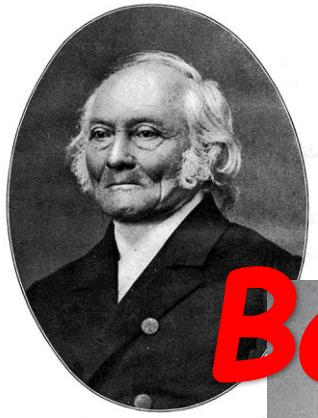
Mitchison & McKee

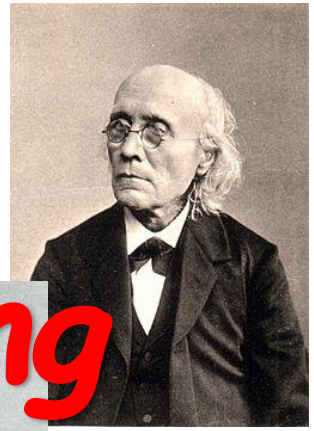
The Psychophysics of Stereo Matching

What exactly is a psychophysicist?

A 19TH Century German Discipline

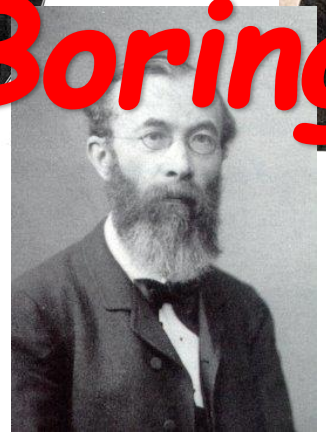


Weber



Fechner

Boring



Wundt

"Principles of Physiological Psychology"

William James

"This book just proves you can't bore a German"

Helmholtz

Conservation of Energy

“Physiological Optics”

“Physiological Acoustics”

And he coined the term ‘psychophysics’

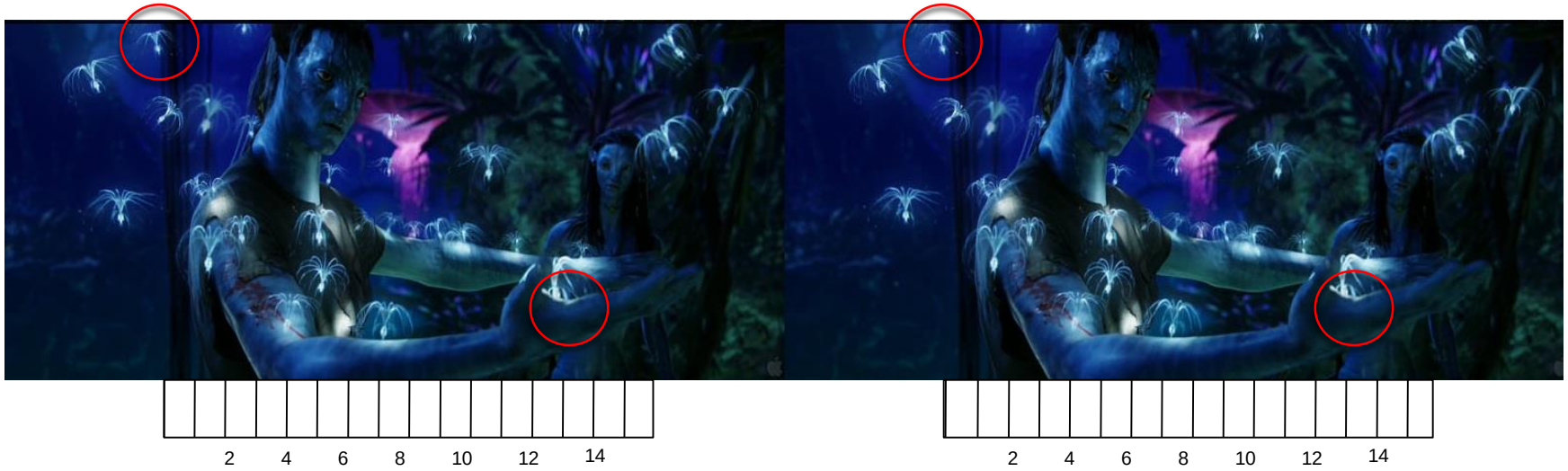
How the nervous system responds to the physical properties of light and sound

What is the stereo matching problem?

Basically, how do we combine the two retinal images into one single ('fused') percept of the visible world.

Each eye sees a slightly different view of the scene in front of us

What appear to be large 3D distances correspond to small differences in the retinal images in the two eyes.



