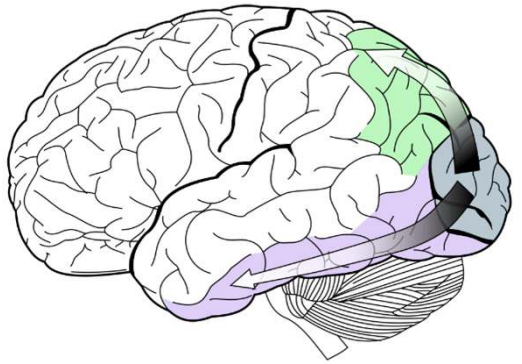
# FAV, Talk no. 9, Visual Cortex,



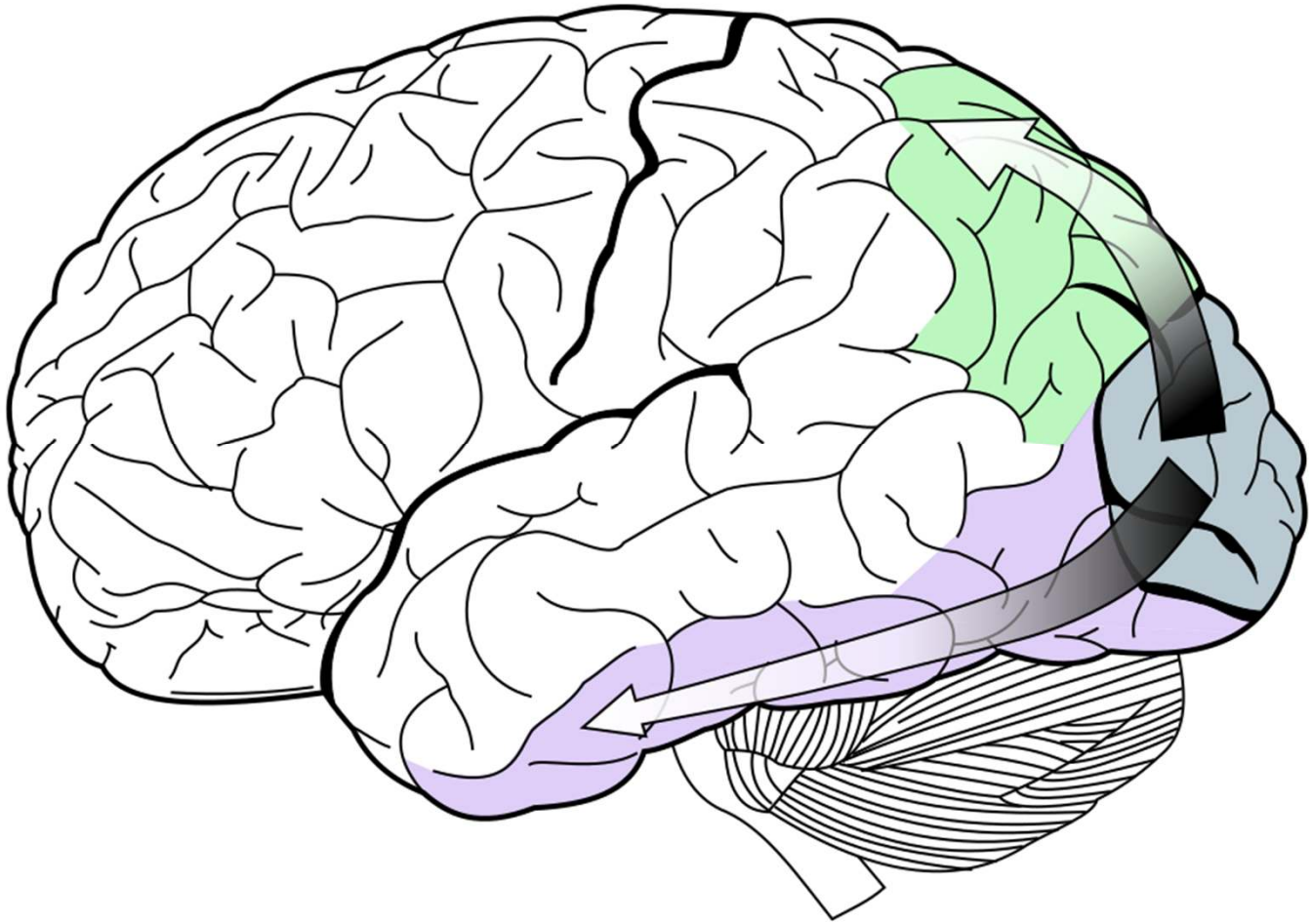
**Petr Maršálek**

Years 2020/ 2021/ 2022

## Outline 9 – Visual Cortex

- Primary and Secondary Visual Areas
- Synthetic Overview: Image Processing, Receptive Fields, Physiological ‘Laws’
- Not All Visual Areas Contain Consciously Accessible Representation – Eye Rivalry
- Magnocellular and Parvocellular Pathways
- V1, V2, V3, V4, MT (=V5) and Other Areas
- Modalities of Vision Based on Cortical Processing
- Features not Residing in Unique Areas: Stereo Disparity, Color
- Features Located To Areas: Dorsal (Location and Motion) versus Ventral (Object) Streams
- Controversies
- Processing Hierarchy of the Visual Cortex

# Ventral and Dorsal Stream



**Warning, this is the Same Slide as in the Hearing talk**

**THIS PANEL IS A SPECULATIVE ATTEMPT TO CLASSIFY BRODMANN AREAS DIFFERENTLY**

**"Binary Trees of Brodmann Areas" and Beyond Brodmann Areas**

- Bit 1: (Left) vs. (Right) Hemisphere
- Bit 2 and 3: (Motor/ Frontal Lobe) (Somatosensory/ Parietal L.)
- Bit 2 and 3: (Auditory/ Temporal L.) (Visual/ Occipital L.)
- Bit 4: (Primary) vs. (Secondary) Sensory projection areas
- Bits 5, 6, 7: subdivisions of visual/ sensory areas
- Sensory Domains: Bits 1 and 7: (Left/ Right) vs. (Bottom/ Top) Extensions, Retinotopy, Spatial Maps
- Bit 8: Temporal encodings: subcortical
- Bit 9: Other modality encodings – Hippocampus (Archi-cortex)/ space navigation, and so on.

Olfactory cortex and Hippocampus (Archi-cortex), Olfacory Bulb (Paleo-cortex), Vestibular Cortex (Part of Temporal lobe), Cortical Projections, Remaining senses: Olfaction, Taste and Touch



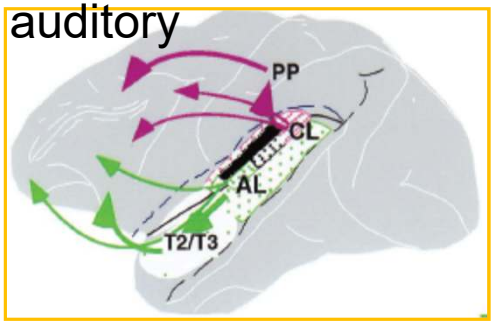
**This is NOT an official anatomical classification.**

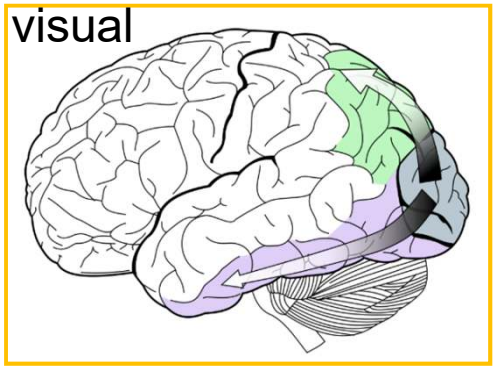
**Warning, this is almost the Same Slide as in the Hearing talk**

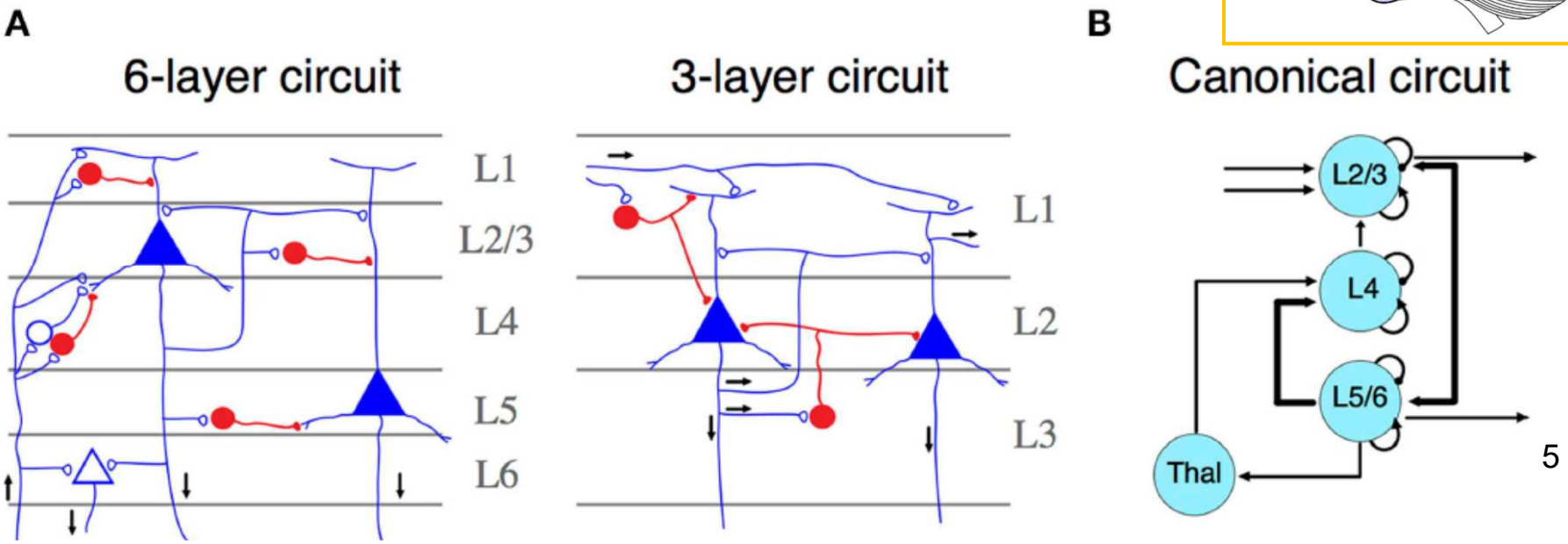
# CORTICAL MICROCIRCUIT

## Neocortex and Other Cortices

(Paleocortex, Olfact. Only: 3 Layers,
Archicortex, Olfact. and Hippocampus,
3 or 4 Layers)

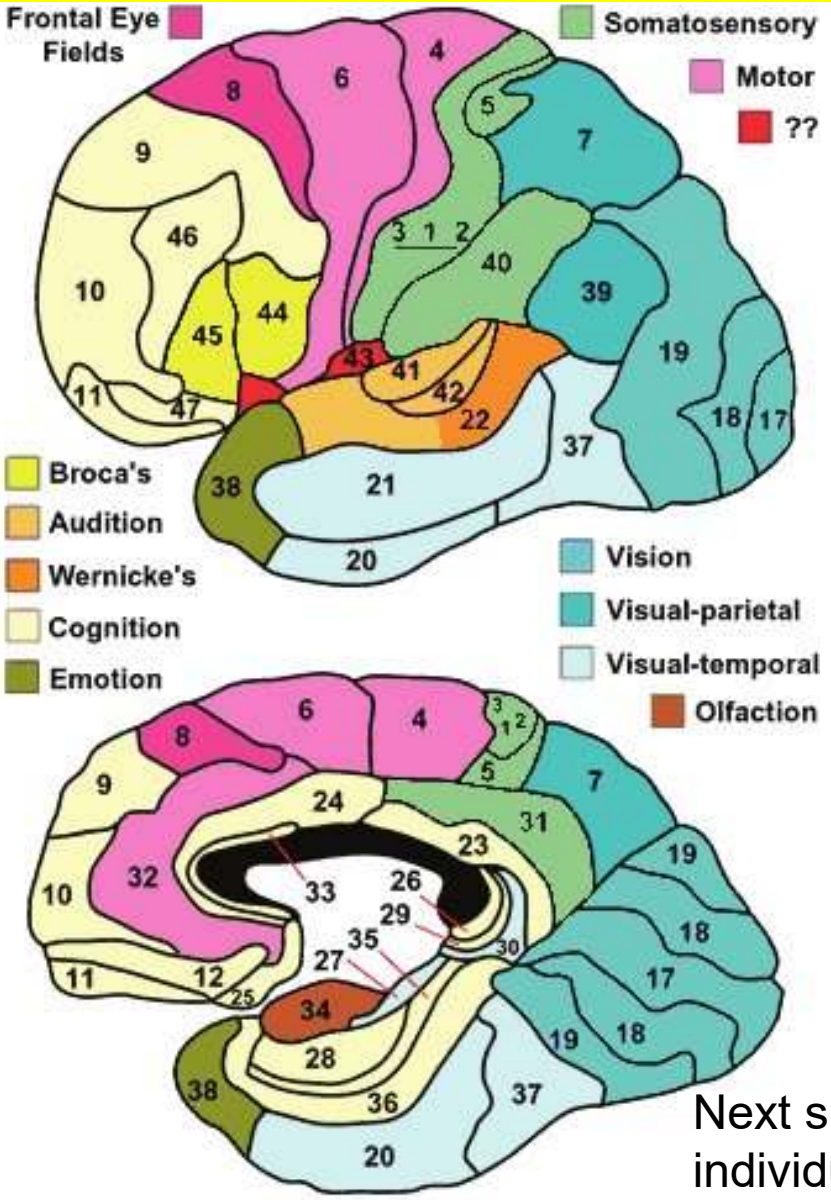


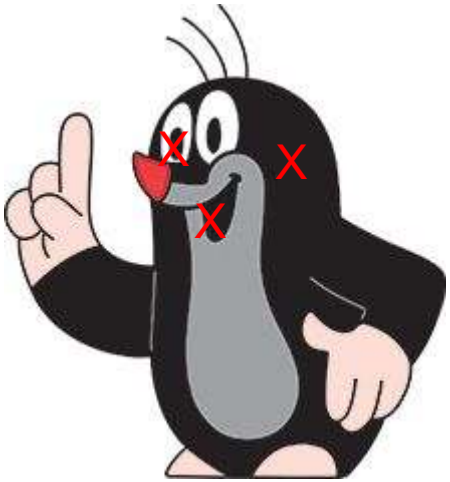
**Warning, this is almost the Same Slide as in the Hearing talk**

