Illusions as Key to Reality

Johannes M. Zanker

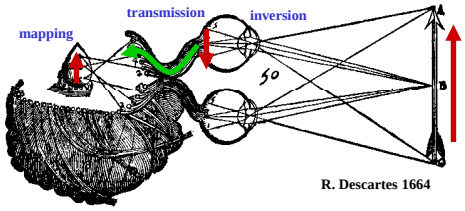
- illusions as part of your everyday experience, as tool of science
- brief revision: basic concepts of visual information processing
- perceiving brightness: contrast illusions, filling in
- real life: the added value of colour information
- theories of colour vision
- encoding contrast in space and time >> more illusions

http://www.pc.rhul.ac.uk/staff/J.Zanker/PS1061/L3/PS1061_3.htm

representing the outside world

fundamental steps of information processing to convert the outside (physical) world into internal (psychological) events: encoding

the flow of visual information



R. Descartes 1664

- is the internal representation a veridical picture of the world ?
- why isn't it upside down ?
- individuals: is it the same for each of us ?

PSYCHOPHYSICS (Gustav T Fechner)

why does this matter ?

understanding information processing helps us to understand the world – and why we our senses give us only an approximation of the world

Watch the "The One Show 13-10-2009"
now on YouTube
http://www.youtube.com/watch?v=VRRM-6g8E1I&NR=1 ….

Gustav Kuhn, our magician > lecture 9 !!!

… illusions in pictorial arts …

illusions play a major role in the scientific study of sensory systems

illusions are most favourite tools in a painter's bag of tricks

(identify various depth cues)

G.B. Tiepolo, 1758
An allegory with Venus and Time
National Gallery, London

contemporary illusion factories

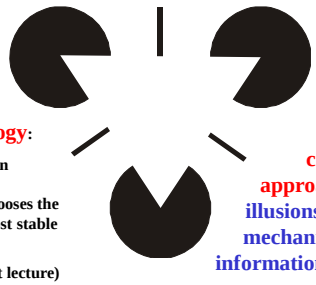
animated arts of the 21st century: cinema - creating big, fast, loud illusions

so what can we learn from illusions about brain function ?

minimal illusions in science

the Kanizsa triangle (Kanizsa, 1976)

illusions reflect perceptual organisation



illusions reflect 'errors' of the processing mechanisms underlying perception

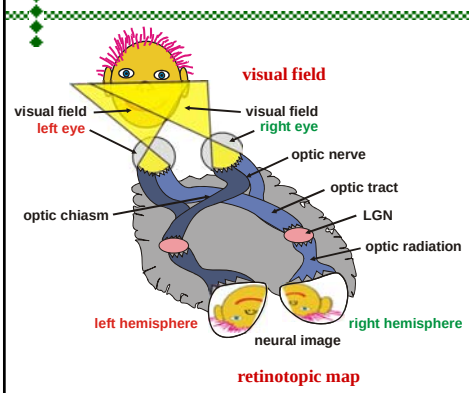
Gestalt Psychology:

the whole is more than the sum of parts - the perceptual system chooses the best, simplest and most stable shape : 'Praegnanz'

(Gestalt 'laws' in next lecture)

computational approach : what do illusions tell us about mechanisms of visual information processing?

a brief revision of the visual system

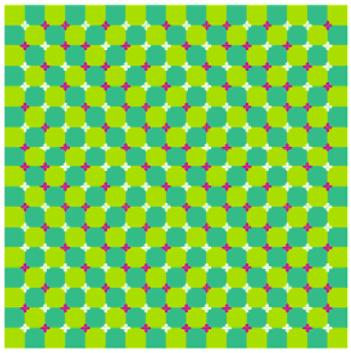


retinotopic map

3D environment
>>>
flat two-dimensional (2D) images in two eyes
>>>
- transmitted
- processed
- re-mapped

>>>
internal 3D representation of objects & events

look at a flat and static world …



simplify the question of representation :

spatial vision

- two-dimensional
- static
- basic properties : brightness & colour

"Primrose's field"
Akiyoshi Kitaoka "Trick eyes"
Tokyo: KANZEN 2002

perceiving bright and dark

white to black: how many shades of grey can you discriminate ?

