COLOR: CONSTANCY AND INCONSTANCY

Vien Cheung*

School of Design, University of Leeds, UK.

*Corresponding author: Vien Cheung, t.l.v.cheung@leeds.ac.uk

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ABSTRACT

Color perception is not a passive process. The visual system does not operate like a physical recording device that records and "reproduces" a faithful rendition of the physical world. Rather, the purpose of the visual system is to extract information from the physical world and to create an internal representation. The purpose of this representation is to enable us to locate objects in and navigate around our environment. This view of vision as a non-passive or cognitive process can explain the many so-called illusions that can be created.

INTRODUCTION

The three factors of color are the light source, the object and the observer (Figure 1). Different light sources have different spectral power outputs. That is, some lights (such as the tungsten bulb used at home) contain lots of long-wavelength light whereas other lights (such as the light from a clear sky in summer) contain proportionately much more of the short-wave light. Objects are colored because they reflect certain wavelengths more than others. An object that we would perceive as red, for example, under normal daylight conditions reflects the longer wavelengths of light and absorbs the shorter wavelengths. The 'fingerprint' of an object's color is the reflectance spectrum which is the proportion of light that is reflected by the object at each wavelength. The most important component of color vision, however, is the observer. The human eye is the sense organ of the visual system (touch, taste, smell and hearing make up the other senses).

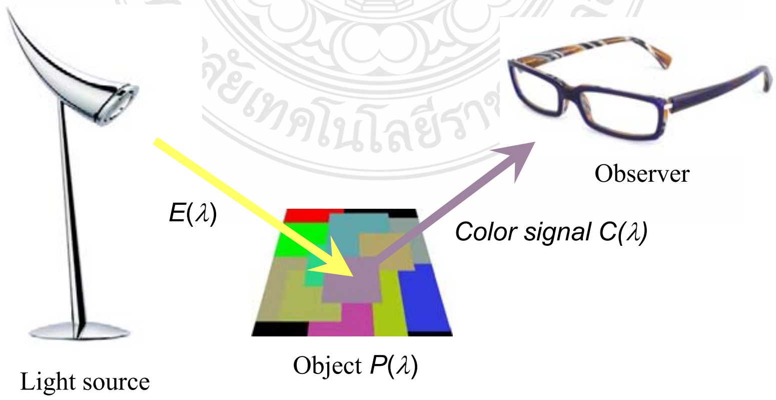

Figure 1. The three factors of color: light source (defined by spectral power distribution $E(\lambda)$), object (defined by spectral reflectance $P(\lambda)$) and observer.

The eye contains three types of cell called cones that are mainly sensitive to long, middle (or medium) or short wavelengths and are sometimes referred to as L, M or S cones. The eye also contains rods, but under normal levels of illumination (referred to as photopic vision) the rods do not operate and color vision is mediated by the three classes of cone. The cones turns the light signals into an electrochemical signal and this signals leaves the eye through the optic nerve and makes it way to the rear part of the brain in an area known as the visual cortex.

The cortex is a very thin part of the outer lining of the brain and is sometimes referred to as gray matter (white matter is inside the brain and is white in color because of the high amount of fat present). Although the cortex is thin it is highly convoluted and the surface area of a typical cortex is the size of a football pitch. The brain consists of a large number (approx. 1012) brain cells called neurones. These cells each received signals from other cells along their dendrites and then pass the signals on along their long axons to other cells. In this way, the visual signal from the retina is processed by many cells in turn and eventually results in cells in the visual cortex being activated. It is not clear how the pattern of activation in the retina gives rise to color perception (nor, indeed, vision at all). Certainly, there is no homunculus (Greek for 'little man') who resides in the brain and watches the pictures transmitted by the eye. In this sense the eye does not work like a television camera. Rather, the actual activation of the cortical cells themselves is responsible for visual perception in much the same way that consciousness arises from the activation of the brain.

COLOR CONSTANCY

One important property of color vision is color constancy. This can be defined as the fact that the colors of most objects in the world tend to remain approximately constant even though the light source may change markedly. It is clear why color constancy should be a desirable property of vision since one important purpose of vision is to be able to recognize objects. It is helpful that the color of objects does not change very much. If the color of an object, such as an apple (Figure 2), changed every time the illumination changed (such as when a cloud passes over the sun or when an apple is viewed under a green-leaf canopy) then it would make the task of identifying the apple much more difficult.

Figure 2. If the color of an object changed every time the illumination changed it would be rather difficult to spot the fruits from the trees.

