.

Figure from Goldstein

Alternative eye designs

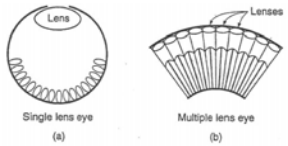
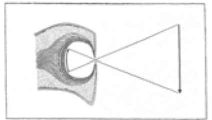


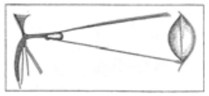
Figure 2.54
(a) Single lens eyes, such as the human's, focus light onto a concave sheet of receptors. (b) Multiple lens eyes, like the compound eyes of insects, focus light onto receptors arranged on a convex surface. Each of the lenses of the compound eye sits atop a structure called an ommatidium, *which contains a visual receptor.*

Figure from Goldstein reading



Pinhole-camera eye
In Nautilus (related to octopus and the squid)

Compound eye
Found in insects. This is a double Compound eye. Top part provides detailed vision. Piece on right provides course, wide-angled vision



Scanning eye
In arthropod *Copilia.* Has lens but only one receptor which moves!

Figures from Wald reading

Alternative eye designs (continued)

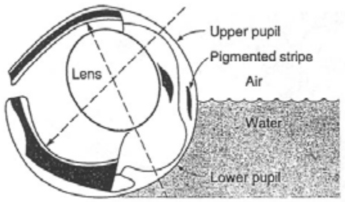


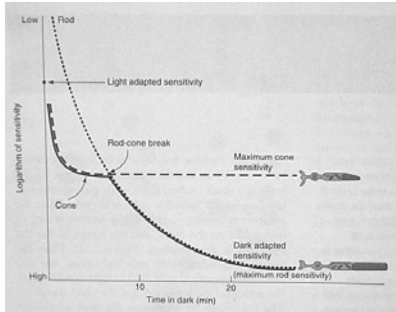
Figure 2.56
Eye of the Anableps. *Light from the water passes through the lower pupil and is focused by the powerful elliptical axis of the lens. Light from the air passes through the upper pupil and is focused by the less-powerful flattened axis of the lens (Sivak, 1976).*

Figure from Goldstein reading

Alternative eye designs (continued)

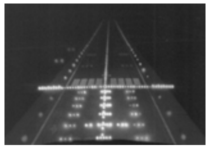
See also 'Bright and dim Light' section in Wald article (p. 96)

How humans deal with Bright and dim light



From PSYC226
Goldstein textbook Fig. 2.22

Dark adaptation refers to the increase in the eye's sensitivity that occurs when illumination changes from light to darkness.



How does dark adaptation affect the pilot's view of the world?

Alternative eye designs (continued)

Figures from Wald reading

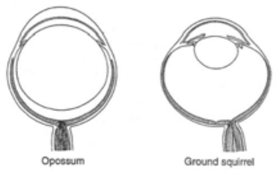
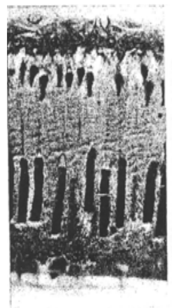


Figure 2.55
Eyes of the nocturnal opossum and the diurnal ground squirrel.

Figure from Goldstein reading



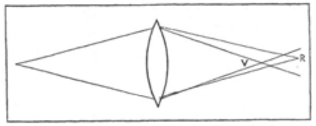
Cones of the ________ are pulled towards the surface of the retina (top) in bright light. Rods remain in layer below the surface.

Rods advance and cones retreat in dim light. This retinal feature is not possessed by mammals.

2. Chromatic aberration

Example of how the visual system has evolved and adapted in order to find the best solution to a problem.

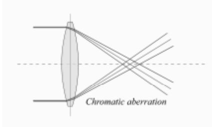
Figure from Wald reading

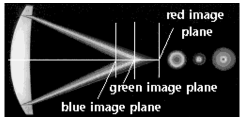


CHROMATIC ABERRATION occurs when light of various colors is refracted by a lens made of one material. The light of shorter wavelength is refracted more than that of longer wavelength, *i.e.*, violet is brought to a shorter focus than red. The image of a white point is a colored blur circle.

Problem with lenses ___________
____

Worse for violet and ultraviolet (short wavelengths) part of the spectrum
See next slide.

