EFFECT OF FOUR DIFFERENT LIGHT SOURCES ON NORMAL COLOR VISION

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ABSTRACT

Background: This clinical study explores the effect that three different lighting sources have on color discrimination in people with normal color vision and no known ocular disease. The purpose of the study is to assess how color discrimination may be affected in different lighting situations, possibly leading to occupational mistakes. *Methods:* Forty-nine subjects were tested using the Farnsworth Dichotomous test (D-15) under 4 different light sources; illuminant C (as a control), a sodium vapor lamp, an incandescent lamp and a metal halide lamp. The caps in the D-15 were arranged in a pre-determined random order for each light source. This order was held constant for each subject. The numerical order of the caps arranged by the subject was recorded and that sequence was used to calculate a color confusion index score using the color vision recorder and to record the number and type of errors. *Results:* There was a statistically significant difference between the mean CCI score of the sodium vapor lights and the incandescent lights as well as the sodium vapor lights and the metallic halide lights. However, no statistical difference was found between the means calculated for illuminant C and the other three light sources. *Conclusions:* One can conclude from this study that the differing light sources minimally affect the performance on the D-15. However, the light sources may have more of an effect if other types of testing are utilized.

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Introduction

This study will assess the affect that four different lighting sources have on color discrimination in people with normal color vision and no known ocular disease. Our primary research question is, will these four light sources produce similar results on the Farnsworth Dichotomous-15, henceforth referred to as the D-15. The four light sources are a sodium vapor lamp, a metal halide lamp, an incandescent lamp and standard illuminant C. Sodium vapor lamps contain a small amount of sodium and neon gas and are used mainly in streetlights. Metal halide lamps are used to light large indoor areas such as supermarkets, gymnasiums, and commercial buildings.[1] Incandescent lighting is used for most small business and residential lighting. Illuminant C is the standard lamp used for color vision testing. Metal halide energy output shows strong peaks in the blue, green, and yellow regions, while sodium vapor energy output is almost exclusively in the yellow region.[2] Based on this information, we believe that the these light sources may affect color dependent tasks. These tasks could include working with colored wiring in a parking lot at night, selecting color palates in a warehouse or supermarket, or identifying colors of cars, clothing, or hair at a crime scene. This study will explore the possible effects the lighting may have on color dependent tasks. Our hypothesis is, there will be a significant difference between the color confusion index (CCI) of the sodium vapor and metal halide lamps, as compared to standard illuminant. We expect no significant difference in the CCI between the incandescent lamp and standard illuminant C.

The CCI is the sum of the color differences between the chips as arranged divided by the minimal possible. The color difference is calculated using the CIELAB color difference formula. These are added together to get the total color difference score

(TCDS). The lowest possible score for the TCDS is 116.9 for the correct chip order, and it increases from there depending on the number and severity of "mistakes".[3] The CCI for each individual test will always be a number higher than 1.00, if the caps are not arranged in the correct order.

Methods

A total of 49 subjects were tested using the Farnsworth Dichotomous test (D-15) under four different light sources; illuminant C (as a control), an incandescent lamp, a sodium vapor lamp, and a metal halide lamp. All four lamps were calibrated to the same illuminance of 28 foot-candles. Subjects included male and female students drawn from the Michigan College of Optometry between the ages of 20 and 35. Since this study was only interested in testing normal color vision, those with abnormal color vision were automatically excluded, while those with ocular pathologies were excluded based on the affects that the condition may have on color vision. In order to establish a control, each subject performed the D-15 under the standard illuminant C prior to testing under any other illumination. Testing proceeded to the incandescent lamp, followed by the sodium vapor and ending with the metal halide. The caps in the D-15 were arranged in a pre-determined random order for each light source. This order was held constant for each subject. Each cap in the D-15 is numbered (1-15) according to its sequence. The patient was instructed to place them in order. The numerical order of the caps arranged by the subject was recorded and that sequence was used to calculate a color confusion index score using the color vision recorder and to record the number and type of errors.

Results

When observing merely the raw data, it would appear that a statistically significant difference would exist between the sodium vapor lamp and illuminant C. It appears this way due to the increased number of subjects who made errors while using the sodium vapor lamp (10), as compared to illuminant C (4). Minimal errors were made with the remaining two light sources, incandescent (2) and metal halide (1). The great majority of the errors, 13 out of 17, were single cap reversals, i.e. cap 2 switched in position with cap 3. Of the four remaining errors, two were made using the sodium vapor lamp.

Using the Vision Color Recorder, Color Confusion Index (CCI) numbers were calculated for all 49 measurements. Table 1 displays descriptive statistics including the means and standard deviations for the CCI data.

