Lecture 5

We have already discussed the transition of the visual process from visual sensation to visual perception. While visual sensation cannot be cleanly separated from visual perception, visual perception is infinitely more complex. During visual sensation, we see the outline of the image of an object. Information from the background is simultaneously analyzed, and memory of past experience is thrown into the mix. The result is a complete perception of not just the object, but also its meaning and/or usefulness to us in everyday life.

The example of the perception of a box was given in earlier lectures. The same process applies to the perception of a word on a page. The letters individually do not make an impression on us. However collectively, they form a word which out of past experience we recognize as good, bad, sad, frightening etc.

As a result of these 'Higher Level Integrations' that result in visual perception, some interesting paradoxes occur in the visual process and these are referred to as ***Optical Illusions.***

OPTICAL ILLUSIONS

We have already mentioned some optical illusions in previous lectures but they will be revisited here.

Simultaneous Contrast

This has been demonstrated in a previous lecture. It is the apparent brightness of a gray square when it is placed against a dark background. However, against a lighter background, the same gray square appears considerably darker.

Simultaneous contrast is the visual manifestation of the retinal ganglion cell receptive field concept. It is easy to figure out if you apply you mind to it.

Assimilation

This effect was first described by von Bezold in 1874, and is now believed to be dependent on spatial integration within retinal receptive fields (i.e. mixing some high and low frequency information on their way to the brain).

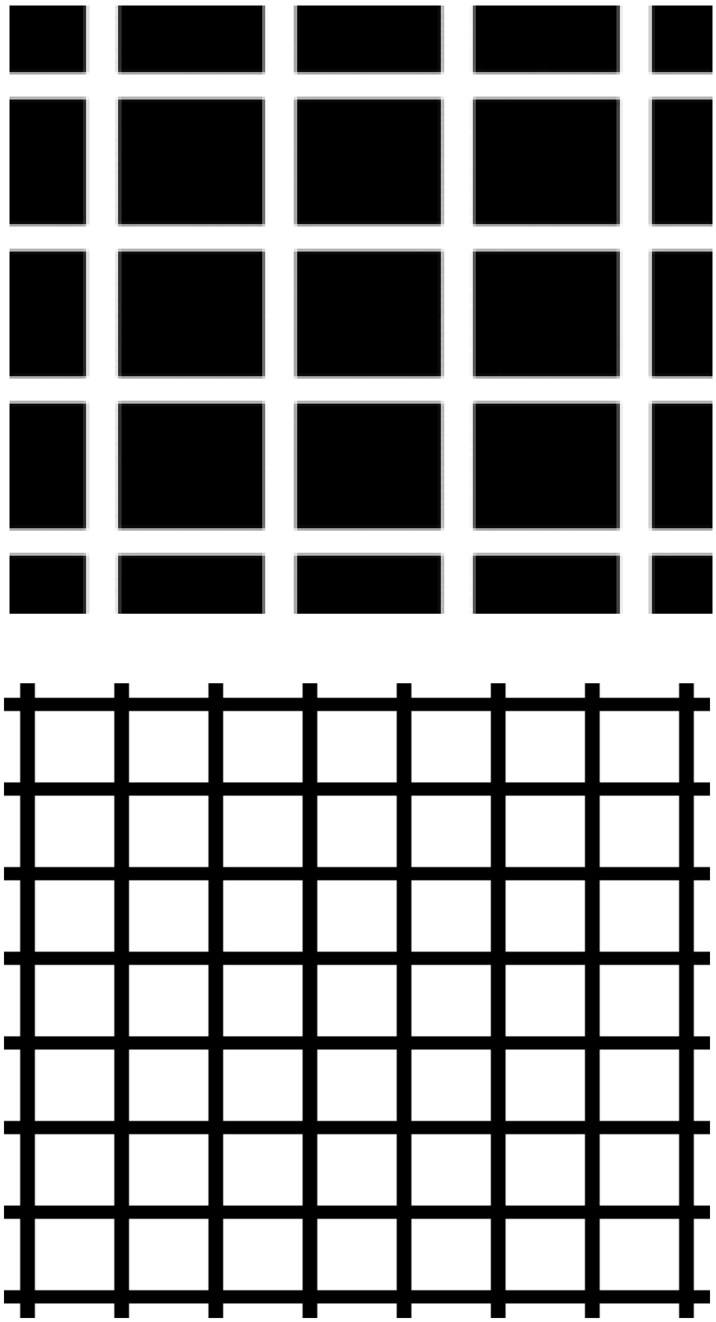

Figure 5-1 a & b:

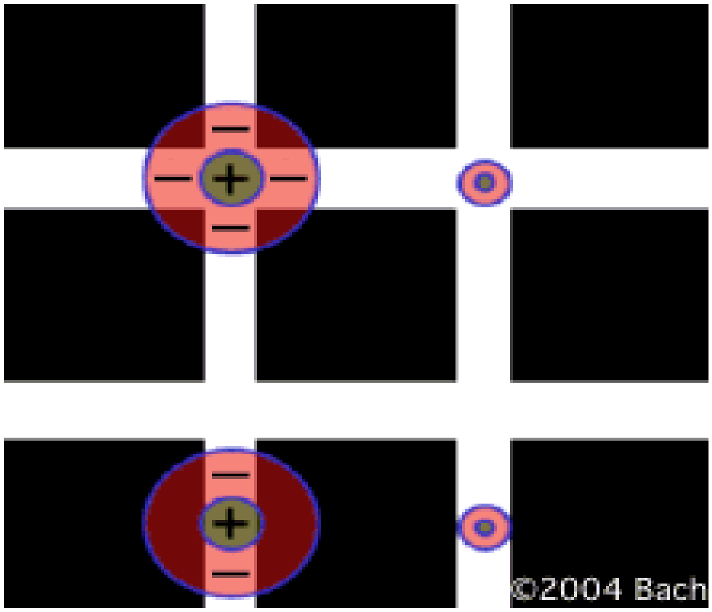

Figure 5-2 The Herman grid illusion and the classical explanation for this illusion

The Herman Grid Illusion

Looking above to figures 5.1a and 5.1b, we see a grid made up of white bars and black squares, and another made up of black bars and white squares. At the junction of any two light bars, darks spots are seen. At the junction of any two dark bars, light spots are seen.

The classical explanation of this illusion is that in fig 5.2b where we have two large on-center GCRFs, the one at the top left corner has four inhibitory incursions while that at the bottom left has only two inhibitory incursions, meaning that the bottom left has a higher spike arte and therefore no dark spots are seen.

It's very easy to disprove this explanation by simply making the lines of the grid curved. This means that there must be other factors at work in the Hermann grid illusion.

Higher Integrative Activity

Inadequate representation

The figures in 5.3 represent the phenomenon of inadequate representation. Figure 5.3a is called ***Schroeder's Staircase*** and 5.3b is called ***Rubin's Vase***.

Schroeder's staircase can be perceived either as a normal staircase going up from right to left or, as an upside down staircase, depending on the observer. If you have trouble perceiving the two possible shapes, concentrate on the figure and slowly turn the page upside down.

The illusion of Rubin's vase is much more easily appreciated either as two adjacent faces, or as a flower vase.

Both illusions are referred to as ***ambiguous figures*** because they are incomplete (or inadequate) representations of the figures they are supposed to depict. Therefore an observer can perceive them as one figure or another.

The illusion of incomplete representations illustrates how abstract visual perception is. In as much as the drawings are grossly incomplete, the brain still manages to take the images, complete them, and lead to the visual perception of one object or another.

The one interesting point to note about incomplete representations is that, for any one observer, one object is dominant (i.e. without any effort, only one of the two or more possible objects is perceived. To appreciate the other object/s, the observer has to make a conscious effort).