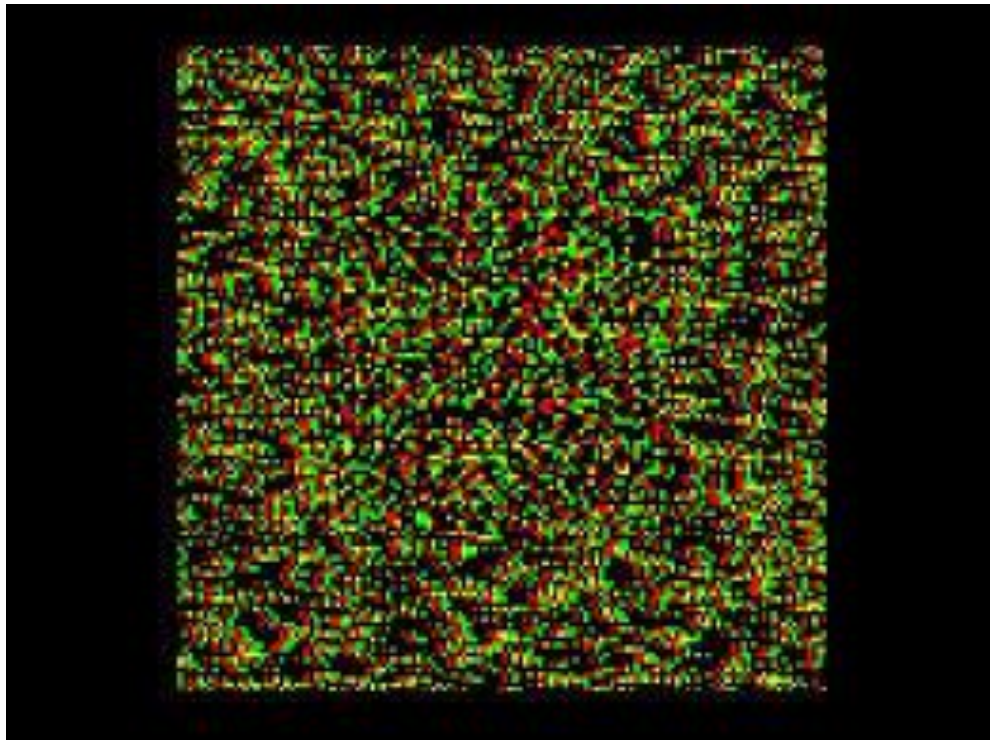
Stereopsis refers to the perceived depth generated by these differences (disparities).

How does the brain combine these two images?

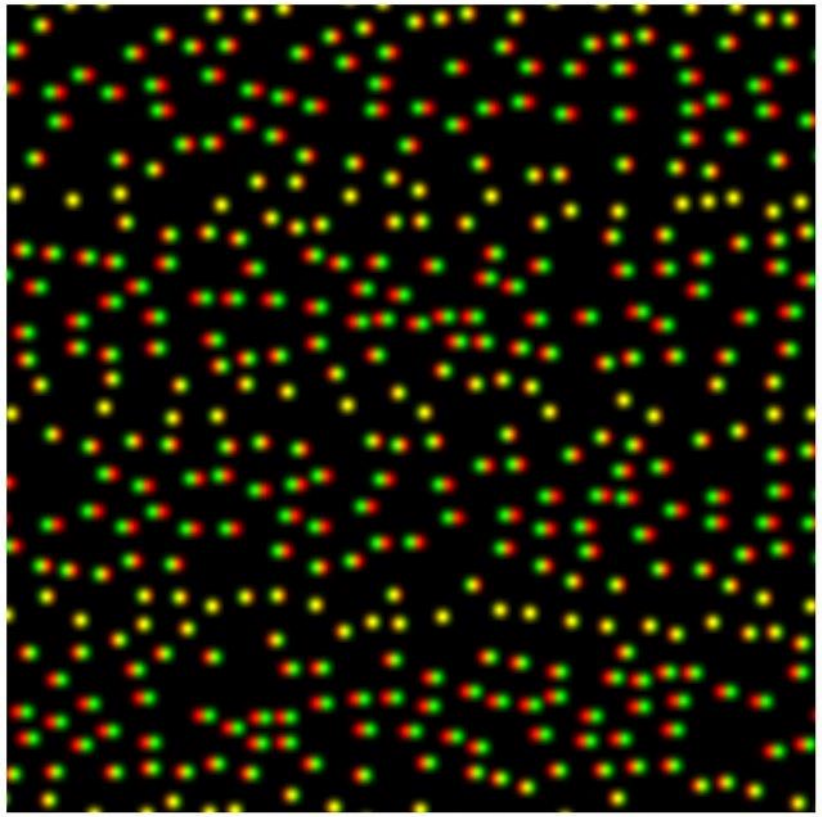
Seems obvious…. Just match similar features in each image…

Corresponding points?

