EFFECT OF FIVE DIFFERENT LIGHT SOURCES ON MATCHING PAINT CHIP SAMPLES

by

Kelly Fisher and Jennifer Chase

This paper is submitted in partial fulfillment of the
requirements for the degree of

Doctor of Optometry

Ferris State University
Michigan College of Optometry
March 2007

ABSTRACT

Background: Color constancy, the perceived stability of color appearance regardless of changes in illumination, is not absolute. The goal of this study was to determine whether color constancy is maintained in matching tasks under five different illuminants. There would be no statistical difference in the number of matches made if color constancy played a role in the matching tasks required in the following study. Methods: Each of the five light sources was calibrated to approximately the same illuminance of twenty eight foot-candles. The sources were then used to illuminate two boards per light source, one containing twenty five paint chip samples numbered 1-25, and the other twenty five samples lettered A-Y. Subjects were asked to match each numbered sample with the corresponding lettered sample, and record their answers on the provided form. Results: Using SPSS, a repeated measures within-subjects ANOVA test was performed on both the number of errors per subject and the completion time per subject. In addition to the ANOVA, a pairwise planned contrast was performed. Mauchly's Test of Sphericity, was also calculated. When using the Huynh-Feldt correction to evaluate the repeated measures analysis, a significant difference between the means was observed for the number of errors per subject, but not for the completion time per subject. Conclusions: The type of light source does affect the ability to perform color matching tasks, but not the time to complete the task.

TABLE OF CONTENTS

LIST OF TABLES

INTRODUCTION:

Color constancy refers to the perceived stability in the color appearance of objects despite spectral changes in the surrounding illumination.[1,2] In the 1930s psychologists described attributes that enhanced the stability of perceived color and lightness. These included the number of distinct surfaces present in the scene and the degree of depth variation.[3] The perceived color of a surface depends on its spectral reflectance properties, which is the proportion of incident light reflected at each wavelength of the spectrum. This whole process is mediated by the cone receptors.[4] When an object is part of a complex scene, the color is not determined only by the object's spectral reflectance properties, but also by the colors of all other objects in the scene. In such situations the visual system is able to maintain constancy by taking all global information into account.[2] When a surface is uniform and presented in a dark field, the challenge is to determine whether the perceived color is due to the objects reflectance properties, or due to the spectrum of the illuminating light.[4]

Quantitative experiments have shown color constancy is not perfect. Several reasons for this have been proposed, including the effects of instruction, inappropriateness of stimuli used, increment-decrement asymmetries, and the size of the illumination shift.[5] Color constancy also varies from scene to scene. Proposed cues to the illuminant include mutual reflection, specular reflection, boundaries, shadows, illuminant gradients, brightest spots, and specular highlights that reflect the illuminating light. Empirical tests show that color perception is affected by specular highlights, mutual reflection, binocular disparity, and perceptual organization.[6] Furthermore, from experimental work, we know that in gradually changing illuminations the color appearance of objects is maintained, even when the illuminant changes, through an adjustment of the visual system that is based on the three cone signals, a principle called Von Kries adaptation. For example, if an illuminant mainly emits light in the long wavelength part of the spectrum, then it is mainly the L-cone signal which is scaled.[7]

Color constancy across light sources has been extensively studied. It has been established that the human visual system can exhibit constancy with respect to such changes particularly when the stimuli are naturalistic and contain a wide variety of cues to the illuminant.[8] The following experiment seeks to determine how changes in illumination affect the ability to make color matches when few global cues are present. If color constancy held true in this situation subjects would have no difficulty making matches under different illuminations. There should be no statistical difference in the number of matches made among the various light sources. The main purpose behind such an experiment is to determine whether persons in professions that require critical color discrimination must take the source of illumination into account. For example, a painter that must match a sample from the local hardware store to a sample in the house he or she is painting. If the painter brings a sample from a home and matches it to a sample under the fluorescent lights of a store will the match be accurate? Furthermore, what about the police officer that is driving down a road illuminated by sodium vapor lamps, will the color he reports a car to be, still be the same color as viewed in a street illuminated by another source?

