UNIT 13 VISION: LIGHT SENSE, NIGHT VISION AND COLOUR VISION

Structure

13.0 Objectives

13.1 Introduction

13.2 Visual Impulse and Perception

13.2.1 Initiation of Visual Impulse

13.2.2 Transmission of Visual Sensation

13.2.3 Analysis of Visual Perception

13.3 Colour Vision

13.3.1 Young's Trichromatic Theory

13.3.2 Details of Colour Vision

13.3.3 Defective Colour Vision

13.4 Light Sense

13.4.1 Adaptation

13.4.2 Dark Adaptation

13.5 Contrast Sense

13.6 Let Us Sum Up

13.7 Answers to Check Your Progress

13.0 OBJECTIVES

After studying this unit, you will be able to understand:

- retinal pigments;
- visual cycle;
- analysis of visual perception; and
- differences between light and dark adaptation.

13.1 INTRODUCTION

It is important for our visual system to adapt to recognize objects clearly in differing conditions of light. The main mechanisms concerned with vision are: initiation of visual impulse in the retina, transmission of visual sensation along the optic nerve and visual perception by the brain.

The functional examination of eye consist of testing the Form Sense, Colour Sense, Light Sense and Contrast.

Form Sense is the faculty which enables us to perceive the shape of objects in the outer world. Here the cones play predominant part, and the form sense is most acute at fovea, where they are most closely set and most closely differentiated. Form Sense is not purely retinal function but also has a large psychological component.

Colour Sense is the faculty whereby we are enabled to distinguish colours as excited by light of different wave length. The ability to appreciate colour is predominantly a function of cones.

Light Sense is the faculty that permits us to perceive light, not only as such but all its graduations of intensity. If the light, which is falling on retina, is gradually reduced in intensity there comes a time when it is no longer perceived—this is called the light minimum. The light minimum for fovea is considered to be higher than for paracentral and peripheral parts of retina. Rods are much more sensitive to low illumination than cones, so that in dusk we see by rods (scotopic vision) whereas in bright illumination cones comes into play (photopic vision).

Sense of Contrast is the ability to perceive slight changes in luminance between regions which are not separated by definite borders. This is as important as too perceive sharp outlines of relatively small objects.

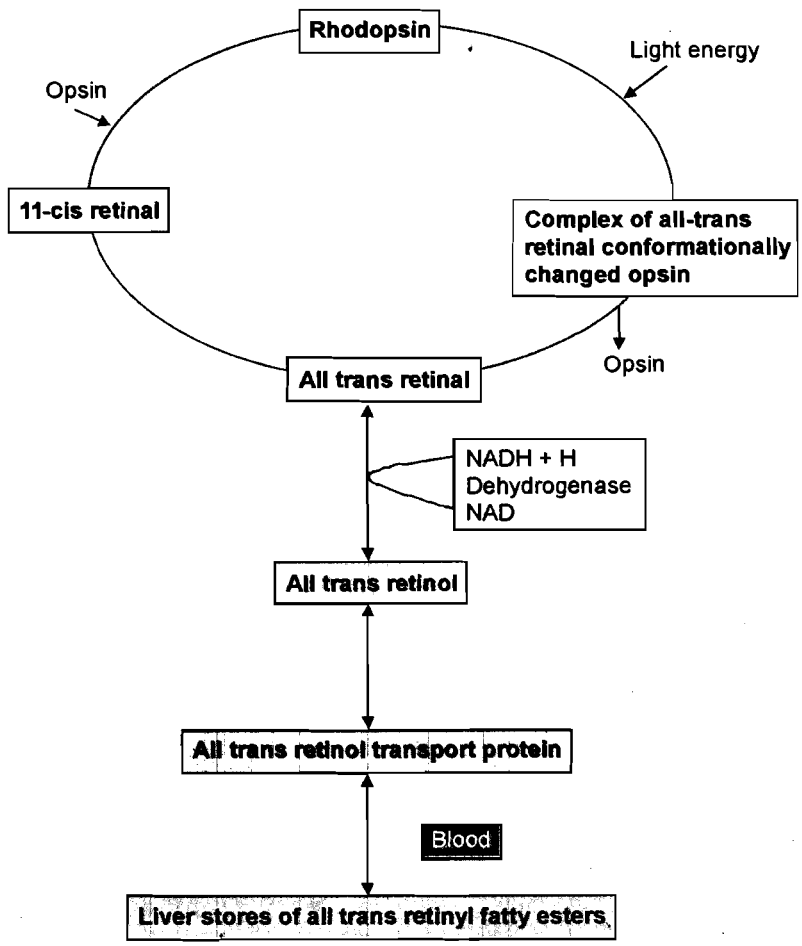
13.2 VISUAL IMPULSE AND PERCEPTION

When light falls on retina, than photochemical changes occuar in photosensitive cells of retina to transfer the visual stimulus to visual contex via optic nevre.

