Visual Effects of Light

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Light is life

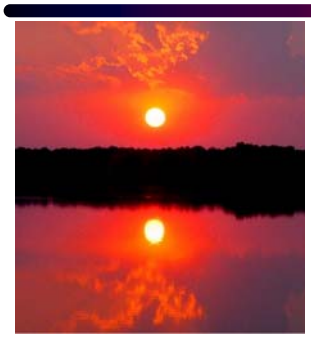
If sun would turn off the life on earth would extinct

Light
Warmth

Sun as a deity (god)

Almost all old religions worship a sun as a deity – to assure that it will come out next morning also.

Rhythm of light is rhythm of life



We don’t worship sun anymore but we are still dependent on its day-cycle.

Rhythm of light: morning

There is very few light in the morning but it increases with the time.

Colour of light changes from red to orange and to yellow.

Diurnal organisms starts with activities which grow together with the light.

We are sleepy in the morning and we are slowly starting out activities.

Rhythm of light: day

Sun is high, there is plenty of bright white light anywhere.

Diurnal organisms are at the peak of their abilities.

We are at the top of our abilities also and at the middle of our working day (coincidence?).

Rhythm of light: evening

In the evening, the light turns red, and is slowly decreasing.
Diurnal animals are getting less active and are preparing for the resting part of the day.

We are tired so we are concluding our work and are also preparing for the night.

Rhythm of light: night

At night the light is “dull and colorless”.

Organisms are, with exception of nocturnal ones, resting.

We are resting and gathering strengths for the next day also.

Visual and nonvisual effects of light

MIND

VISION

HEALTH

How light influences human being?

EMOTIONS

FEELING

MOOD

Visible & invisible light

Light allows us to use one of the senses - vision

The sun's rays that spread among the trees, we see only because they are reflected by particles in the air mist. Otherwise they would remain invisible to our eyes.

Light is the main source of information

We obtain over 80% of information from the environment through the vision.

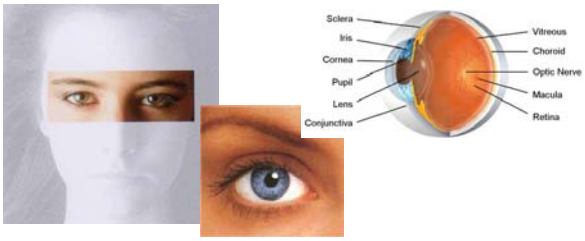
Light not only enables but also affects our perception of the environment.

How do we feel if we can not see?

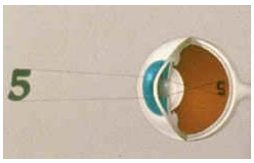
What technology was developed because of vision:
Written language, drawings, formulas, plans, photographs ...

Human eye – the visual organ

- The human eye, one of the most complete optical instruments.



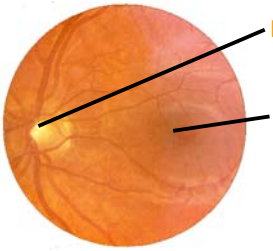
The human eye as a camera or vice versa



Pupil, ocular lens and retina function similarly to:

Aperture, lens and film (CCD sensor) in a camera.

How do we see - retina



Blind Spot

Macula with fovea (without choroid, which would reduce visual acuity)

Retina contains foto-receptors that are sensitive to light.

Blind spot

Close your left eye and watch an apple with your right eye. Bring the image closer and suddenly orange will disappears. Its image is located in the blind spot.
(diameter 2 cm, distance between 12 cm)

How do we see - receptors

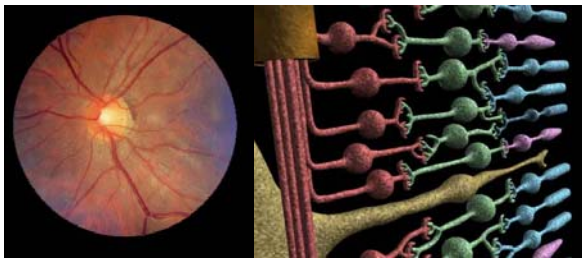
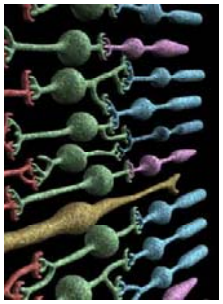


Foto-receptors in the eye convert incident light into pulses that nerves lead to the brain.