In the following experiment, subjects were asked to perform color matching tasks under five different light sources. The five light sources consisted of illuminant c, color temperature 6740 and color rendering index one hundred using the MacBeth Easel Lamp, a fluorescent Sylvania thirteen watt CFT13WDS/EC/841 lamp with a color temperature of 4100 and color rendering index of eighty two, incandescent using a Philips sixty watt Duramax soft white bulb of color temperature 2700 and color rendering index one hundred, sodium vapor using a Philips fifty watt C50S68/M, color temperature 2100 and color rendering index twenty one, and metal halide using a GE Mercury hundred watt HR100DX38/Med with a color temperature of 3900 and color rendering index of fifty.

The color rendering index is a measure of how closely the lamp renders colors of objects compared to a standard. The standard sources include daylight and any blackbody. Any incandescent and halogen source is considered to have a color rendering index of one hundred. The higher the color rendering index, the more natural the appearance of the source, and the richer the colors appear. Using this theory, it can be assumed that if there is a difference in the matching tasks the incandescent and illuminant c sources should affect matching tasks the least, and the sodium vapor the most. However, if color constancy is maintained then the observers should be able to maintain accurate matches regardless of light source.

The data was collected with two goals in mind. The first goal was to determine if the number of matching errors was affected by light source, and the second goal was to see if the time to make matching choices was affected by the light source. If color constancy applies to this situation, there should be no statistically significant difference between the mean number of errors per subject or the time for completion per subject under the five different light sources.

METHODS:

The stimuli in this experiment were 250 paint chip samples, ten chips per each color. The chips were arranged randomly into two vertical columns on each of ten poster boards. Two boards were designed per light source, one board lettered A-Y, the other numbered 1-25. The boards were then placed in a dark room with five separate stations, each illuminated with a different light source (see photos appendix A). The five light sources illuminant c with a color temperature of 6740 and color rendering index one hundred, using the MacBeth Easel Lamp, a fluorescent Sylvania thirteen watt CFT13WDS/EC/841 lamp with a color temperature of 4100 and a color rendering index of eighty two, incandescent using a Philips sixty watt Duramax soft white bulb of color temperature 2700 and color rendering index one hundred, sodium vapor using a Philips fifty watt C50S68/M color temperature 2100 and color rendering index twenty one, and metal halide using a GE Mercury hundred watt HR100DX38/Med with a color temperature of 3900 and color rendering index of fifty. Care was taken to calibrate each light source to approximately the same illuminance of twenty eight foot-candles.

Thirty three subjects, all optometry students, ranging in age from twenty-one to thirty-seven participated in the experiment. Each of the students, with normal color vision and no ocular pathology, were assigned a random number, and asked to perform matching tasks at each of five stations. They were to match the numbered sample with the lettered sample of the same color and record their answers on the provided form(appendix B). Their age, gender, and assigned numbers were collected and recorded. The test administrators included the time required to complete each matching task. Each subject's responses were then transferred to an Excel spreadsheet for analysis. For each subject, the number of correct and incorrect responses for each light source was determined and put in an Excel spreadsheet (Table 1).

Table 1: Errors Per Subject

Number	Sex	Age	Sodium Vapor	Incandescent	Metal Halide	Fluorescent	Illuminant C	Total Errors per subject
1	F	23	15	8	14	3	2	42
2	M	28	12	8	13	7	13	53
3	M	30	16	11	12	8	12	59
4	M	26	13	6	10	5	11	45
5	F	22	12	8	16	10	11	57
9	F	23	14	6	10	4	5	39
10	F	24	7	2	13	0	7	29
11	F	23	12	1	12	6	13	44
12	F	24	7	3	13	8	8	39
13	F	22	8	4	6	3	4	25
17	F	24	13	5	14	3	t4	39
19	M	25	8	2	11	5	8	34
20	M	25	5	0	9	6	5	25
21	F	22	10	3	11	3	9	36
22	F	24	12	7	12	8	11	50
23	F	22	9	5	9	4	5	32
24	F	25	12	10	18	9	7	56
25	F	22	8	1	6	7	5	27
26	M	35	8	3	11	7	8	37
27	M	26	11	6	14	6	8	45
28	M	29	11	4	13	6	6	40
29	M	25	10	7	13	7	4	41
30	M	25	10	8	9	8	6	41
31	F	26	8	2	14	0	4	28
32	M	26	16	10	15	6	10	57
34	M	24	13	8	15	3	9	48
35	F	37	12	4	8	6	12	42
36	F	29	10	3	16	7	13	49
37	M	28	12	5	13	8	6	44
38	M	29	13	8	15	5	12	53
39	F	21	9	2	9	4	4	28
40	M	27	7	3	14	7	7	38
15	F	22	11	6	7	7	6	37
Total:	**18 Females**							
	15 Males		**354**	**169**	**395**	**186**	**255**	**1359**
	Age Range 21-37							
Error range			5-16	0-11	6-18	0-10	2-13	
Number making errors:			33	32	33	31	33	