(8 bit computer screen: 256 grey levels < 5000 perceptual !)

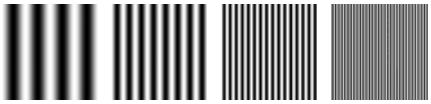
objective luminance >>> subjective brightness :
interpret visual system as measurement device (like a ruler)

what is the metric of brightness?
5000 discriminable greylevels : all of same size (linear intervals like ruler) ?

what is the most meaningful measurement?
absolute levels of grey ? differences between neighbouring regions: contrast ?

perceiving spatial detail

spatial resolution :
what is the finest pattern you can resolve ?



what is the metric of detail (spatial change) ?

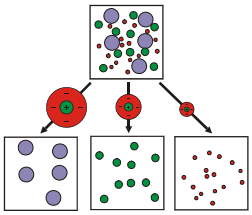
spatial frequency : number of pattern cycles (black and white stripes) per degree of visual angle (Wilson 1991)

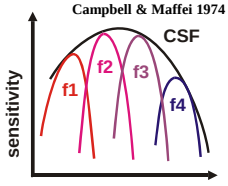
100% visual acuity: approx. 50 cycles per degree

fundamental concept: filtering

parallel sets of pattern analyzers (banks of opponency filters) are operating in the visual stream

size of receptive fields >> optimum size of encoded stimulus: filter mechanism

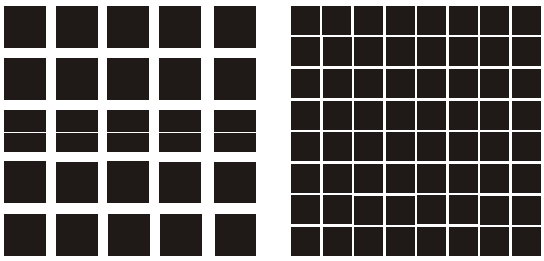




the retinal image is represented in different spatial frequency channels

parallel sets of filters for other properties: colour, orientation, velocity, …

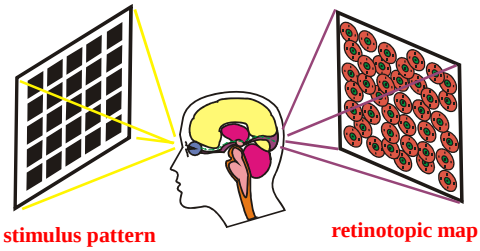
contrast & brightness illusions …



can you see grey spots in the white intersections of lines of this 'Hermann Grid' ???

looking through the eye/brain ...

the outside world is represented in retinotopic maps of neurons with, for example, centre-surround receptive fields : opponency filtering (contrast enhancement, redundancy reduction, spatial filtering)

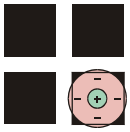


stimulus pattern

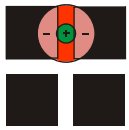
retinotopic map

... and a neural explanation

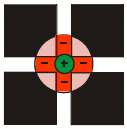
the grey spots in the Hermann grid are believed to be the result of opponency filtering (contrast enhancement)



inside black squares: no stimulation of excitatory centre and inhibitory surround : no overall excitation >> perceived as dark

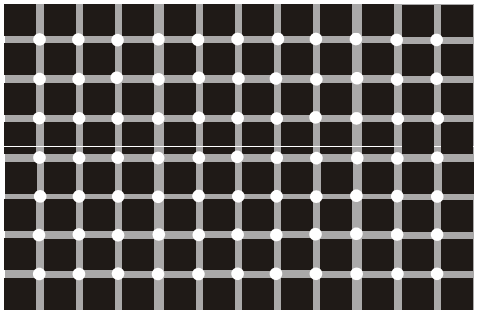


white bars: only small parts of the inhibitory surround are stimulated: excitation dominates inhibition >> bright



white intersections: larger parts of the inhibitory surround are stimulated: small overall excitation >> apparent reduction of brightness

