REVIEW OF HUMAN VISION FACTS

VISION FLASH 40

by

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20 MAR 1973

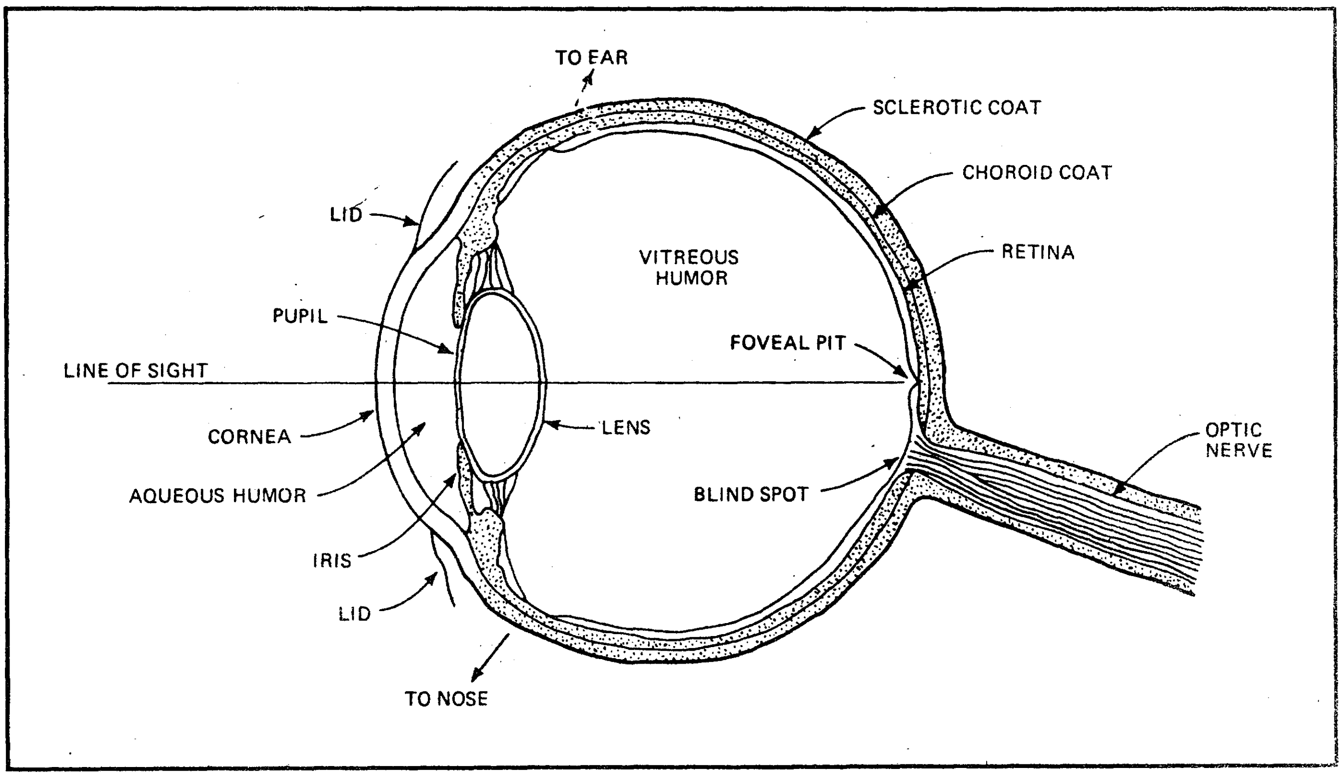
Abstract

This note is a collection of well known interesting facts about human vision. All parameters are approximate. Some may be wrong. There are sections on retina physiology, eye optics, light adaptation, psychological curios, color and eyeball movement.

Work reported herein was conducted at the Artificial Intelligence Laboratory, a Massachusetts Institute of Technology research program supported in part by the Advanced Research Projects Agency of the Department of Defense and monitored by the Office of Naval Research under Contract Number N00014-70-A-0362-0005.

Vision Flashes are informal papers intended for internal use.

FRONTISPIECE



RETINA PHYSIOLOGY

1. The retina faces the back of the eye, forcing the light that reaches the receptors to pass through several layers of cells and blood capillaries. Distortions that would be caused by this are reduced because the photoreceptors adapt completely to images on the retina that don't change. A stabilized image disappears after 4 seconds. Also one small region of the retina, the foveola, has no blood vessels and is bypassed by nerves on their way to the blind spot.

2. There are several layers of cells in the retina:

Receptors
Horizontals
Bipolars
Amacrine
Ganglion

Information flow is from Receptors to Bipolars to Ganglion cells. The Horizontals and Amacrines provide cross connection.