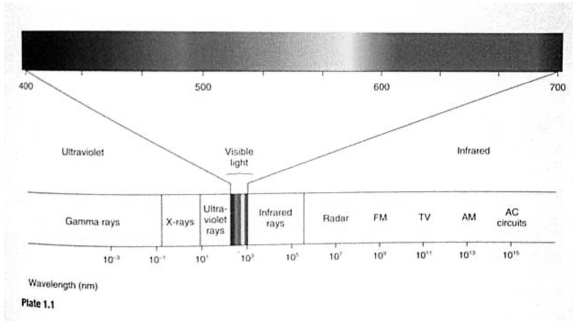




Figures
From Wikipedia
and web.

•Visible light is a form of energy called electromagnetic radiation

Review from PSYC103, 226



Reminder: Visible light is part of the electromagnetic spectrum.
Wavelength is measured in ________________

Chromatic aberration (continued)

See special glasses demo

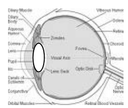
Photos from Wikipedia

Top - Corner detail from a photograph taken with a good quality lens.
Bottom - Detail from a similar photograph taken with a wide angle lens showing visible chromatic aberration (especially at the dark edges on the right).

Chromatic aberration (continued)

Three solutions:

1) Yellow lens.



'The human lens is not only a lens but a color filter.'

It sharply cuts off the far edge of the violet, in the region of wavelength 400 nm.
Wald , p. 97.

‘Persons who have lost their lenses in the operation for cateract and have had them replaced by clear glass lenses, have excellent vision in the ultraviolet.’ *Wald, p. 97.*

Visible light

UV light

http://www.naturfotograf.com/UV_RUDB_HIR.html#top

‘I have heard it said that for this reason aging artists tend to use less blue and violet in their paintings.’ *Wald, p. 97.*

Monet paintings (Japanese bridge)
Left = 1899, right = 1924.
Monet had cataracts and yellowing of lenses in his eyes.

From: MaxPlank Research 2002.

Chromatic aberration (continued)

Three solutions:

1) Yellow lens.

2) Daylight vision = cones which are more sensitive to red end of spectrum.

(see Spectral sensitivity curves, Fig. 2.25 Goldstein next slide).

Review from PSYC226

Spectral Sensitivity: The receptor’s sensitivity to light at each wavelength across the visible spectrum.

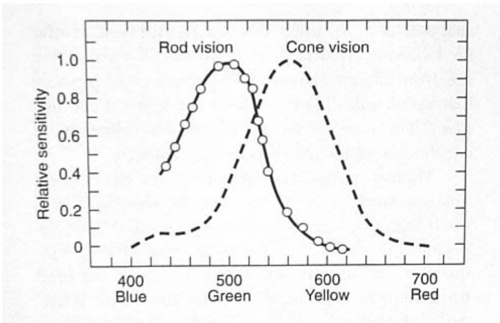


Fig. 2.25 Goldstein textbook

Spectral sensitivity curves are different for rods and cones.

Chromatic aberration (continued)

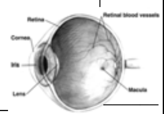
Three solutions:

1) Yellow lens.

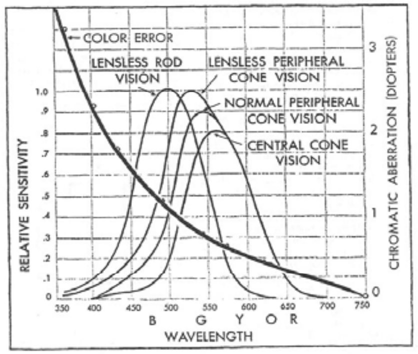
2) Daylight vision = cones which are more sensitive to red end of spectrum.

(see Spectral sensitivity curves, Fig. 2.25 Goldstein next slide).

3) Yellow pigmentation around fovea (___________)



Chromatic aberration (continued)



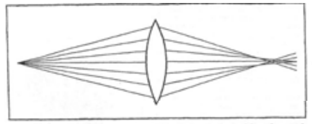
CHROMATIC ABERRATION of the human eye is corrected by various stratagems which withdraw the cones from the region of maximum aberration, *i.e.*, the shorter wavelengths. The horizontal coordinate of this diagram is wavelength in millimicrons; the colors are indicated by initial letters.

Summary of previous slides
From Wald reading.

It would be hard to explain some properties of the eye if you did not know about chromatic aberration.

