Scaling Human Perception of Color Differences

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Abstract

The Commission Internationale de l'Éclairage (CIE) first established a method for measuring color as it relates to human vision in 1934. There are specific methods for comparing two colors, a reference color to a sample, and assigning a color difference value based on the CIE LAB ordered system for quantifying color. In order for the numerically defined color tolerance systems published by the CIE to be applicable for color reproduction, it must be correlated with human perception of color differences. Human participants evaluated perceived color differences between reference and sample images, and ranked the degree of color accuracy. The same reference and sample images were measured according to CIE LAB to rank the objective degree of color accuracy using CIE formulas defined in 1976 and 1994. Outcomes of this research include the correlation between human perceptions of color differences with objective calculations of the same. The results from this research will be used to further evaluate and revise process control systems for objectively defining color matches, and to provide consumer product companies with added consistency of color reproduction and brand identity of their products with consumers.

Introduction

Color tolerancing calculations allow manufacturers of printing and packaging to quantify their system for managing customer's colors throughout the manufacturing workflow. In order for color tolerancing formulas to succeed, a unit of one difference in a red area of the color spectrum must correlate to one unit of difference in a blue area of the color spectrum. The human eye is susceptible to color shifts in different degrees, based on the color being evaluated.

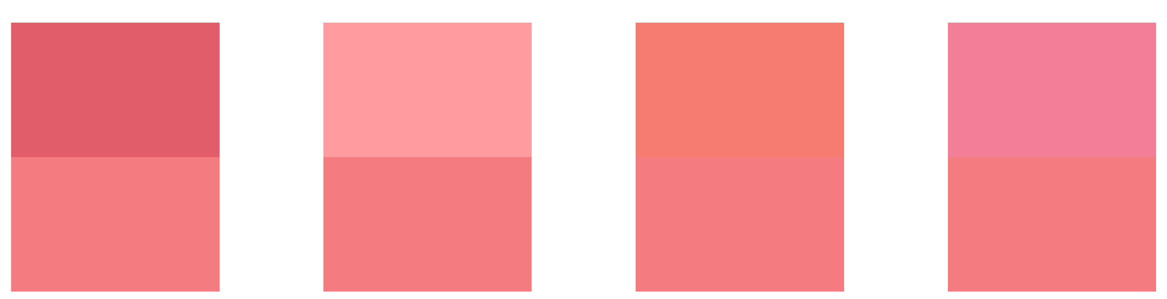

Figure 1: All sets of colors are 10 Delta E units apart using CIE 76. The bottom color remains the same for all color pairs.

There are two specific formulas for calculating color difference according to the CIE evaluated in this trial. The initial formula released in 1976 allowed manufacturers to begin quantifying color differences, but failed to discriminate uniformly. The CIE published a new formula in 1995 to correlate to human vision in a more uniform order. This study researches how humans scale color images containing various photographic elements in a comparative ranking order.

- Can color tolerancing equations be used to quantify human discrimination of color images?
- How do human's rank color image discrimination?
- Can color's be sampled from imagery to assist in calculating objective color differences?