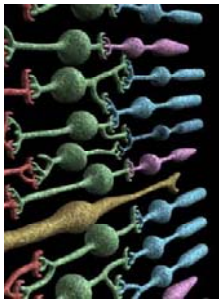
Cones and Rods



Cones

- There are 4.500.000 cones in average eye.
- They are less sensitive to light.
- They distinguish colors.
- They are arranged mostly in fovea and macula.
- They contribute to vision in well lit environment – photopic vision.

Cones and Rods

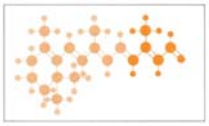


Rods

- There are 90.000.000 rods in average eye.
- They are more sensitive to light
- They can't distinguish colors.
- They are placed mostly outside macula.
- They contribute to vision in dark environment- scotopic vision.

Cones and Rods

retinal in dark



retinal on light

In rods there is a pigment rhodopsin, which consists of two parts: opsin and retinal. Under the influence of light, the retinal moves and allows chemical substances to break into the opsin which causes the nerve cells to begin to emit action currents.

Rhodopsin is red but bleaches under the influence of light.

Cones and Rods

Your manor, which in sunny day looks like this ...

Cones and Rods

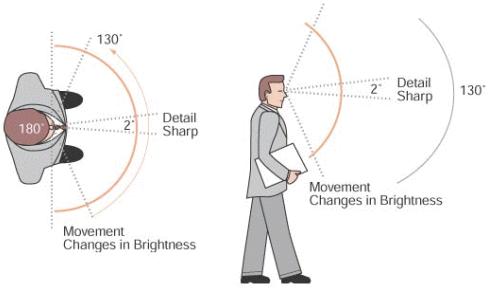
A black spot in the middle is due to the fact that there is no rods in fovea and therefore this area can not be seen at night.

... looks in the middle of the night like this.

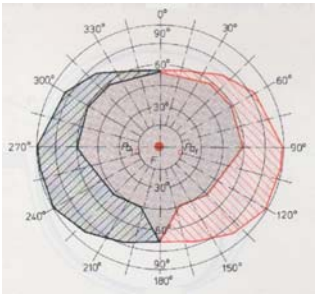
Characteristics of human eyes

Field of vision
Dynamic range
Visual acuity
Eye adaptation
Eye accommodation
Depth perception
Optical aberration

Field of vision



Field of vision



The approximate field of vision of a human eye is:

95° out,

75° down,

60° in,

60° up.

Luminance dynamic range

Daylight luminances from 10 cd/m² to 10^{+4} cd/m²

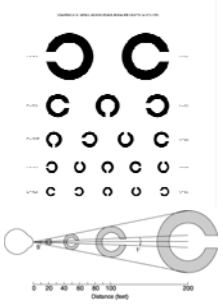
Road lighting luminances from 10^{-2} cd/m² to 10 cd/m²

Moonlight luminances from 10^{-6} cd/m² to 10^{-2} cd/m²

Temperature range ? from 15 °C to 25 °C

Static contrast ratio (no adaptation) is 1:100; dynamic range (with adaptation) is 1:1.000.000.

Visual acuity

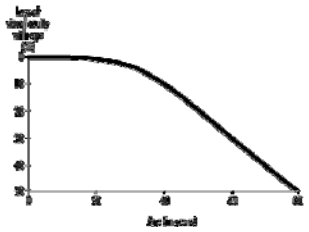


Visual acuity is a measure of the spatial resolution; ability to see a gap in a broken ring.