Other sources of imperfection in retinal image:

•Spherical aberration
(Well corrected in
human eye. See Wald article)



SPHERICAL ABERRATION occurs when light is refracted by a lens with spherical surfaces. The light which passes through the edge of the lens is brought to a shorter focus than that which passes through the center. The result of this is that the image of a point is not a point but a "blur circle."

•Random variation in lens power across pupil
- The rays from two separate points entering pupil may end up focussed on different planes.

•Light Scatter
- The media in the eye contain tiny particles that scatter light.

•Diffraction
-Light paths diverge as they pass through an aperture.
- The pupil is an aperture and causes diffraction.

3. Visual Slant perception

Visual slant perception

⇩

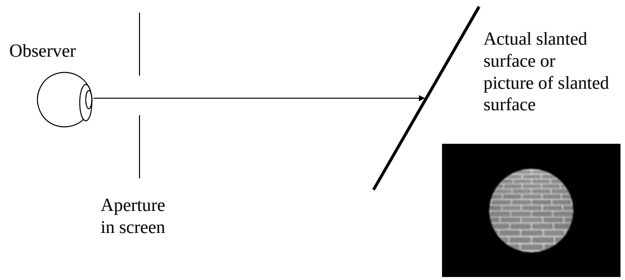
Approach and landing errors in aviation

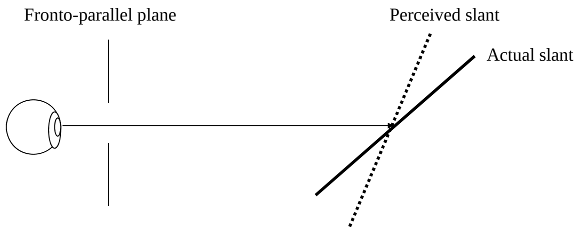
An example of applying 'pure research' to an applied topic.

This also relates to Laboratory Report # 2

Visual slant perception experiments

Gibson, J. J. (1950).
The Perception of Visual Surfaces. *Am. J. of Psych., 63*, 367-384.





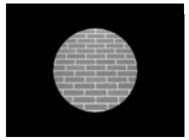
Visual slant underestimation: Surfaces are seen as being ____________________(fronto-parallel plane) compared to their actual physical slant.

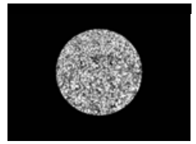
Gibson (1950) data
with 'brick' pattern

Actual slant	Judged slant
10°	-0.8°
22°	8.6°
30°	18.9°
45°	25.3°

Gibson (1950) data
with 'texture' pattern

Actual slant	Judged slant
10°	6.4°
22°	7.8°
30°	9.9°
45°	23.9°


30°


40°

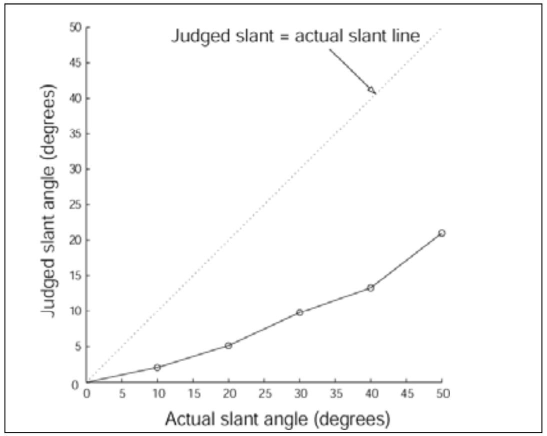
Smith, A. H. (1956). Gradients of Outline Convergence and Distortion as Stimuli for Slant. *Canad. J. Psychol., 10*(4), 211-218.

Smith (1956) data
with slanted rectangles

Actual slant	Judged slant
10°	2.1°
20°	5.1°
30°	9.8°
40°	13.3°
50°	21.0°

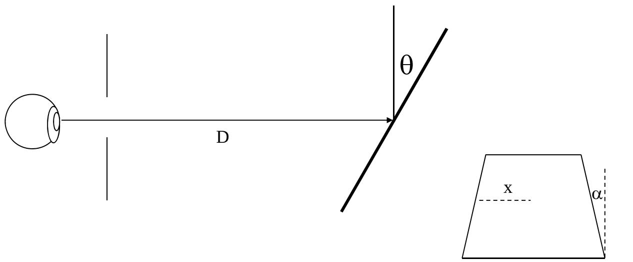

30°

Typical slant perception data showing slant underestimation



This was a problem for Gibson's theory of surface perception

Actual slant angle can be estimated from angles and distances in the 2-dimensional image.