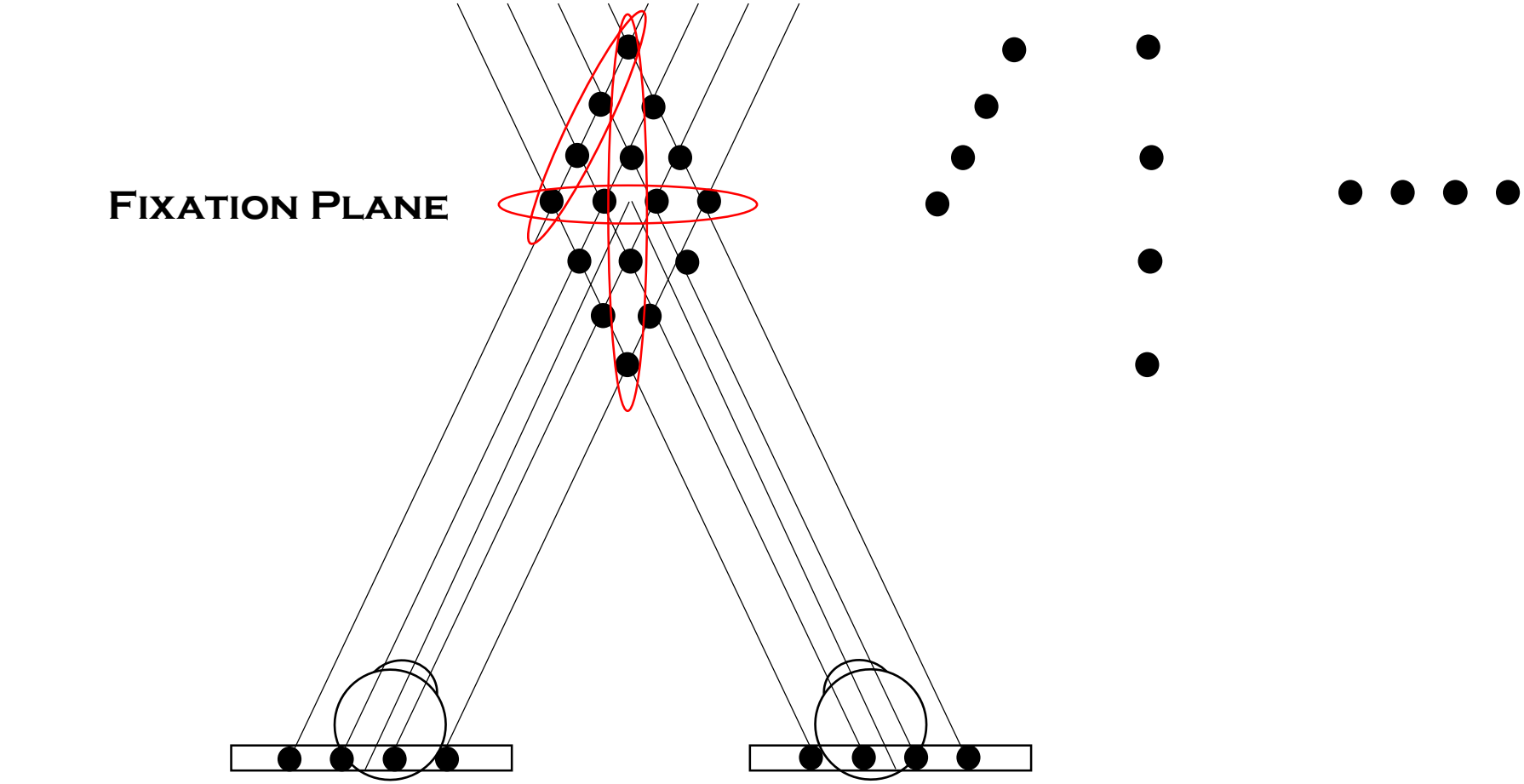
The stereo system does not initiate matching by finding similar features in the two retinal images



Julesz stereogram



All the dots look the same, so how does the stereo system determine which dots belong together?


Fixation Plane
Left eye retina
Right eye retina
Local correlators

The brain may solve stereo matching by:

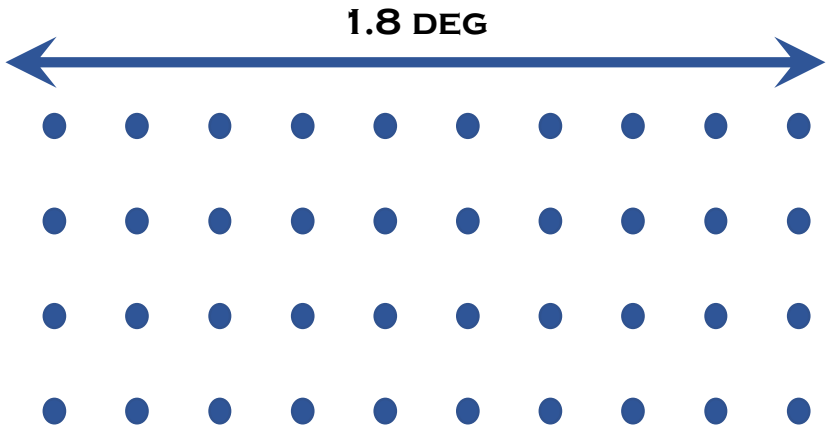
Local correlation of corresponding retinal regions

Plus detectors that reject false matches (Read & Cumming,2007; Goncalves and Welchman)

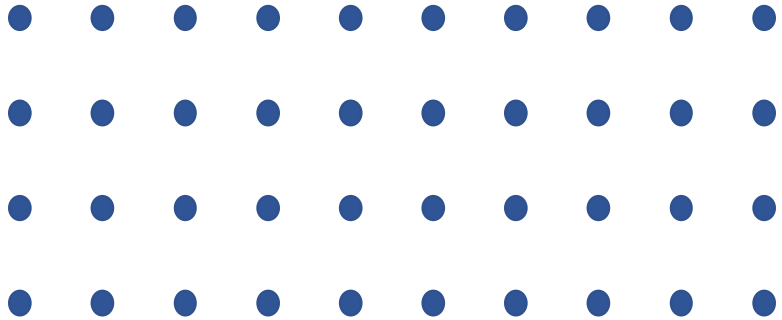
Graeme's experiments demonstrated another