**Can you find differences between Auditory and Visual Areas?**



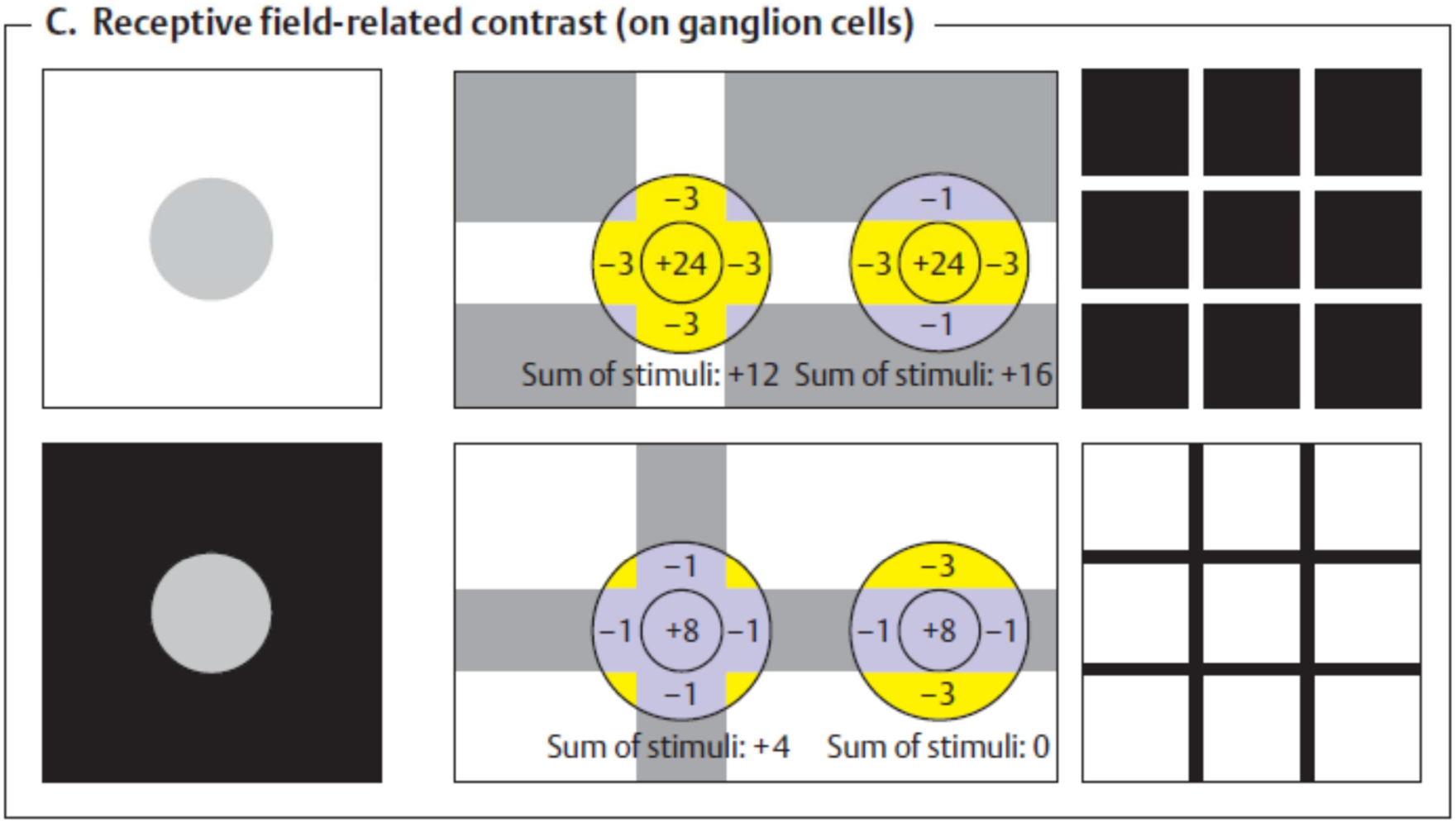

# Brodmann Areas

## (Outer and Inner Hemisphere Parts)



Next slides will be in search of the function of individual visual areas, V1, V2, V3, V4, et cetera…

# Visual Pathway Inner Workings



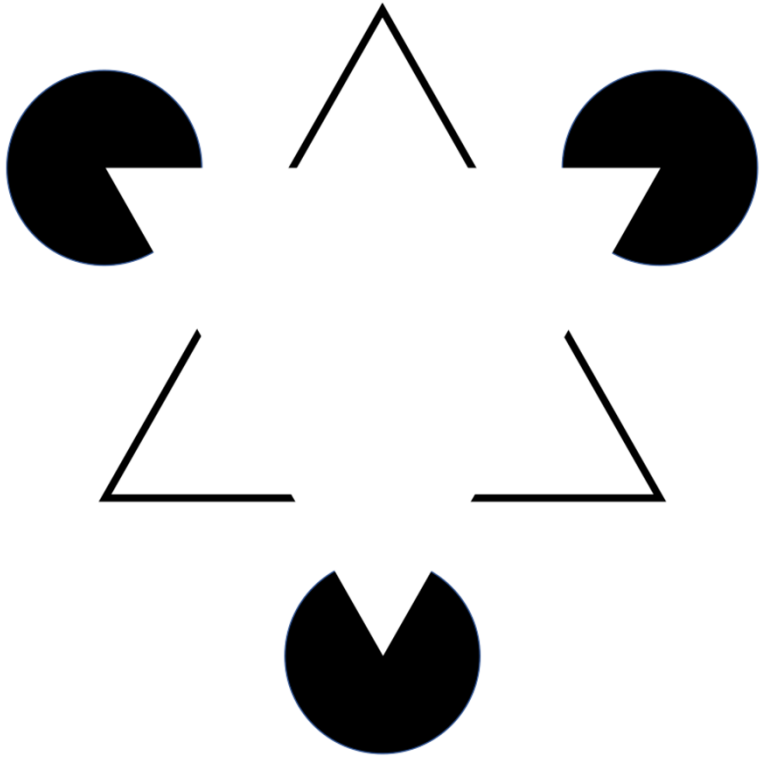

Both Peripheral (=Retinal) and Central (=Cortical) Mechanisms Contribute to Contrast Perception

# The Kanisza Triangle

= An illusory triangle pointing to the bottom of the figure.

**Gaetano Kanizsa** (1913-1993), Italian artist and psychologist.

Experimental Construction of Receptive Fields:
Simple and Complex Cells in Primary Visual Cortex, Area V1,
Illusory Contours by von der Heydt, Area V2, and Higher Areas

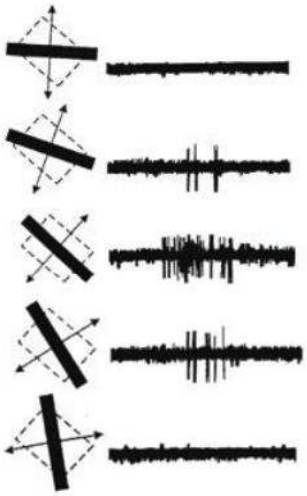


# What We See Results from Expectations

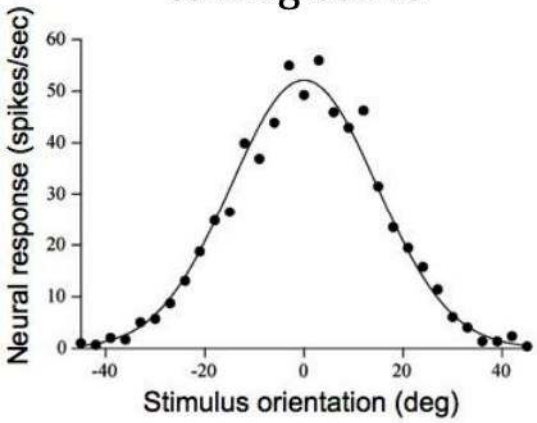
Comment/ question:
when do we see and when don’t see yellow banana?

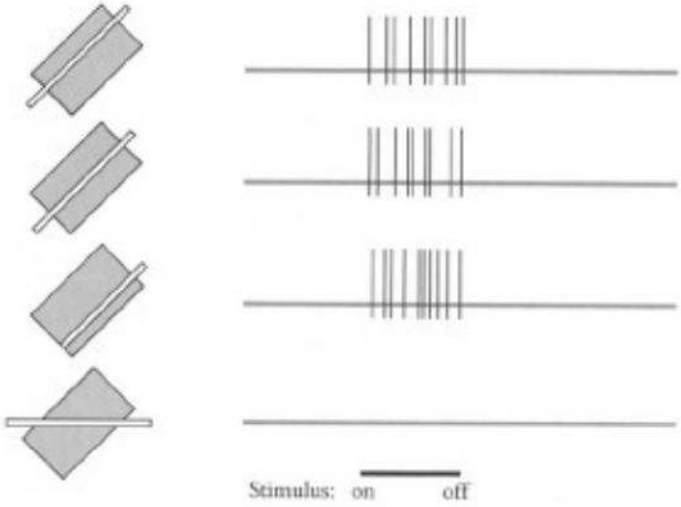
# V1 simple & complex cells

**simple cells** respond best to edges or bars of a particular position, orientation, and sign of contrast



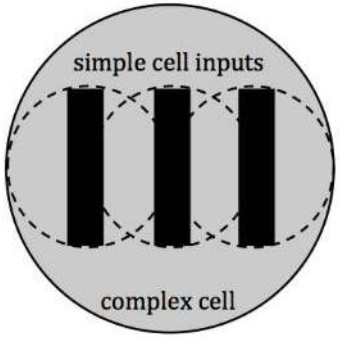
tuning curve



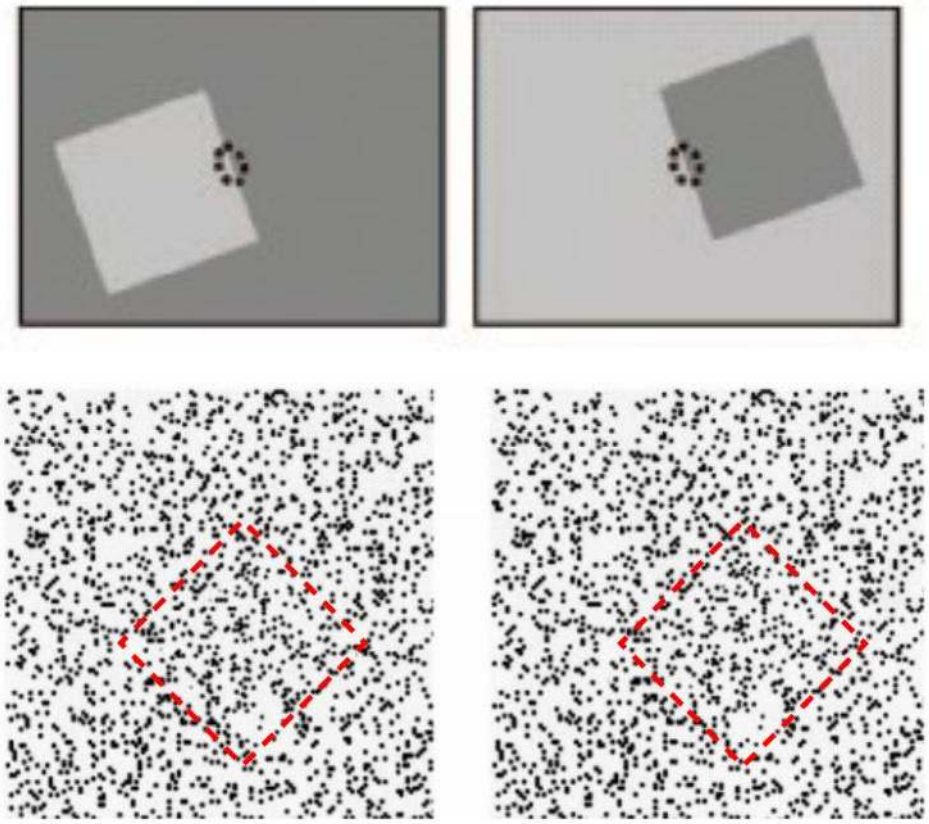

**complex cells** have larger receptive fields and are more tolerant to position

Kreiman, 2013



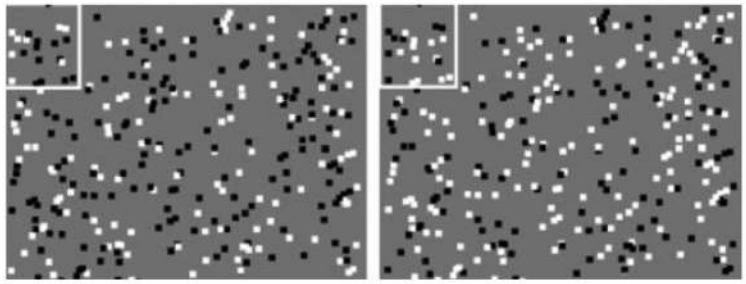

complex cell may "pool" inputs from many simple cells within receptive field

# Selectivity for *stereo boundaries* in V2



Von der Heydt & colleagues:

Some V2 cells are selective for the orientation, contrast, and *side of border ownership* of an edge ... for edges defined by luminance *or stereo disparity*



"anti-correlated" stereogram

Later, in area V4, neural responses to stereo disparity appear to correspond more closely to perceived depth

# Visual/Illusions

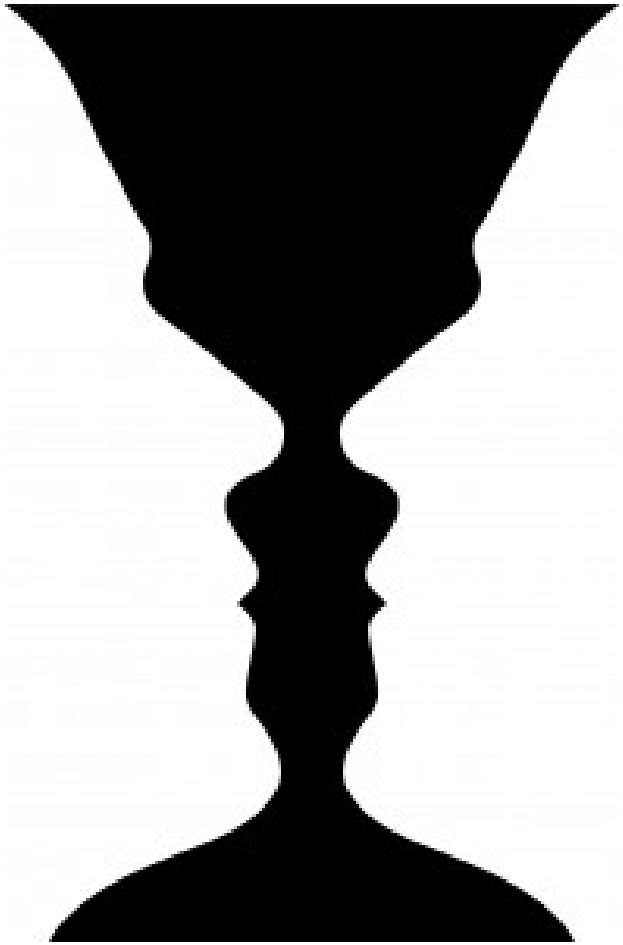
## Examples of visual illusions

(This is not a complete list, these are rather random examples.)

