Visual Acuity

Adler's Physiology of the Eye 11th Ed.
Chapter 33 - by Dennis Levi

http://www.mcgill.ca/mvr/resident/

Visual Acuity

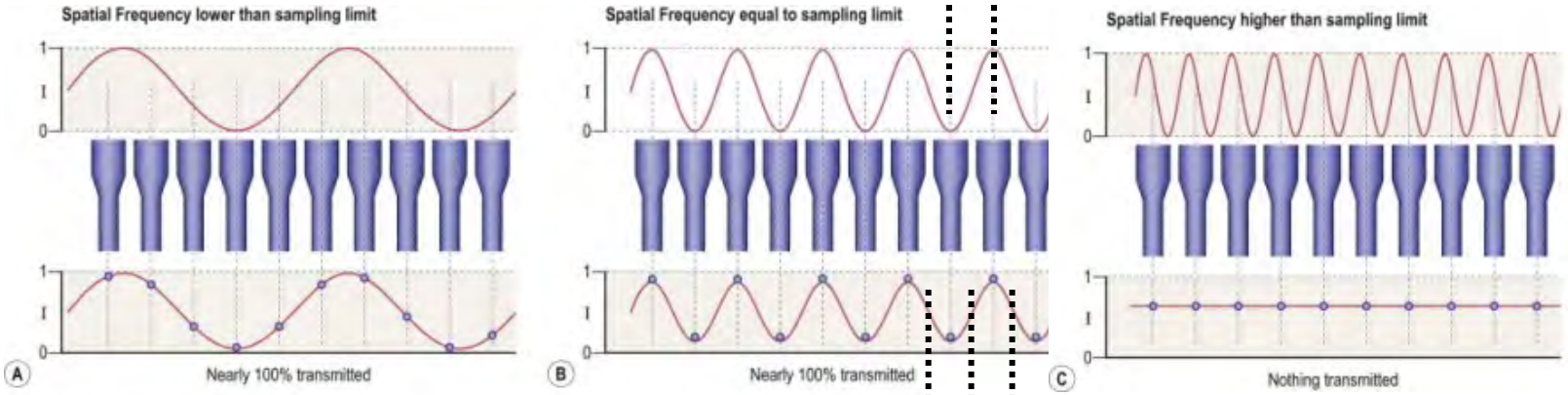
- Keeness of Sight, possible to be defined in different ways

- Minimum Visual Acuity - detection of a feature, intuitive, has roots in astronomy, but not a spatial limit per se. Actually limited by contrast sensitivity, depends on background illumination, limit about **0.5 arcsec** for a wire.

Visual Acuity

- Minimum Resolvable Acuity - separation of 2 features (i.e., double stars), finest high contrast detail visible, for width of light and dark bar of a grating, limit about **1 arcmin** (0.017 deg) for fovea. Determined by photoreceptor sampling

0.5 arcmin



Nyquist Limit-
spatial period
2x the cone spacing

60 cycles per degree grating

Visual Acuity

• Minimum Recognizable Acuity - angular size of the smallest Feature that one can recognize or identify

Snellen Chart
block letters 5 times stroke size.
normal defined at 20 ft, 6 m.
20/20 = 5 arcmin letter = **1 arcmin** stroke

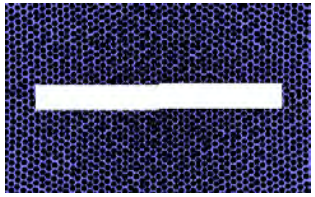
In MAR units 20/20 =1, 20/40 = 2

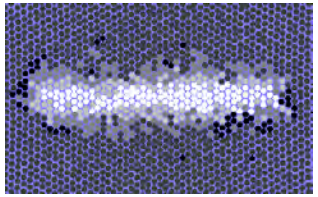
Other notations:
1/MAR, LogMAR, Log(1/MAR)

Visual Acuity

• Minimum Discriminable Acuity - angular size of the smallest *change* in a feature (e.g., position) that one can identify. Vernier acuity is termed a *hyperacutiy*, limit of **3 arcsec** (0.0008deg).