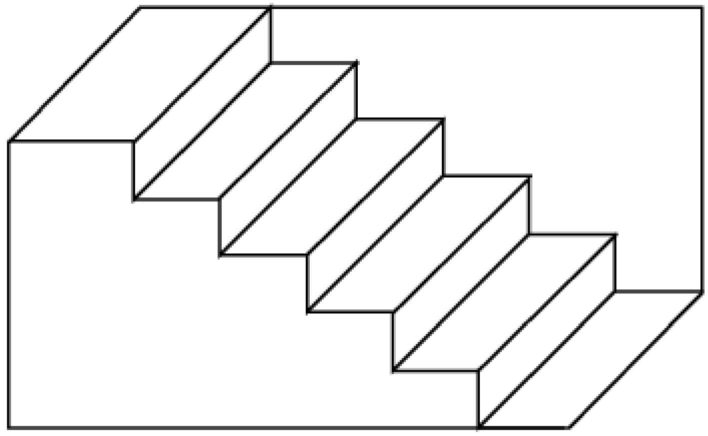

Figure 3a: ***Schroeder's Staircase***

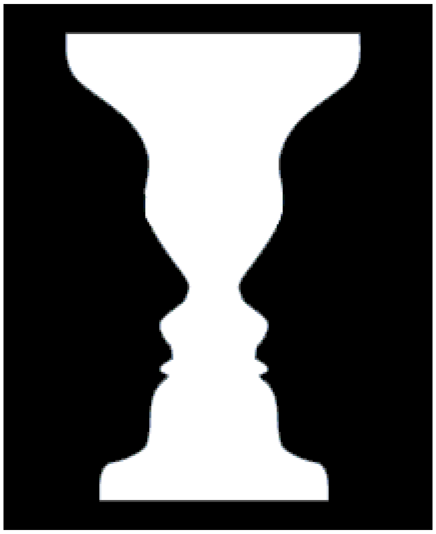

Figure 3b: ***Rubin's Vase***

False Projection

When the image of an object falls on the retina, we can say that the image of that object is projected into space to a location corresponding exactly with the position of that object.

If that eye is suddenly, passively, moved in one direction, the object of regard appears to move the opposite way.

This is believed to occur because the proprioceptive mechanisms of that eye are 'unaware' that the eye has moved. Therefore, as far as they are concerned, the eye is stationary. To then account for the change in the actual object position, they have to assume that the object has moved in the direction opposite to that of the eye.

The Apparent Movement of an After-image

This is an excellent example of psychological compensation.

Imagine you look at a bright light sources for a few seconds. When you look away from the source, you will still perceive its after-image. Now, because the after-image is not an actual object but an entopic phenomenon, as the eyes move, the after-image will move in the same direction.

Figural After-Effects

Imagine looking at a curved line long enough to adapt to it. Firstly, the line appears less and less curved the more you look at it. Also, after adaptation, a straight line immediately presented to you will look curved in the opposite direction.

Vestibular Influences

Whenever the head tilts, the eyes roll within the sockets to compensate for the movement of the head, and therefore maintain the normal orientation of the visual field. These ***compensatory rotations*** are grossly inadequate and are only about one-tenth to one-fifth of the inclination of the head. Interestingly however, a horizontal line always appears horizontal no matter how much the head is tilted. Therefore in this case there must be some form of psychological compensation involved, presumably furnished from information provided by the labyrinthine (semicircular canal) network.

That the psychological compensation is not adequate however is demonstrated convincingly by ***Aubert's Phenomenon***.

In this phenomenon, if a subject is observing a light slit in a completely dark room, on bending his head to one side, the slit appears to bend in the opposite direction. Should the lights in the room be switched on, the slit again appears vertical.

If instead of tilting the head slowly the subject tilts it rapidly, the slit remains vertical at first, and then after a short while, inclines in the opposite direction.

Aerial Perspective

As a result of the scattering of light by the atmosphere, the colors of distance objects gives some clue as to their separation from the observer. The scattered light is predominantly blue and violet, and the eye views the distant object through a “wall” of blue light. The thicker this wall, the bluer the object. This is why distant mountains appear blue.

A self-luminous object is seen as a result of the light emanating from it. A distant white light will appear yellow or red when being looked at through haze. This is because the blue light is scattered and therefore only the red portion of the light reaches the observer.

The Pulfrich Phenomenon

This will be demonstrated during the lecture. It should suffice here to state that instead of the perception of the movement of a normal pendulum from left to right, when a blue or green filter is placed in front of one eye, and a dark red filter in front of the other, the pendulum appears to move in an elliptical path.