1. Hyperacuity (llll////)
2. Group of illusions based on perceptual figure-ground alternation
3. Kanisza and Bregman-Kanisza illusory occluded objects
4. Cortical “inertial mechanisms“ creating after-effects
5. Impossible 3-dimensional object designs (e.g. drawings by M. C. Escher)
6. Binary (Necker cube like) illusory percepts: they are important mechanisms how to register two variants of the binocular outer world that cannot be distinguished by creating only one probable input.
7. The rivalry between the two eyes is another mechanism for how to arrive at a plausible outer world scene. Intricate displays addressing these mechanisms demonstrate that part of what we see cannot be accessed consciously [Koch and others.]

# Faces/ Vase (Gestalt Illusion)

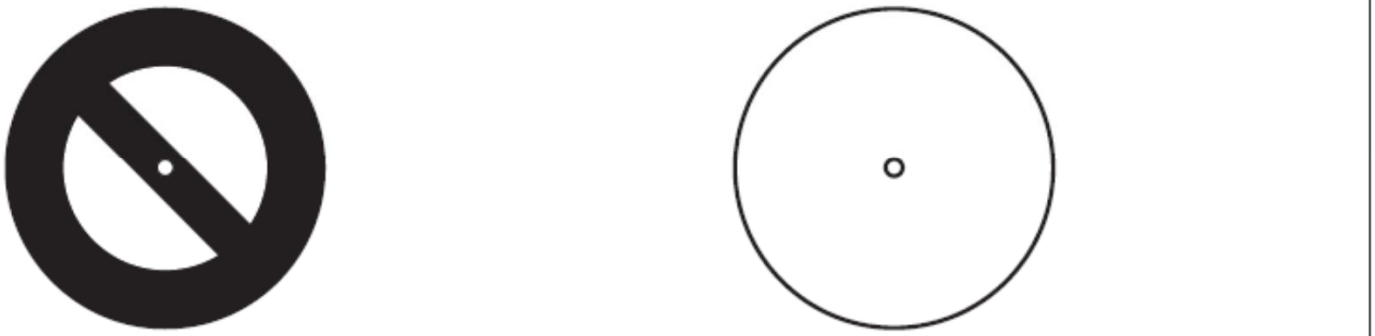
Definitions:
What are
1/ illusions (following slides)
2/ pseudo-hallucinations
(example: migraine perceptions)
3/ hallucinations (seeing unreal scenes)



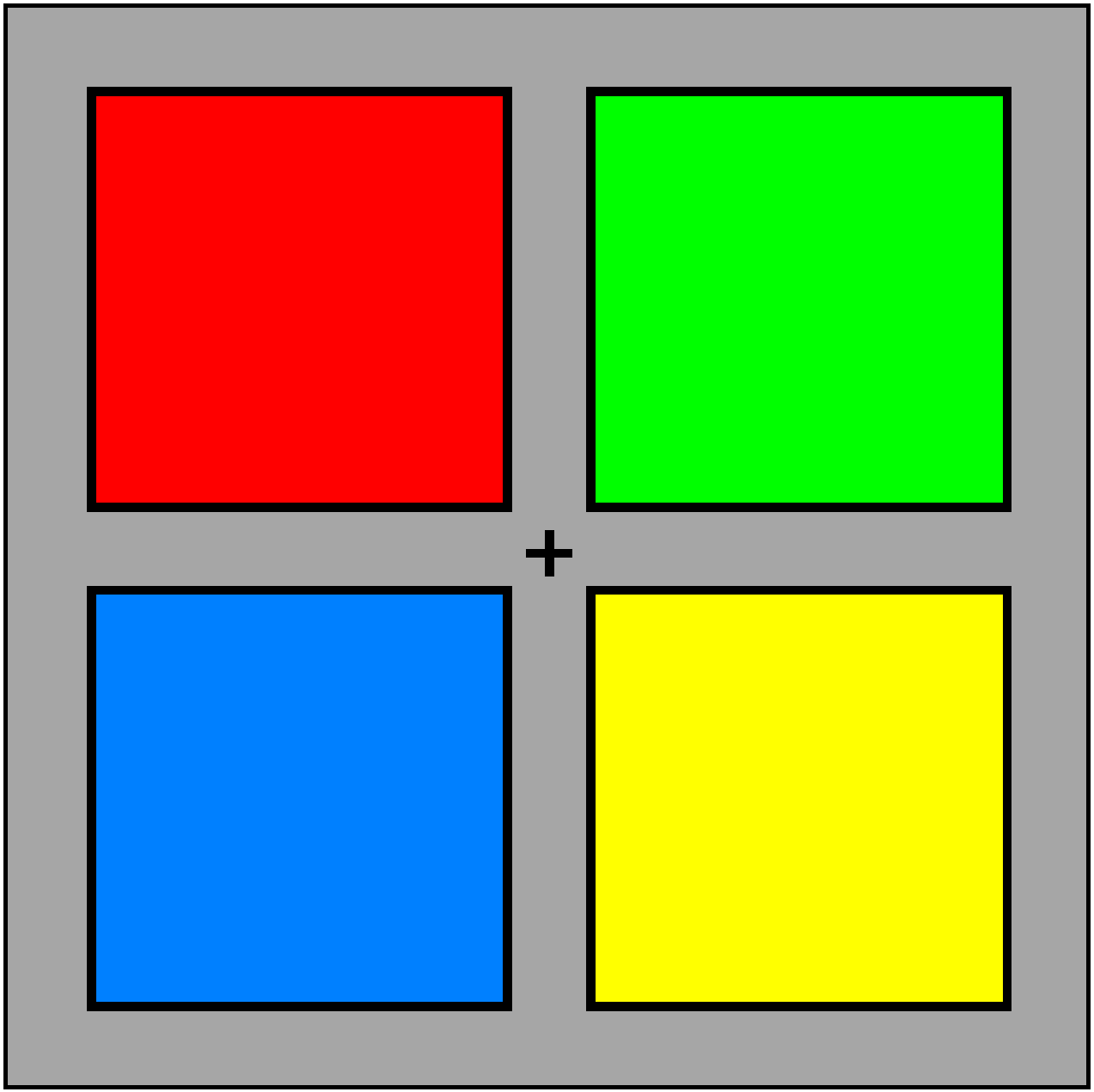
Comment:
figure and ground alternate, based on to what we attend.

# Mechanisms in visual cortex are powerful in constructing, what we see, and sometimes in constructing illusions

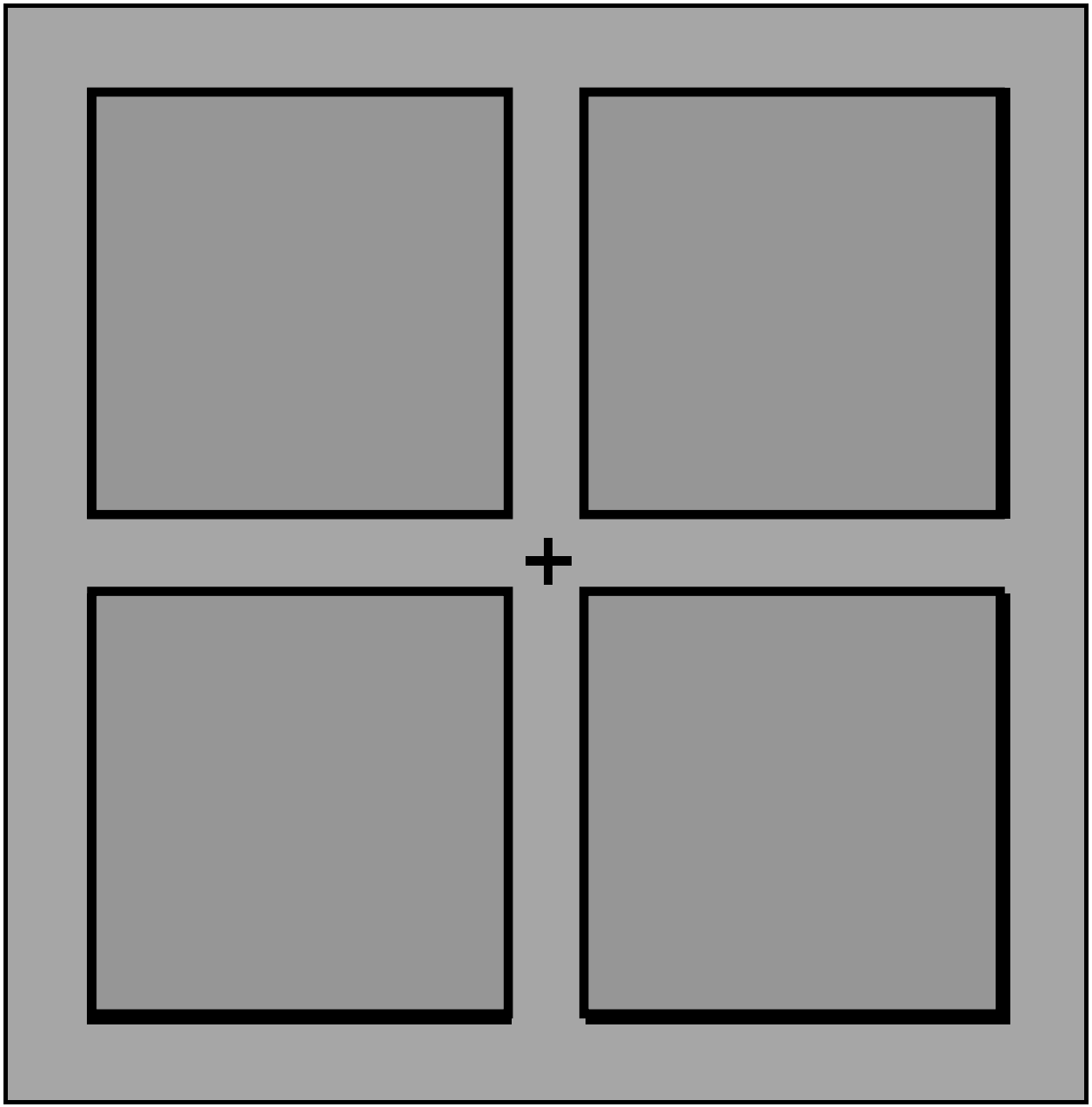
**D. Successive contrast ("local adaptation")** (see text)



Comment:
first fix the center of the left image, after circa 10 second move your eyes to fixate the center of the right image.

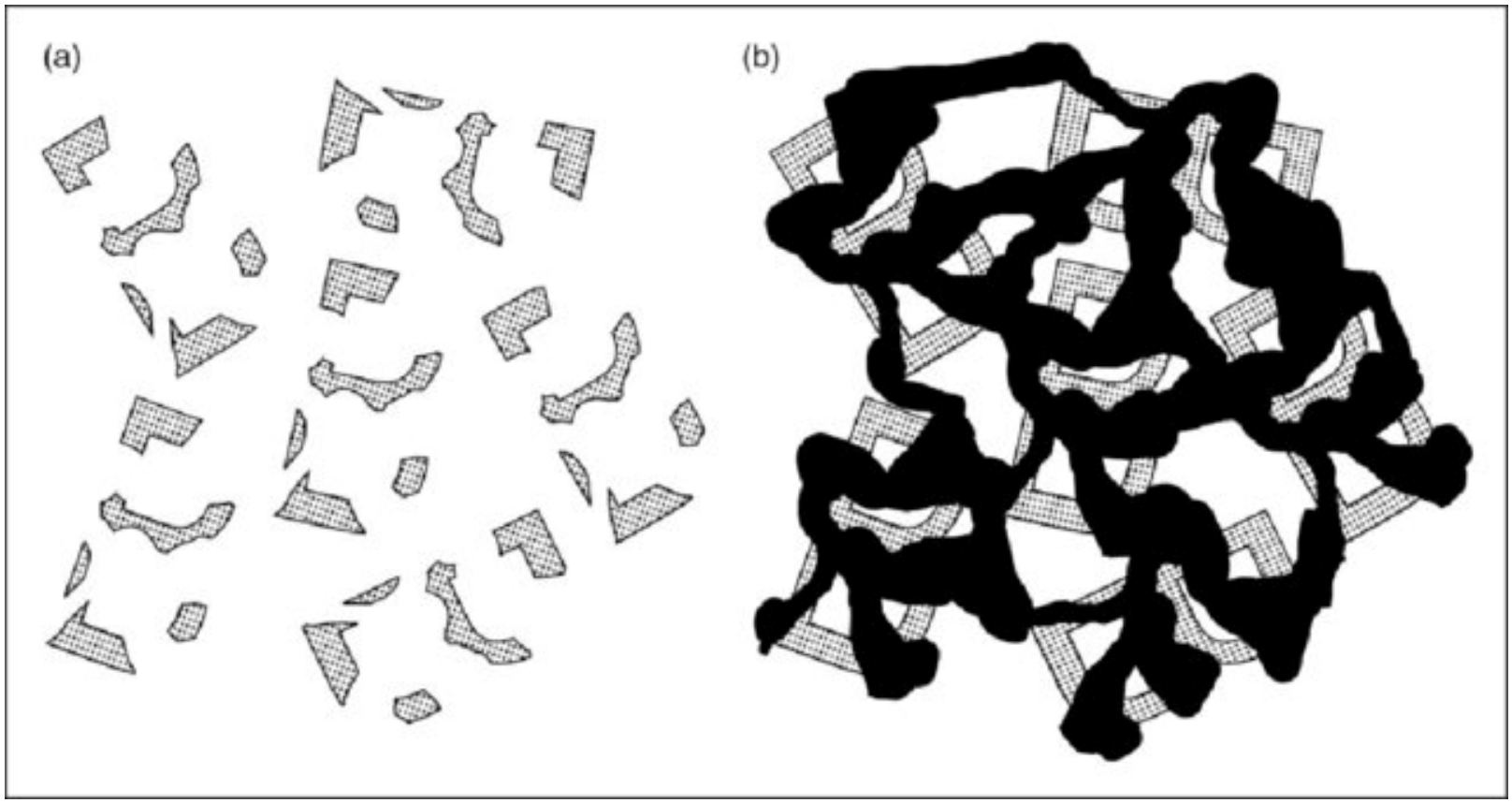


Comment:
fixate cross 10 secs. Then move to next slide



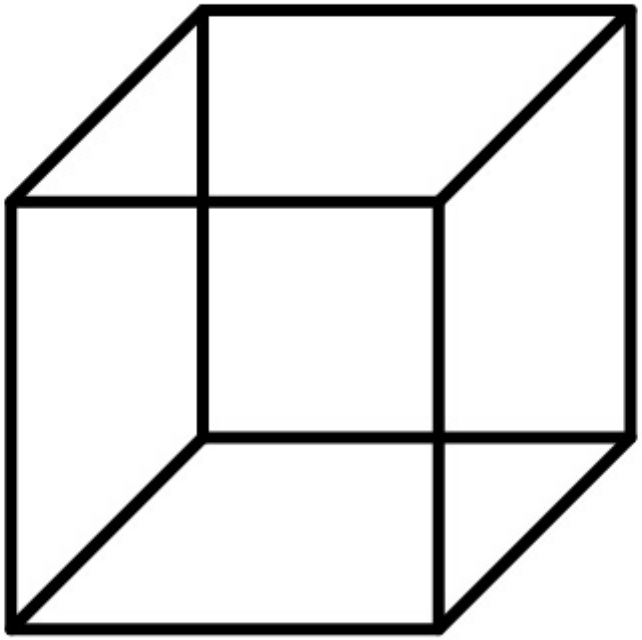
Comment:
fixate cross 10 secs. When colors fade go to the previous slide

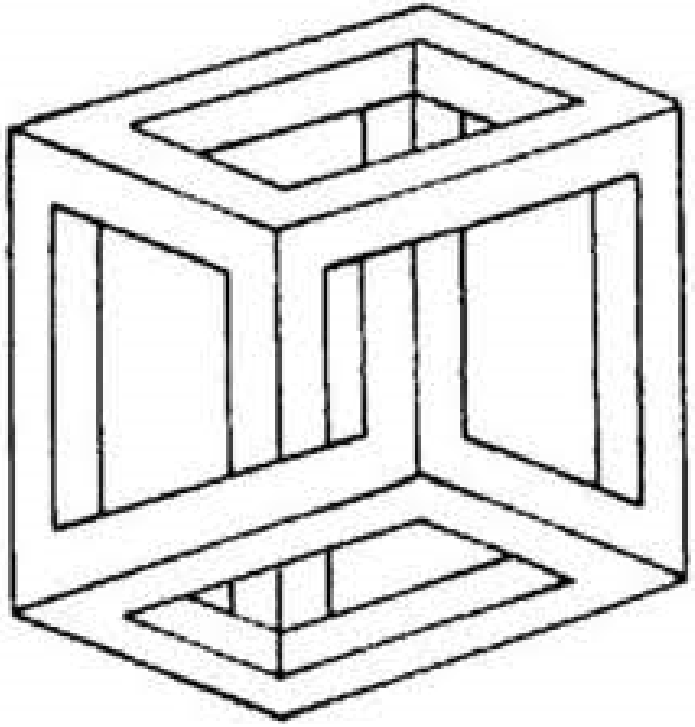
# Bregman - Kanisza Illusion




Comment:
the Bs on the right panel are more legible than those on the left.