13.2.1 Initiation of Visual Impulse

When light falls on the retina it is absorbed by the photosensitive pigments of rods (rhodopsin) and cones (photopsin). It initiates photochemical changes such as rhodopsin bleaching and regeneration that stimulate electrical changes. Rhodopsin consists of a protein (opsin) and a carotenoid-11-cis retinal. Light that is absorbed by rhodopsin converts 11-cis retinal into trans retinal. This process is an isomerisation that occurs through the formation of many chain reactions and the reduction of c-GMP. The reduction of c-GMP is responsible for closure of sodium channel, leading to hyperpolarisation and electric response in bipolar cells and other neural cells. Thus producing electric response. Then all trans retinal reisomerise into 11-cis retinal and then combine with opsin to form rhodopsin. A similar process occurs for photopsin.

Visual Cycle (Wald's Cycle)



13.2.2 Transmission of Visual Sensation

This process takes place in the visual pathway from the retina to the visual cortex. The impulse originating in the retina travels along the optic nerve through the optic chiasma, optic tract, lateral geniculate body, optic radiation and finally ending in the visual cortex (Area 17 of striate cortex).

13.2.3 Analysis of Visual Perception

The visual cortex is the final location for all visual interpretation. There is a duplex mechanism for the visual process. The retina adapts itself to dim illumination through a property called scotopic (rod) vision. Similarly, it adapts to bright light through photopic (cone) vision. Rods contain the pigment rhodopsin and cones contain the pigment iodopsin. Iodopsin is a carotenoid protein similar to rhodopsin. The carotenoids of rhodopsin and iodopsin are identical, only the proteins are different. Rhodopsin contains scotopsin and iodopsin has photopsin. The cones have three different pigments based on light sensitivity:

1) chlorolabe—green absorber,
2) erythrolabe—red absorber,
3) cyanolabe—blue absorber.

The maximum density of cones is found at the fovea and of rods at the peripheral retina.

Check Your Progress 1

Give in detail the visual cycle and mechanism of generation of impulse.

.....

.....

.....

.....

.....

.....

13.3 COLOUR VISION

The human eye can see about 150 different colours in the visible spectrum (400-750 nm). Red, green and blue are said to be the primary colours and can be mixed to create different colours. Colour sense is the ability of the eye to perceive the specificity of wave length and the intensity of light. Colour vision occurs because of cones. The perception of colour also depends on the background. In dim light all colours are visualized as grey, due to the Purkinje shift phenomenon. Colour is better appreciated in photopic vision and should be tested for in broad daylight. There are three qualities specific to colour vision— hue, saturation, and brightness.

Hue: Hue is the function of a wave length (i.e. rainbow). This quality is illustrated when colours in the four areas—red, yellow, green, and blue—merge.

Saturation: A stimulus that results in a single hue. The greater the mixture with white light the less the saturation.

Brightness: The ease at which an image is seen.

13.3.1 Young's Trichromatic Theory

According to Young's theory, three types of cones exist, each sensitive to a particular pigment—erythrolabe (red), chlorolabe (green), and cyanolabe (blue). The three classes have a spectral sensitivity that peak at, blue (440-450 nm), green (535-555 nm), and red (570-590 nm). Although the peak wave lengths are different, the three classes of cones have overlapping spectral sensitivity. This occurs because there is a secondary band of absorption that allows sensitivity of all visual pigments to fall off sharply on the wave length side of the peak but less sharply on the short wave length side of the peak.

13.3.2 Details of Colour Vision

The genes for colour sense are located on the X chromosome (recessive inheritance) and on chromosomes 3 and 7. Changes in the cone pigments as well as biochemical alterations produce a cone receptor potential. This potential is transmitted by electric conduction across the retina. The colour coding can be seen first at the ganglion cell layer.