Vision 6/6 (20/20): gap is seen from distance of 6 m

the size of the gap is so, that from the distance of 6 m represent 1 arc minute.

Visual acuity



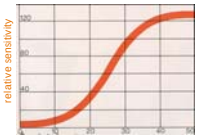
Visual acuity deteriorates with age.

Maximum visual acuity is in centre of the field of vision because of the densely packed cones in the fovea.

Eye adaptation

Eye adaptation is the ability of the eye to adjust to various levels of darkness and light

Eye adaptation



The eye takes approximately 20 – 30 minutes to fully adapt from bright sunlight to complete darkness.

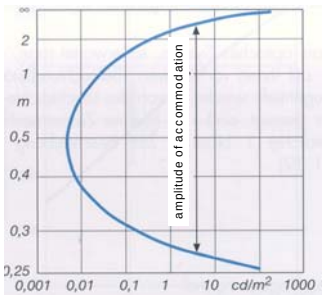
A minor mechanism of adaptation is the pupullary light reflex, adjusting the amount of light that reaches the retina.

Changes in the sensitivity of rods and cones in the eye are the major contributors to dark adaptation.

Eye accommodation

Accommodation is the ability of the eye to focus objects lying at different distances.

Eye accommodation

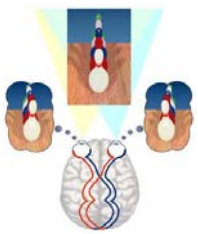


The amplitude of accommodation is influenced by the luminance level to which the eye is adapted.

The amplitude of accommodation declines with age.

Depth perception

Depth perception is the ability to see the world in three dimensions and to perceive distance.



Depth perception arises from a variety of depth cues:

- **binocular cues that require input from both eyes and**
- **monocular cues that require the input from just one eye.**

Binocular cues:

- **stereopsis,**
- **convergence,**
- **shadow stereopsis.**

Depth perception

Monocular cues provide depth information when viewing a scene with one eye (or on picture):

- motion parallax,
- perspective,
- familiar size,
- aerial perspective,
- accommodation,
- peripheral vision,
- texture gradient,
- lighting and shading.

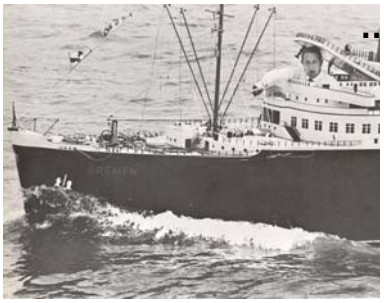
Depth perception

But the monocular cues are not always reliable – optical illusions.

Depth perception

So we can not always rely on familiar size …

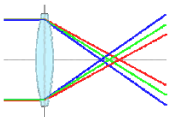
Depth perception

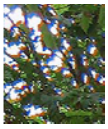


…especially if we do not see the whole picture.

Optical aberration

Optical aberration is an imperfection in image formation by an optical system





Spherical aberration, which occurs when light rays strike a lens or mirror near its edge

Chromatic aberration, caused by differences in refractive index for different wavelengths of light

Functioning of the eye - vision

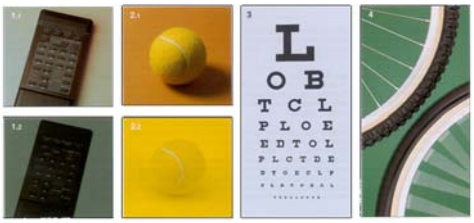
The human eye distinguishes following:

- difference in brightness
- difference in color
- shape
- movements or motion
- distance

But only if there is enough light. Better the lighting conditions better the performance of the eye.

Functioning of the eye - vision

- Four minimum requirements need to be met to permit perception!



Minimum luminance

of observed objects and surroundings

Objects that can be easily identified in detail during the day become indistinct at twilight and are no longer perceptible in darkness.