From the table, the total amount of errors per subject, the total amount of errors per light source, the number of volunteers making errors, and the total number of errors were calculated. An average time per light source was also determined, for each light source the range of errors was calculated. A separate Excel spreadsheet was created to compare how often each particular color was missed, and the colors each sample was confused with (Table 2, see appendix C).

RESULTS:

Using SPSS, a repeated measures within-subjects ANOVA test was performed on both the number of errors per subject and the completion time per subject. In addition to the ANOVA, a pairwise planned contrast was performed. Mauchly's Test of Sphericity, which compares the variance within the light sources, was also calculated. Mauchly's Test of Sphericity was found to be significant ($p=0.007$) with a value of 0.474 for the number of errors per subject, and was found to be significant ($p<0.001$) with a value of 0.202 for the completion time per subject. 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 for the number of errors per subject, but not for the completion time per subject. Analyzing the number of errors per subject, table 3 reveals that the Huynh-Feldt test found a statistically significant difference at the alpha = 0.05 level between the light sources ($F = 56.369$, $p < .001$) and the number of errors per subject using those light sources.

Table 3: Tests of Within Subjects Effects-Errors

Tests of Within-Subjects Effects					
Source		df	F	Sig.	Observed Power
MATCH	Sphericity Assumed	4	56.369	.000	1.000
	Greenhouse-Geisser	3.234	56.369	.000	1.000
	Huynh-Feldt	3.640	56.369	.000	1.000
	Lower-bound	1.000	56.369	.000	1.000

Analyzing the completion time per subject (Table 4) reveals that the Huynh-Feldt test did not find a statistically significant difference at the alpha = 0.05 level between the light sources ($F = 2.281$, $p < .095$) and the completion time per subject when using those different light sources.

Table 4: Tests of Within-Subjects Effects- Time

Tests of Within-Subjects Effects					
Source		Df	F	Sig.	Observed Power
TIME	Sphericity Assumed	4	2.281	.064	.652
	Greenhouse-Geisser	2.361	2.281	.100	.490
	Huynh-Feldt	2.561	2.281	.095	.513
	Lower-bound	1.000	2.281	.141	.311

Table 5 reveals there was a statistically significant difference between the mean number of errors per subject of all light sources except for the combination of incandescent and fluorescent lights.

Table 5: Comparisons between Light Sources

Pairwise Comparisons						
(I) MATCH	(J) MATCH	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Illuminant C	Incandescent	2.606	.658	.000	1.265	3.947
	Fluorescent	2.091	.553	.001	.965	3.217
	Metal Halide	-4.242	.644	.000	-5.554	-2.930
	Sodium Vapor	-3.000	.597	.000	-4.215	-1.785
Incandescent	Illuminant C	-2.606	.658	.000	-3.947	-1.265
	Fluorescent	-.515	.535	.343	-1.605	.575
	Metal Halide	-6.848	.556	.000	-7.981	-5.716
	Sodium Vapor	-5.606	.328	.000	-6.275	-4.937
Fluorescent	Illuminant C	-2.091	.553	.001	-3.217	-.965
	Incandescent	.515	.535	.343	-.575	1.605
	Metal Halide	-6.333	.623	.000	-7.602	-5.065
	Sodium Vapor	-5.091	.584	.000	-6.281	-3.900
Metal Halide	Illuminant C	4.242	.644	.000	2.930	5.554
	Incandescent	6.848	.556	.000	5.716	7.981
	Fluorescent	6.333	.623	.000	5.065	7.602
	Sodium Vapor	1.242	.572	.038	.0076	2.408
Sodium Vapor	Illuminant C	3.000	.597	.000	1.785	4.215
	Incandescent	5.606	.328	.000	4.937	6.275
	Fluorescent	5.091	.584	.000	3.900	6.281
	Metal Halide	-1.242	.572	.038	-2.408	-.0076

Table 6 reveals there was a statistically significant difference between the mean completion time per subject for the combination of incandescent and sodium vapor lights.