13.3.3 Defective Colour Vision

Defective colour vision is often called colour blindness. The ability to appreciate one or more of the primary colours is lacking. This can be either acquired or congenital. The Greek words for first, second, and third (protos, dueteros, and tritos) are used for the three primary colours. The suffix is added depending on the degree of severity—partial (-anomaly), complete (-anopia), and unspecified (-an). Dyschromatopsia is a condition in which there is colour confusion due to deficiency of colour. Achromatopsia is a condition in which there is a complete lack of colour sensation. Trichromatic vision is the terminology used for normal vision, those who require all three primary colours to make a match with an unknown colour. Anomalous trichromats are those who utilize all three colours to make a match with an unknown colour but at lesser amounts. Usually, these people are colour weak, not colour blind. Dichromats are those who only need two primary colours to make a match with an unknown colour. This occurs because of an absence of one colour pigment. Monochromatism is a very rare condition in which only one primary colour is completely appreciated.

Acquired colour vision defects can occur after damage to the optic nerve or macula and in some cases, because of blue blindness in old age due to lenticular sclerosis (absorption of blue rays by the nucleus).

Incidence

Defects in colour vision can either be congenital or acquired. Males are more affected than females.

Out of the population of colour blind people only 0.03 per cent are affected by Achromatopsia (total colour blindness that leads to day blindness and nystagmus). The majority are either dichromates or anomalous trichromates.

Tests for Colour Vision

Various tests can be performed to test the intensity of colour deficiency in patients:

Pseudoisochromatic Plates

Commonly known as **Ishihara's plates,** these reveal one pattern to the normal eye and another to the colour deficient. Coloured numbers are seen against a background of dots. The advantage of performing this test is that it is easy, quick and sensitive for screening. Disadvantage is that it does not test for tritanope, it does not differentiate protans and deutrans and it does not grade the degree of

colour defect. **Hardy Rand Ritter** (HRR) is the only pseudoisochromatic test that can diagnose all three types of colour defect.

Fransworth 100 Hue Panel Test

This is a simple and useful test using colour chips arranged in a particular sequence. Colour deficient patients make errors in arranging the chips. This is more accurate in classification of the type of colour defect and results are recorded on a graph.

Lantern Test

The patient names colours displayed in the lantern and the mistakes are analyzed. This is not the best method of testing because it depends on the nature and intensity of the light source.

Holmgren's Wools

This is a matching test of coloured pieces of wool. While this is not a highly favored method of testing it does show serious defects in colour perception.

Nagel's Anomaloscope

The patient is asked to match a yellow with a mixture of red and green wave lengths. A defect can be detected based on the amount of red and green required. Protoanomals (red deficient) usually require too much red and deuteroanomals (green deficient) need too much green.

Ishihara's Plates: Following plates are available— Transformation, Vanishing, Hidden Digit and Diagnostic plates.

1) The plates are designed to be viewed correctly in a room that has an adequate amount of daylight. Direct sunlight or electric light may interfere with the results because of a change in the shades of colour.

2) The plates are held 75 cm away from the subject and tilted so that the plane of the paper is at right angles to the line of vision.

3) The plates should be read number-wise and each answer should be given without more than 3 seconds delay.

4) If the subject is unable to read numerals, plates 26-38 are used and the winding lines between the two X's are traced with the brush. Each tracing should be completed within 10 seconds— for illiterates.

5) The order of the plates may be changed if it appears that there is a deliberate deception on the part of the patient.