Lecture 6

ENTOPIC PHENOMENA

The eye's function is to form an inverted image of an object on the retina for the brain to interpret.

Visual sensations can also arise from shadows of opacities within the eye, mechanical pressure on the globe (phosphenes), and a variety of other causes.

Visual sensations that result from mechanisms, other than the optical image formation by the apparatus of the eye, are referred to as ***Entopic Phenomena***.

These phenomena can be subdivided as follows:

Optical

- Shadows
    - Due to objects in the media
    - Due to perception of blood vessel silhouettes

- Hadinger's Brushes
- Maxwell's spot

Physiological

- Phosphenes
- Blue arcs
- After-images
- Troxler Effect

Note: Visual sensations arising in the visual cortex such as hallucinations or complete scenes in dreaming are excluded from this definition.

Unless an opacity is nearly the same size of the exit pupil, or very close to the retina, it will not cause a noticeable shadow.

The easiest way the illicit a shadow from an opacity within the eye is to illuminate the eye with a very bright source of light which has to pass through a small pinhole (about 0.25mm) and observe the projection of that light into the fundus, through the pinhole.
Should the ocular media be clear, then the patch of light on the retina will be unremarkable. If not, the opacity will cast a shadow on the retina.

Entopic Shadows

Causes

- Lashes, lid margins and their associated tear prisms.
- Mucus or oil globules in the tear layer.
- Rubbing or pressing the eye disturbs corneal integrity and causes an entopic effect of mottling.
- Len sutures
- Lens opacities
- Vitreous floaters
- Muscae Volitantes (Floater, flying flies) These are lacy or chain-like opacities seen without a pinhole because they are caused by fine opacities positioned close to the retina.

Haidinger's Brushes

This is a propeller-like pattern perceived by the observer, caused by a polarized filter rotating behind a blue filter, against a white background.

Many structures have been suggested as being the sources of Haidinger's brushes. These include:

- The neuroglial fibres of Müller
- The neural outer plexiform layer (Henle's fibres)
- The Macula

To date, the macula appears to be the most suitable candidate because experiments have demonstrated an excellent agreement between the visibility of Haidinger's brushes using light of various wavelengths, and the absorption of the macular pigment at these wavelengths.

Maxwell's Spot

The yellow pigment of the macula will be expected to absorb more light than surrounding areas and therefore cause a slight blue shadow around the fixation point. But blue receptors in the macula adapt by increasing their sensitivity.

If however a bright source of light is fixated on through a cobalt blue and gray filter, an irregular dark-red spot will be seen through the cobalt-blue filter.

Physiological Entopic Phenomena

Phosphenes

Phosphenes are vague visual sensations caused by the stimulation of the retina by energy other than light. Of course the non-luminous energy has to be very large for any form of visual sensation to occur. The eye usually has to be dark-adapted to perceive phosphenes.

X-rays can stimulate the retina and have been used in axial length measurements in the past. But their excessive use can lead to serious side effects.

Mechanically induced phosphenes may be of ***internal*** or ***external*** origin.
Retinal detachments, fluid vitreous, and some other pathologies of the retina and choroid will lead to ‘flashing lights’.

Direct pressure on the globe with a finger will stimulate the underlying receptors and cause a phosphene to be projected in the visual field to the opposite direction from the finger pressure.

Version movements of the eyes from side to side, may give rise to dull phosphenes because of the traction effect of the lateral and medial rectus muscles on the globe. A ring phosphene has been reported on accommodating.

Blue Arc

Around a dim light viewed in a dark room can be seen faint blue-gray arcs which occupy that part of the visual field corresponding to the retina where the nerve fiber bundle passes from macular ganglion cell bodies to the optic nerve.
These blue arcs of the retina are an entoptic phenomenon in which action potentials of the nerve fiber bundle presumably excite adjacent neurons.

Lecture 7

COLOR VISION

Overview

The vivid colors we encounter in the environment are not only for enjoyment purposes. These colors are integral to survival, feeding, conspicuity, camouflage, and even education.

Following are a few examples of how colors are put to use in the plant and animal kingdoms.

- Flowers compete for pollinators, and as such have developed different pollinators colors, to attract birds, bats, insects, butterflies, etc. This ensures pollination and guarantees survival through generations.

