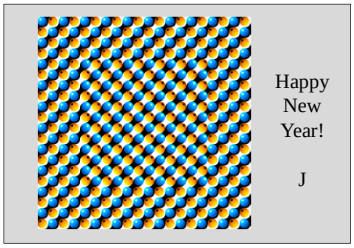
Illusions as Key to Reality

Johannes M. Zanker



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

Learning Outcomes

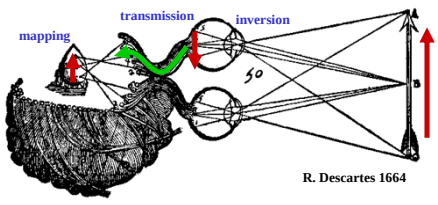
at the end of this lecture, you should be able to understand

- how illusions are a part of your everyday experience
- how illusions can be used as a tool in science
- that perceiving brightness is affected by boundaries: contrast
- the added value of colour information
- the main aspects of the main theories of colour vision
- how contrast is encoding in space and time

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 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,
psychologist & 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

use of illusions in advertising, computer games, movies

gaming industry – explore other universes

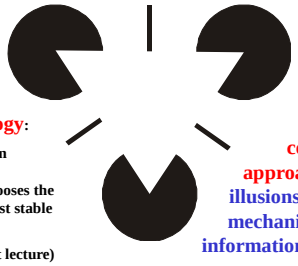
animated arts of the 21st century: cinema - creating big, fast, loud illusions

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

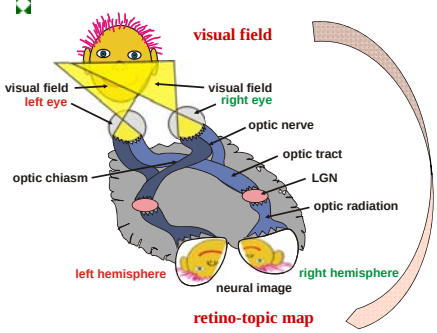
Gestalt Psychology:

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



3D environment

>>>

flat two-dimensional (2D) images in two eyes

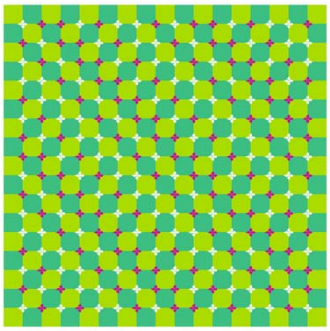
>>>

- **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 shades of grey !)

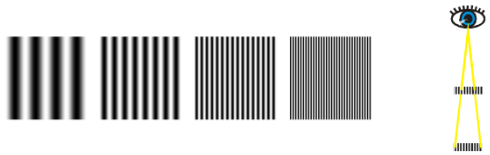
objective luminance >>> subjective brightness :
interpret visual system as measurement device (like a ruler)

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) ?

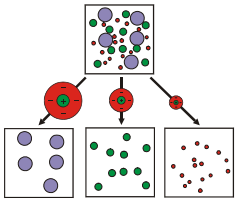
spatial frequency : number of pattern cycles (black and white stripes) per degree of visual angle (Wilson 1991)

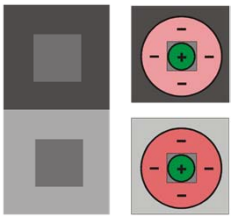
100% visual acuity: approx. 50 cycles per degree

fundamental concept: filtering

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

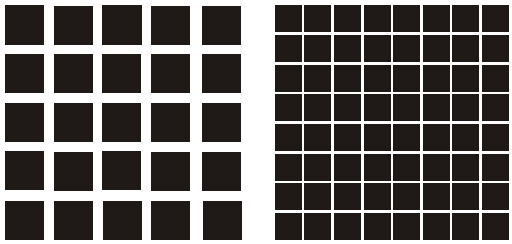
area of receptive fields >> optimum size
of encoded stimulus: filter mechanism





excitation and inhibition of neurons
can explain
perceived contrast enhancement

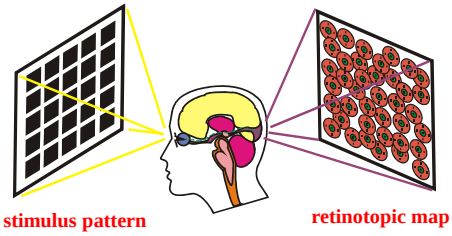
contrast & brightness illusions ...



