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On Edwin H. Land's Retinex Theory: Developing a Classroom Demonstration for Color Vision

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ON EDWIN H. LAND'S RETINEX THEORY: DEVELOPING A CLASSROOM DEMONSTRATION FOR COLOR VISION

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Introduction

The phenomenon of visual perception is a fundamental process that many take for granted. [Color perception] in primates coevolved with seed dispersal mechanisms because the ability to detect colors allowed primates to distinguish various food sources from their environment (Regan et. al. 2001). Despite its fundamental importance, color perception is a concept that is widely misunderstood.

Before the development of the The Retinex Theory it was generally thought that color perception was a function of the physical properties of light that reached our eyes. For example, a blue object was thought to reflect more wave-lengths of blue light than a red object (Land 1971). However, Edwin H. Land observed that the wavelength of light reflected by an object does not necessarily correspond to the color that is perceived. When he realized this he coined the term, "Retinex" to demonstrate that color perception involves all levels of visual processing, from retina to cortex.

The process of color vision begins when photosensitive pigments in the retina absorb light. In humans there are four photosensitive pigments, one that has the highest absorption around 425nm (blue pigment), two highly similar pigments with maximum absorption around 530nm and 560nm (green and red pigments respectively) and rhodopsin (plays a minute role in color perception) (Nathans 1999). Individually, each pigment gives little information about color. It is by processing the ratio between excitation of different pigment types and the level of excitation that color perception occurs. Therefore in practice, activation of only two of photo pigments allows for the perception of colors.

We developed a simplified and inexpensive classroom demonstration to present the basic principles of The Retinex Theory, modeling Land's original experiment. Our hope is that this demonstration can be used in a classroom setting to educate and excite students about the process of color vision.

Materials and Methods

- One black and white image was taken using a red filter and processed to produce a positive transparency, which was then projected with orange light with a wavelength centered at 600nm (bandwidth=10nm)
- Another black and white image was taken of the same object using a green filter and processed to produce a positive transparency, which was then projected with yellow light with a wavelength centered at 580nm (bandwidth=10nm)
- Both images were passed through a f=50mm convex lens to focus the image onto a white projection screen simultaneously.
- The emission spectrum for each image (orange and yellow) was measured using a spectrometer

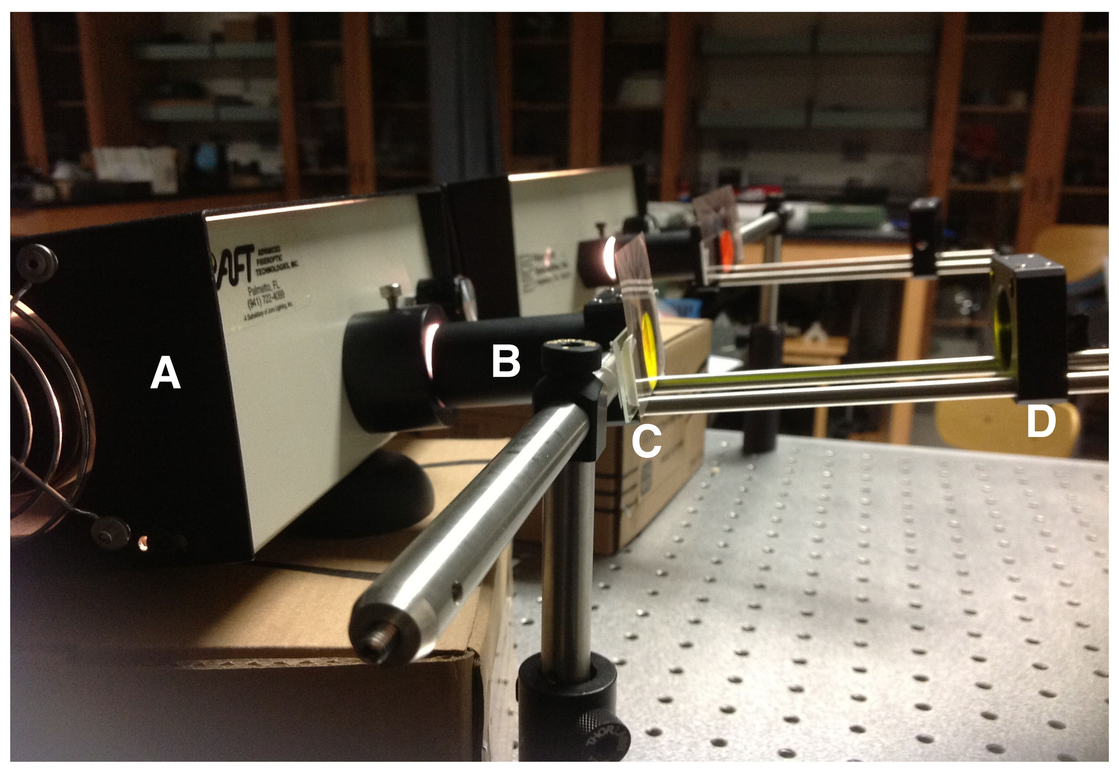

Figure 1. The set up of the apparatus.
A. Halogen Lamp **B.** Lens tube containing filter. **C.** Transparency. **D.** f=50mm lens