important process in human stereo matching

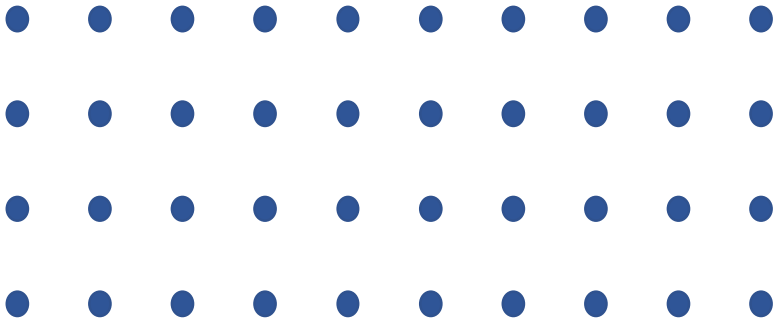
Stereo Interpolation



LEFT EYE



RIGHT EYE

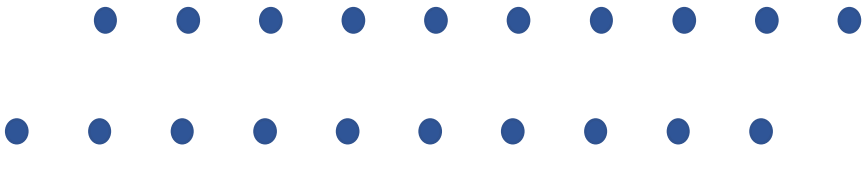


RIGHT EYE

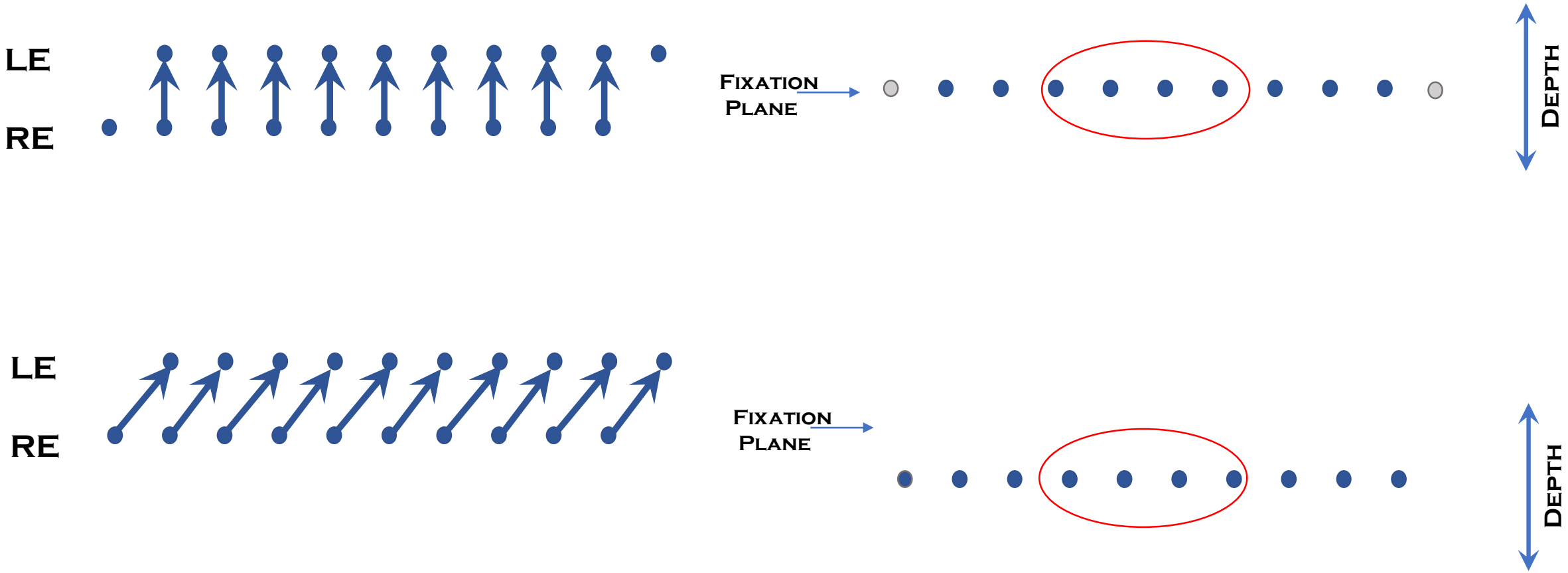
One row of grid

LE

RE



For the psychophysics experts, duration 160msec, fixation square to aid convergence present until stimulus presentation, viewing distance 1.5m, polarized images from two screens superimposed by a beam-splitter and viewed through polarized glasses. Observers judged whether grid was in front or behind a probe target that varied depth position from trial to trial.