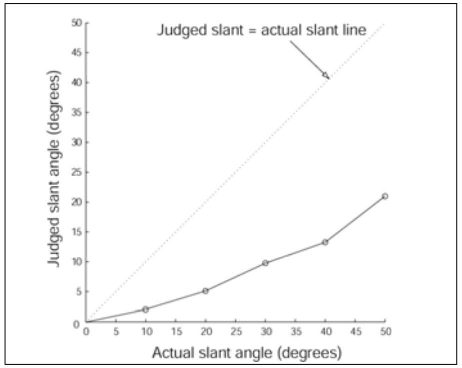


$$\theta = \arctan\left(\frac{\tan\alpha}{\tan\phi}\right)$$

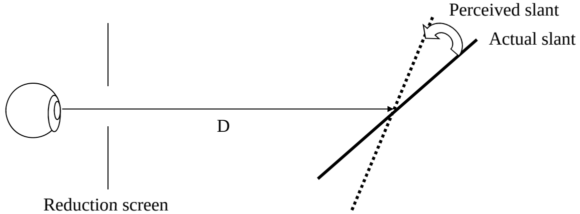
You don't need to know these equations

$$\phi = a\tan\frac{x}{D}$$

So why do humans make such large errors?

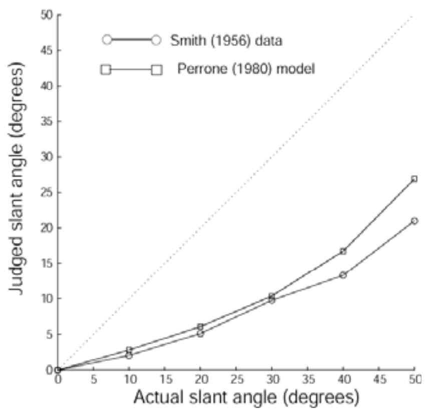


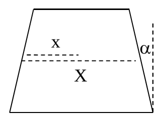
Early theories on why slant is underestimated suggested that the slant misperception was caused by the reduction screen used in the experiments. Judged slant was displaced towards the direction of the screen.



These theories do not explain how slant underestimation occurs when there is no reduction screen (see slope illusion in later slides) and they cannot explain why the amount of underestimation varies under different conditions (e.g. texture surfaces versus rectangles).

Perrone, J. A. (1980). Slant Underestimation: A Model Based on the Size of the Viewing Aperture. *Perception*, *9*, 285-302.





Slant errors caused by incorrect use of 2-D information?

Errors seem to be related to distance misperception.

Effect of distance of rectangle upon convergence angle of sides:

D = 500 cm

D = 400 cm

D = 300 cm

D = 200 cm

D = 100 cm

The convergence angle gets larger as the rectangle gets closer.

Slant angle = 60^{o} in all cases

Effect of distance of rectangle upon convergence angle of sides:

D = 500 cm

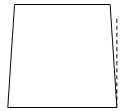
D = 400 cm

D = 300 cm

D = 200 cm

D = 100 cm

The convergence angle gets larger as the rectangle gets closer.



D = 100
(not 500)

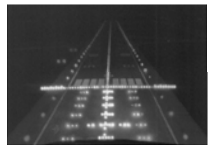
Possible reason for underestimation:

Rectangle seen to be closer than real distance. Small convergence angle = small slant

Summary of slant perception results:

- Surface slant is underestimated in many situations.
- Underestimation seems to be caused by misperception of the distance (or width) of the slanted rectangle.
- Specific cause of slant misperception is currently unknown although a number of models exist which can predict the amount of underestimation.

4. Approach and landing errors in aviation



http://www.burningserver.net/rosinski/Steamboat/pa050111.640x480.jpg

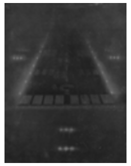
http://www.infratil.com/images/dynamic/kia_runway_approach.jpg

http://myweb.tiscali.co.uk/vanbergen/final_22.jpg

A successful landing requires that the pilot follows the correct approach path (usually a 3 degree glide slope) and that they touchdown at the correct point on the runway.

Under some conditions pilots make landing errors and land ‘short’ or ‘long’ (undershoot or overshoot) the runway. They also sometimes land too ‘hard’.