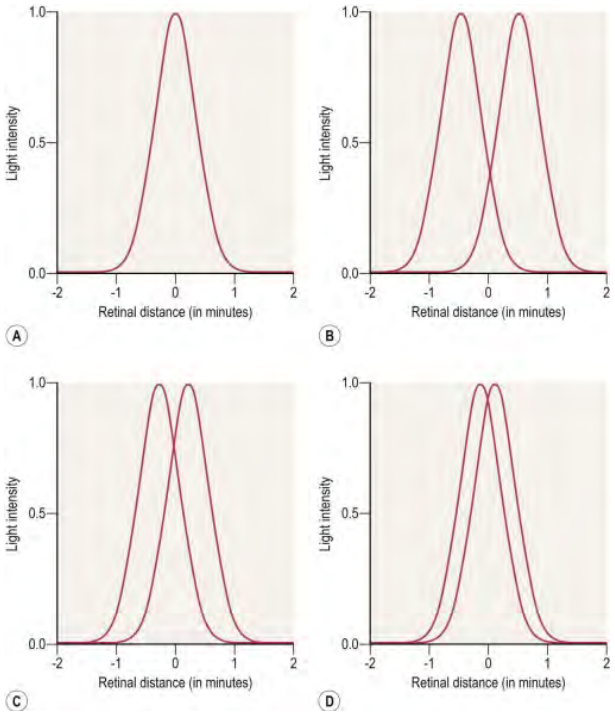
This is 10 times smaller than width of a foveal cone. Optics of eye spread out the photons, and the information to distinguish A from B is present, but it must be cortical neurons that interpolate this information with high resolution.





What Limits Visual Acuity?

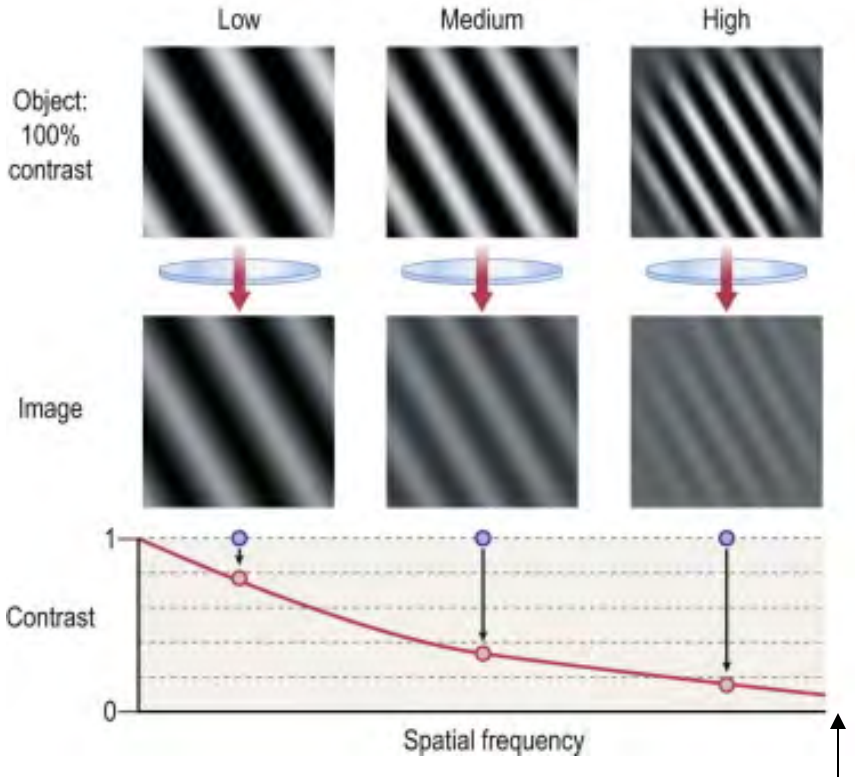
Optics of the Eye - far from perfect, spreads the retinal image, a point becomes a Gausian, called *point spread function*



Rayleigh Limit - distance between points exceeds half the spread of each point, determined by pupil size & wavelenth of light.

What Limits Visual Acuity?

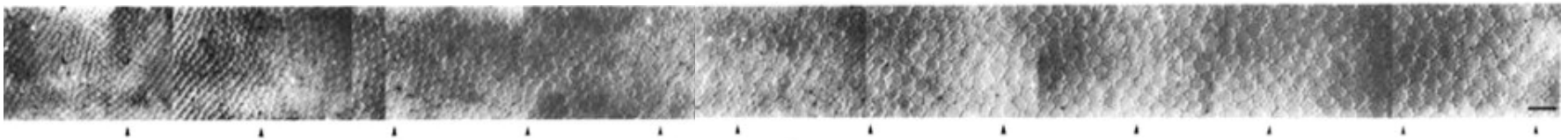
Optics of the Eye - far from perfect, sinewave gratings lose contrast, depending on SF, called *modulation transfer function*



MTF - ratio of image contrast to object contrast for a range of SF.