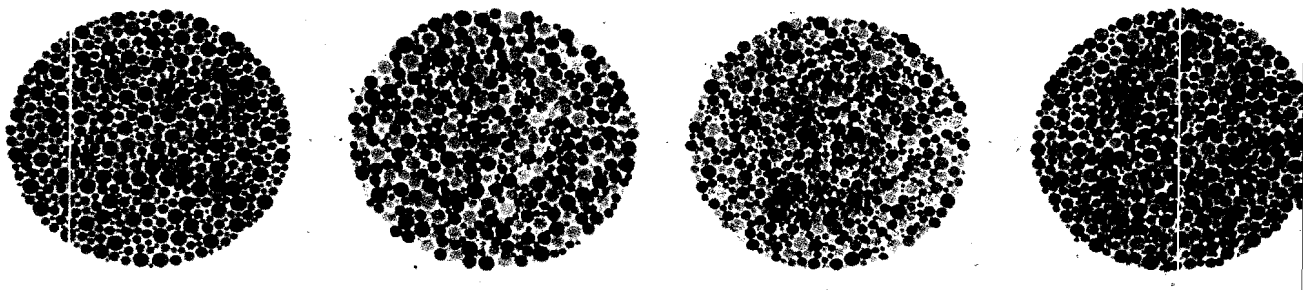


Fig. 13.1: Ishihara plates

Number of Plate	Normal Person	Person with Red-Green Deficiencies	Person with Total Colour Blindness and Weakness
1	12	12	12
2	8	3	X
3	6	5	X
4	29	70	X
5	57	35	X
6	5	2	X
7	3	5	X
8	15	17	X
9	74	21	X
10	2	X	X
11	6	X	X
12	97	X	X
13	45	X	X
14	5	X	X
15	7	X	X
16	16	X	X
17	73	X	X
18	X	5	X
19	X	2	X
20	X	45	X
21	X	73	X

		PROTAN		DEUTAN		
		Strong	Mild	Strong	Mild	
22	26	6	(2)6	2	2(6)	
23	42	2	(4)2	4	4(2)	
24	35	5	(3)5	3	3(5)	
25	96	6	(9)6	9	9(6)	

Analysis of Results

- The mark X shows that the plate cannot be read.
- Blank space denotes that the reading is indefinite.
- The numerals in parenthesis show that they can be read but they are comparatively unclear.

Colour Deficiency—

There are two types of colour deficiency:

a) Congenital

b) Acquired

Congenital colour Deficiency	Acquired colour Deficiency
1) Present at birth (identify at 3 month)	1) Onset at birth (after 3 months)
2) Type and severity is the same through out life	2) Type and severity changes with time
3) Type of deficiency can be classified and diagnosed precisely	3) Not easy to classify. Characteristics may combine those of more than one type of congenital colour deficiency.
4) Both eyes equally affected.	4) Monocular differences in severity frequently occurs.
5) Binocular examination is satisfactory.	5) Monocular examination is required
6) Visual acuity and visual fields are normal.	6) Reduced visual acuity or visual field defect
7) Predominantly red-green in order	7) Predominantly tritan. Prevalence: deutan/protan/tritan.
8) Higher prevalence in males.	8) Equal prevalence in male and females.

Check Your Progress 2

1) What are different methods to measure the colour vision defects.

.....

.....

.....

.....

2) What is Ishihara chart?

.....

.....

.....

.....

3) What are advantages and disadvantages of Ishihara chart?

.....

.....

.....

.....

13.4 LIGHT SENSE

You must be aware that when you enter into a cinema hall, you are unable to see and find out your seat initially for a few minutes; but, after few minutes you are able to locate the seat. Similarly, when you come out of a dark room in a sunny day, you feel yourself blind for a few seconds. But, you are able to see the things seconds after.

13.4.1 Adaptation

The terms scotopic and photopic vision are relative to the lighting conditions of an individual place. Light adaptation is a very quick process and is complete within a few minutes. Dark adaptation usually takes much longer. In the dark, the concentration of rhodopsin increases. Under these conditions, the sensitivity of the eye is more than ten thousand times greater than the light adapted eye. When light is admitted to the dark adapted eye breakdown of rhodopsin occurs. Once the eye reaches a steady state level, it becomes more light adapted and it's sensitivity decreases. Therefore, an increase in rhodopsin and a decrease in the amount of end products in the retina yields a higher light sensitivity.

13.4.2 Dark Adaptation

Dark adaptation is a phenomenon by which retina and pupil react to decreased illumination. Test is performed using Goldmann-Weeke's adaptometer. Subject is pre- adapted to a standard amount of illumination and then presented with a series of light at 11° below fixation. Intensity of flashes is controlled by neutral density filter. Sensitivity curve is a bipartite curve, initial rapid phase represent cone function and second slower segment represent rod function. The inflection on the curve where the rod begins is known as rod cone break (alpha point) and in the healthy eye it occurs 7-10 minutes of dark adaptation. It is useful to detect Vitamin A deficiency, anoxia, tobacco, opacities, degenerations, myopia and glaucoma by this.