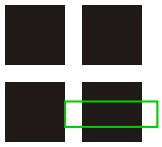
what about the scintillating grid ?



for a solution of this puzzle, see Schrauf et al. 1997

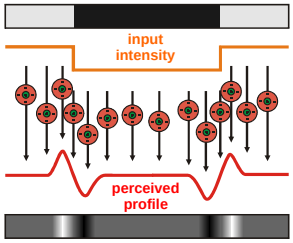
can you see black spots jumping around in the white discs (grid crossings) ???

encoding: image compression



why are the central regions of the black squares not perceived as brighter than boundary regions ?

what you have



opponency >> encode spatial changes

removing redundant (non-informative) image components

what you should see

add-on: image reconstruction

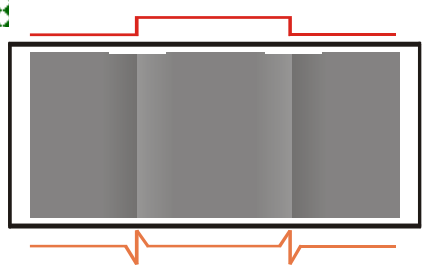
why are the central regions of the black squares not perceived as brighter than boundary regions ?

how is average intensity reconstructed in the brain ?

cortical reconstruction mechanism 'filling in'

regions enclosed by clear boundaries assume same intensity

the Craik-Cornsweet illusion



perceived brightness profile

reconstruction mechanism from sparse data

Cornsweet 1970

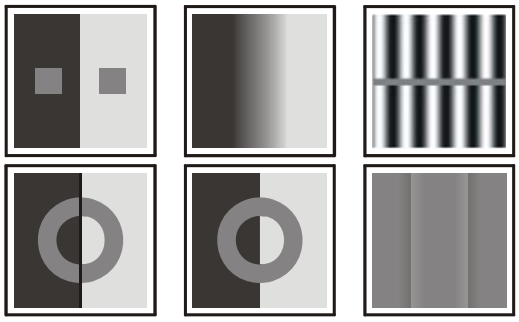
physical luminance profile

this illusion demonstrates ' filling in ' : surfaces between boundaries are apparently covered with uniform brightness !!

if you just encode changes you have to assume uniform properties between changes (and therefore subtle gradients may be ignored)

a Zoo of brightness illusions

simult.contr. Mach-Bands induced grating



Koffka-Ring Craik-Cornsweet

... break ...

questions ?

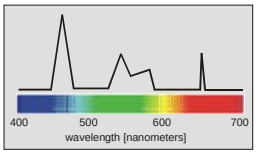
colour information

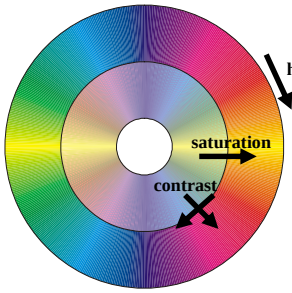
how do you identify objects ??

colour adds a lot of information to an image !!

how to describe colour

physical : two independent dimensions
spectrum = wavelength + intensity





perceptual :

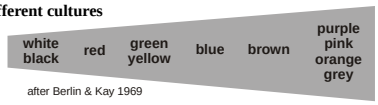
- hue (dimension1: colour type)
- saturation (dimension2: intesity)
- contrast: changes in two directions!

how to measure colour

what is the metric for colour perception ?

problem: spectral composition >>> 2 dimensions: hue & saturation

(1) ask for colour names: different number of names in different cultures



after Berlin & Kay 1969

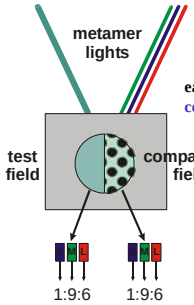
(2) arrange colours according to similarity : colour circle

measure discrimination thresholds: colour space

how many different colours can you discriminate?