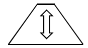
The most common situation for landing errors is under ‘black-hole’ conditions (night time, fog, approaches over the sea) when only the runway lights are visible.

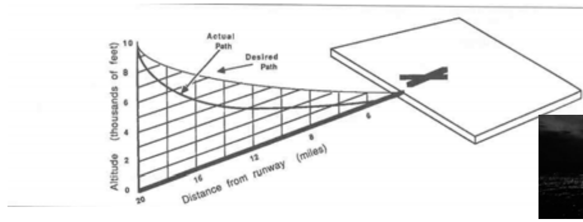


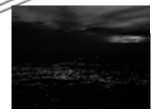
Explanation for errors: 1. Conrad Kraft

Kraft, C. L. (1978). A Psychophysical Contribution to Air Safety: Simulator Studies of Visual Illusions in Night Visual Approaches. In H. L. Pick (Ed.), *Psycology: From research to practice.* (pp. 363-385). New York: Plenum Press.

Pilot keeps ______________________________as they descend.







Comparision of the approach path flown by pilots during a night visual approach with the desired altitudes. Altitude is in the thousands of feet; distance from the runway is in miles. (After Kraft, 197.) Illustration reproduced from Human Factors in Aviation by Earl Wiener and David Nagel, Academic Press Inc., 1988.

Explanation for errors: 2. Runway slope and shape effects

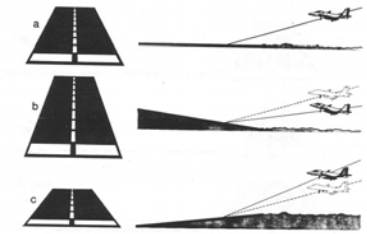


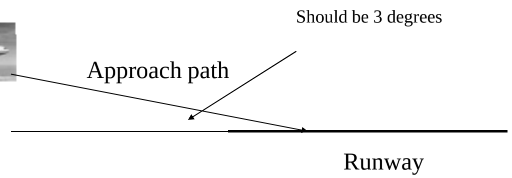
Figure 14. Effect of runway slope on pilot's image of runway during final approach (left) and potential effect on approach slope angle flown (right). a. Flat runway--normal approach. b. Upsloping runway creates illusion of being high on approach--pilot flies approach too low. c. Downsloping runway has opposite effect.

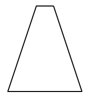
A runway that is narrower than that to which a pilot is accustomed can also create a hazardous illusion on the approach to landing. The pilot tends to perceive the narrow runway to be longer and farther away (i.e., that he is higher) than is

From: Gillingham, K.K, & Wolfe, J.W. (1986). Spatial orintation in flight. USAF School of Aerospace Medicine report. USAFSAM-TR-85-31.

Explanation for errors: 3. Slant underestimation

The visual approach part of landing seen as a slant estimation problem



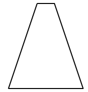


Too High?
Too Low?

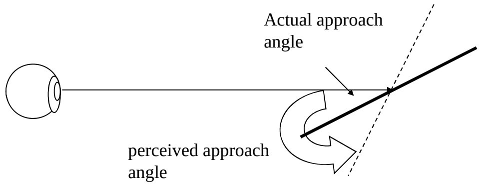
NASA Ames conducts the fundamental research and technology development that make NASA missions possible and support the Vision for Space Exploration. NASA Ames' research activities range from aeronautics to space sciences, from Earth science to astrobiology and the cutting–edge fusion of information technology, biotechnology and nanotechnology.

Man-Vehicle Systems Research Division
Human Systems Integration Division

Reduced cue landing situations
(night landings or 'black-hole' landings

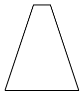


Pilot just sees the runway outline

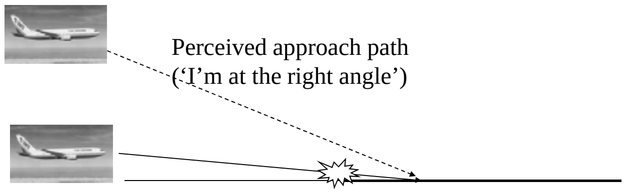


Perrone theory:
Slant misperception causes approach angle to appear larger than it really is.
When on the correct approach (3 deg) it feels too high.
Therefore the pilot flies lower than they then normally would.