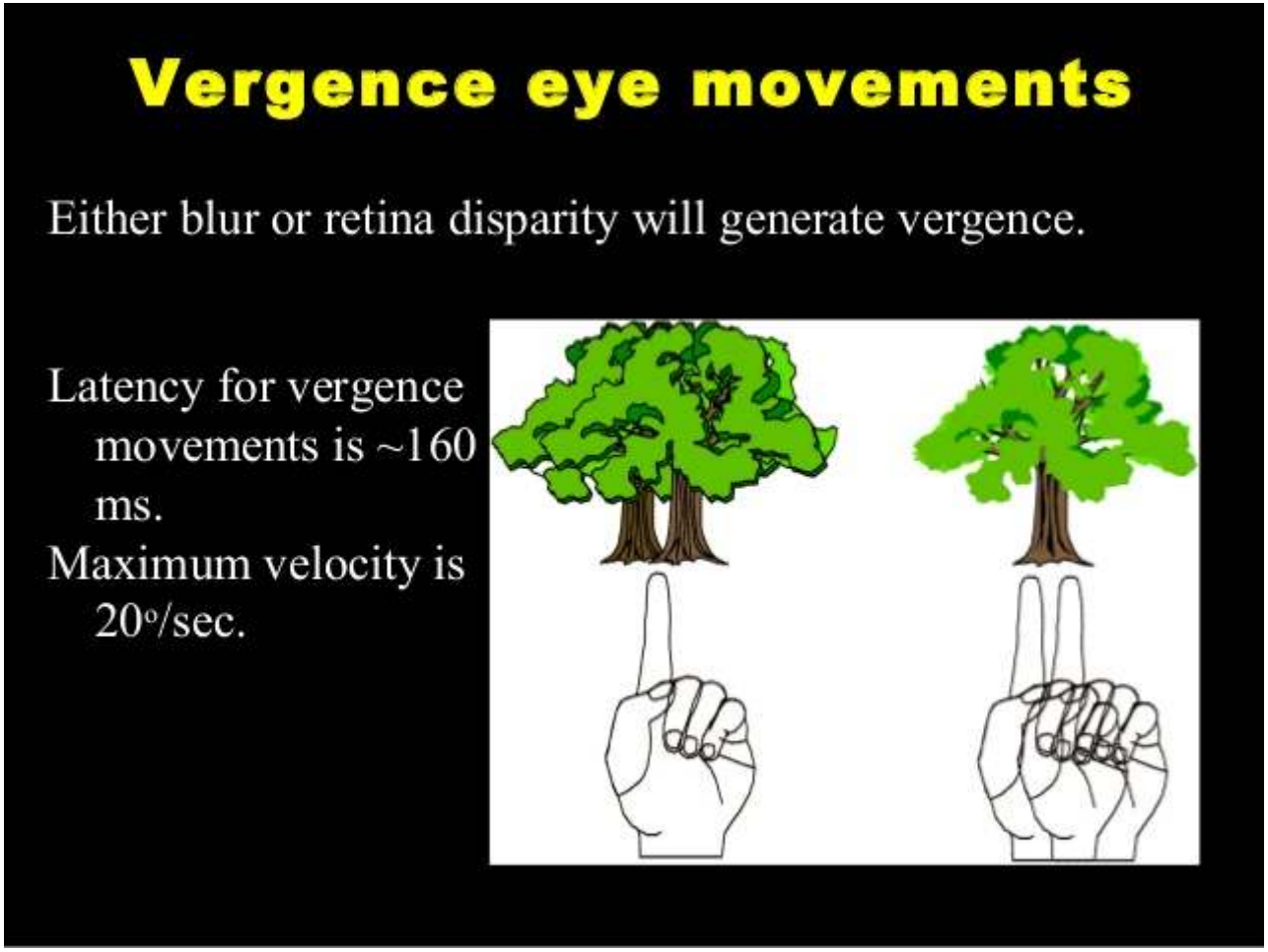
# Necker Cube/ Impossible Necker Cube





Comment:
attend to the top and the bottom inner vertex of the cube.

# Binocular Focusing is Realized by Eye Con- and Di-Vergence




Mostly involuntary and rarely voluntary subcortical vergence control is needed for proper stereo vision and disambiguating binocular perceptions.

(Con)vergence disorder is called strabism.

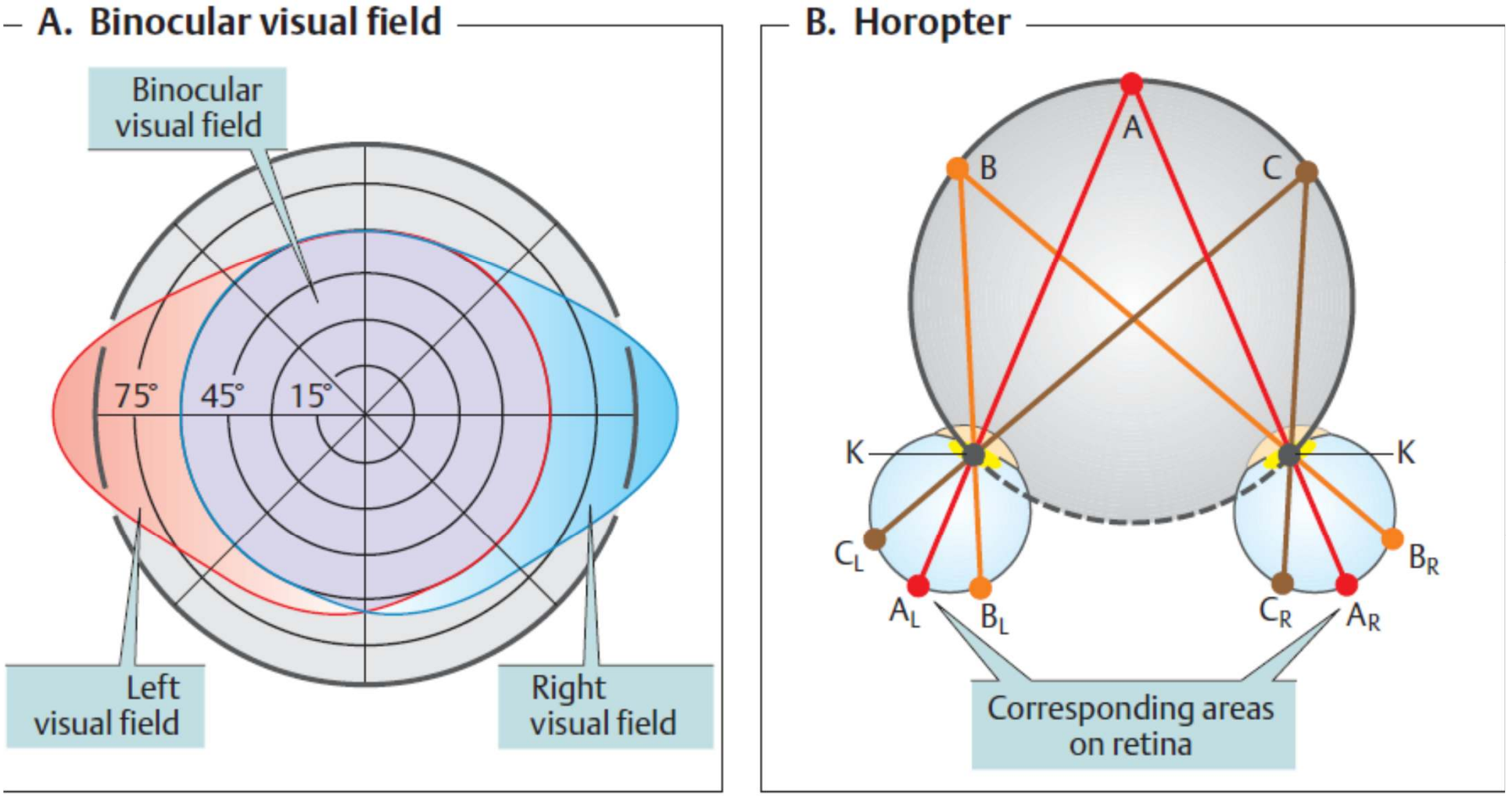
# Binocular Rivalry in Conflicting Images To Left and Right Eye

## What Functional Purpose This May Have?

- Not All Visual Areas Contain Consciously Accessible Representation –> Eye Rivalry

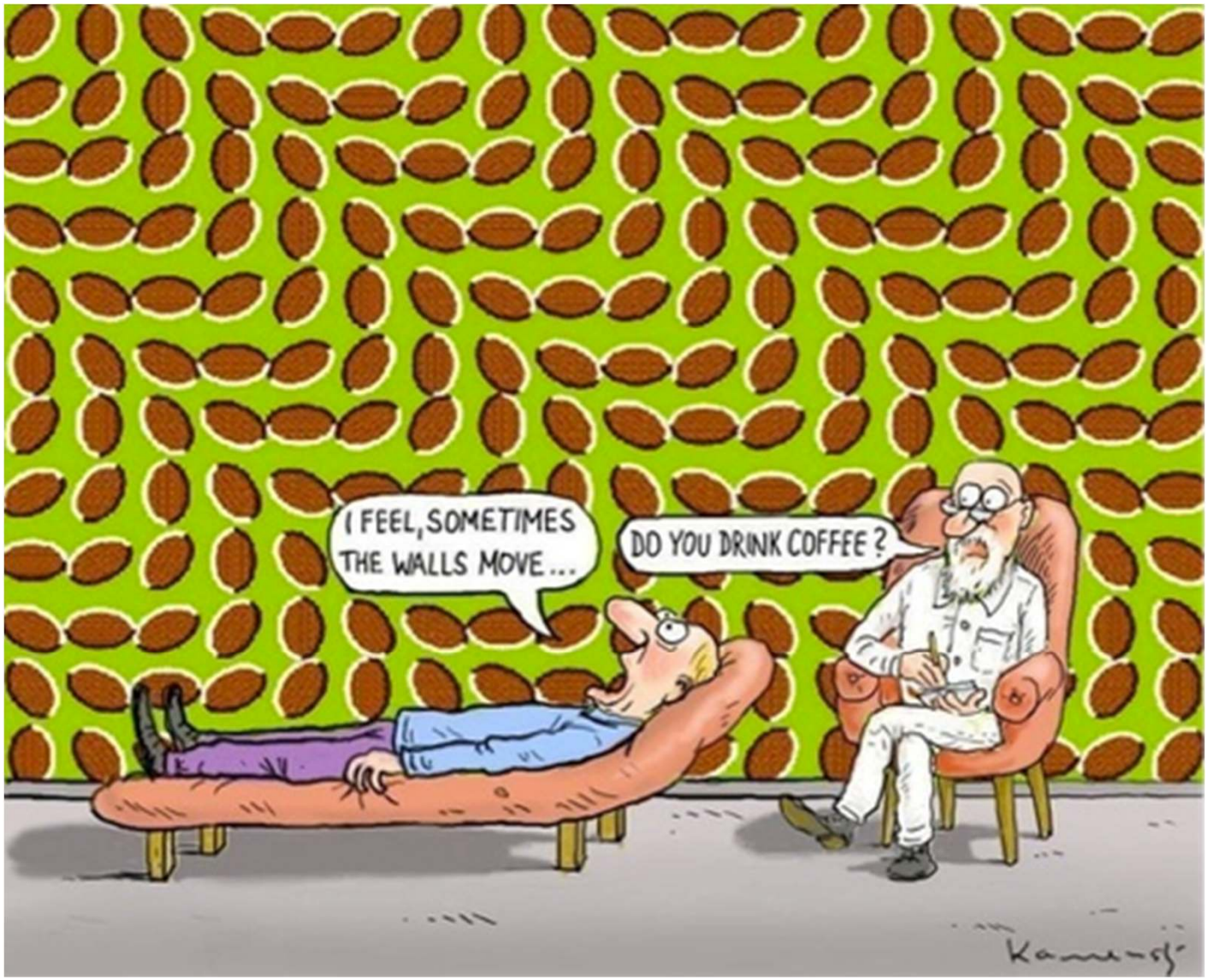
[Koch and others.]