(24 bit monitor; 16M > 3M perceptual)

mixing colours: theory 1



additive colour mixing:
superposition of coloured spotlights produces new colours

each colour can be matched by a mixture of three components : metamers (primaries: S M L = blue green red)

Hermann von Helmholtz (1821-1894)

trichromatic theory of color vision

Young (1802)
Helmholtz (1852)

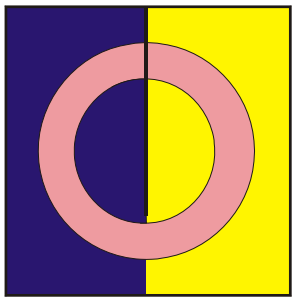
simultaneous colour contrast

simultaneous contrast is the enhancement of colour differences in space

Josef Albers, The Interaction of Color, 1963

… strawberries look most tempting when embedded in green leaves …

opponent colours : theory 2



- **colour contrast is always in blue-yellow or green-red**
- **there is no greenish red or blueish yellow, etc.**
- **contrast enhancement > opponency**

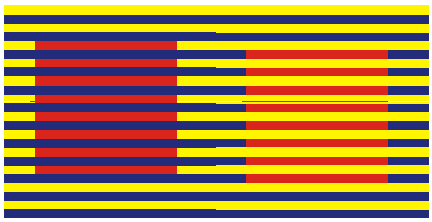
Ewald Hering (1834-1918)

opponent-process theory of colour vision

each of the two theories capture some crucial aspects of colour vision

can you see true colours?

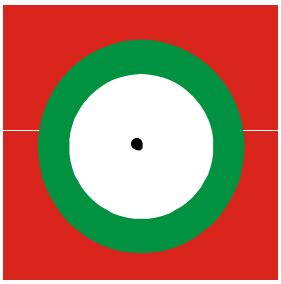
Munker-White (1979) effect : assimilation of colour!



do you know other factors that influence perceived colour?

illumination, tinted glass, colour blindness

successive colour contrast …



fixate the black dot in the centre for 60 seconds ...

… afterimages

… and watch this !

(afterimages are the consequence of encoding stimulus change in time)

the logic of aftereffects

so what happened?

(1) adaptation :

- **after green-red stimulus onset the response jumps to a maximum value and then gradually returns to resting levels**
- **NOTE: this encodes only changes (remove redundancy in time)**

(2) opponency :

- **stimuli of opposite quality (red-green) are subtracted from each other**
- **NOTE: this is conventional feature contrast enhancement**

(3) aftereffect :

- **after stimulus offset grey (= red + green light) appears red where the green channel is adapted: larger neural signal for red than for green : imbalance**
- **NOTE: this creates contrast enhancement in the time domain**

contrast in space and time

successive and simultaneous contrast illusions demonstrate that image properties are not perceived absolutely, but relative to context (space & time)

in other words: contrast encoding is a fundamental process in the visual system in the spatial and temporal domain

What does this mean ?

we have a starting point to develop a general theory of vision, such as:

opponency filters (centre-surround receptive fields) increase/decrease the apparent brightness of a line in front of a darker/brighter background - correspondingly for colour, other features (even faces), and for temporal relationships

summary: brightness & colour

- illusions often are explained as constructing solutions to puzzles, but many of them are a consequence of basic information processing strategies
- visual information is re-organized, compressed, and categorized by parallel and hierarchical processing in the visual stream
- opponent encoding by centre-surround receptive fields - or filters - is a crucial strategy to increase contrast and remove redundancy, and is common in the processing of brightness, colour, etc.
- opponency can account for a number of illusions such as aftereffects and contrast enhancement, but additional mechanisms (like filling-in) are required to deal with other aspects of perception
- how far does this approach take us to understand a large variety of illusions ?

http://www.pc.rhul.ac.uk/staff/J.Zanker/PS1061/L3/PS1061_3.htm
see also chapter 3 & 4 of Zanker 2010;
and 'Visual Illusions' R.L.Gregory, Scientific American 219, 1968

… questions ???

… have a nice weekend (soon) !