Literature Cited

Land, E., and J. McCann. 1971. Lightness and Retinex Theory. Journal of the Optical Society of America. 61:1-11.

Nathans, J. 1999. The Evolution and Physiology of Human Color Vision: Insights from Molecular Genetic Studies of Visual Pigments. Neuron 24: 299-312

Regan, B.C, B. Julliot, F. Simmen, P. Viénot, P. Charles-Dominique, and J. D. Mollon. 2001. Fruits, Foliage and the Evolution of Primate Colour Vision. Philosophical Transactions: Biological Sciences. 356: 229-283.

Results and Discussion

- The apparatus that was developed was created using inexpensive materials and is simple to reproduce (Figure 1).
- A color image was produced using only yellow and orange light (Figure 3).
- The wavelengths were verified by measuring the spectrum of the projected image (Figure 2).
- We successfully observed a wide spectrum of colors that could not be characterized by the emission spectrum that was measured (far left image, Figure 3.)
- Color perception occurs due to relative intensities of short and long wavelengths of light and processing of that information in the visual cortex.
- A digital camera responds to light in a manner similar to how humans process images in the visual cortex

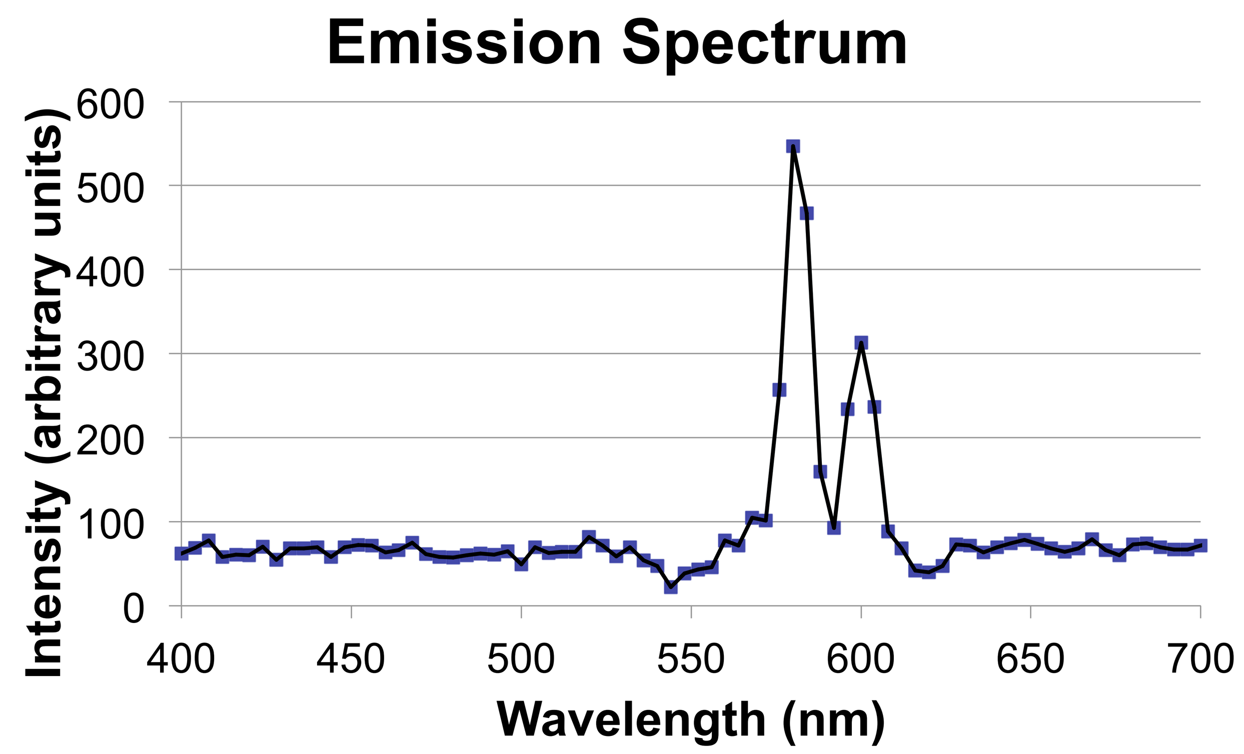

Figure 2. The emission spectrum was measured from the colored image (shown in Figure 3). It shows two distinct emission bands, one with a maximum emission at 580nm(yellow) and another with a maximum of 600nm (orange).