Using SPSS, a repeated measures within-subjects ANOVA test was performed on the CCI data. In addition, a pairwise planned contrast was performed. Mauchly's Test of Sphericity, which compares the variance within the light sources, was also calculated and found to be significant ($p<0.001$) with a value of 0.395. This means that equal variances between the light sources cannot be assumed. Since equal variances could not be assumed, a Huynh-Feldt correction was employed.

When using the Huynh-Feldt correction to evaluate the repeated measures analysis, a significant difference between the means was observed. Table 2 reveals that the Huynh-Feldt test found a statistically significant difference at the alpha = 0.05 level between the light sources ($F = 4.961$, $p = .015$).

Table 3 reveals there was a statistically significant difference between the mean CCI score of the sodium vapor lights and the incandescent lights as well as the sodium vapor lights and the metallic halide lights. However, no statistical difference was found between the means calculated for illuminant C and the other three light sources.

Discussion

According to the results of this study, there is no significant difference in color discrimination between illuminant C and the three other light sources, however there are some differences amongst the other light sources. There is a difference in color discrimination between the sodium vapor and incandescent light, and the sodium vapor and metal halide. Although different light sources only seem to effect fine discrimination abilities, such as differentiating between two shades of the same color, the small differences can have a large effect on color discrimination in the real world. Certain occupations, such as decorators, mechanics, electricians, etc., need very accurate color vision. The small differences caused by less desirable light sources can make a big difference if a mechanic uses the wrong color of wire causing something to malfunction.

One can conclude from this study that the differing light sources minimally affect the performance on the D-15. However, the light sources may have more of an effect if other types of testing are utilized. The D-15 is actually a modification of the Farnsworth-Munsell 100 Hue Test, and is primarily used as a color vision screener. It is not intended to be used for diagnostic purposes as is the 100 Hue Test.[4] In fact, according to one study, the D-15 is not suitable as a single test for occupational selection because it will pass 20% who cannot name surface colors correctly, and fail 30% who can.[5]

Some of the limitations of this study were that optometry students were used as participants. These students are savvier than the average consumer on color vision. In addition, this study only evaluated the Farnsworth D-15. Alternative color vision tests such as matching colored wiring, the desaturated D-15 or the psuedoisochromatic plates, may reveal different results. Further studies should be performed to assess the more subtle effects that lighting may have on color discrimination especially in those with color vision deficiencies.

Table 1

Descriptive Statistics			
Light Source	Mean	Std. Deviation	N
Illuminant C:	1.007	0.026	49
Incandescent:	1.004	0.020	49
Sodium Vapor:	1.028	0.066	49
Metal Halide:	1.002	0.016	49

Table 2

Tests of Within-Subjects Effects							
Source		Type III Sum of Squares	Df	Mean Square	F	Sig.	Observed Power
Light Source	Sphericity Assumed	0.021	3	0.007	4.961	0.003	0.907
	Greenhouse-Geisser	0.021	1.520	0.014	4.961	0.016	0.715
	Huynh-Feldt	0.021	1.560	0.014	4.961	0.015	0.723
	Lower-bound	0.021	1	0.021	4.961	0.031	0.588
Error(FACTOR1)	Sphericity Assumed	0.204	144	0.001			
	Greenhouse-Geisser	0.204	72.966	0.003			
	Huynh-Feldt	0.204	74.857	0.003			
	Lower-bound	0.204	48	0.004			

Table 3

Pairwise Comparisons		Mean Difference	Std.		95% Confidence Interval for Difference	
(I) FACTOR1	(J) FACTOR1	(I-J)	Error	Sig.	Lower Bound	Upper Bound
Illuminant C:	Incandescent:	0.003	0.005	0.502	-0.006	0.013
	Sodium Vapor:	-0.021	0.011	0.053	-0.042	0.000
	Metal Halide:	0.005	0.004	0.262	-0.004	0.014
Incandescent:	Illuminant C:	-0.003	0.005	0.502	-0.013	0.006
	Sodium Vapor:	-0.024	0.009	0.011	-0.042	-0.006
	Metal Halide:	0.002	0.004	0.633	-0.006	0.009
Sodium Vapor:	Illuminant C:	0.021	0.011	0.053	0.000	0.042
	Incandescent:	0.024	0.009	0.011	0.006	0.042
	Metal Halide:	0.026	0.010	0.011	0.006	0.046
Metal Halide:	Illuminant C:	-0.005	0.004	0.262	-0.014	0.004
	Incandescent:	-0.002	0.004	0.633	-0.009	0.006
	Sodium Vapor:	-0.026	0.010	0.011	-0.046	-0.006

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