# Binocular Fusion



# Paintings by Maurits Cornelis Escher (1898-1972)

# Cartoon: Drinking coffee and illusions



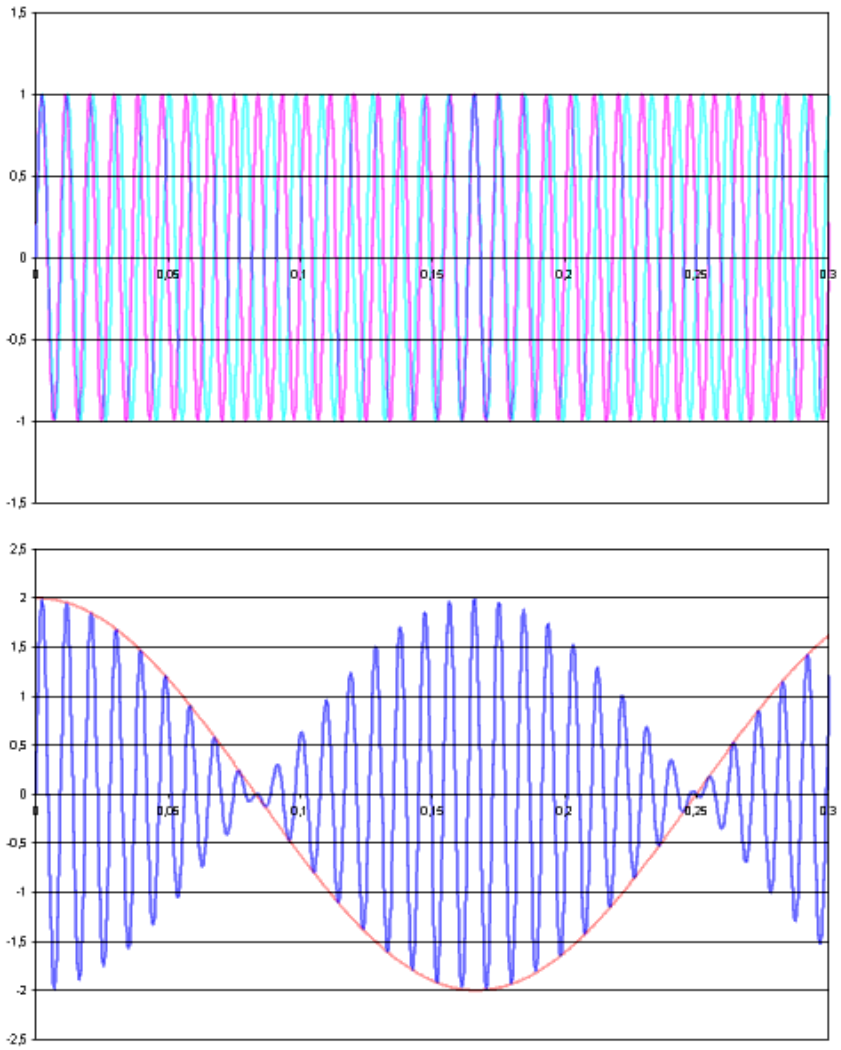
# Auditory Illusions

Examples of auditory illusions/ Some of these are binaural

- Binaural beats (comment: this is rather a regular sound perception)
- The constant spectrum melody
- Scale illusion by (Diana Deutsch in1973), this is a binaural melody presentation potentially usable as a diagnostic for some neocortical defects
- Illusory continuity and illusory discontinuity of tones
- Hearing a missing fundamental frequency, given other parts of the harmonic series
- Illusory „circular pitch scale (octave)“
- Various effects using lossy audio compression (some based on the aliasing effects/ Octave illusion/ Deutsch's high–low illusion)
- Auditory pareidolia: hearing indistinct voices in random noise (comment: Recall babble noise).
- perceptually ambiguous stimuli (analogy to Necker cube)

# Binaural Beats

Comment:
top: left and right ear channels,
bottom: resulting beating sound.



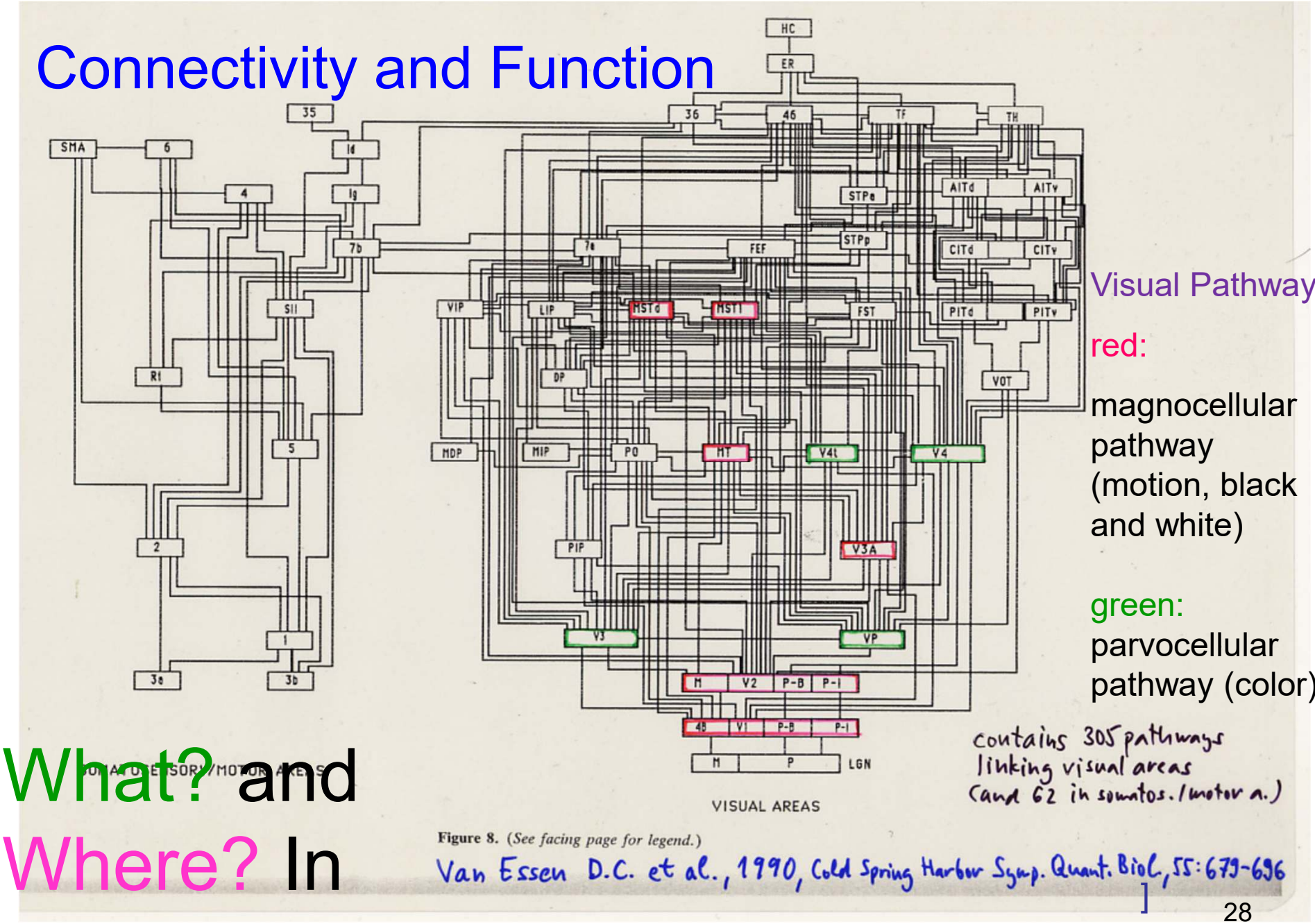
# Circular pitch

This continuum is known as pitch height. However pitch also varies in a circular fashion, known as pitch class: as one plays up a keyboard in semitone steps, C, C♯, D, D♯, E, F, F♯, G, G♯, A, A♯ and B sound in succession, followed by C again, but one octave higher. Because the octave is the most consonant interval after the unison, tones that stand in octave relation, and are so of the same pitch class, have a certain perceptual equivalence—all Cs sound more alike to other Cs than to any other pitch class, as do all D♯s, and so on;

# Combined Visual and Auditory Stimuli

- Visual and auditory objects are localized in the same quadrant/ location of outer space
- Ventriloquism effects are based on „binding“ visual and auditory disparate parts of „speech“
- Other perceived objects can be „multisensory“ /examples include visual and touch objects/ and „synesthetic“ /examples include smell, taste, and cold touch sensation of menthol on a skin
- Augmented /Sound /Image /Video /Reality
- Unity of outer space is disturbed in a rare cognitive disorder condition: hemineglect

# Connectivity and Function




Visual Pathways

red:

magnocellular pathway (motion, black and white)

green:

parvocellular pathway (color)

contains 305 pathways linking visual areas (and 62 in somatos./motor a.)

**Figure 8.** (*See facing page for legend.*)

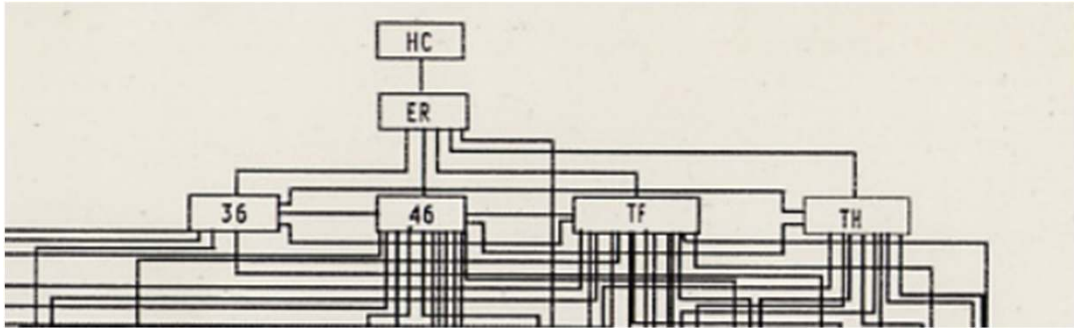
Van Essen D.C. et al., 1990, Cold Spring Harbor Symp. Quant. Biol., 55:679-696

What? and

Where? In

Visual Cortex

What is HC? Is it a (H)igher (C)enter, (H)ippo(c)ampus, (H)ommun(c)ulus, Is there Anything At All On the Top of Cortical Hierarchy?




Visual Cortices are Primary and Secondary (Any Sensory Are Like This)

What? is in (ventral=) facing cortical projection areas

Where? is in (dorsal=) rear cortical projection areas

# Too Complicated Way to Explain Visual Cortex

## Connectivity and Function

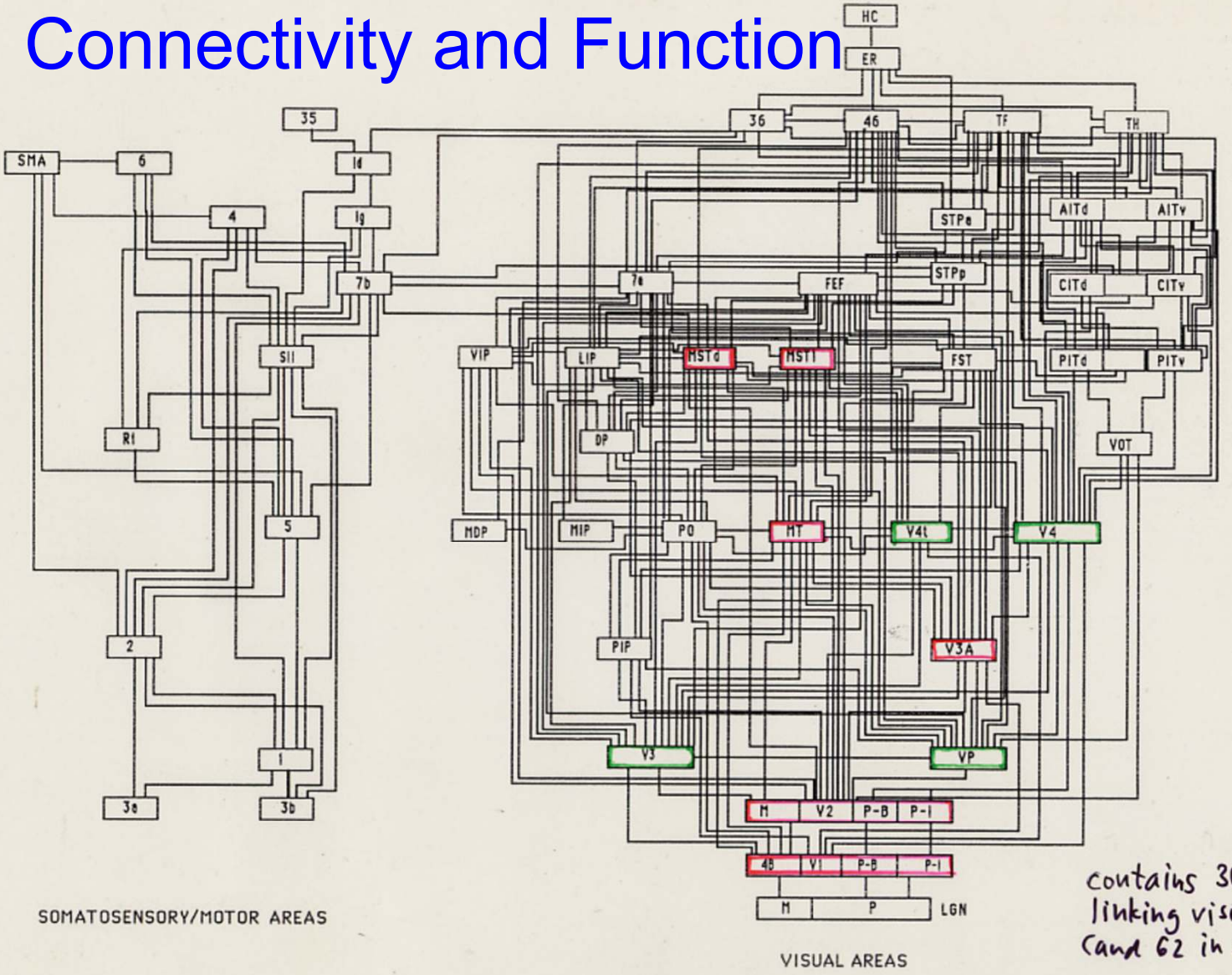



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**Figure 8.** (*See facing page for legend.*)

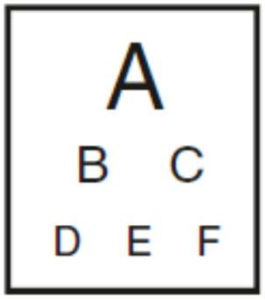
Van Essen D.C. et al., 1990, Cold Spring Harbor Symp. Quant. Biol, 55: 679-696

# Alternative Way to Explain Vision…

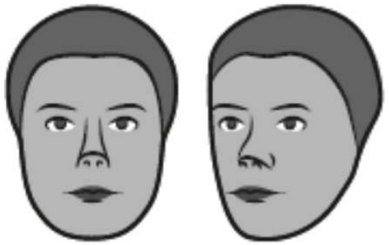
Overview of higher functions of visual cortex