Minimum contrast

in brightness or colour

Same color but luminance contrast.

Same luminance but color contrast.

Minimum size

Objects need to be of a *minimum size!*

Objects need to be of a *minimum size!*
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Objects need to be of a *minimum size!*

Minimum time

Minimum time for adaptation:

eyes need time to adapt to the environmental luminance.

Minimum time for observation:

wheels turning slowly can be made out in detail but become blurred when spinning at higher velocities.

Perception

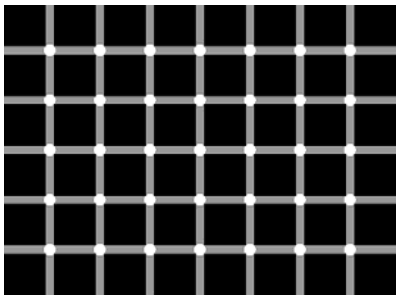
What we see (perceive) is not always the same as what our eyes see.

Perception is the process of attaining awareness or understanding of sensory information. What one perceives is a result of interplays between past experiences, including one's culture, and the interpretation of the perceived.

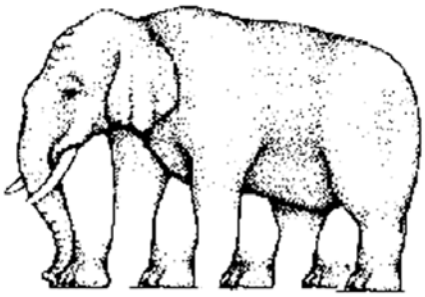
Perception

What was wrong with the previous picture?

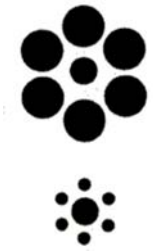
Perception



Perception



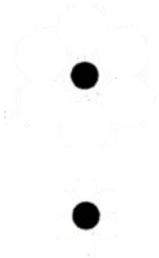
Perception



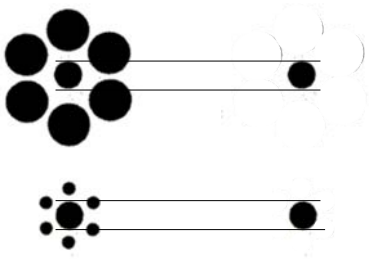
Are dots in the middle of the same size?

Perception

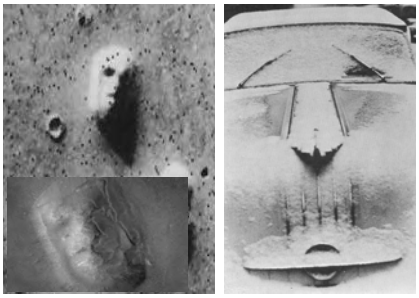
Are these two dots of the same size?



Perception



Perception

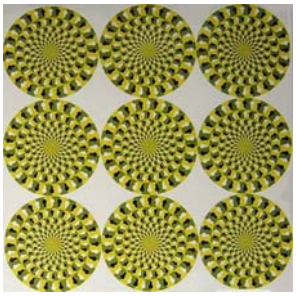


Why some pictures remind us on faces?

Perception

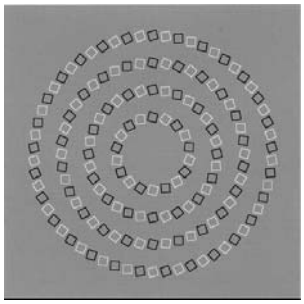
Will the man in the middle jump into the pool or …?

Perception



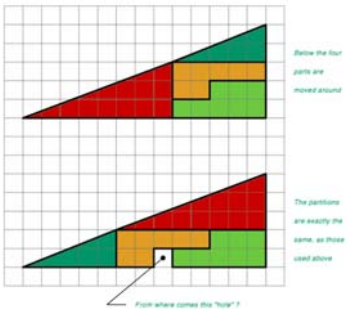
Which of these wheels is turning left and which right?

