

Purves and Lotto 2003

Sensation and perception

Color: What and Why?

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Sensation and perception

- Terms with different and unclear definitions.
- Sensation: what happens in the vision process in the eyes/brain before conscious awareness of objects in the line of vision
- Perception: conscious experiences, in case of vision: forms, colors, textures, relationships, etc. It is not clear that this is a useful distinction and today usually 'perception' is used.
- Perception is one of the 9 components of consciousness. It involves representation in the mind of external input data.

Why colors ?

They give information about the nature of objects in our surroundings.

Color not necessary for object detection and identification. Colors speed up identification of objects and provide information about properties of known objects.

What are colors?
Are they out in nature or just in our heads?

J. Nathans, 2003

What are colors?

- Colors are psychological experiences. Others: sounds, tastes, feelings of pleasure and pain.
- A majority of visual scientists believes colors are **only in our mind**; symbolic representations helping to distinguish objects and to operate successfully in the world.
- Colors: response of the human visual system to light streams entering through the eyes from the visual space in front of us.

What is light?

2005/01/19 19:19 NASA

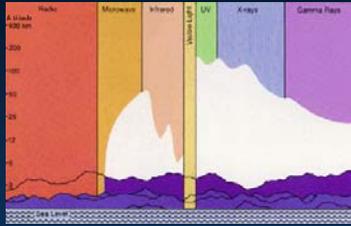
Light sources: natural manmade: miner's lamp

- Light: electromagnetic radiation of a particular range of energy, approx. 380-750 nanometers (nm) of wavelength.
- Its fundamental nature is not understood. Forms: waves or individual packets of energy (quanta, photons).

Wavelength	Region
1 nanometer	Gamma rays
1 micrometer	X-rays
	Ultraviolet
1 centimeter	Infrared
1 meter	Microwaves
1 kilometer	TV and radio broadcast
	Long waves

visible spectrum 400-700 nanometers

Why did nature choose this particular range of wavelengths for vision?

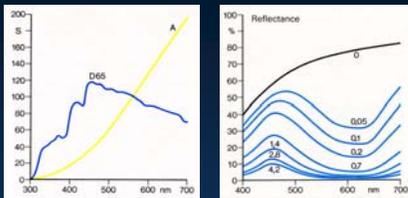


Only range of wavelengths not dangerous to living organisms. Penetrates all the way down through atmosphere and into sea level.

Light and living organisms

- Most living matter can **sense light** in some manner and react to it, from plants to microbes and animals.
- Light is **essential for most life**, in multiple roles.
- Light is abundant: important **source of energy**. Causes life sustaining chemical reactions at an energy level usually not damaging to living organisms.
- Light: **information carrier**. Simple effect: day and night Complex: enables split-second (perhaps life-or-death) decisions, or to appreciate nature or great works of art.

Light can carry a lot of information. Information about **lights** is **direct**, about **objects** **indirect**.



Lights differ in the amounts of rays of different wavelengths they contain.
Objects differ in the amount of light that they reflect at each wavelength.

- Vision is the **most highly developed** of human senses. Of all senses vision's operation occupies the largest brain area.

- Knowledge about the biology of the visual system is considerable: eye, retina, the visual path from eye to the visual center at the back of the brain. But much remains unknown, including:

How and where in the brain the information light generates in the eye's retina is converted to conscious experiences of light and color.

- Somewhere in brain/mind, qualitative and quantitative **perceptual symbols** (lightness, hue) get attached to the signals by a still mysterious process.

Light sensors: natural and artificial

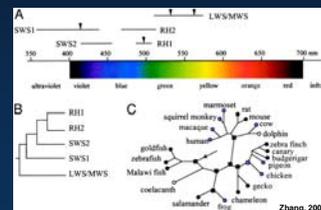
- **Natural light sensors:** various, somewhat different but genetically related
- **Man-made light sensor types:** first invented in the 19th century.



Natural light sensors

Animals with backbones have from 1 to 5 types, only 3 exist in primates (incl. humans).

Human sensor types: RH1, SWS2, and LWS/MWS. RH1 is for night vision and SWS and LWS/MWS for daylight vision.



Color Vision: 540 million years old?

Surface structures producing color stimuli were found in some fossilized animals, dated to about 540 MYA.

Australian zoologist Andrew Parker: color vision is at least that old and originated under water.



Primitive sea worm with diffraction grating effects on head structures.

Time sequence of human light sensor development

- Rhodopsin (in RH1): believed to have originated some 2.5 BYA ago.
- The genetic basis of other human light sensors: about 550 M years old.
- Human "ancient" system for color (SWS2 and LWS sensor): in place in ancestors some 250 MYA.
- Separate expression of LWS and MWS sensors based on the same visual gene type: about 35 MYA in primate ancestors, resulting in the trichromatic system.
- First homo sapiens leave Africa about 100 TYA.