Similar computation processes enable us to recognize an object (such as a chair) no matter which angle it is viewed from or even if it is partly obscured. However, what is less clear is how color constancy occurs. The changes in the intensity and color of the light that we experience when we move from indoors to outdoors or from one time of day to the other are large and yet seem to have no effect on the colors that we perceive for objects. One process that is probably connected with color constancy is retinal adaptation. For example, the visual system would like to extract illuminant-invariant information for objects (e.g. Finlayson, Drew and Funt, 1994; Hurlbert, 2002; Foster, 2003). However, retinal adaptation is unlikely to be the only factor involved and cognitive processes are also known to be involved.

COLOR INCONSTANCY

Contrast

It is extremely well known that a gray patch displayed on a dark background will look brighter than a physically identical gray patch on a light background (see Figure 3). This is spatial contrast (Hurlbert, 2002). Figure 3 illustrates an example of lightness contrast, but the same type of phenomenon occurs for color stimuli. Thus, a yellow patch viewed on a green background will appear more reddish than the same physical yellow patch on a red background. Spatial contrast occurs because the visual system computes the contrast in the image that it views; this computation helps the visual system achieve its aim to extract invariant information from the image. Invariant information is information that does not change.

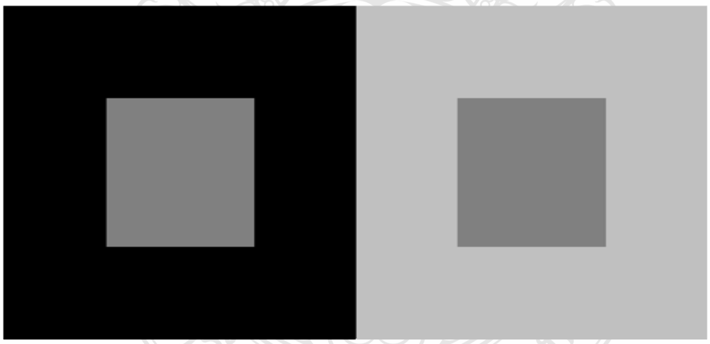

Figure 3. The two small gray squares are physically identical but do not have the same appearance because they are displayed against different backgrounds.

Assimilation

The process of spatial contrast is a consequence of the active process of vision. However, sometimes a gray patch appears darker when it is on a dark background than on a white background. Figure 4 illustrates the opposite of contrast (where the object takes on the opposite color of the background) and it is referred to as assimilation (Ripamonti and Gerbino, 2001). Whether contrast or assimilation occurs depends upon the nature of the image and is not entirely understood.

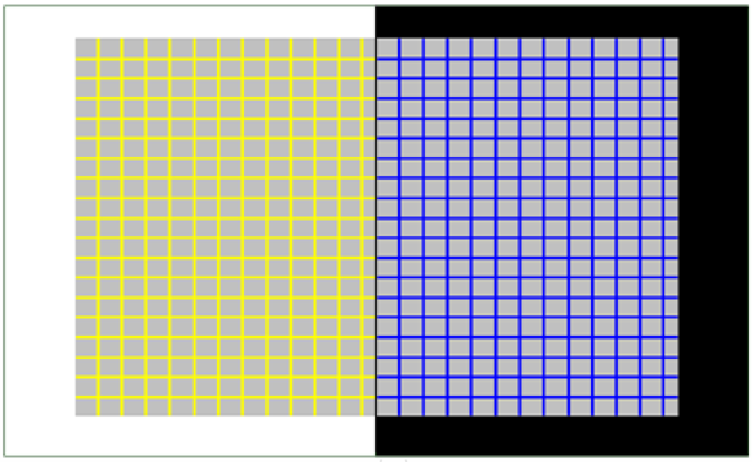

Figure 4. The color of a patch takes on the hue of the surrounding background rather than contrasting with it.

CONCLUSIONS

Color is a perceptual phenomenon; a sensation. Color is not the property of an object. The eye captures the light reflected by objects in a way that is analogous to a camera in many respects. However, color vision is much more complicated than the operation of a camera because the signals detected by the eye are processed by the neural network of the brain. It is believed that the activity in the brain that most closely correlates to color perception occurs at the back of the brain in an area referred to as the visual cortex. If color occurs anywhere it is in the visual cortex. However, it is important to realize that the visual system does not simply record the information out there in the world; rather, it constructs an internal representation of the world. When it comes to vision; what you see is not what is out there but rather what you think is out there. Vision is an active process.

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