- It is known that surface pigmentation on animals is affected by seasonal hormones. This fact is exploited by some species to indicate readiness to mate.

- Many animals use colors for camouflage. Further, such animals have these color camouflages in form of patches, which are designed to break up their patterns (edges) and thus conceal the shape of the animal. As we discussed in earlier lectures, a stationary animal without distinct edges, and which is colored so as to blend with its environment is extremely difficult to see. For example, a tiger's striped patterns conceal it in dry grassland.

- Humans also use and exploit colors in much the same ways as animals. For example, soldiers have uniforms where the colors and patterns vary according to the terrain where they expect to fight their battles. Again, there are patchy patterns on these uniforms to conceal the edges of, and thus hide the shapes, of the soldiers. For instance, desert soldiers were sandy-brown uniforms with slightly darker brown patches.

- Humans also use colors for signaling. Red, green, and yellow (amber) are used to control road and rail transport. Red, green, white, and yellow are used for maritime and aviation signals. Red usually indicates stop, danger or hazard; green indicates go; and yellow indicates a warning or caution.

- Humans also use color codes to denote pipeline and chemical containers, as well as to educate young children in nursery and early primary school.

- Finally, the widespread availability of colors in visual display units (VDUs) – such as your computer screen –have for example, made computer use less monotonous, and less strenuous for the eyes. However it is important to note that this advantage can be lost if one does not stick to the general rule of having a dark background and bright letters.

Color Production

Light is an electromagnetic radiation. What we see as light (the visible spectrum) is the range of wavelengths between 380 and 780 nanometers (nm). One nanometer is 10^{-9} meters.

Within this visible spectrum, a person with normal color vision can see about 150 colors.

In the visible spectrum, the following color names are associated with the following wavelengths:

- Below 380 nm ---- Ultraviolet
- 380 - 450 nm ---- Violet
- 450 - 490 nm ---- Blue
- 490 - 560 nm ---- Green
- 560 - 590 nm ---- Yellow
- 590 - 630 nm ---- Orange
- 630 - 780 nm ---- Red
- Above 780 nm ---- Infrared

It is of some importance to note that in the ultraviolet region of the electromagnetic spectrum, we have x-rays, and in the infrared region, we have TV waves, radio waves, and terahertz waves.

Terahertz waves promise to revolutionize our lives in the future. They can be used to 'see' through walls, clothing, and our body tissue. They can also be used to detect tumors and cancerous cells in the body. Therefore, the potential application of these waves in airport screening facilities, and in preventative and diagnostic medicine (to name just a couple of areas), is enormous.

Normal Color Vision

As we know, there are two receptor types in the retina – Rods and Cones. Color vision is a characteristic of cone-vision only. This means we can only appreciate different colors only when our cone photoreceptors are functioning. Therefore, in the fully dark-adapted eye, we only see in black and white, using contrast to differentiate between different objects.

There are about 7 million cones, and 120 million rods in the normal human retina, but neither rods nor cones are uniformly distributed on the retinal surface.

Cones have their highest density immediately around the fovea centralis, in a zone that is essentially rod-free.

While the cones have there maximum concentration 2^0 from central fixation, the rods have their maximum concentration 5^0 from central fixation.

Both receptor types reduce in density toward the periphery.

Whereas rods are not directionally-sensitive to light, cones display a marked directional sensitivity. For rays which pass into the eye through the periphery of the pupil and are incident on the retina at oblique angles, the cone response to them is weak or absent. In such cases, monochromatic light (light that has just the one color) appears to change in both hue and saturation.

Some Definitions

Hue: ***This refers to the particular shade of a color, for example a particular shade of red. Earlier we mentioned that the visible spectral wavelengths between 630 and 780 nm are 'red' wavelengths. These red wavelengths are all different shades of red from very bright red, to very dark red.***

We can thus say that the spectral wavelengths from 630 to 780 nm represent all the different hues of red.