Table 6: Comparison of Completion Time

(I) TIME	(J) TIME	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval for Difference	
					Lower Bound	Upper Bound
Illuminant C	Incandescent	38.727	19.718	.058	-1.436	78.891
	Fluorescent	26.576	18.341	.157	-10.783	63.935
	Metal Halide	24.152	19.702	.229	-15.981	64.284
	Sodium Vapor	3.636	14.199	.800	-25.286	32.558
Incandescent	Illuminant C	-38.727	19.718	.058	-78.891	1.436
	Fluorescent	-12.152	8.470	.161	-29.404	5.101
	Metal Halide	-14.576	12.183	.240	-39.392	10.241
	Sodium Vapor	-35.091	17.163	.049	-70.051	-.131
Fluorescent	Illuminant C	-26.576	18.341	.157	-63.935	10.783
	Incandescent	12.152	8.470	.161	-5.101	29.404
	Metal Halide	-2.424	11.717	.837	-26.291	21.443
	Sodium Vapor	-22.939	15.216	.141	-53.934	8.055
Metal Halide	Illuminant C	-24.152	19.702	.229	-64.284	15.981
	Incandescent	14.576	12.183	.240	-10.241	39.392
	Fluorescent	2.424	11.717	.837	-21.443	26.291
	Sodium Vapor	-20.515	12.062	.099	-45.085	4.055
Sodium Vapor	Illuminant C	-3.636	14.199	.800	-32.558	25.286
	Incandescent	35.091	17.163	.049	.131	70.051
	Fluorescent	22.939	15.216	.141	-8.055	53.934
	Metal Halide	20.515	12.062	.099	-4.055	45.085

There were 1359 errors total for all five light sources, with metal halide having the most and incandescent the least. The average number of errors for these light sources was 11.96 and 5.12 respectively. Table 5 reveals it is more difficult to make matches under the different illuminations. For example, comparing metal halide to incandescent, an average of 6.848 more errors was made with the metal halide, and an average of 5.091 more errors was made with sodium vapor than fluorescent. The only exception to this is among the incandescent and fluorescent, with these two light sources results reveal people would make the same number of matching errors. The number of errors among the subjects ranged from 25-59 with an average of 41.18. It was found that there was not a statistically significant difference in the average completion time for the different light sources, except when comparing the difference between sodium vapor and incandescent in which it takes an average of 35.091 more seconds to complete the matching tasks under sodium vapor.

Table 2 (see appendix C) demonstrates how many times each color was missed, and the most often made mistakes. For example, under illuminant c the most often made error was the color Bare Pink, which was missed twenty four times. There were five other colors Bare Pink was confused with, Siesta Sand nineteen times, Pale Ecru two times, Albatross, Rosewood, and Mountain Gray each one time. Under the other four light sources this color was mistaken far less, five times with sodium vapor, six with incandescent, one with fluorescent, and nine times with metal halide. Often, the color mistaken most was consistent across all five sources. For example, Tiara was confused with Orchid Lane, and Rosewood with China Doll, under each of the five light sources.

DISCUSSION:

The main conclusion of this experiment is that light sources do have effect on matching tasks, but not on the time to complete the task. This means that color constancy must not hold true in this case. If color constancy held true, there would be no statistical difference in the ability to match colors under each light source. Furthermore, the colors that were missed would likely be the same colors under each of the different sources, which by analyzing table 2 is not the case. Analyzing the results based on the color rendering data the most likely light to affect the matching task would be sodium vapor with a color rendering index of twenty one, followed by metal halide, fluorescent, illuminant c, and incandescent. In fact, the light that most affected the matching task was metal halide, followed by sodium vapor, illuminant C, fluorescent, and finally incandescent. In this case, the color rendering index did in fact affect the matching tasks. While it was not completely as expected, sodium vapor should have affected matching tasks more than metal halide, data does suggest a strong correlation between ability to match and color rendering index.