What Limits Visual Acuity?

Photoreceptor Spacing - photoreceptors are densely packed in a triangular array, with foveal cones spaced about **0.5 arcmin**, so Nyquist sampling limit is 1 minute = 60 cpd.



fovea

periphery

Cone to ganglion cell convergence:

Fovea: 1 cone ->1 ganglion cell

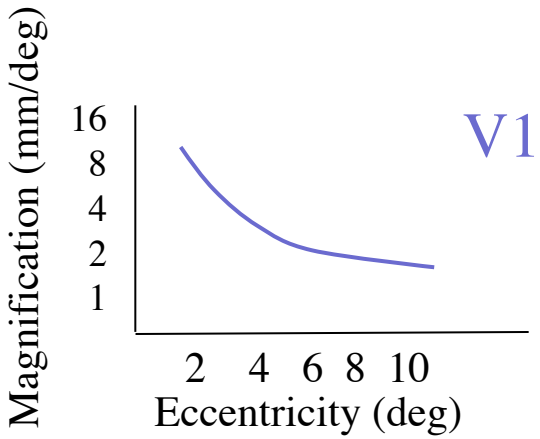
Periphery: many cones -> 1 ganglion cell

*Neurons matched to optics at fovea, but fall dramatically in periphery.

What Limits Visual Acuity?

Eccentricity and Cortical Magnification Factor - Many visual Functions decline approx. linearly with eccentricity (E_2 = eccentricity at which foveal value has doubled). Peripheral vision is also limited by the CMF, which reflects retinal anatomy, but is further enhanced in cortex.

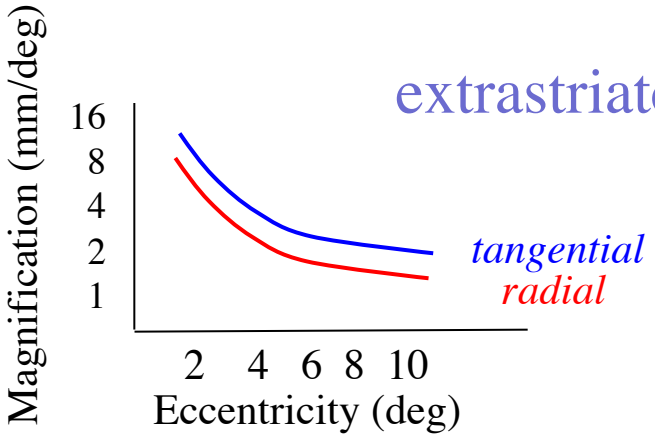
at fovea 1 deg = 20mm
at 10 deg 1 deg = 1.5mm



What Limits Visual Acuity?

Crowding - In peripheral vision, the identification of a letter, which can be easily identified in isolation, is severely impaired by neighboring letters. Spatial extent of crowing can be as much as 0.5 times the target eccentricity – significant.

In addition to theoretical interest, this has practical implications for testing vision, for reading, and for amblyopia.