Saturation: ***For any one hue of red, we could add white light to it, to make it appear brighter in appearance. The quantity of white light in any particular color determines the saturation of that color. This does not mean that adding white light to dark red, will bring it to the same color as a lighter red.***

If we were to take dark green as an example, if we keep adding white light, we would end up with a very bright green. The green will not suddenly become red or blue. This is because the particular wavelength (e.g. 543 nm) that defines that green hue is constant, and does not change.

For the same reason, one hue of green cannot change to another hue of green because of added white light.

Trichromatic Color Vision

Normal color vision is Trichromatic. Any secondary color can be derived by an appropriate mixture of the three primary colors (which Red, Green, and Blue). The exception to this rule is that above 520 nm, all wavelength hues are matched (by the eye) by an appropriate mixture of red and green. The blue-sensitive cones do not contribute to deriving colors in this category.

The mixing of only red and green, in the normal eye, to match spectral hues above 520nm, is known as a **'Rayleigh Match'.**

Thus far, we have referred to the cones as Red, Green and Blue. This is wrong. They are actually L-Sensitive, M-Sensitive and S-Sensitive cones (for Long, Medium and Short wavelength-sensitive cones respectively). Be careful to understand that L-Sensitive cones are not sensitive to only long wavelengths, but they respond to all three wavelengths. However, they are MORE sensitive to long wavelength light in the visible spectrum. Actually, any wavelength in the visible spectrum between 420 and 660nm will elicit a unique set of three responses from the three cone types. It is this unique set of three responses that determine the color that we see. If one of those responses is totally absent, or different from normal, then the color that we see is different from normal.
This brings us nicely to the Problem of Univariance and why we cannot call our three different cones red, green and blue cones. *The problem refers to the fact that a* single type of cone photoreceptor cannot tell us anything about the color of an object. It is the unique responses of the three cone types that combine to tell us that an object is 'red' or 'purple'.

The L-sensitive, M-Sensitive, and S-Sensitive cones have maximum sensitivities in the long (560 nm), medium (530 nm), and short (420 nm) parts of the visible spectrum.

In the central of the retina the majority of photoreceptors are M-Sensitive photoreceptors.
The scarcity of S cones in the central retina renders the normal retina blue-blind if an object field subtends less than 0.5^0 at the nodal point of the eye. This phenomenon is known as 'Small-field tritanopia'.

Note: Metamers

If two different luminance spectra are perceived as the same colour then these two spectra are metamers of each other. When viewed in isloation, if two differently coloured surfaces (ie with different luminance spectra) produce the same cone outputs then they are perceived as the same colour.

To explain Metamers, let us assume I have two patches of light. On one patch I have a light that appears yellow, which I obtain by mixing 'orange' (610nm) and 'green' (500nm) lights. On the other patch I have a yellow patch of light from a 'yellow' (570nm) light source. The thing is that the yellow from both light patches look exactly the same. So I have a combination of wavelengths (610nm + 500nm) that appear to be exactly the same color as a completely different wavelength (570nm). Whenever we have different wavelengths that appear to be the same color, they are called Metamers.

Metamers occur because color is a mental phenomenon not a physical phenomenon.

Physiological Variations with Color Vision

The main physiological sources of variation in normal color vision are:

- The selective absorption of short wavelengths by the crystalline lens, and the yellow macular pigment. This lens absorption increases with age, and after the age of 50 years the discrimination of short wavelength hues becomes significantly reduced. This discrimination reduction is even more marked if a cataract develops.

- The macula is a major source of variation in short wavelength sensitivity between the wavelengths of 450 and 490 nm, in all age groups. The individual variations in sensitivity that inevitably arise make it difficult to detect short wavelength color deficiencies.