These results suggest an important implication for color matching. If a painter is to perform a paint matching task under the lights of a store illuminated by fluorescent light, then returns to a house illuminated by illuminant C and tries to make the same match he may be unable to do so. This may result in improper color matching, and unhappy clients. This may also be applied to several other tasks. For example, police officers identifying the color of clothes a suspect is wearing, the color of car someone is driving, matching sock colors when doing laundry, or matching the color of socks to the color of slacks. Electricians and the various wires they must work with may also be affected, if under illuminant C the ability to match wires may be different than the ability to match under metal halide. However, before determining the above to be true, the question must be asked, why does color constancy not hold true in the above experiment?

Several studies have been done on color constancy, one such study by Kraft and Brainard studies the effects of local and global cues on color constancy. Their study used two scenes under differing light sources, the first scene, a gray background paper under a white light source, and the second, a blue background under an orange-reddish source. If local contrast were the only contributing factor to constancy, the constancy index should have dropped to zero, however, this was not the case. This implies that local contrast is not the only factor affecting color matching. The constancy index in this study dropped from eighty-three to fifty-three percent indicating local contrast plays a major role in color constancy.

Global contrast may also play a role in color constancy. In a second experiment, by Kraft and Brainard, the contribution from global contrast was silenced, while the contribution from local contrast opposed color constancy. In this experiment the constancy index dropped to thirty-nine percent, but not to zero which indicates other cues must still play a role. In a final experiment, all accessory objects were removed and only a background and test surface remained, the observers still showed some degree of constancy, eleven percent. The major implication is that there is a role for mutual reflections in color constancy. It also indicates that local and global cues are the major contributors to color constancy.[9]

One possible limitation of the color matching experiment above is when applying the results to every day situations one must take care to recognize the experiment was geared at eliminating most global and local cues. In an everyday situation, such as selecting sock colors or paint colors, there will be several other cues that indicate the color. Other cues include the carpeting of the floor, the color of surrounding furniture, and other lighting in the scene.

Extensive experimentation has been done into color constancy, and while several contributing factors have been determined, there is not a complete picture as to why or how color constancy works. To date several of the experimentation methods used have been questionable and results remain difficult to apply to every situation. The results of the above experiment may give some insight into color constancy. They do indicate that it may be necessary to maintain a standard illuminant when performing critical color matching tasks.

However, further investigation into the phenomenon of color constancy must still be undertaken. It remains a field in which several questions must be answered. What are the true mechanisms that affect color matching? What factors in a scene affect color constancy? Is there a way to achieve perfect color constancy? Is there a way to minimize the affect of lighting on color appearance?

REFERENCES

1. Nieves J, Garcia-Beltran A, Romero J. Response of the human visual system to variable illuminant conditions: An analysis of opponent-colour mechanisms in colour constancy. Opthal. Physiol. Opt. 2000;20(1): 44-58.

2. Rinner O and Gegenfurtner K. Cone contributions to colour constancy. Perception 2002;31: 733-746.

3. Maloney L and Schirillo J. Color constancy, lightness constancy, and the articulation hypothesis. Perception 2002;31: 135-139.

4. Foster D. Does colour constancy exist?. TRENDS in Cognitive Sciences 2003;7(10): 439-443.

5. Schultz S, Doerschner K, Maloney L. Color constancy and hue scaling. Journal of Vision 2006;6(10): 1102-1116.

6. Yang J and Shevell S. Surface color perception under to illuminants: The second illuminant reduces color constancy. Journal of Vision 2003;3(5): 369-379.

7. Bauml K. Simultaneous color constancy: how surface color perception varies with the illuminant. Vision Research 1999;39: 1531-1550.

8. Delahunt P and Brainard D. Color constancy under changes in reflected illumination. Journal of Vision 2004;4(9): 764-778.

9. Hurlbert A. Colour Vision: Is colour constancy real?. Current Biology 1999;9: 558-561.

APPENDIX A

TESTING BOARD PHOTOS

APPENDIX B

SAMPLE RECORDING FORM

Effects of Five Different Light Sources on Matching Paint Chip Samples
Recording Form for Illuminant C:

Number:____________ Any ocular pathology: Y N
Age:______________ Best corrected visual acuity 20/20: Y N
Gender:________________

Please record the letter of the paint chip sample that most closely matches the numbered sample.