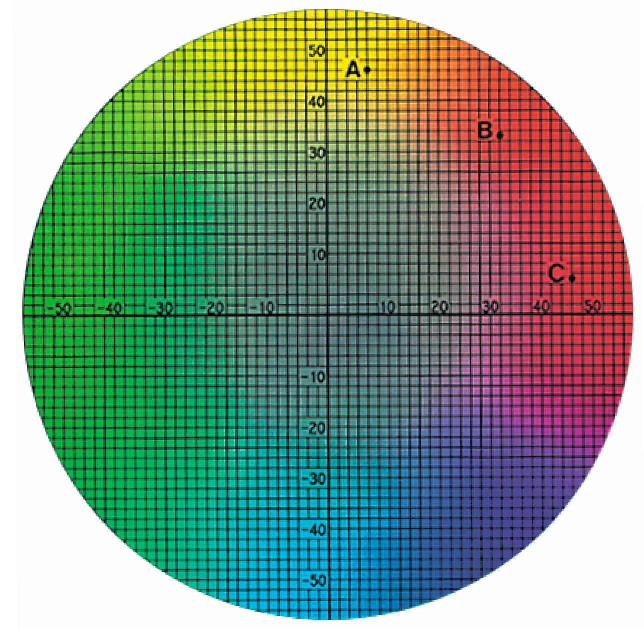

Figure 2: CIE LAB 76 Color Ordering System

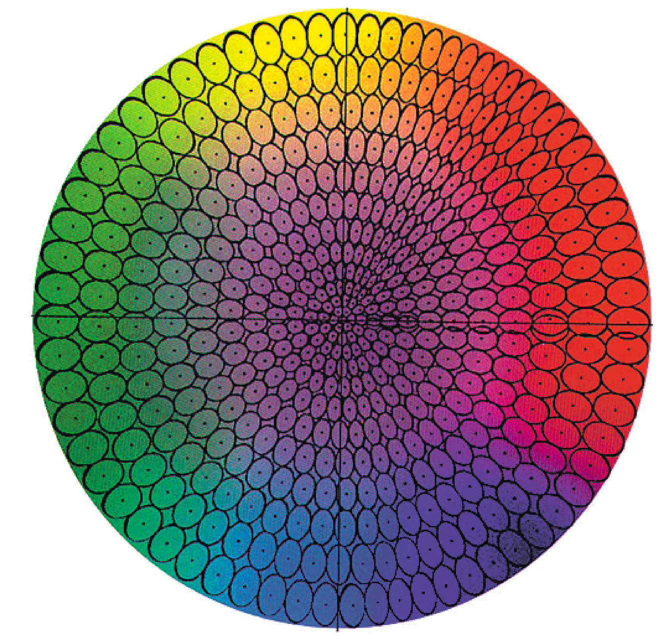

Figure 3: CIE LAB 94 Elliptical Based Tolerance

Method

Thirty-one students and faculty in the Department of Graphic Communications at Clemson University were asked to rank seven pairs of color images in order from best color match, 1, to worst color match, 7. The seven image pairs had a CIE LAB color difference (Delta E) ranging from 2.47 to 4.56, and Delta E 94 ranging from 1.92 to 4.04. Images were evaluated under controlled lighting with a temperature of 5000 Kelvin, had a median age of 22, and were 36.7% male. Participants did not report any visual problems that would affect color judgment.

Procedure

Results from the color survey were ordered with objects (image pairs) in columns, and judge rank for each object in rows. Variance stable rank sums were calculated for each object. Objects were then scaled according to their ranked sum for analysis and plotted on a unidimensional scale (Figure 4). The human scaled ranking was correlated via Kendall's Tau to both CIE LAB 76 and CIE LAB 94 ranking. An ALSCAL multidimensional scaling procedure (MDS) of human ranks was conducted with three dimensions. MDS plots were evaluated for conceptual interpretations of the axes.