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)



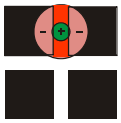
stimulus pattern

retinotopic map

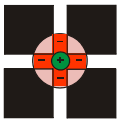
... and a neural explanation

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

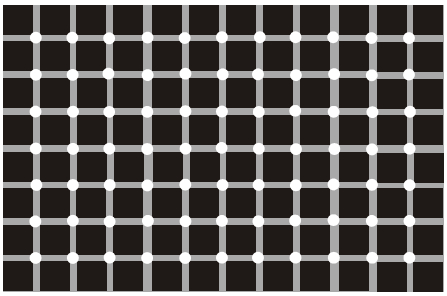


white bars: only small parts of the inhibitory surround are stimulated: excitation dominates inhibition >> bright



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

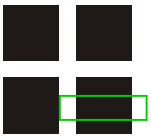
what about the scintillating grid ?



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

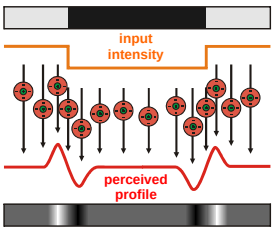
can you see **black** spots jumping around in the white discs (grid crossings) ???

encoding: image compression



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

what you have

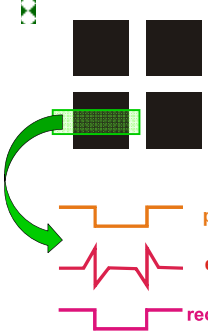


opponency >> encode spatial changes

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 ?

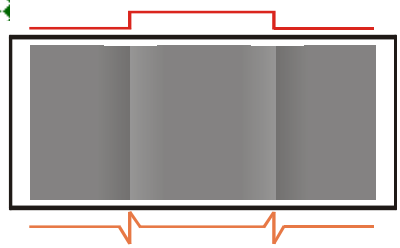
how is average intensity reconstructed in the brain ?

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

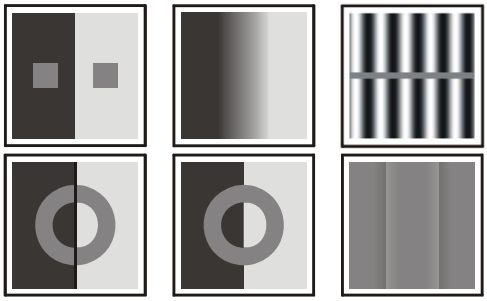
physical luminance profile

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 ?

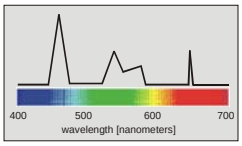
colour information

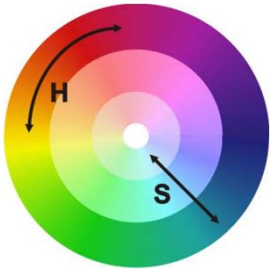
how do you identify objects ??

colour adds a lot of information to an image !!

how to describe colour

physical : two independent dimensions
spectrum = wavelength + intensity





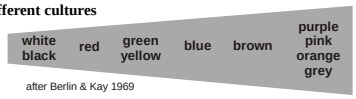
perceptual :

- **H - hue (dimension 1: colour type)**
- **S - saturation (dimension 2: intesity)**
- **C - 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



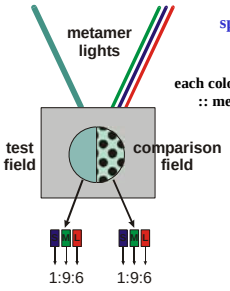
after Berlin & Kay 1969

(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: L M S = red green blue RGB)

Hermann von Helmholtz (1821-1894)

trichromatic theory of color vision

Young (1802)
Helmholtz (1852)

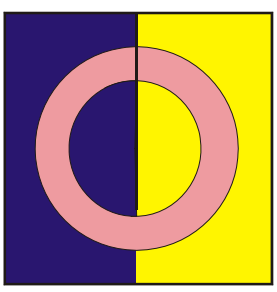
simultaneous colour contrast

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**

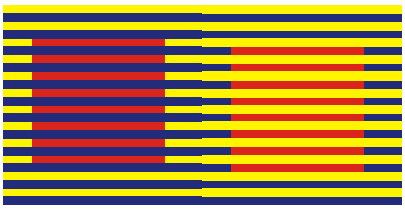
Ewald Hering (1834-1918)

opponent-process theory of colour vision

NOTE: 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 in absolute terms,
but relative to context (in 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 mechanisms**
- **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 week !