1.____________________
2.____________________
3.____________________
4.____________________
5.____________________
6.____________________
7.____________________
8.____________________
9.____________________
10.____________________
11.____________________
12.____________________
13.____________________
14.____________________
15.____________________
16.____________________
17.____________________
18.____________________
19.____________________
20.____________________
21.____________________
22.____________________
23.____________________
24.____________________
25.____________________

APPENDIX C

TABLE 2: COMPARISONS OF COLORS MISSED

Table 2: Comparison of Number Missed Per Color

	Pale Ecru	Orchid Lane	Bare Pink	La Minuet
Illuminant C	19	4	24	14
	14-G Peach Linen	4-N Tiara	19-D Siesta Sand	12-C China Doll
	2-J Prairie Winds		2-L Pale Ecru	1-B Rosewood
	2-R Country Beige		1-M Albatross	1-D Siesta Sand
	1-O Bright Star		1-B Rosewood	
			1-H Mountain Gray	
Sodium Vapor	26	9	5	12
	18-K Peach Linen	9-G Tiara	4-N Siesta Sand	5-N Siesta Sand
	2-R Mountain Gray		1-D La Minuet	4-T China Doll
	2-N Siesta Sand			1-Q Prairie Winds
	1-M Albatross			1-I Rosewood
	1-C Bare Pink			1-L Moondance
	1-O Country Beige			
	1-I Rosewood			
Incandescent	13	8	6	5
	9-K Peach Linen	8-N Tiara	5-G Siesta Sand	2-Q China Doll
	2-V Mountain Gray		1-N Tiara	1-D Rosewood
	2-L Country Beige			1-G Siesta Sand
				1-P Bare Pink
Flourescent	10	5	1	2
	9-S Peach Linen	5-C Tiara	1-N Pale Ecru	2-V China Doll
	1-H Siesta Sand			
Metal Halide	22	7	9	21
	7-O Mountain Gray	6-P Gossamer Wing	6-V Country Beige	8-V Country Beige
	6-U Peach Linen	1-C Bright Star	1-O Mountain Gray	6-T China Doll
	4-V Country Beige		1- X Siesta Sand	5-X Siesta Sand
	2-M La Minuet		1-K Albatross	1-O Mountain Gray
	2-X Siesta Sand			1-B Rosewood
	1-N Prairie Winds			
	90	33	45	54

Table 2: Comparison of Number Missed Per Color

	Shiny Silk	Soft Cream	Tiara	Dawn's Early Light
Illuminant C	4	6	10	8
	4-W Spice Delight	4-W Spice Delight	8-I Orchid Lane	4-Y Delicate Petal
		1-I Orchid Lane	2-Q Bare Pink	2-E Gossamer Wing
		1-B Rosewood		2-O Bright Star
Sodium Vapor	4	25	5	8
	3-S Spice Delight	16-S Spice Delight	5-B Orchid Lane	3-V Delicate Petal
	1-F Soft Cream	9-E Shiny Silk		3-P Bright Star
				1-X Haunting Hue
				1-Y Gossamer Wing
Incandescent	2	1	9	8
	2-S Soft Cream	1-F Shiny Silk	9-H Orchid Lane	3-W Bright Star
				3-T Haunting Hue
				2-M Gossamer Wing
Flourescent	1	2	4	0
	1-R Soft Cream	2-K Spice Delight	3-G Orchid Lane	
			1-B Bare Pink	
Metal Halide	10	19	3	20
	8-Q Spice Delight	8-B Rosewood	3-G Orchid Lane	11-C Bright Star
	2-L Soft Cream	7-Q Spice Delight		4-J Haunting Hue
		1-A Bare Pink		2-K Albatross
		1-U Peach Linen		2-P Gossamer Wing
		1-I Pink Ecru		1-L Soft Cream
		1-E Shiny Silk		
	21	53	31	44