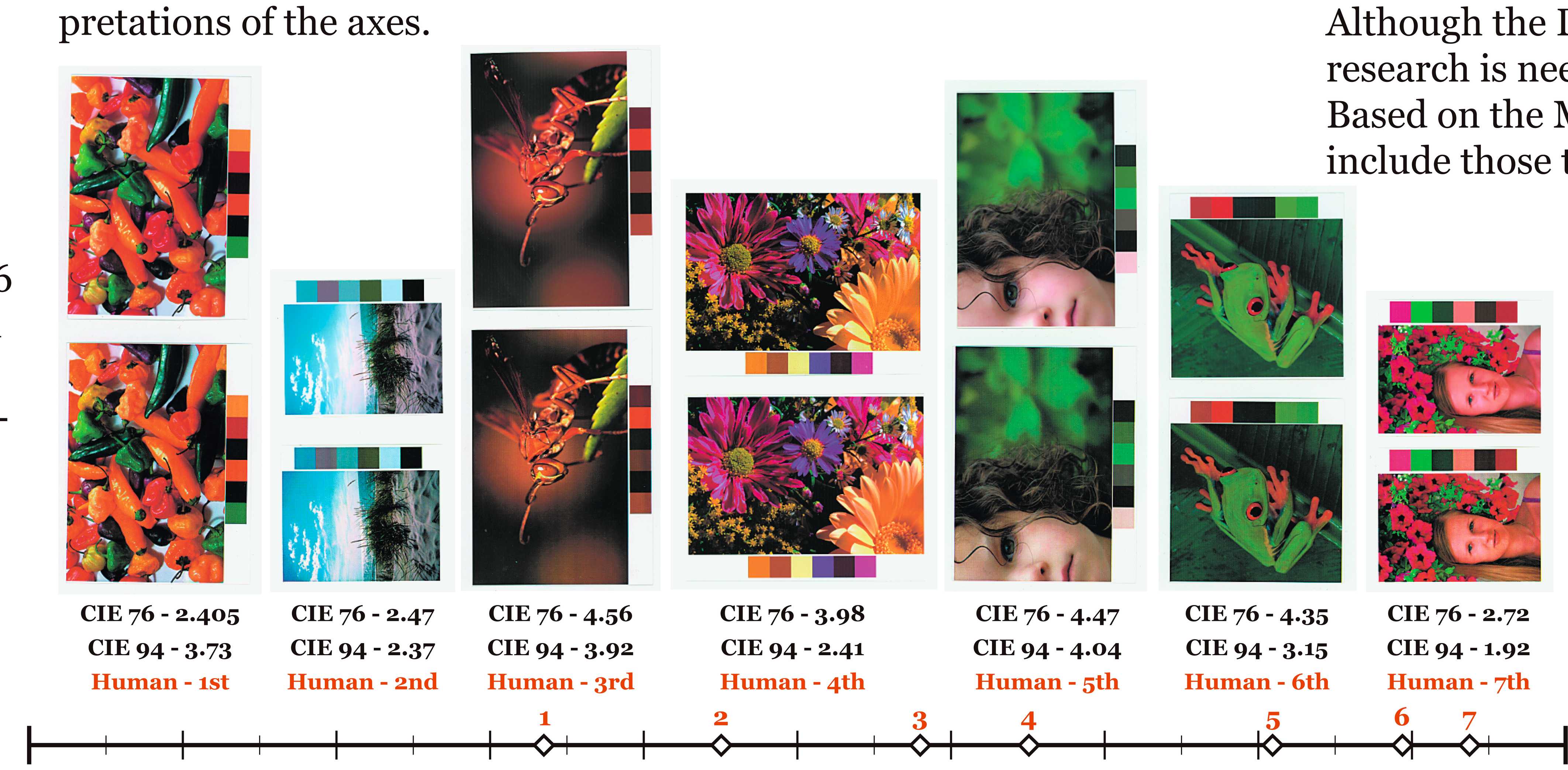

Figure 4: Unidimensional variance stable rank sum scale for human scaling from best color match to worst color match.

Results

The Kendall Tau nonparametric correlation coefficient between CIE LAB 76 and human scaling was .238 and -.143 for CIE 94 and the same human scale. A visual inspection of the multi-dimension scale plot resulted in the following conceptual interpretation of the x and y axis. The x-axis, or dimension 1, places images with a defining focus point on the negative, and moves toward more abstract or busy images on the right. The y-axis, or dimension 3, places images containing saturated colors on the positive, and moves toward neutral images on the negative.