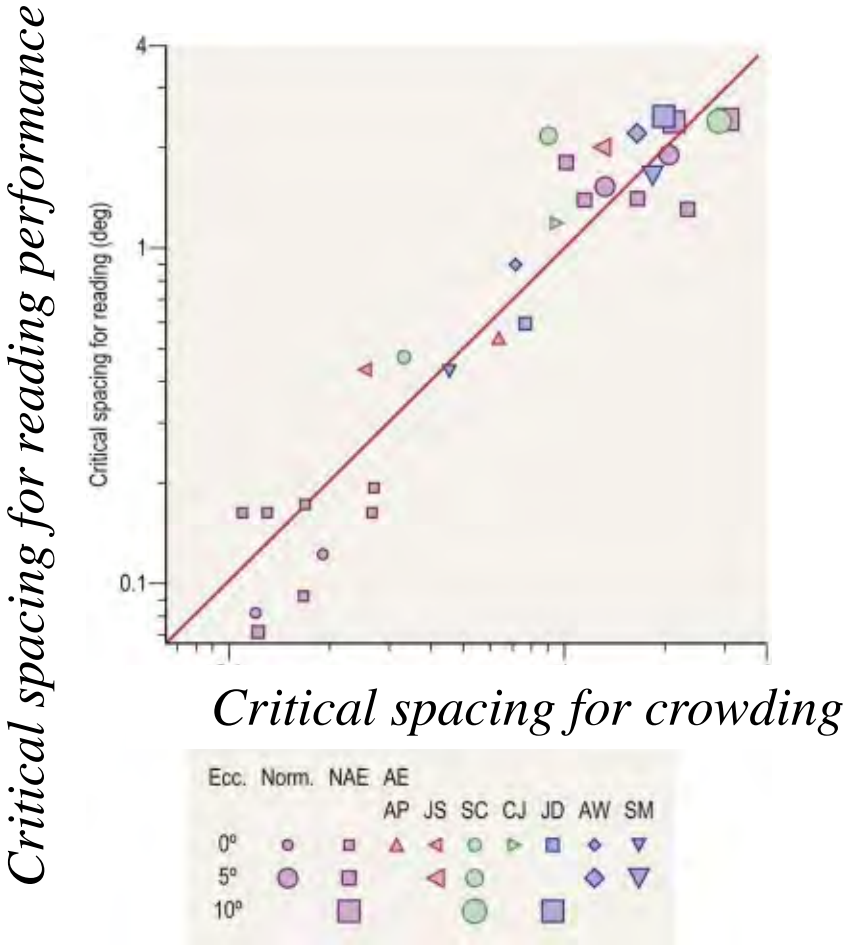


extrastriate,V4?

*radial crowding is worst

What Limits Visual Acuity?

Reading - performance highly correlated with crowding, the Letter spacing seems to be more important than letter size.

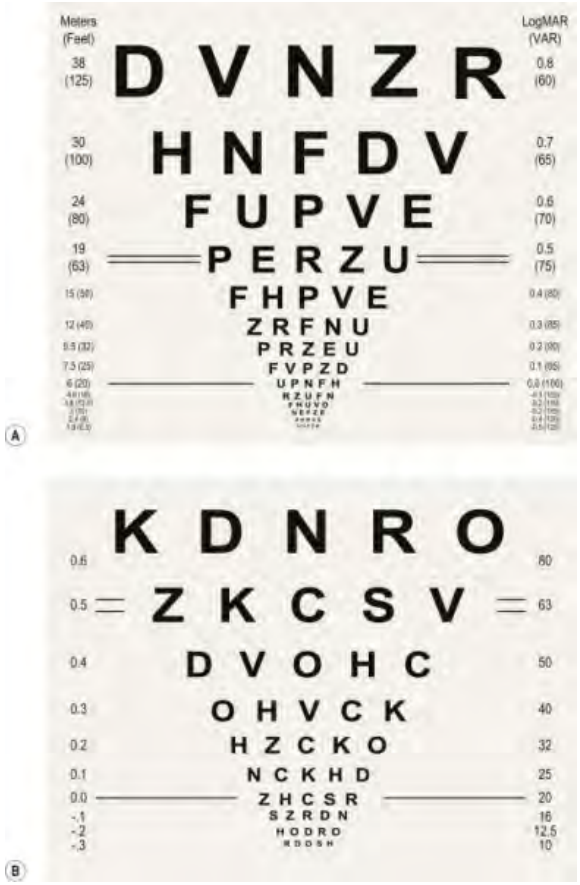


What Limits Visual Acuity?

Luminance - at moderate photopic luminance, visual acuity Remains fairly constant, however under very low luminance scotopic conditions, acuity is mediated by rods, at around 20/200

Contrast - visual acuity is strongly dependent on visual contrast, around 20/40 for 10% contrast, 20/60 for 5% contrast.

Clinical Tests of Visual Acuity



Modern Principles:

Same number of elements on each line
Constant ratio from one size to the next
Proportional spacing between letters and lines
Nearly equal legibility of optotypes

Hence, V shaped appearance

*Note however that crowding in periphery and Strabismic amblyopia follows a fixed not Proportional spacing rule

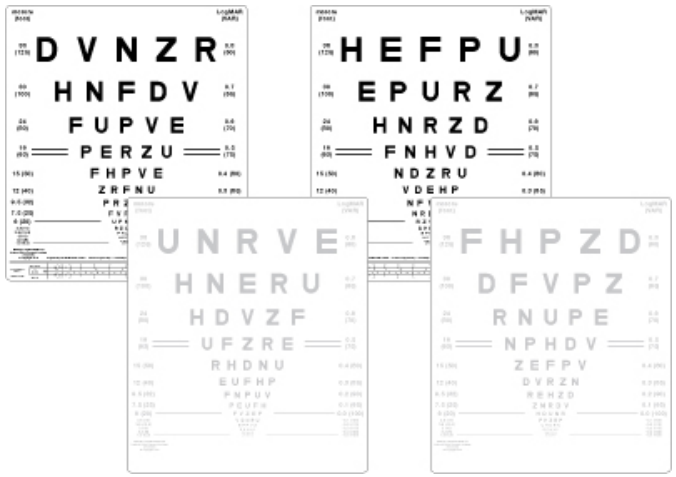
Clinical Tests of Visual Acuity

Pelli-Robson CS Chart

0.5 deg at 3m
20/120

Although not routinely measured, several clinical chart tests of contrast sensitivity are available. They will emphasize different SF depending on letter size.