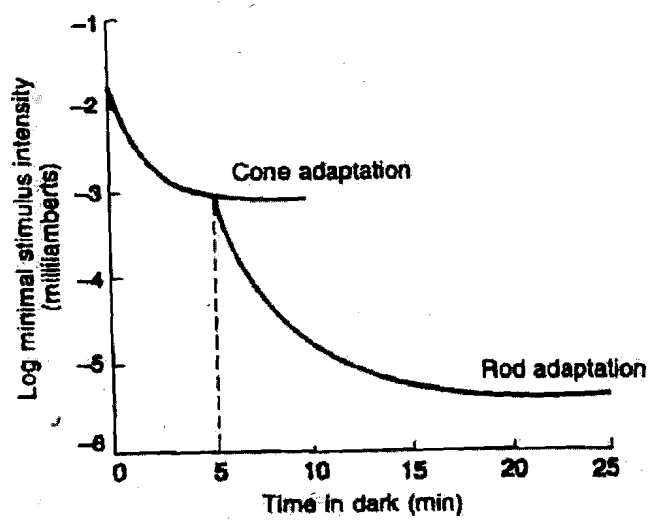


Fig. 13.2: Dark adaptation: sensitivity curve

Check Your Progress 3

What is dark adaptation?

.....

.....

.....

.....

13.5 CONTRAST SENSE

Sense of contrast is the ability to perceive slight changes in luminance between regions which are not separated by definite borders. This is as important as to perceive sharp outlines of relatively small objects.

$$\text{Contrast Sensitivity} = \frac{Lmax - Lmin}{Lmax + Lmin}$$

Note: Lmax is the maximum luminance and Lmin is the minimum luminance.

Contrast sensitivity is reciprocal contrast at threshold. It is defined as the visual function measured using a range of sinusoidal grating pattern as the visual stimuli.

Various method to check for contrast sensitivity are Arden grating, Cambridge low contrast grating and Pelli Robson contrast sensitivity chart.

Factors affecting contrast sensitivity are refractory refractive error, age of the patient, any lenticular changes and ocular or systemic diseases.

Check Your Progress 4

What is contrast sensitivity?

.....

.....

.....

.....

.....

13.6 LET US SUM UP

In this unit you have learnt that when light falls on the retina it is absorbed by the photosensitive pigments of rods (rhodopsin) and cones (photopsin). It initiates photochemical changes such as rhodopsin bleaching and regeneration that stimulate electrical changes.

Dark adaptation is a phenomenon by which retina and pupil react to decreased illumination. Sensitivity curve is a bipartite curve, initial rapid phase represent cone function and second slower segment represent rod function.

Red, green and blue are said to be the primary colours and can be mixed to create different colours. Colour sense is the ability of the eye to perceive the specificity of wave length and the intensity of light.

Contrast sensitivity is reciprocal contrast at threshold. It is defined as the visual function measured using a range of sinusoidal grating pattern as the visual stimuli. In next unit you will learn about visual pathway, fields and visual cortex.

13.7 ANSWERS TO CHECK YOUR PEOGRESS

Check Your Progress 1

Chart visual cycle followed by text (sub-section 13.2.1).

Check Your Progress 2

1) Pseudo Iso chromatic plates (Ishihara's plates), fransworth 100 HUE panel test, lantern test, Holmgren's wools, Nagel's anomaloscope.

2) Ishihara chart or pseudo isochronative charts are plates that rereal one pattern to the normal eye and another to the colour deficient.

3) Advantage:

It is easy, quick and sensitive for screening.

Disadvantages:

a) It does not test for tritanopes.

b) It does not differentiate protans and deutrans.

c) It does not grade degree of colour defect.

Check Your Progress 3

Dark adaptation is a phenonenon by which ratina and pupil react to decreased illumination. The concentration of rhodopar increases and the sensitivity of the eye is more than ten thousand times greater than the light adapted eye. It is useful to detect Vitamin A deficiency, anoxia, tobacco, opacities, degeneration, myopia and glaucoma.

Check Your Progress 4

Sense of contrast sensitivity is the ability to perceive slight changes in luminance between regions which are not separated by definite borders.

Maximum luminance and minimum luminance contrast sensitivity can be measured by Arden grating, Cambridge low contrast grating and Pelli Robson Chart.