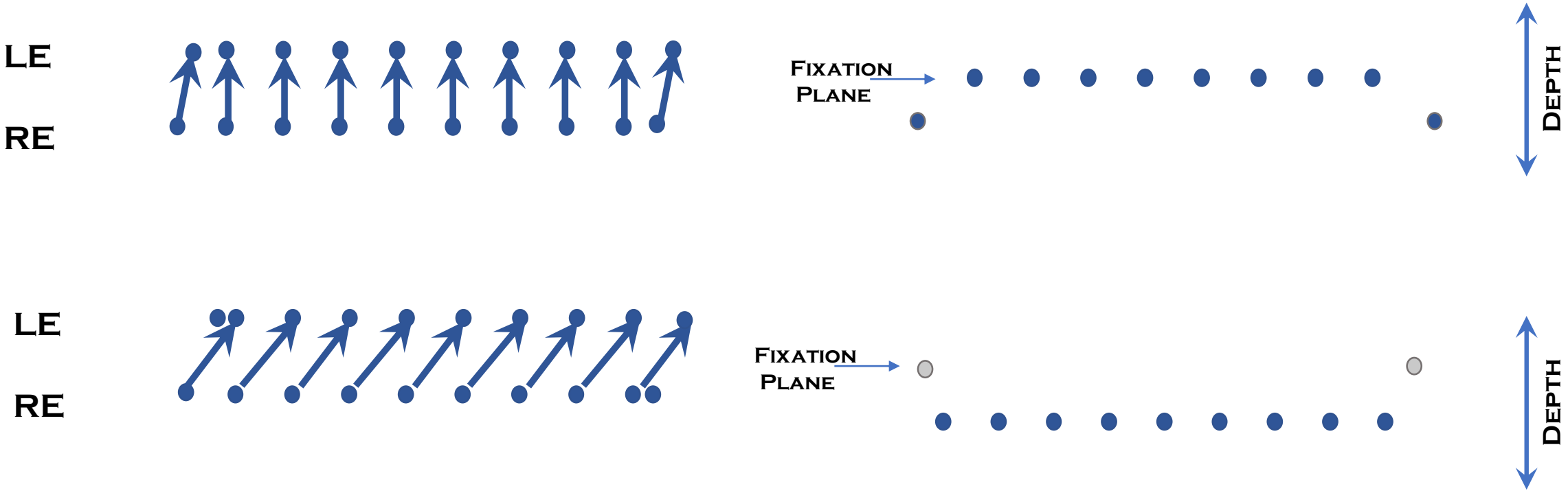
Of course, this plane has the highest correlation….

Local correlators

Three Adjacent Grids

Based on a ~~global~~ correlation, all three grids should appear in the same plane

What happens if the edges are not shifted a full period?



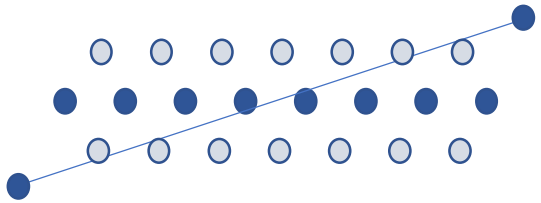
The plane of the grid depends on the size of the edge shift

This is the finding for coarsely-spaced points (>6 arcmin)

For closely-spaced points(< 6 arcmin), something different happened

The grid appeared in the depth planes of the edges, even though the individual dots could not be matched in these planes

By putting the edge points at two different disparities, Graeme showed that the grid of dots appeared slanted in depth

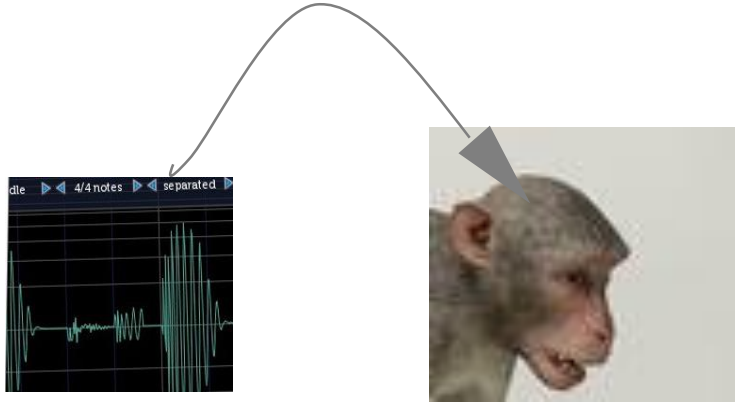


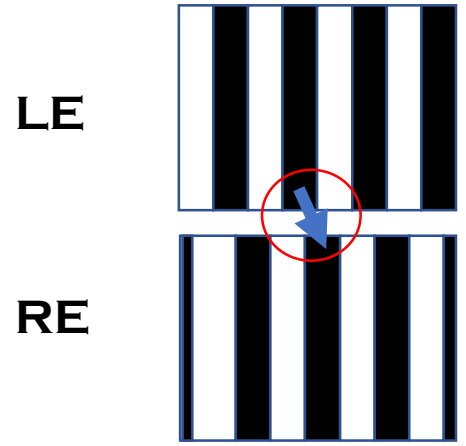
Graeme's Hypothesis:

The edges of an ambiguous pattern define a depth plane that serves as a "scaffolding" for other matches.

The intervening points are matched at depths that are closest to the plane defined by the edges.