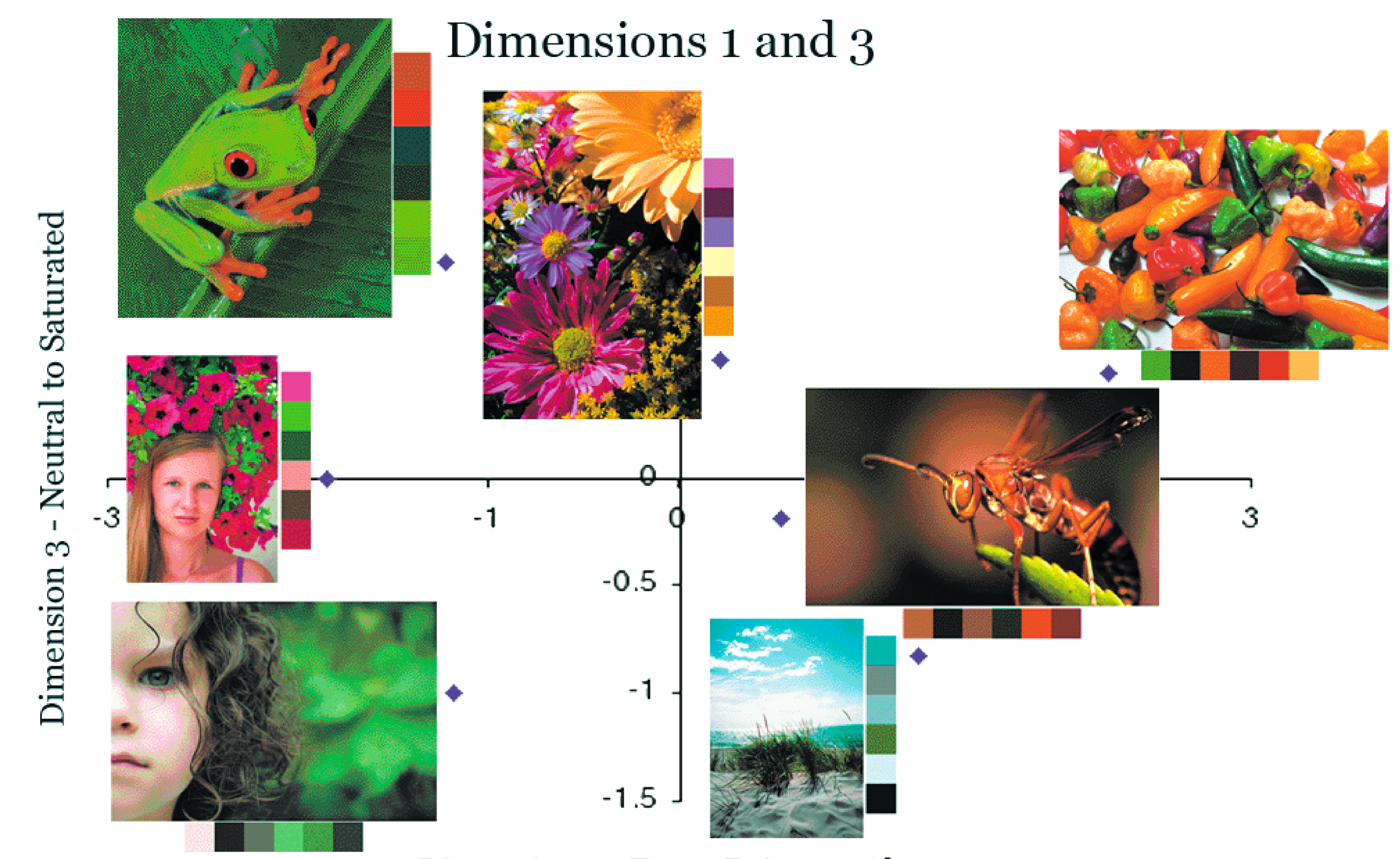

Figure 5: Multi-Dimension scale of stimuli

Conclusion

Results from this study support the idea that is difficult to correlate color image differences with objective Delta E values assigned using CIE formulas. Data shows that human's differentiate color shifts using criteria associated with content of the image, along with color type of image. Although the Delta E calculations quantify raw color differences, more research is needed to apply this quantitative approach to color images. Based on the MDS results, colors sampled from images should primarily include those that are most saturated, and colors found in focus areas.

Significance

Tighter demands from consumer product companies require print manufacturers to deliver products that meet a strict criteria of color acceptance, both in brand colors, i.e. Coke Red, Kraft Blue, and in printed color imagery, i.e. photographs of products. Color tolerancing allows both customers and manufacturers a set variance for acceptable brand color, but fails to accurately relate to printed imagery. This study allows a foundation to build systems for managing output image colors for quantitative evaluation.