Early vs. Late vision

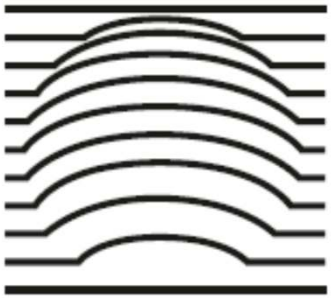
Navigation



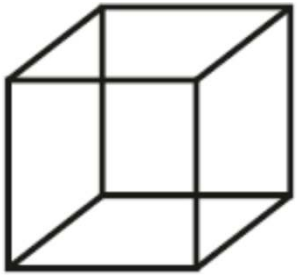

Reading



Face recognition

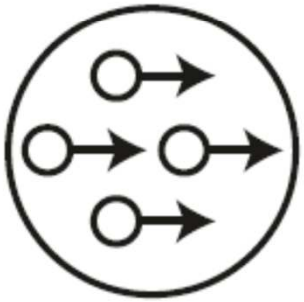


Shades



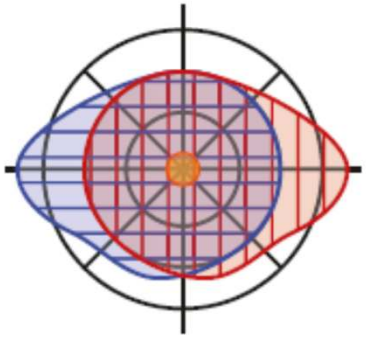
Contours

Stereo disparity



Motion

Color



Form

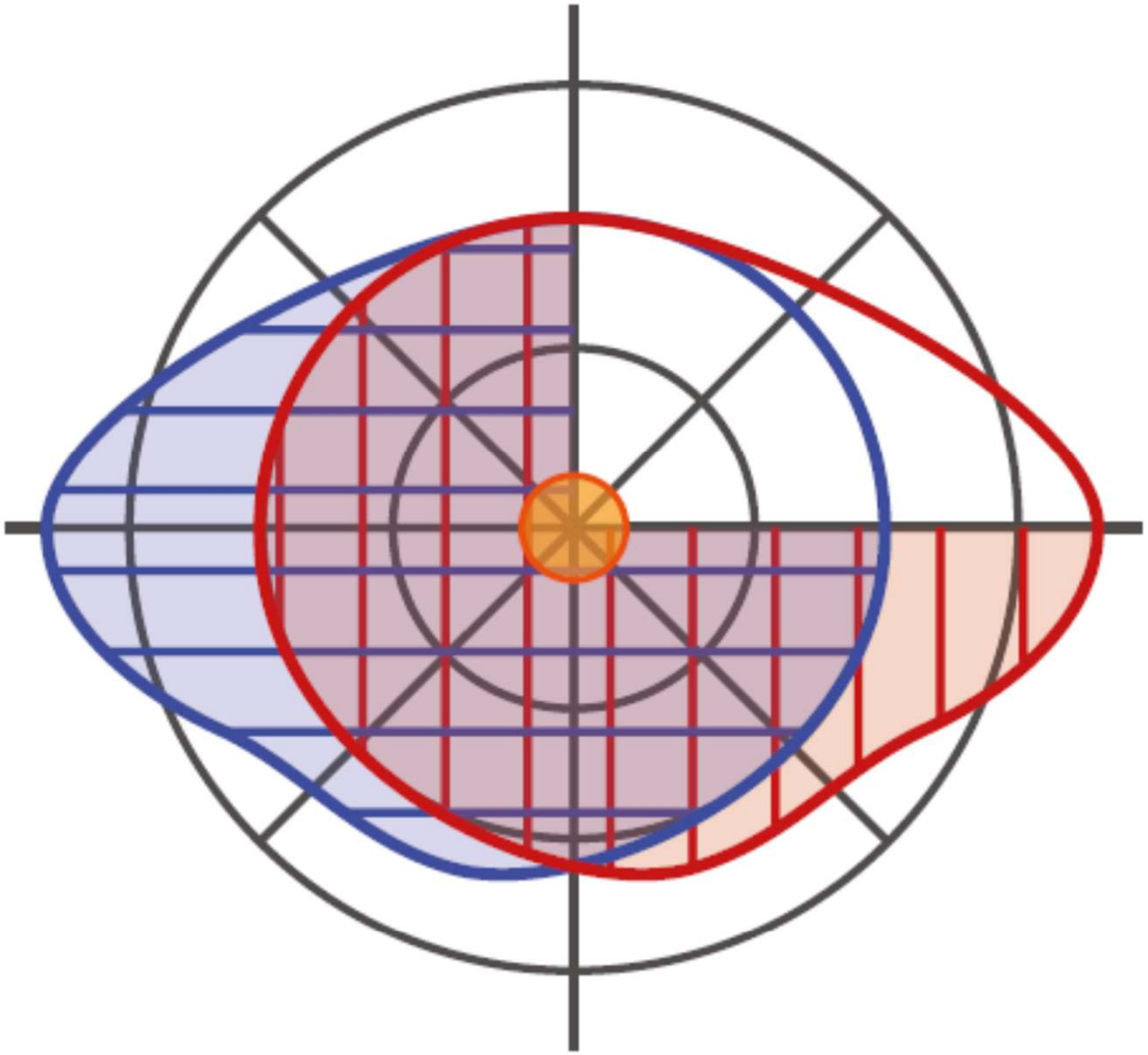


**Fig. 2.3** Binocular visual field, subjective view. The binocular visual field spans 40,000 deg $^2$. The homonymous visual defect typically affects one quadrant (here top right) while the region of best visual acuity (fovea) is spared, due to the overlap of left and right optic radiation

Face recognition – to recognize these blurred faces, some degree of visual acuity is needed

# Blurred faces, however these famous people are recogizable from the context

2 G. Bush Sr.[+] – 5 B. Obama – 4 G.W. Bush – 3 B. Clinton – 1 J. Carter

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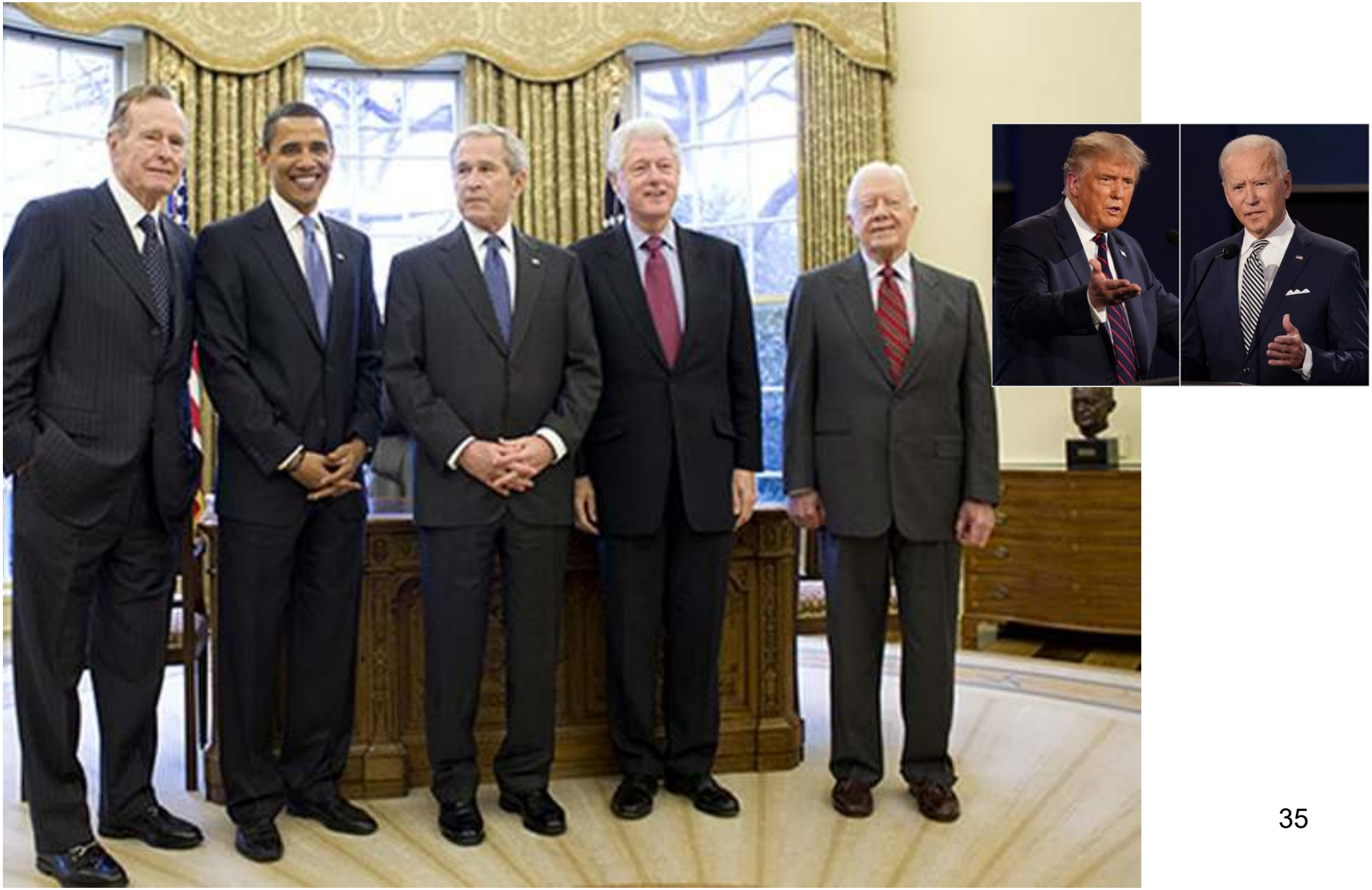
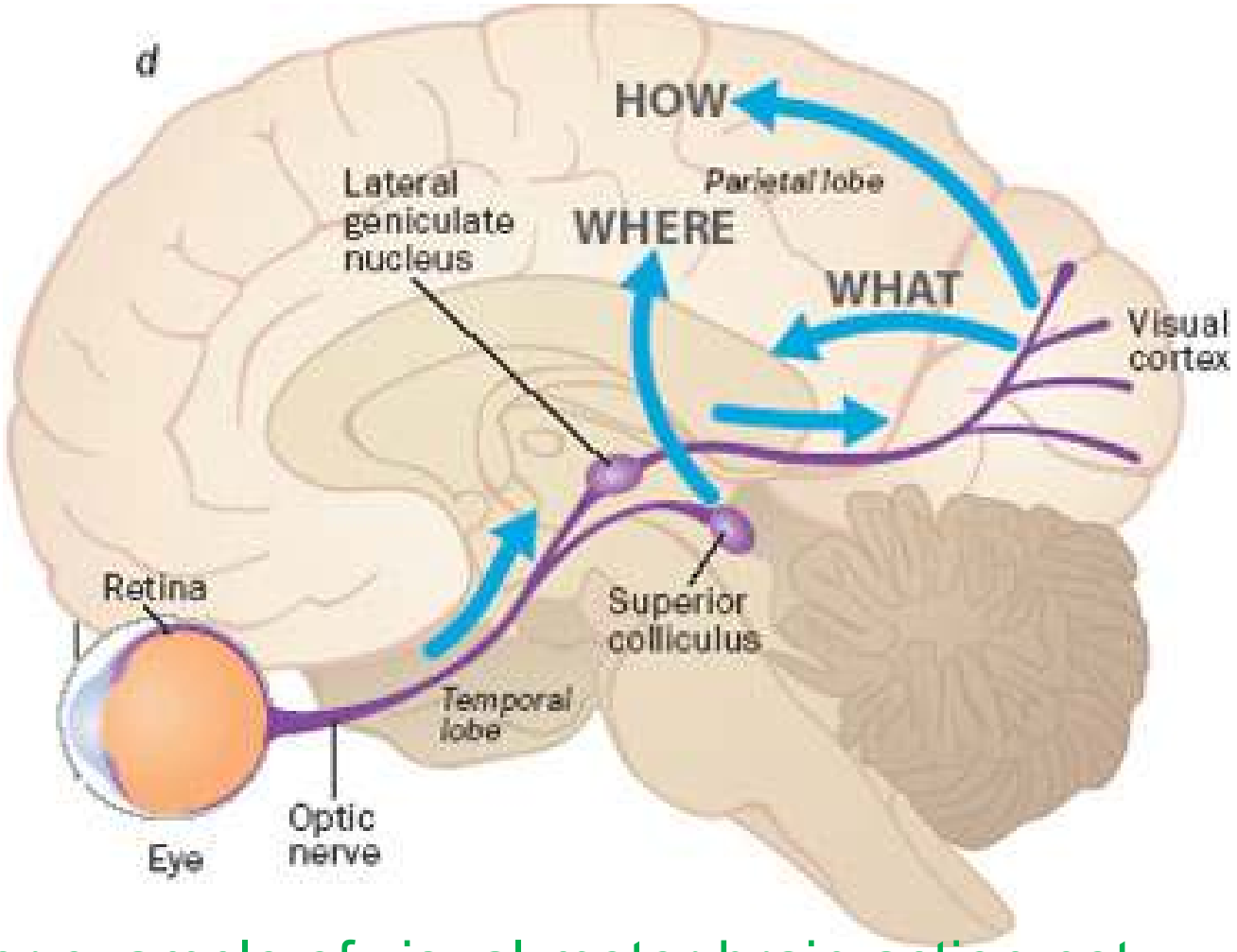


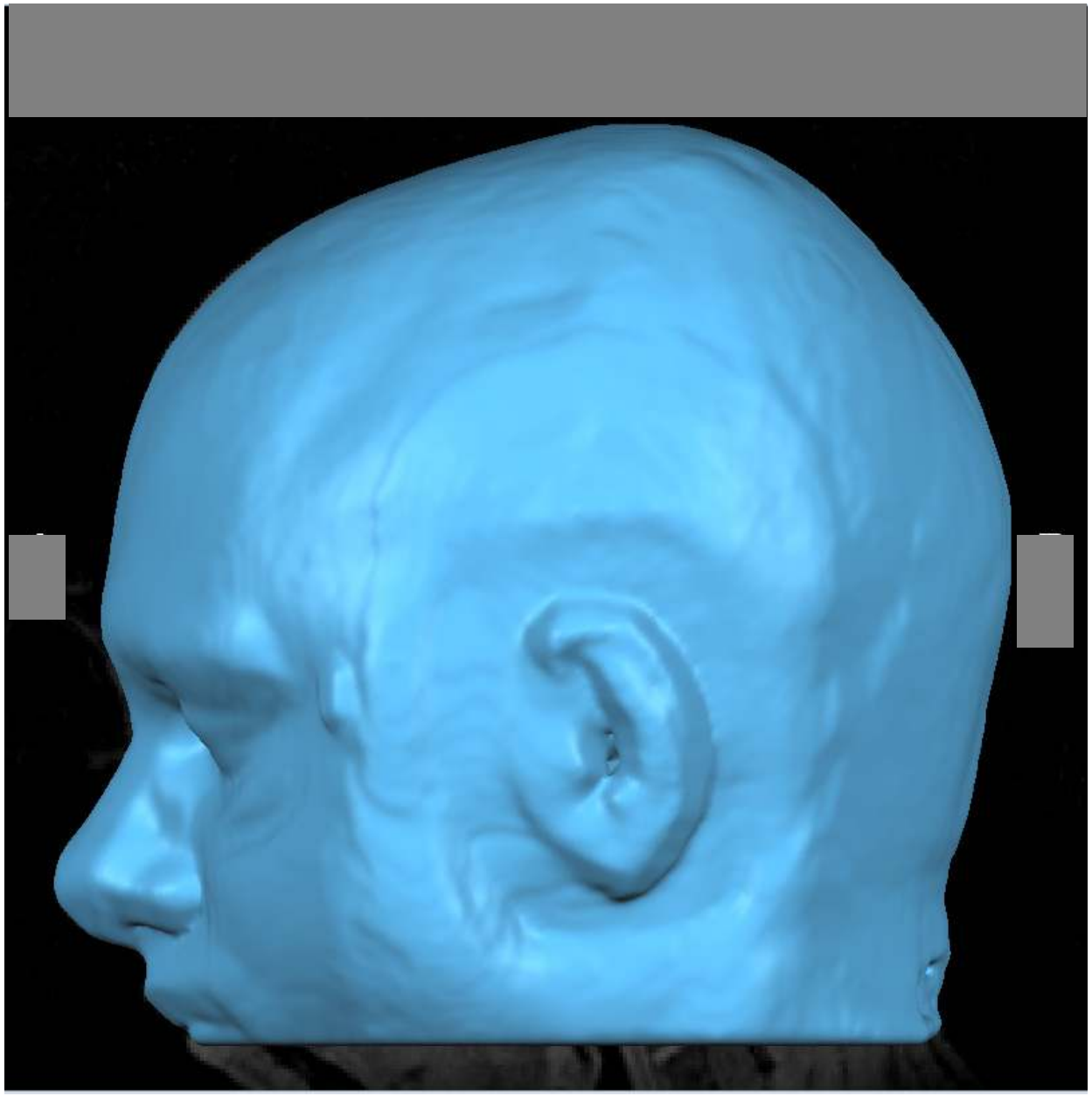
# Blindsight (= slepo-zrakost…)