Bailey-Lovie Chart

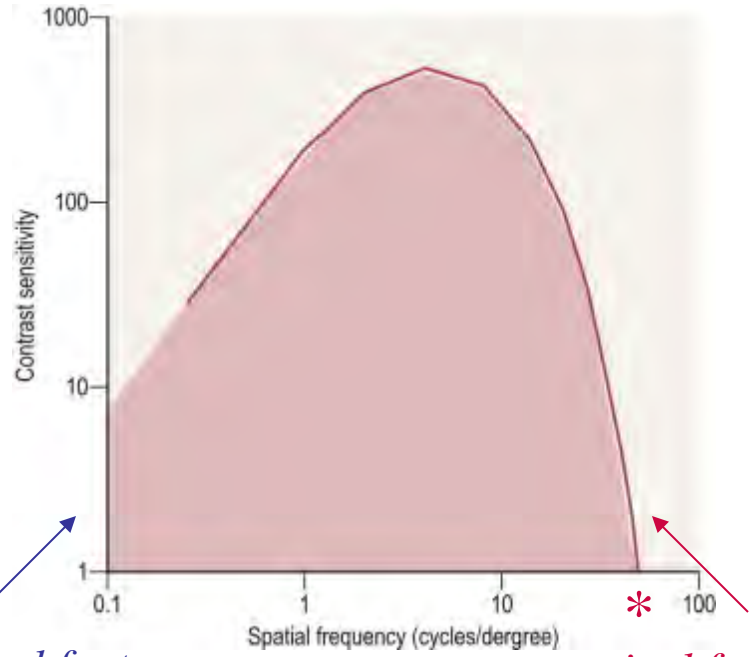


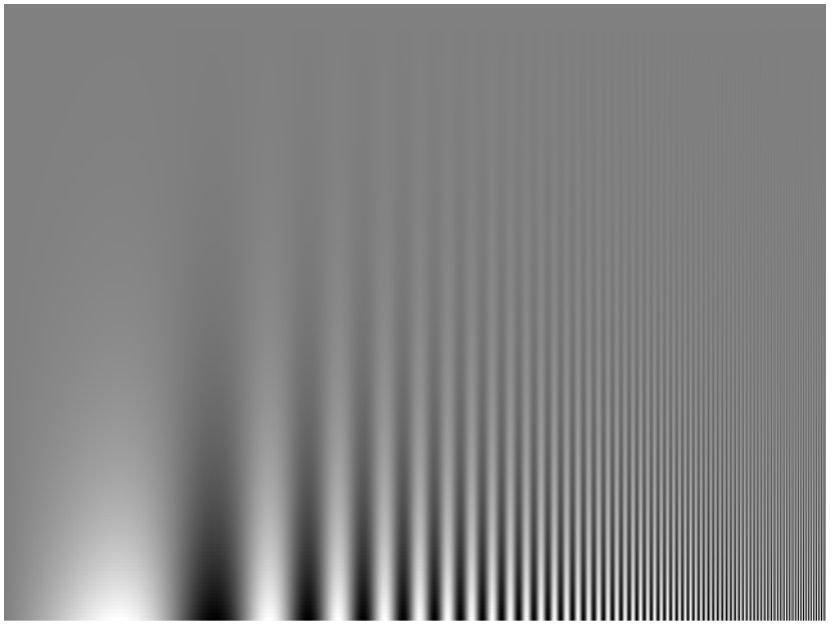
Vision at Low Contrast

How can we characterize our sensitivity to larger objects, that may not have high contrast?

Contrast Sensitivity Function (CSF)

Sensitivity = 1/threshold





neural factors

optical factors

$*$ = resolution limit at 100% contrast

Contrast Sensitivity Function

The CSF changes shape under different conditions.
This reflects changes in neural substrates, e.g.

- scotopic (less high sf), mesopic, photopic
- static vs. flickering (less high sf)
- foveal vs. peripheral (less high sf)