Reduced cue landing situations
(night landings or 'black-hole' landings



Pilot just sees the runway outline



Actual approach angle
Results in landing short

Runway

Using a slant underestimation model to predict landing approach errors:

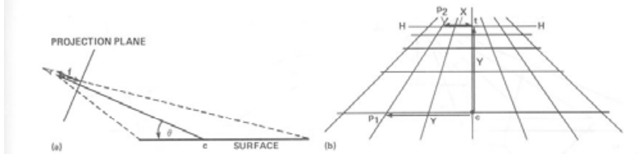
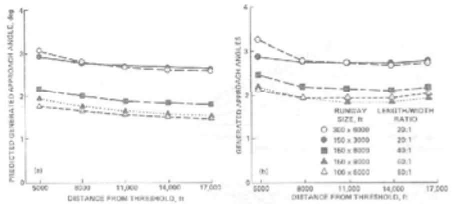
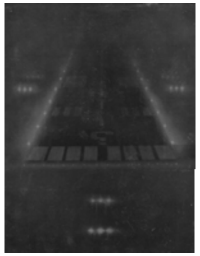


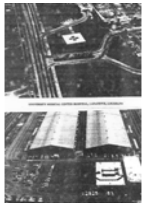
Fig. 1. An example of two-dimensional information on a projection plane. (a) The two-dimensional information reaching the eye is analysed on a theoretical projection plane an arbitrary distance f from the eye. (b) The slant angle may be extracted from this information using Eq. 1. All measurements are made within the plane of the page.

Fig. 6. Generated approach angle as a function of distance from threshold and runway dimensions. (a) Theoretical predictions. (b) Actual data values obtained by Mertens and Lewis (12).



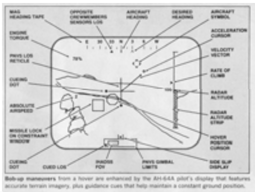
From: Perrone, J. A. (1984). Visual slant misperception and the "black-hole" landing situation. *Aviation, Space, and Evironmental medicine., 55,* 1020-1025.

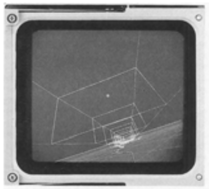


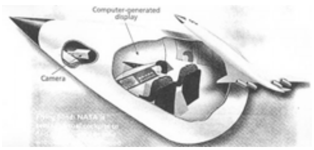


Even though research has been done on the problem and new systems are used to ‘automate’ the landing process, landing approach accidents continue to happen.

New technologies can help the pilot during the landing phase but they sometimes introduce a new set of perceptual problems.







Research on vision, perception, cognition	⟺	Applied problem

We have only discussed one phase of the landing process (i.e., 'static' slant estimation when the pilot is some distance from the runway). As they get closer, motion becomes important and the pilot must use motion information to help them touch down at the correct point on the runway.

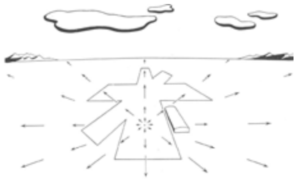
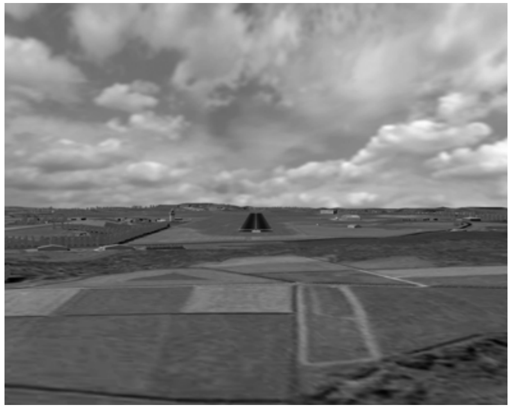


FIGURE 5E. Gradients of Deformation during a Landing Glide

From Gibson's book:
Perception of the visual world (1950)

Tyre marks on the runway showing a range of touchdown points.



Example of a movie sequence used by Natalie Reynolds in her Master's Thesis : An investigation into landing approach visual Illusions.

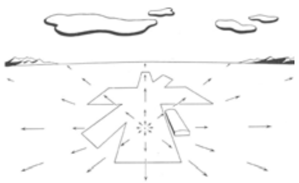


FIGURE 5E. Gradients of Deformation during a Landing Glide

See lecture my Lect 4 material on visual navigation and motion cues