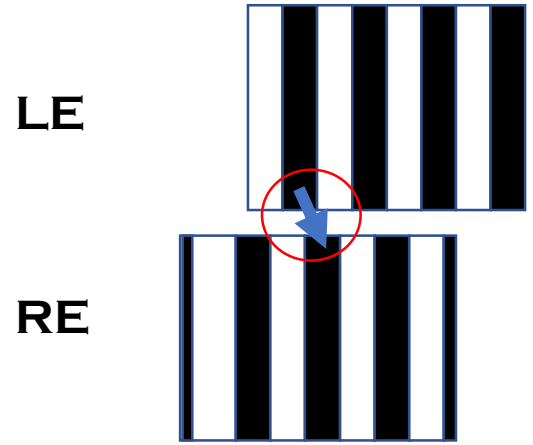
Cumming and Parker, 2000

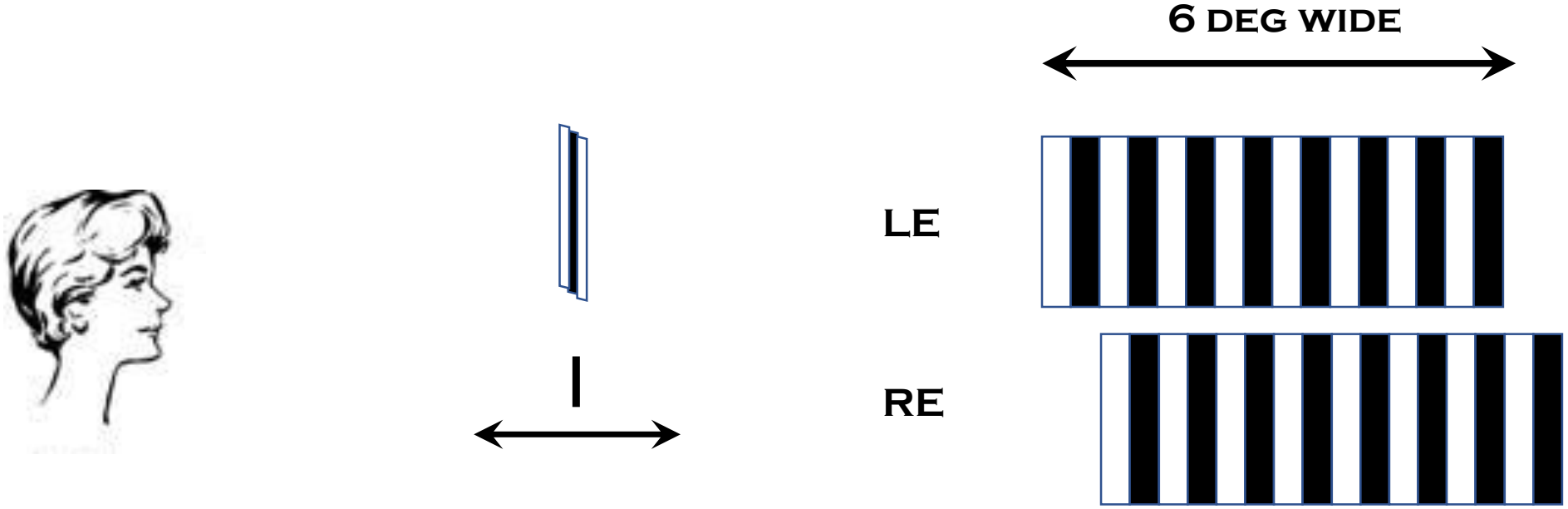




The neuron's response was unaffected by the shift in the edges (envelope) of the grating.

Both the humans and monkey saw the grating shift to a different depth plane.





Probe line was presented in one of seven positions in front or behind grating.

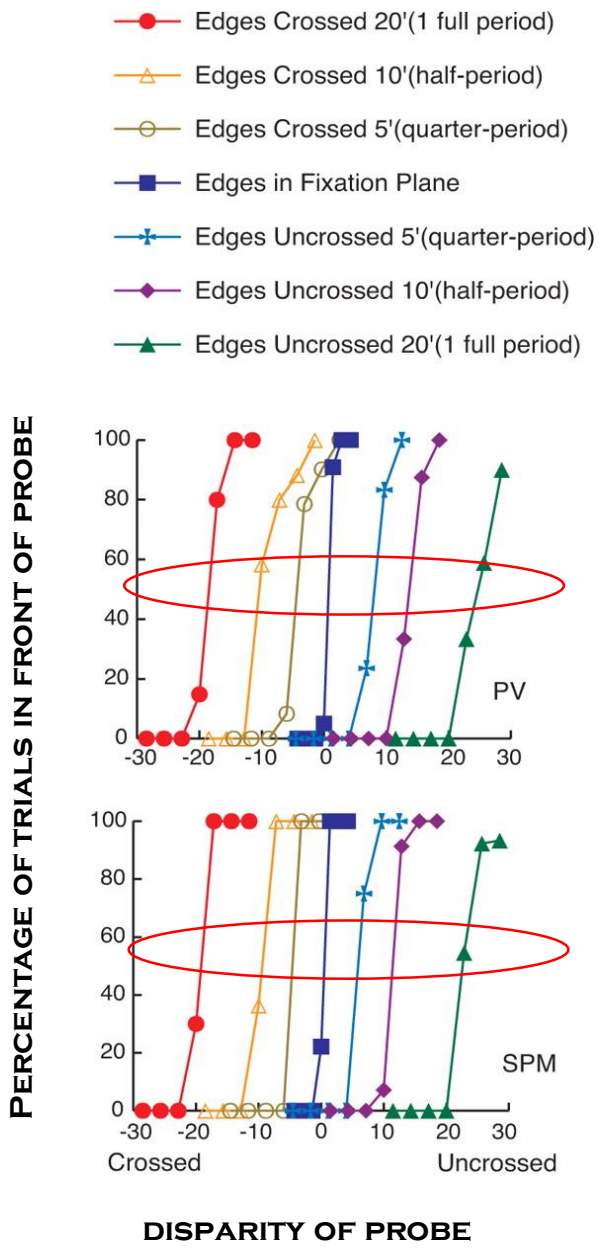
Subject judged whether probe was in front or behind the depth of the grating