Table 2: Comparison of Number Missed Per Color

	Rosewood	Navajo White	Peach Linen	Moon Dance
Illuminant C	15	1	15	14
	11-C China Doll	1-S La Minuet	12-L Pale Ecru	7-H Mountain Gray
	2-D Siesta Sand		2-R Country Beige	2-N Tiara
	1-W Spice Delight		1-B Rosewood	2-G Peach Linen
				1-R Country Beige
				1-M Albatross
				1-O Bright Star
Sodium Vapor	10	22	21	20
	6-T China Doll	9-F Soft Cream	16-A Pale Ecru	7-M Albatross
	1-O Country Beige	4-Q Prairie Winds	3-O Country Beige	6-Y Gossamer Wing
	1-D La Minuet	3-T China Doll	2-I Rosewood	4-R Mountain Gray
	1-A Pale Ecru	2-K Peach Linen		2-O Country Beige
	1-K Peach Linen	1-S Spice Delight		1-P Bright Star
		1-D La Minuet		
		1-O Country Beige		
		1-I Rosewood		
Incandescent	9	1	14	2
	7-Q China Doll	1-X Albatross	8-B Pale Ecru	2-V Mountain Gray
	1-B Pale Ecru		5-L Country Beige	
	1-Y Navajo White		1-A Prairie Winds	
Flourescent	9	2	12	11
	9-V China Doll	1-K Spice Delight	6-N Pale Ecru	6-M Gossamer Wing
		1-N Pale Ecru	4-A Country Beige	5-Q Bright Star
			1-E Mountain Gray	
			1-K Spice Delight	
Metal Halide	26	0	19	29
	11-T China Doll		6-I Pale Ecru	25-K Albatross
	6-M La Minuet		6-O Mountain Gray	2-P Gossamer Wing
	5-I Pale Ecru		4-A Bare Pink	2-C Bright Star
	2-U Peach Linen		2-N Prairie Winds	
	1-X Siesta Sand		1-X Siesta Sand	
	1-V Country Beige			
	69	26	81	76

Table 2: Comparison of Number Missed Per Color

	Albatross	Siesta sand	Country Beige	Bright Star
Illuminant C	5	6	16	9
	5-H Mountain Gray	2-L Pale Ecru	8-H Mountain Gray	7-E Gossamer Wing
		1-Q Bare Pink	3-G Peach Linen	2-V Dawns Early Light
		1-G Peach Linen	3-J Prairie Winds	
		1-S La Minuet	2-L Pale Ecru	
		1-B Rosewood		
Sodium Vapor	18	22	25	19
	15-R Mountain Gray	9-D La Minuet	8-K Peach Linen	10-Y Gossamer Wing
	1-K Peach Linen	4-M Albatross	8-A Pale Ecru	7-L MoonDance
	1-N Siesta Sand	3-T China Doll	3-M Albatross	1-X Haunting Hue
	1-T China Doll	2-R Mountain Gray	2-R Mountain Gray	1-T China Doll
		2-C Bare Pink	2-N Siesta Sand	
		I-2 Rosewood	1-D La Minuet	
			1-I Rosewood	
Incandescent	2	9	13	11
	2-L Country Beige	3-P Bare Pink	10-V Mountain Gray	8-M Gossamer Wing
		2-J La Minuet	3-K Peach Linen	3-C MoonDance
		2-B Pale Ecru		
		1-D Rosewood		
		1-V Mountain Gray		
Flourescent	2	6	17	18
	2-E Mountain Gray	4-N Pale Ecru	12-E Mountain Gray	11-M Gossamer Wing
		1-I Rosewood	3-S Peach Linen	5-O Dawns Early Light
		1-S Peach Linen	2-P Prairie Winds	1-Y Haunting Hue
				1-Blank
Metal Halide	21	21	24	16
	12-H MoonDance	12-V Country Beige	12-A Bare Pink	9-P Gossamer Wing
	5-P Gossamer Wing	3-A Bare Pink	4-M La Minuet	3-Y Dawns Early Light
	2-C Bright Star	2-H MoonDance	3-X Siesta Sand	2-K Albatross
	1-M La Minuet	2-S Tiara	2-O Mountain Gray	1-H Moondance
	1-X Siesta Sand	1-K Albatross	1-S Tiara	1-J Haunting Hue
		1-O Mountain Gray	1-I Pale Ecru	
			1-B Rosewood	
	48	64	95	73