Perception



Spirals or …?

Perception



Where is the missing square?

Perceptual constancy

There are several types of perceptual constancies in Visual perception:

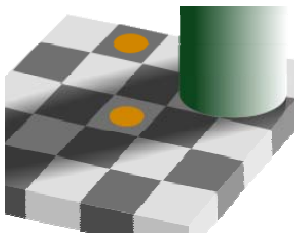
shape constancy,
size constancy,
color constancy,
lightness constancy,
distance constancy,
location constancy.

Color constancy means perceiving a color as "constant under changing conditions of illumination" and is the achievement of a very complicated "calculation" by an unconsciously working apparatus within our central nervous system.

Color constancy

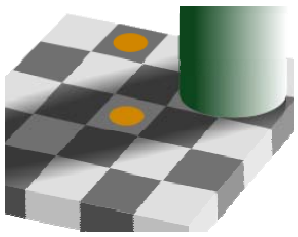
Everybody knows that this mug has just one color. It just looks different because of light and shadow.

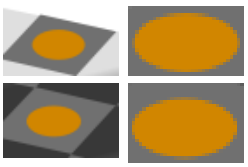
Color constancy



But what about these two orange dots? are their colors same or different?

Color constancy





Light helps at work

Good light(ing) can bring greater productivity, quality and safety.

But not always …

In some cases light might be disturbing.

Disturbing effects of light – glare

Glare is caused by a significant ratio of luminance between the task or surrounding and the glare source.

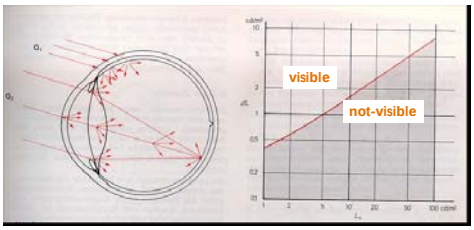
Glare can be divided into two types:

- **discomfort glare,**
- **disability glare.**

Discomfort glare results in an instinctive desire to look away from a bright light source or difficulty in seeing a task. Disability glare renders the task impossible to view, such as when driving westward at sunset.

Disturbing effects of light – glare

Glare is caused by the inter-reflection of light within the eyeball, reducing the contrast between task and glare source to the point where the task cannot be distinguished. Glare can be so intense that vision is completely impaired.

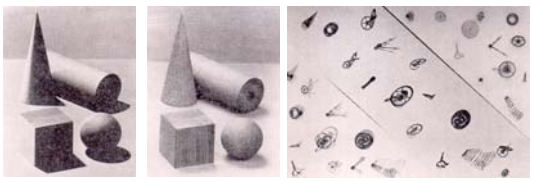


Disturbing effects of light – reflected glare

Reflected glare causes the same kind of disturbance as direct glare - reduces the contrasts needed for trouble-free vision.

Disturbing effects of light – shadows

Light and shadow are vital to ensure that objects, surfaces and structures are clearly identifiable - shadows make it easier to detect 3D objects. However, within deep shadows with hard edges everything becomes unrecognizable; even potentially dangerous optical illusions can occur



Disturbing effects of light – double light

Double-light is when we place two spatially separated sources with different colors of light in a room. In such case the appearance of the object and the shadow depends on the current position and orientation of the object in space so eyes need to adapt and accommodate to each position. Double light can causes fatigue, burning eyes and headaches.

Disturbing effects of light – flashing light

If the intensity of the light is not constant, but light is flashing, it can cause similar problems as a double light. In addition, there might be a stroboscopic effect, which prevents the correct perception of moving or rotating objects.

I hope you remembered:

- More than 80 % of information from the environment come through the vision!
- No light no vision!
- Four minimum requirements need to be met to permit perception: minimum luminance, contrast, size and time!
- Good lighting can help, bad lighting might be disturbing!

… and now:

Questions?