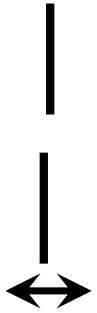
The edges (envelope) of the grating were shifted spatially without any change in grating phase (location of bars).

These wide gratings (3CPD) were matched in depth close to the disparity of their edges.

Probe seen half of trials in front and half in back of grating

The same results were found for gratings composed of 2CPD (coarse scale) or 10CPD (fine scale).



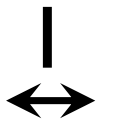


In young adults, stereoacuity is about 10 arcsec on average

At arms's length, 10 arcsec is 0.1 mm

Judging the relative distance separating a set of features is much harder

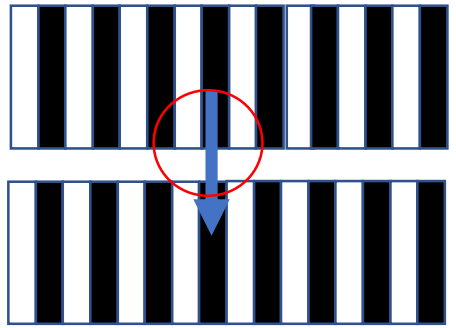
Incidentally, the neurons studied by Cumming & Parker are sensitive enough to respond consistently to these small disparities.