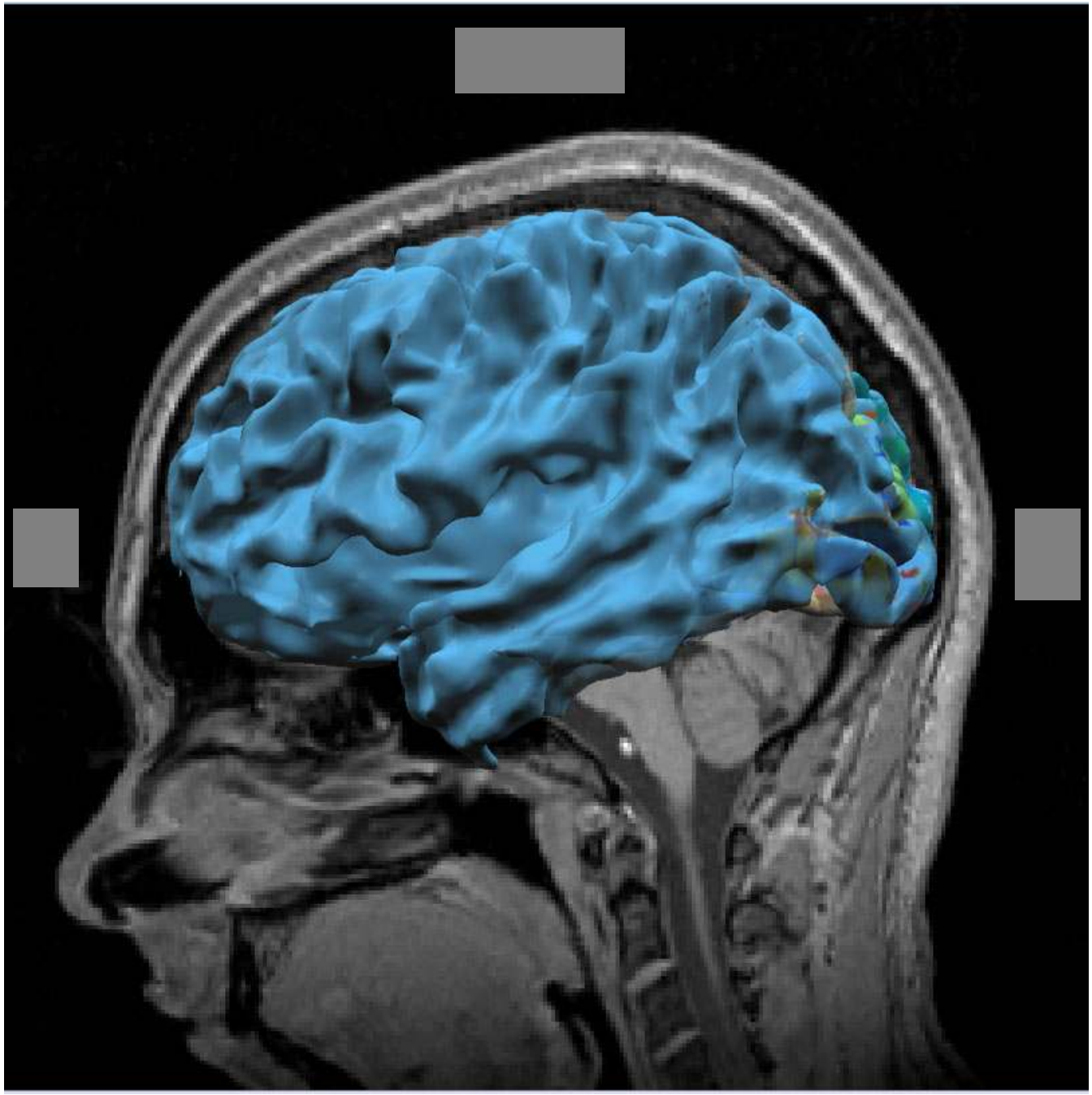


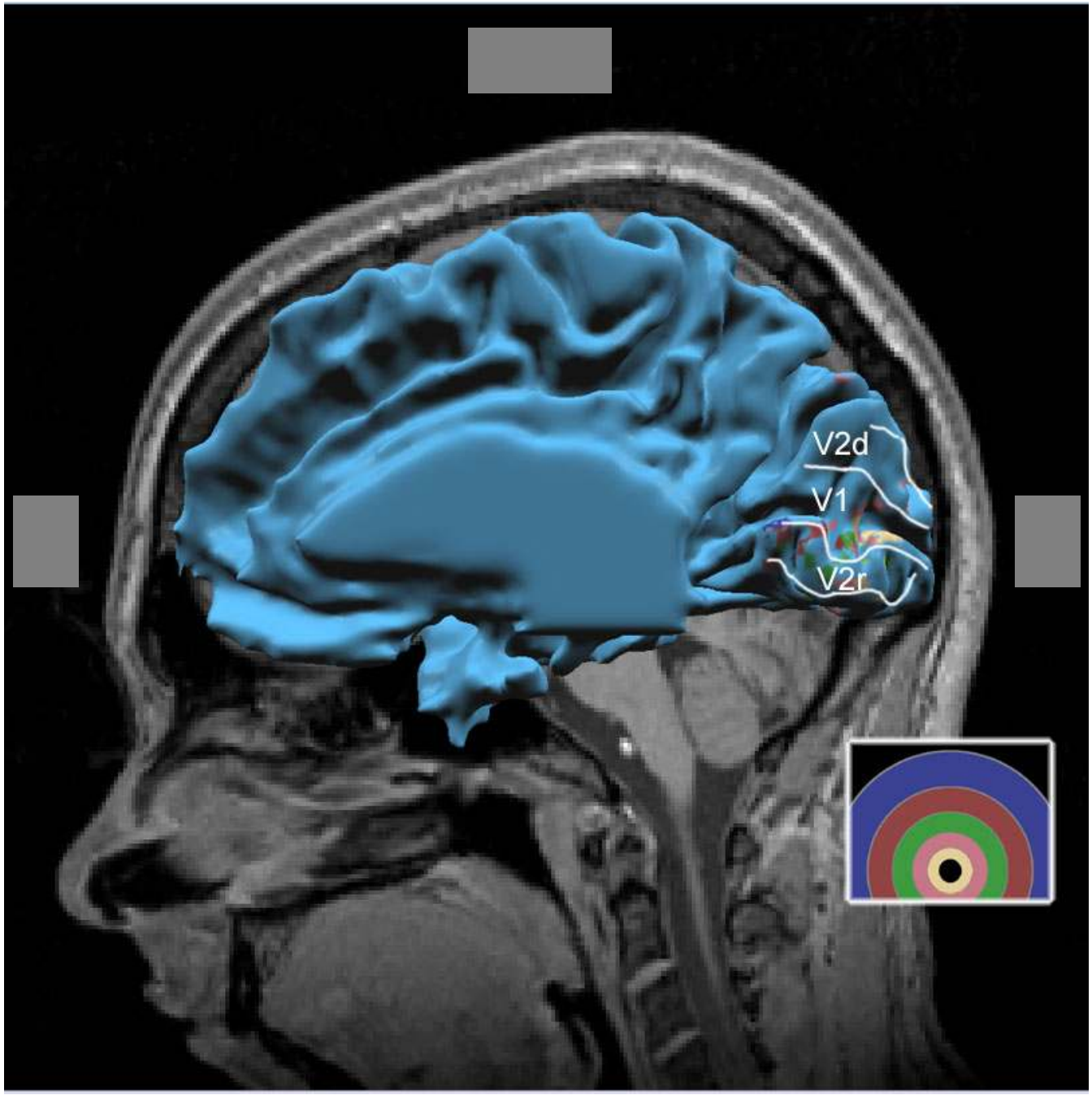

This is another example of visual-motor brain action not accessible to consciousness.

Retreating to Sensory Diagnostic Methods
Magnetic Resonance Imaging (MRI)
(Spatial Domain)
Functional MRI, fMRI
(Spatial and Time Domain)
Evoked Responses, ER, EP, EEG
(Time Domain)

Around year 2000:
Caltech's 3.0 T Trio Siemens magnetic scanner



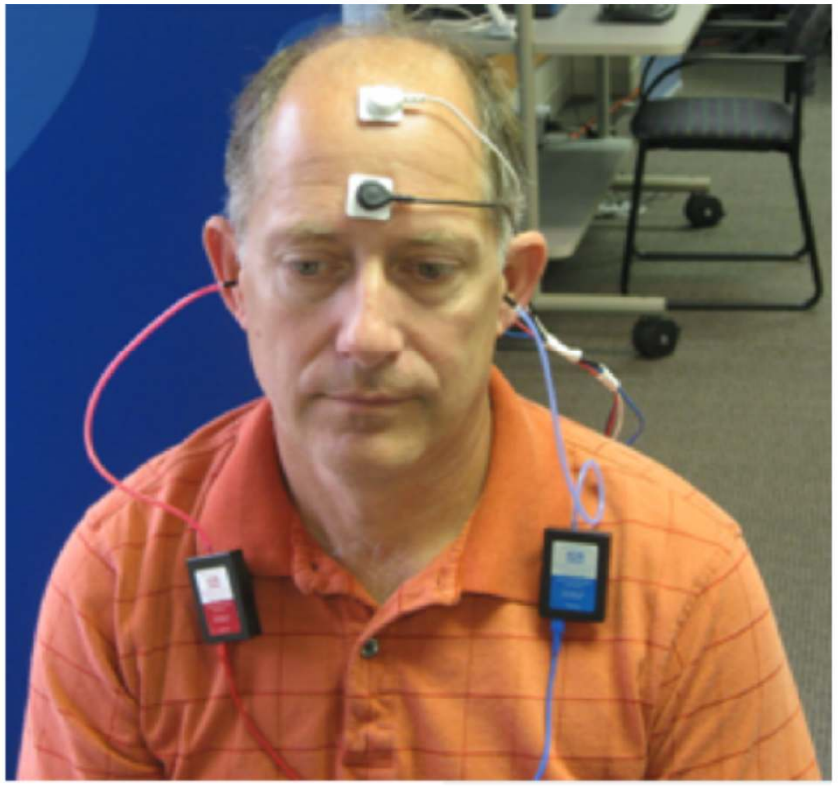



V2d
V1
V2r

# Auditory brainstem responses

## Talk no. 4 – Hearing Loss, Diagnostic Methods in Audiology

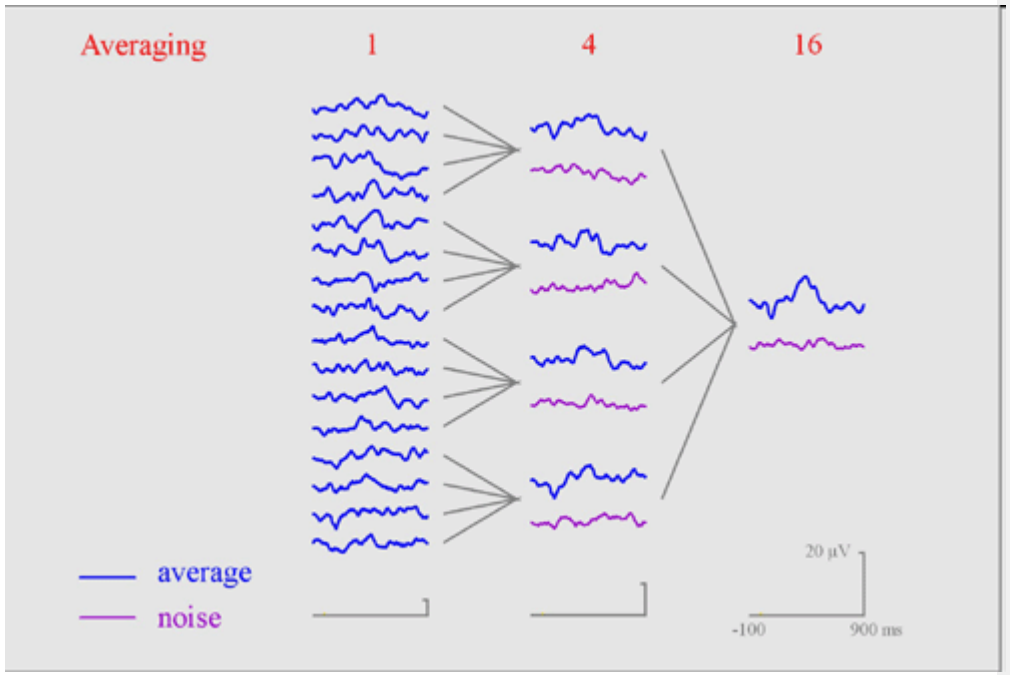
- Auditory brainstem reponses (ABR or BERA) can be recorded by using eletrodes placed on the scalp
- Responses are evoked potentials, i.e. electrical potentials generated in the neural system due to external stimulation (acoustical stimulation in case of ABR)
- Evoking stimulus is a transient signal (click)