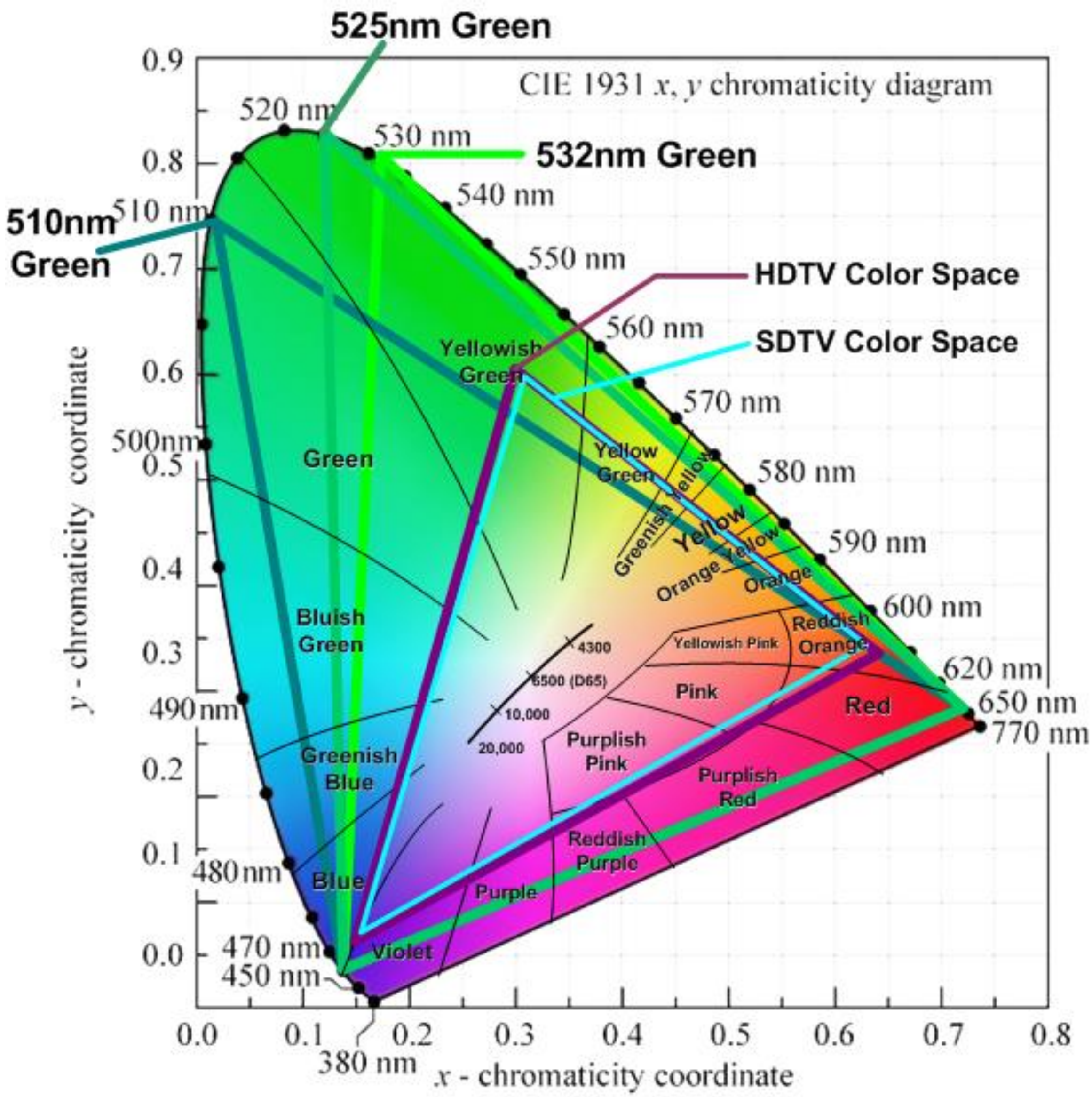

Figure 7.1 The Chromaticity Diagram: **The area within the big curved triangle shows all the colors the human eyes can perceive. The light blue and purple triangles show the colors that Standard Definition Television (SDTV) and High Definition Television (HDTV), respectively, can reproduce.**

http://www.google.com.sa/url?sa=i&rct=j&q=&esrc=s&source=images&cd=&cad=rja&docid=zOu2iwLvR_4-cM&tbnid=RM53j1AeR-UluM:&ved=0CAUQjRw&url=http%3A%2F%2Fwww.kguttag.com%2F2011%2F12%2F16%2Fdiode-green-lasers-part-1-wavelength-and-efficiency%2F&ei=cWh6UujzEu7Y0QWchoDADw&psig=AFQjCNF_kxvfG14YGjoZ0H3pOWhl4fN5Ew&ust=1383840162116587