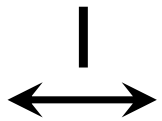


~10 ARCSEC

LE

RE

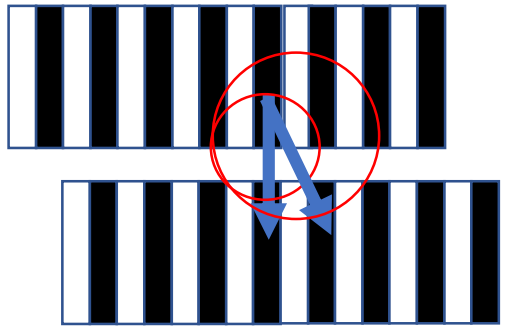




~50 ARCSEC

LE

RE

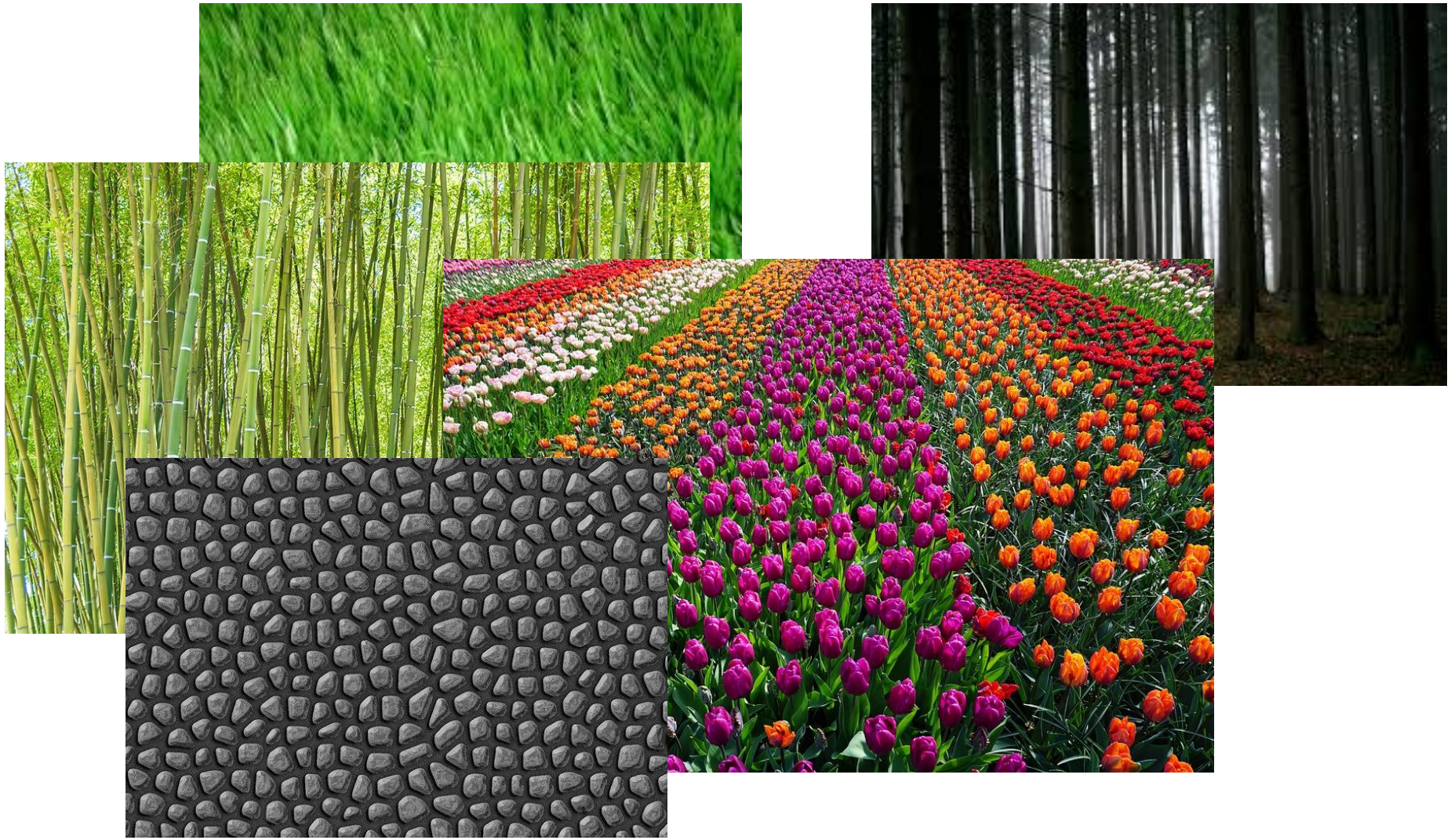


Graeme was right

The edges do provide a framework ("scaffolding") for resolving ambiguous matches

Local matches are selected to be consistent with the plane defined by the edges.

What do all these rows of dots and gratings have to do with natural viewing?

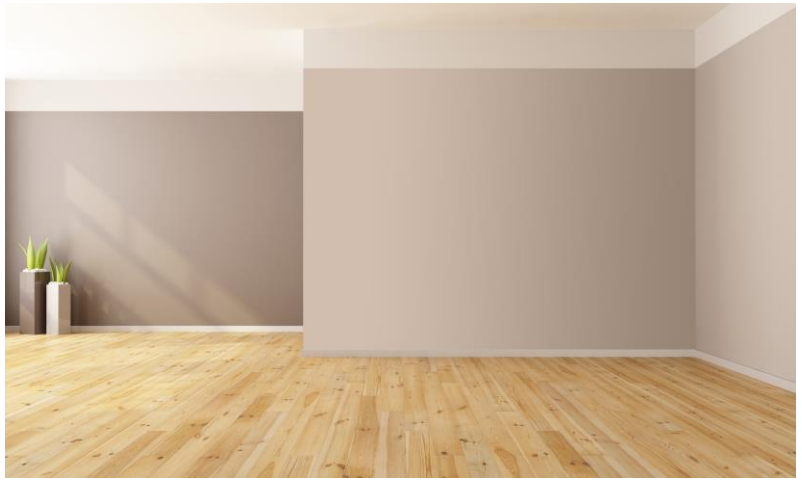


Many natural images are quasi-periodic

AGA KHAN MUSEUM

HUMANS LOVE REPETITIVE DESIGN PATTERNS

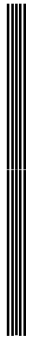
For unmarked surfaces, depth is interpolated from the edge disparities.

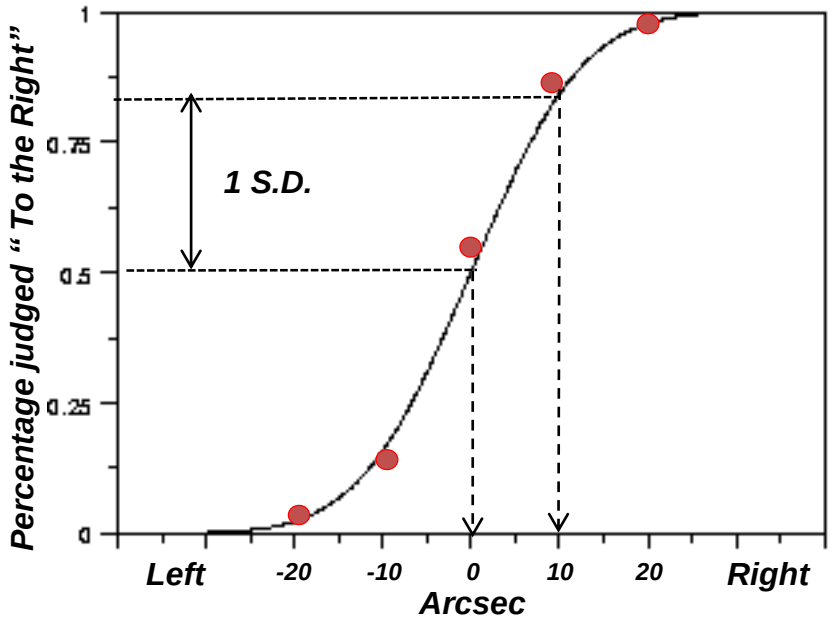


Thank you

In fond remembrance of my colleague and friend, Graeme Mitchison

A simple example (Vernier Acuity):





A measure of pattern perception: relative position, size and orientation of elements of any object are used for identification.

10" corresponds to .02mm at arm's length