Table 2: Comparison of Number Missed Per Color

	Prairie Winds	Mountain Gray	Spice Delight	China Doll
	9	17	8	10
Illuminant C	5-R Country Beige	10-R Country Beige	5-A Shiny Silk	7-B Rosewood
	3-X Navajo White	3-J Prairie Winds	3-F Soft Cream	3-S La Minuet
	1-H Mountain Gray	2-G Peach Linen		
		1-L Pale Ecru		
		1-F Soft Cream		
	13	12	22	17
Sodium Vapor	3-O Country Beige	5-O Country Beige	17-F Soft Cream	15-I Rosewood
	3-V Delicate Petal	2-K Peach Linen	1-E Shiny Silk	1-D La Minuet
	2-W Hint of Mint	2-M Albatross	1-U Lime Meringue	1-K Peach Linen
	2-F Soft Cream	1-F Soft Cream	1-J Navajo White	
	1-U Lime Meringue	1-D La Minuet	1-V Delicate Petal	
	1-J Navajo White	1-L Moon Dance	1-Q Prairie Winds	
	1-K Peach Linen			
	6	13	6	14
Incandescent	4-V Mountain Gray	9-L Country Beige	3-S Soft Cream	13-D Rosewood
	1-X Albatross	3-K Peach Linen	3-D Rosewood	1-J La Minuet
	1-Y Navajo White	1-B Pale Ecru		
	7	18	24	4
Flourescent	6-A Country Beige	13-A Country Beige	20-R Soft Cream	4-I Rosewood
	1-E Mountain Gray	3-P Prairie Winds	4-T Shiny Silk	
		2-S Peach Linen		
	16	22	24	18
Metal Halide	6-O Mountain Gray	5-H MoonDance	15-L Soft Cream	6-V Country Beige
	3-K Albatross	5-X Siesta Sand	6-B Rosewood	6-B Rosewood
	3-H MoonDance	5-N Prairie Winds	2-E Shiny Silk	3-X Siesta Sand
	1-J Haunting Hue	3-K Albatross	1-T China Doll	1-I Pale Ecru
	1-B Rosewood	2-V Country Beige		1-R Navajo White
	1-R Navajo White	2-U Peach Linen		1-O Mountain Gray
	1-I Pale Ecru			
	51	82	84	63

Table 2: Comparison of Number Missed Per Color

	Lime Meringue	Delicate Petal	Hint of Mint	Haunting Hue
Illuminant C	6	2	8	4
	5-P Hint of Mint	1-U Lime Meringue	7-U Lime Meringue	2-E Gossamer Wing
	1-Y Delicate Petal	1-0 Bright Star	1-O Bright Star	1-V Dawns Early Light
				1-R Country Beige
Sodium Vapor	6	6	10	2
	5-W Hint of Mint	2-W Hint of Mint	7-U Lime Meringue	2-P Bright Star
	1- F Soft Cream	1-Q Prairie Winds	1-Q Prairie Winds	
		1-U Lime Meringue	1-O Country Beige	
		1-J Navajo White	1-E Shiny Silk	
		1-H Dawns Early Light		
Incandescent	3	0	3	2
	3-R Hint of Mint		3-I Lime Meringue	1-W Bright Star
				1-I Lime Meringue
Flourescent	5	4	9	1
	5-L Hint of Mint	2-F Lime Meringue	9-F Lime Meringue	1-V China Doll
		2-L Hint of Mint		
Metal Halide	18	0	6	4
	16-F Hint of Mint		5-D Lime Meringue	2-P Gossamer Wing
	1-N Prairie Winds		1-N Prairie Winds	1-X Siesta Sand
	1-E Shiny Silk			1-C Bright Star
	38	12	36	13

Table 2: Comparison of Number Missed Per Color

	Gossamer Wing
Illuminant C	21
	10-O Bright Star
	7-T Moon Dance
	4-V Dawns Early Light
Sodium Vapor	15
	13-P Bright Star
	1-L Moon Dance
	1-F Soft Cream
Incandescent	9
	8-W Bright Star
	1-C MoonDance
Flourescent	12
	Q-10 Bright Star
	O-1 Dawns Early Light
	1-Y Haunting Hue
Metal Halide	20
	12-C Bright Star
	5-J Haunting Hue
	1-K Albatross
	1-U Peach Linen
	1-Y Dawns Early Light
	77