3. Horizontals may effect Bipolars, other Horizontals and Receptors. Amacrines may effect Ganglions, other Amacrines and Bipolars.

4. Signals in the Receptors, Horizontals and often also Bipolar cells are potentials, not pulses. Signals in the Amacrine and Ganglion cells are proper nerve impulses (often superimposed on varying levels).

5. The Horizontals mostly are responsible for lateral inhibition of steady illumination. The Amacrines serve this function for varying fields.

6. There are two kinds of Ganglions, the sustained ganglion which is connected directly to the Bipolar cell and the transient which is also connected through the antagonistic Amacrines.

7. In retinas having both cone and rod photoreceptors most of the ganglion cells in the retina receive input from both cones and rods. There are some ganglion cells that receive input from cones only, but usually there are no cells receiving input from only rods.

8. Ganglion cell fields are usually opposing in nature (an on-field surrounded by an off-field or vice versa) and, if uniformly illuminated over the entire fields, the inhibitory effect of the off-field will exactly cancel the excitatory effect of the on-field and the output of the cell will be the same as though it were in the dark. Lateral inhibition builds up with time. Short exposure results in bad acuity.

9. There is greater sensitivity for time-varying stimuli. For bright light optimum is 30 cps. For dim light optimum is 3 cps.

10. There is greater sensitivity for spatially varying stimuli. For bright light optimum is 5 cycles/degree. For dim light optimum is 1 cycle/degree. Sensitivity to low frequencies is 10 times less than optimal. Cutoff of the system is around 40 cycles/degree.

11. The eye has about 10^8 rods, 10^7 cones and all funnels into 10^6 optic nerve fibers.

12. In the fovea the cone density is about 147,000 cones per square mm. Cone density is about 5,000 cones per square mm over the rest of the retina, the rods outnumbering the cones everywhere outside the fovea. The maximum human rod density is about 160,000 rods per square mm.

13. The central area of the fovea is a mere 20' across. Two thousand cones are packed into this horizontal, elliptically shaped area.

14. Edge of retina has very few cones, hence little color vision. Central area of retina has few rods, hence not sensitive in dark. Man may lack blue cones in central fovea. Their existence elsewhere seems to be established now.

EYE OPTICS

1. The eye has a diameter of 25 mm. The index of refraction of the lens varies from center to outside averaging about 1.43. The rest of the eye is about 1.35.

2. The lens is not required to change shape when focusing from an infinite distance to 15 to 20 feet. At closer distances the ciliary muscles must contract to thicken the lens and maintain good focus.

3. The spacing of central foveal cones is 20"-30". Depending on definition used, resolution is about 1'-2'. Note that many more cones would not help as diffraction effects set in and with a 5mm pupil size (maximum) a point is smeared across about 25". Spread is greater of course with a smaller pupil. Note that diffraction tracks off against lens aberration Net result is that humans can resolve points about .1mm apart at the standard 25 cm near point. Birds may do 2 to 4 times better.

4. One minute in the world projects onto about 7.5 microns on the retina. Green light has a wavelength of about .5 microns.

LIGHT ADAPTATION

1. Rod adaptation to darkness takes about 30 minutes to complete. Cone adaptation to darkness takes about 5 minutes to complete.

2. Rods are about 10 times as sensitive as cones. While their operating curve does shift with increase in illumination it is flattened out and saturates at about 10,000 times the minimal detectable. At intensity sufficient for the blue cones, rods are all bleached out.

3. Cones do not seem to saturate and their operating curve shifts without flattening out. Each sensor in a given surrounding light level covers a range of about 1:1000 in intensities. Shift in operating point takes about 5 seconds and is mostly due to chemical changes in the receptors.

4. Bipolar cells only have a range of about 1:10 however, but their operating point is adjusted by the input from the horizontal cells of their neighborhood in a fraction of a second.

5. Typically the ratio of average light outside to average inside is 1000 to 1.

PSYCHOLOGICAL CURIOS

1. Fixations occur mainly at unpredictable or unusual details, in particular on unpredictable contours that change direction rapidly and irregularly.

2. Infants can detect depth and size constancy using motion parallax, but are unable to use stereoscopic parallax.

3. Almost all animals can use motion parallax in a visual cliff experiment to tell depth. (A visual cliff is produced by placing the animal on a piece of glass in a frame. Half the glass is covered with an opaque, patterned material and the other half left clear leaving a visual cliff when suspended several inches off the floor.)

4. Some color adaptation is not mediated in the retina.

COLOR

1. The important feature of the mechanism is that it is trying to estimate surface reflectivity when all it has to work on is the reflected light.