Who has a trichromatic system?

- Trichromatic system (3 color sensor types): mostly limited to humans, other primates, and Old World monkeys.
- Most other mammals, including most New World monkeys have dichromatic or even monochromatic systems (night creatures).

What caused the development of the third cone type in primates?

Food hypothesis.

Are humans uniformly trichromats?

- Many human females have the genetic potential for four or even five chromatic sensor types. Resulting differences in color perception not yet known.
- Females have two sets of genes for sensors (father's and mother's) in their chromosomes, males have only one set (mother's). Result:

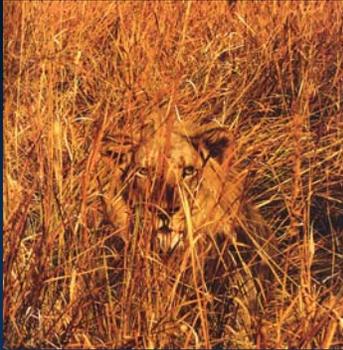
Females: more variants of LWS and MWS sensors, some tetra- and pentachromats possible.

Males: higher percentage (ca. 10%) with impaired color vision, with 2 or only 1 chromatic sensor types.

Original purposes of color vision: Locating food



Young leaves vs. older leaves



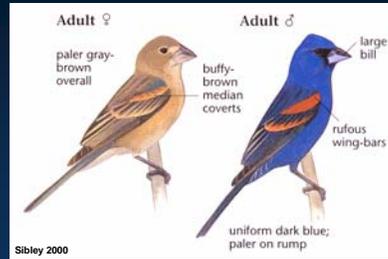
Original purposes:

Object identification

Aggressor:
camouflage

Potential victim:
Ability to distinguish fine spectral differences

Original purposes:
Sexual signaling



Sibley 2000

Blue Grosbeak

Later also: **Pleasurable consequences of color vision**

Appreciation of beauty of nature.



Esthetic pleasures

Calla lilies

Colors in flowers attract fertilizers (bees, etc.), flowers later cultivated for human pleasure.

Pleasurable and mythic consequences

• Humans initially used a very limited palette of pigments in what we consider to be works of art in the paleolithic period (30-10,000 BC)



Chauvet cave
France
ca. 30,000 BC



Esthetic pleasures
Art

Vincent van Gogh
Night Cafe

Esthetic pleasures

Architecture



The Hazrat Ali Mosque in Mazar-i-Sharif, Afghanistan, ca. AD 700

Ethnic signaling



Clothing and body coloring as ethnic identifiers and magic expressions

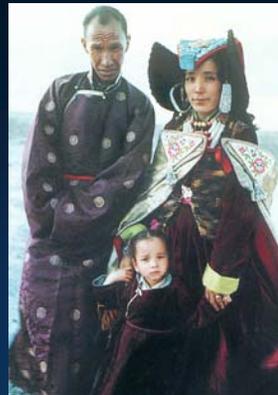
Kayapo Indians of the Brazilian Amazon

Ethnic color



Masawa Indian women, Mexico

Ethnic color



Ladakh family from Tibet

Colors as symbols

Royal Power



King Edward I of England pays homage to France's King Philip the Fair

French 15th c. manuscript

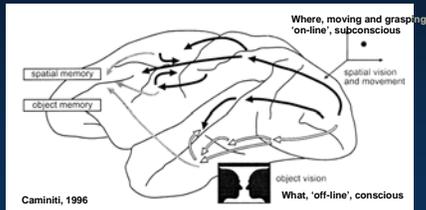
Military power: Flags and uniforms



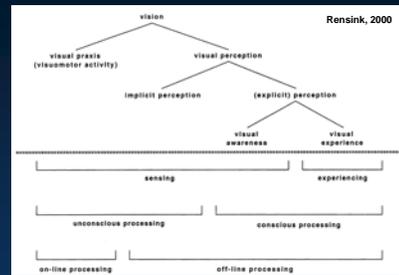
Albrecht Altdorfer
Alexander's Battle
1529

Two visual systems

Primates, including humans, have two visual systems: the 'Where' and the 'What' system. The first operates outside, the second within consciousness. It is possible to be blind in one or the other. Both feed into separate memory systems in front of the cortex.



Vision: a highly complex process



Change blindness: an effect showing that things not paid attention to are often not consciously seen.

Summary

- Color vision: a **strategy** of the brain to help distinguish between and interpret regions sending light of different spectral distribution to the eye.
- Implemented in **different ways** in the animal kingdom depending on the ecological niche in which the species flourished. Humans have a system largely completed about 35 MYA (before there were humans).
- Humans have learned to also make use of the color sense in various unique ways, e.g. derive esthetic **pleasure** from colors.