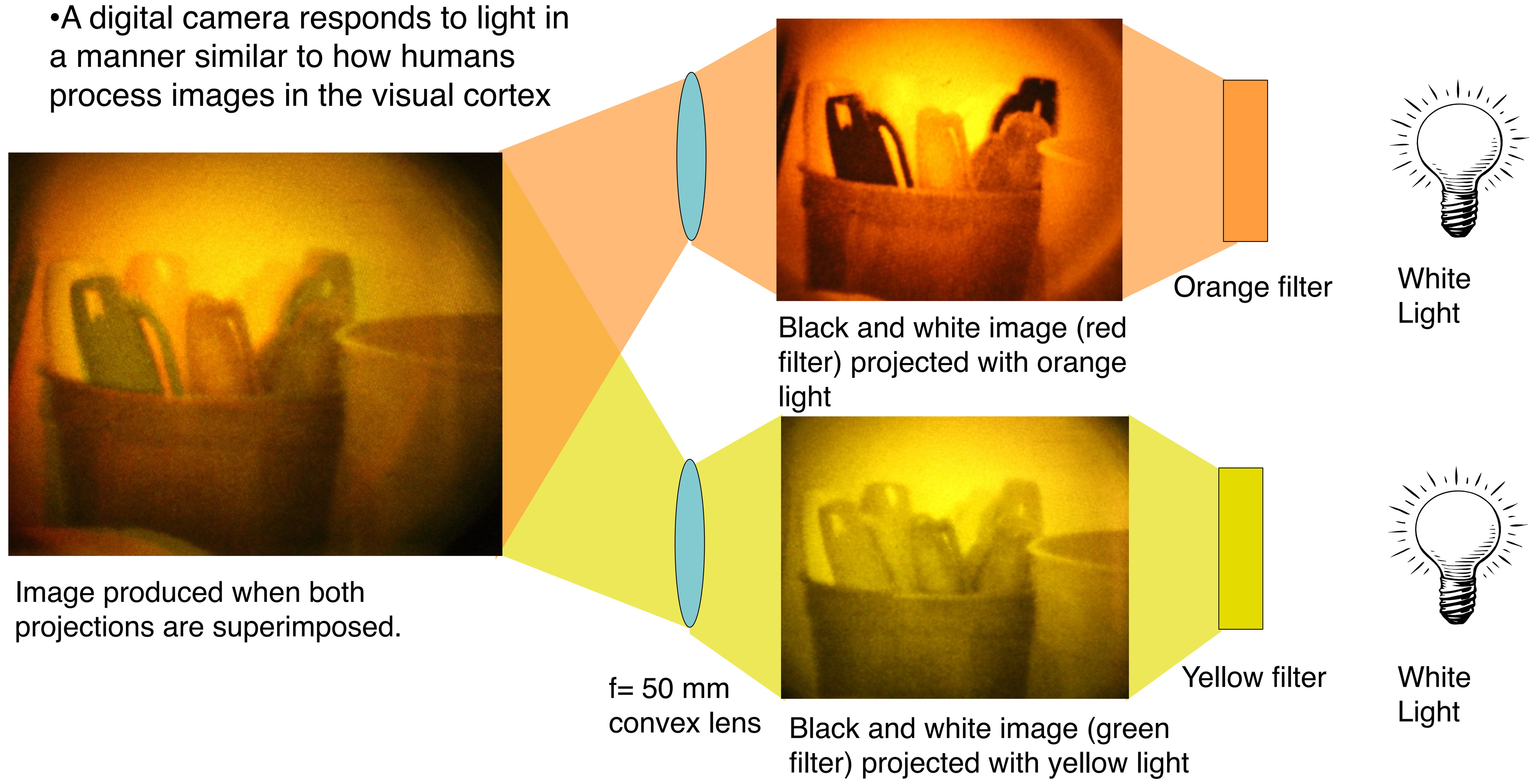

Figure 3. If the Retinex Theory were not true the only colors in the final image would be mixtures of yellow and orange light. However, the final image shows a variety of colors that cannot be explained by the physical properties of light that were being reflected. Also it is interesting to note that the images above were taken with a digital camera exhibiting that cameras are able to process light in a manner similar to the visual cortex in humans.

Acknowledgements

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