2. Points, lines and areas may appear to be colored. Edges between colored areas may greatly affect the appearance of the areas. Particularly if the color of the edge is not a combination of the two bordering colors.

3. Lettvin believes three line vertexes are crucial in color perception. Most vertices are obscuration T-joints, some are shadow-crossing X-joints. In either case we have 3 degrees of freedom in choosing lightness at such a vertex. Lettvin argues that this fact makes a 3 color system optimal in some sense.

4. There are several experiments reported by Land; here we will list three:
Land effect I is the apparent constancy of color names under widely differing illuminations. This discounts various simple-minded modifications of the standard tri-stimulus theory.
Land effect II is the impression of full color one gets from slide projections from two monochromatic projections. Land effect II can be seen with red and white in the projectors. A special case is just enough red to excite the red cones and just enough white to excite the rods. This argues for interaction of the rod and cone systems.
Land effect III involves the perpendicular projection of red and white wedges. As expected, one sees red, white and various pinks. But if the square is divided into small squares and then scrambled, one sees many colors. In the first case the ratios of intensities are constant at each vertex. When the squares are jumbled up this is no longer true and we see many colors.

5. Eight to ten % of males have red/green color deficiency. It appears mostly in males since it depends on a recessive gene on the X chromosome. The color matches made by dichromats lie along straight lines in the standard color diagram.

6. More rare is lack of blue system. Afflicted people cannot see the Land red/green slide-projection effect where blues and purples appear despite the fact that the red and green sources do not stimulate the blue system. The same problem is found when the blue system is bleached out by overexposure. Very rare is color deficiency in one eye only.

7. Often one of the processes is not missing but just weak. This is vaguely like reduced sensitivity, but not like color adaptation! A test for type and amount of deficiency done by using the anomalovscope. Here the sum of green and red is matched against a yellow.

8. Much evidence suggests that the three color systems are not treated equally. Blue in particular may play a more subsidiary role. A person lacking red or green sensors has an altered curve of sensitivity to light. A person lacking blue on the other hand had normal sensitivity. This suggests that the blue process is not involved in determination of lightness.

9. Birds, fish, reptiles and insects have color-vision. Of mammals only primates do.

10. Insects with protective coloration for the benefit of some birds (?) often also match their background through our eyes. Other birds may foil the protective coloration through many (16-20) sets of sharp cut-off filters consisting of pigmented oil droplets.

11. Usually no color effect are induced by exposing the eyes to different stimuli. Instead retinal rivalry sets in and a "glossy" or "lustrous" appearance may result.

12. In some cases sclerosis of the optic nerve causes a plaque to form which later disappears. Resolution is at times restored but color vision is lost, despite the fact that impulses are still coming from the cones.

13. After-image when light is removed is first the same color, then complementary and finally fades. It can still be invoked for a long time however by changing the illumination.

EYEBALL MOVEMENT

1. The eye has an irregular, largely horizonal tremor with an amplitude on the order of 10' and a frequency of 20 to 100 Hertz.

2. The eye undergoes flicks of amplitude on the order of 1' to 25' at intervals of .03 seconds to 5 seconds. Velocities are $<$ 600' per second. This involves both pitch and yaw.

3. There is roll motion as well as pitch and yaw. Tremor involves 45' amplitudes, and flicks, 2'.

4. Flicks in the two eyes typically are in the same direction but different amplitude.

5. Motion falling near the edge of the retina causes reflexive shift in attention without conscious motion detection.

6. Even during fixation on a point, the image involuntarily drifts away from the fovea at a rate of about six minutes of arc per second.

BRAIN PROCESSING

1. About 80% of the optic nerve fibers in the human terminate in the lateral geniculate body, the remainder end in the superior colliculus or pretectum.

2. Cells in the visual cortex have been found that detect only lines of specific orientations in specific places. These appear to go on to other cells that detect lines of specific orientations in regions, which then go on to cells which detect lines of specific orientations in certain regions with a particular type of background.

3. Cortex appears to be organized into columns, often of about .5 mm wide. Each column is mostly connected perpendicularly to the surface of the cortex. The different layers often do different things. Some columns are constant depth columns. Disparity between adjacent columns is about .6° for cats. Some columns are constant direction columns (from one eye). Spacing is about 4° between adjacent columns for cats.

MISCELLANEOUS

1. The "white" of the eye is not very opaque to red.

2. Stabilized image destroys operation of focus system. Focusing is harder with monochromatic light.

3. Stero disparity of 2' is the minimum detectable by the eyes.

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