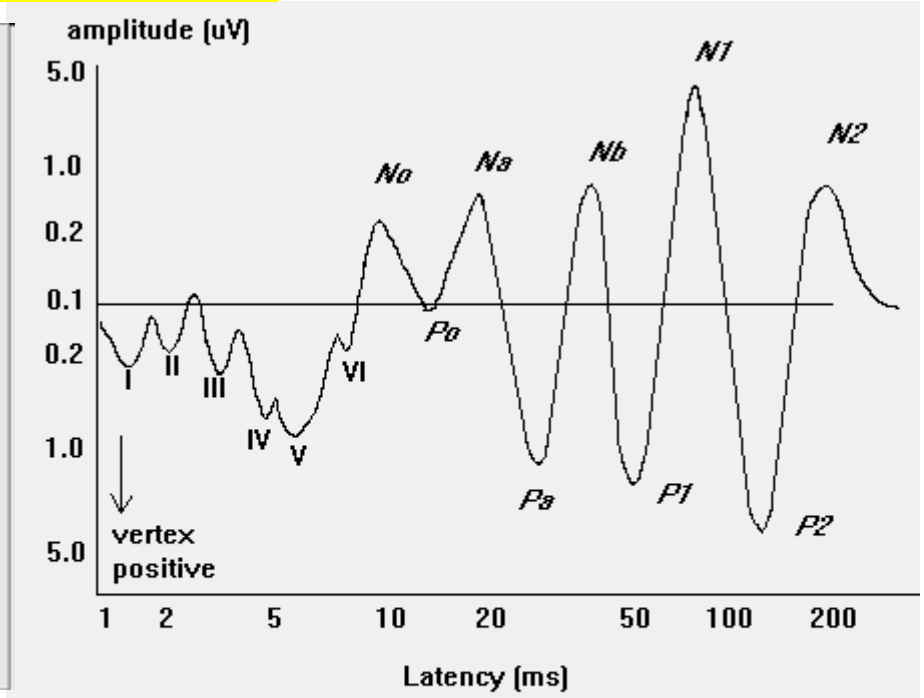


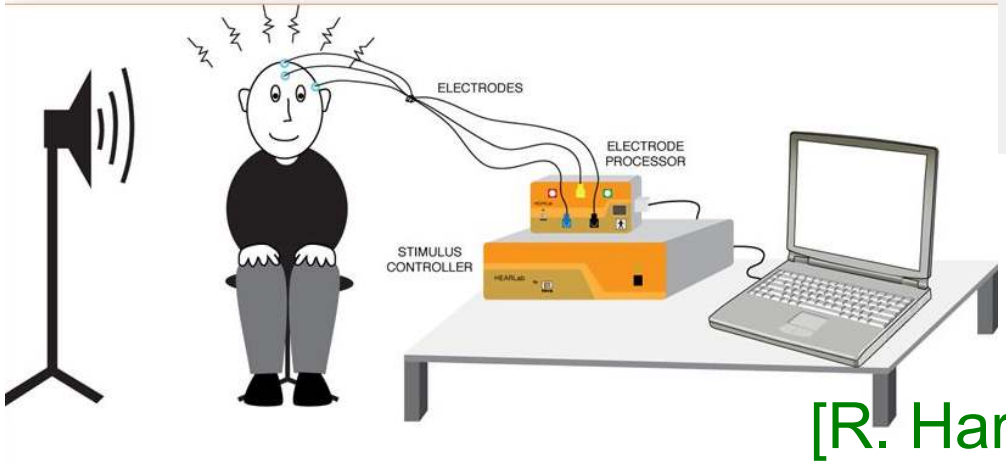
Taken from https://www.audiologyonline.com/articles/evoked-potentials-part-1-good-23607

# Auditory and Visual Cortical Evoked (~~Response~~) Potentials

AEP – Auditory EP
VEP – Visual EP



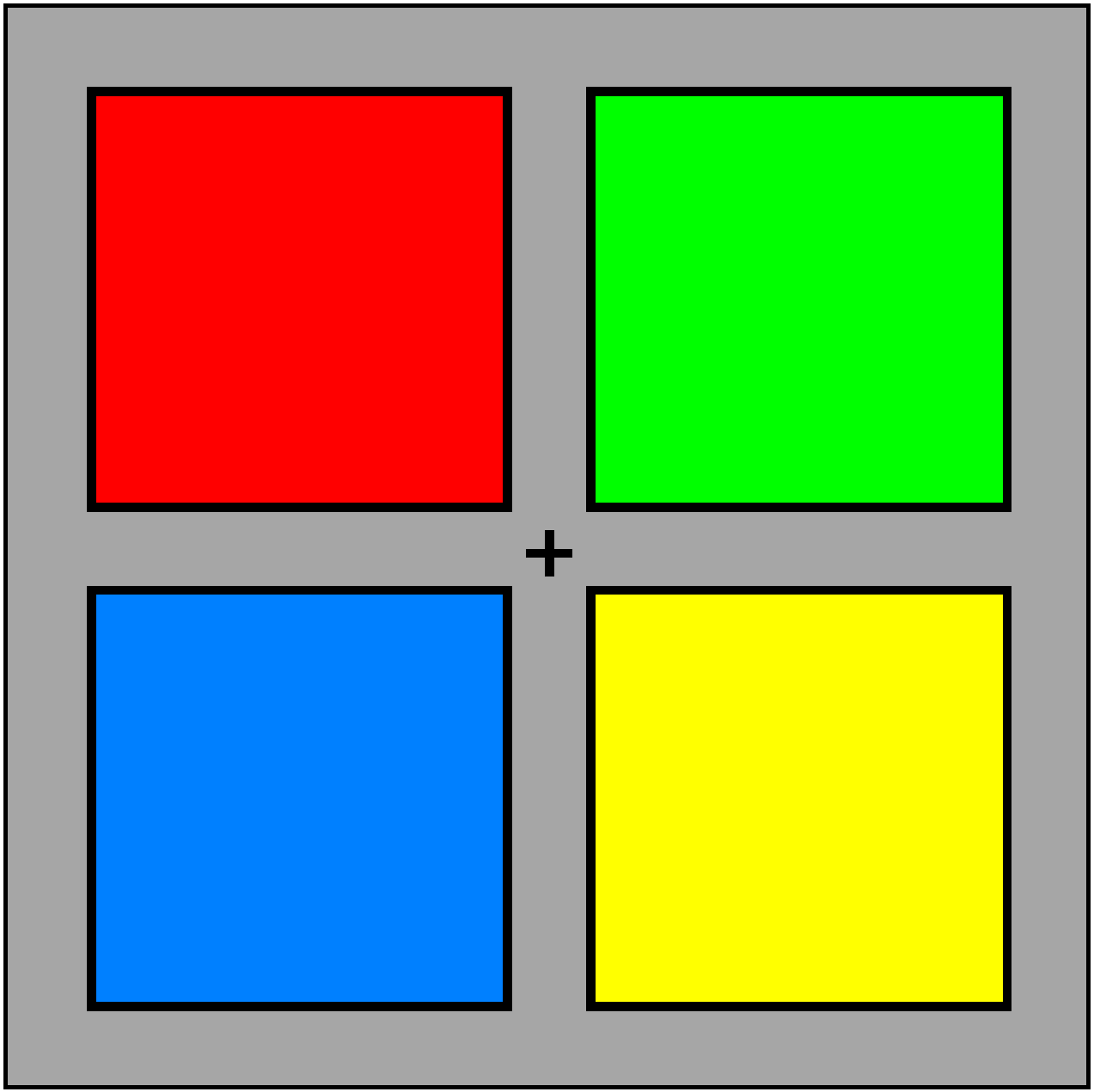




Repetition rate in brainstem ER audiometry

Can be of low freq. sound (40 Hz).CZ:BERA,EN:ABR

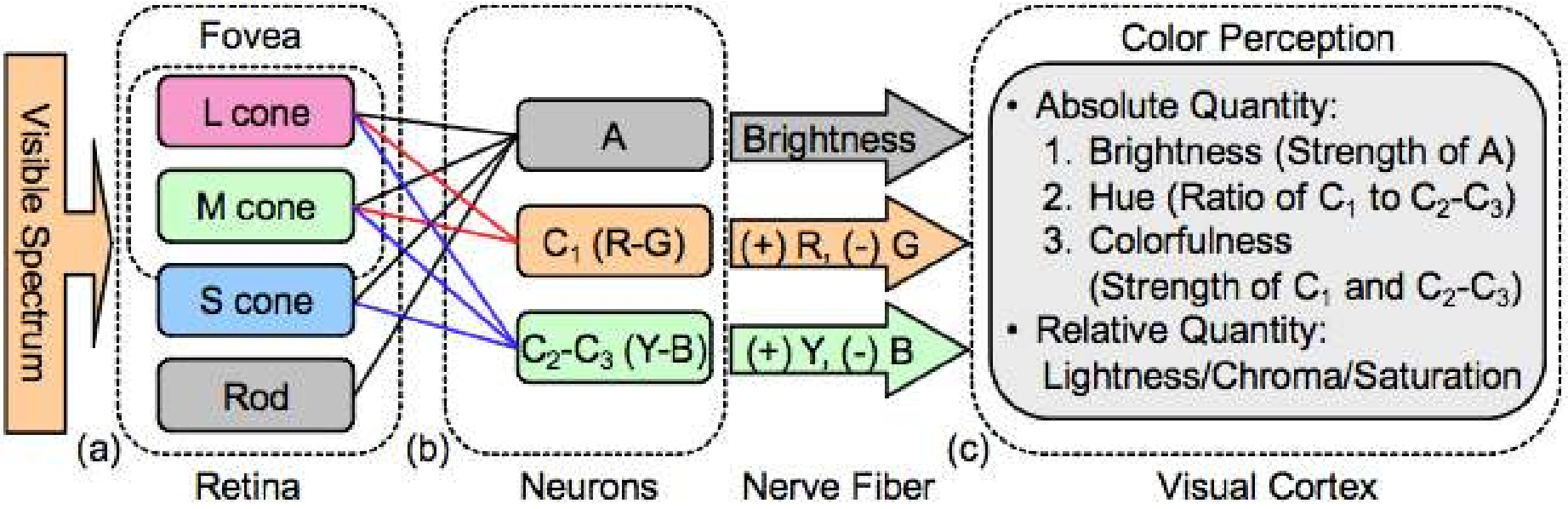
[R. Hari et al., Exp. Brain Res., 1980]



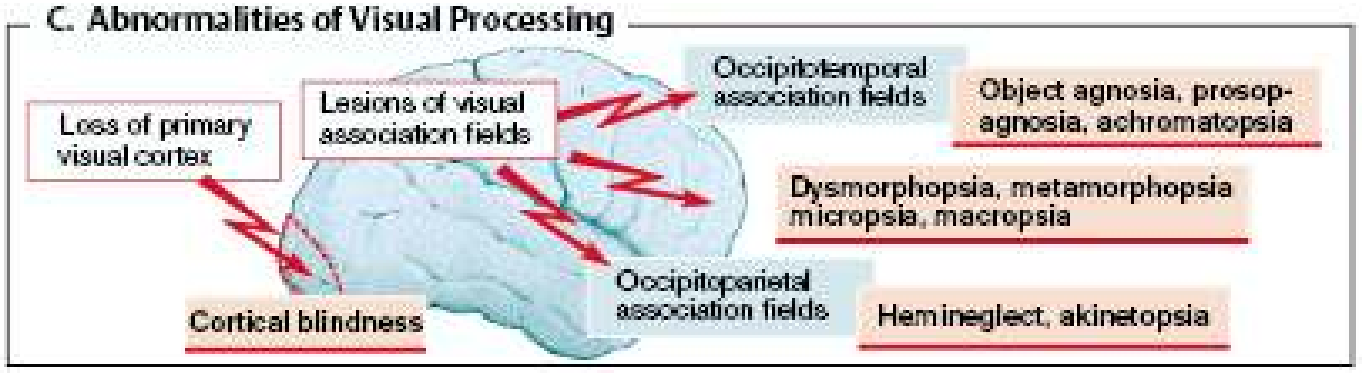
What are the cortical origins of these after-images?

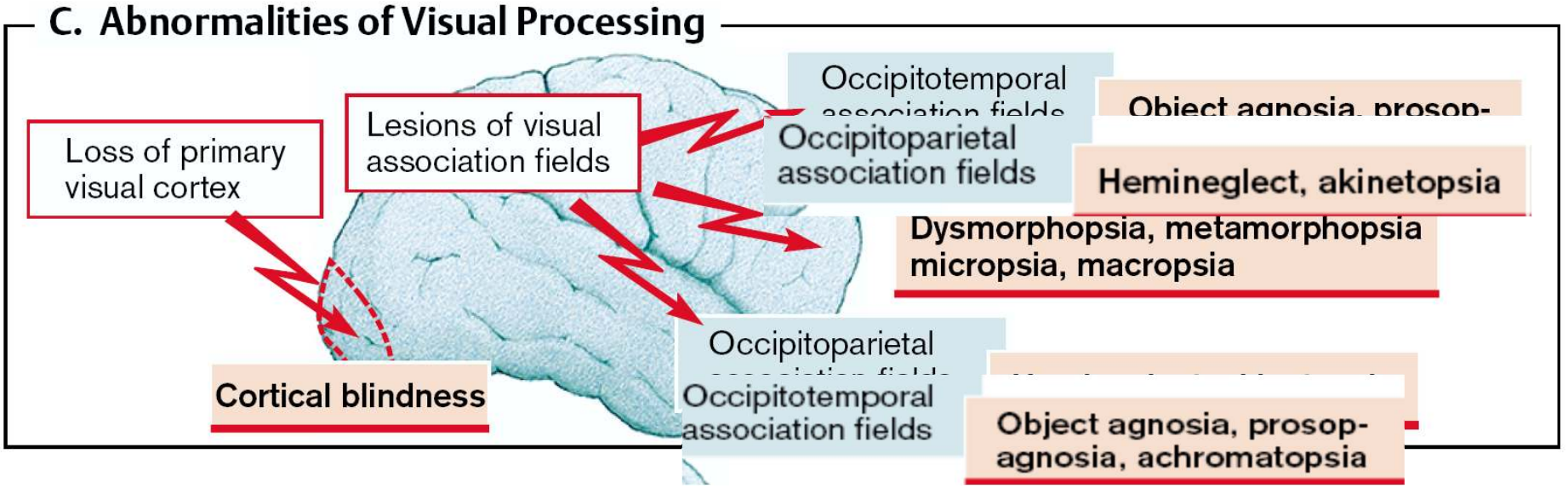
# Color Opponent Processes

# Color Opponent Processes




Color Opponent Processes




# Disorders of Visual Association Cortices

Atlas of Patophysiology, 1st English edition, 2000, p. 327

# There are Many More Numerous Understanding and Interpretation Difficulties, How To Explain Visual Perception as... Physiological, Neural, Psychological Process…

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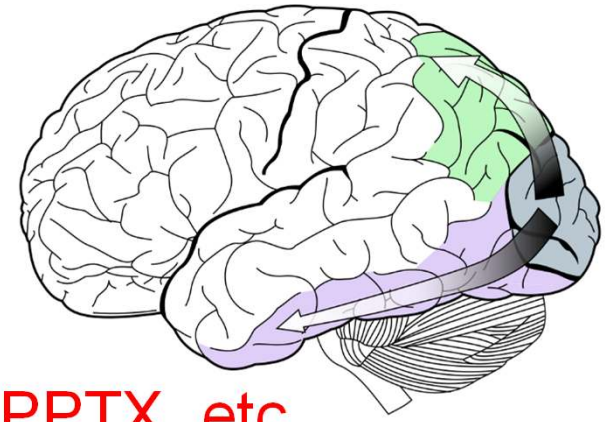
Thanks for your attention



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# END
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