Determining Typical Human Color Difference Thresholds Between Opposite Sexes

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Abstract

In an effort to discover if there is a difference between the color difference thresholds of males and females with typical color vision, eighty six participants were asked to complete two qualifying color tests and one color difference threshold test. The results can lead to further studies in the field as they show a preliminary result that there is no difference between males and females in regards to color difference thresholds.

Introduction

Generally speaking in the world of color vision, it is widely regarded that on average women are less likely to have color deficiencies than men. This leads to the assumption that women see color better than men on average. However, there are a host of variables that can determine color vision. Instead of simply measuring color vision, which has been done before, this study focuses on the measurement of color difference and the thresholds between men and women when they have been prequalified to have similar color vision.

In order to study color difference, we must determine the best form of measurement. The Delta-E measurement is widely regarded as the most common way of expressing color differences in regards to the L*A*B* color space, which is a digital representation of all of the colors a typical human can see. It is currently regarded that an average human can tell a difference in two colors if they have a color difference of 3 Delta-E's or greater. It is also regarded that an average human cannot see a difference between two colors with a color difference of 1 Delta-E or less. We are interested in finding out if there is a difference between the color differences that one sex can detect versus the opposite sex.

Pittsburg State University

Statement of the Problem

It is not known if there is a difference between the color difference thresholds of males and females with typical color vision.

Research Questions/Objectives to be addressed

1. What is the difference between male and female color vision thresholds when viewing two color samples that have a color difference of less than 1 Delta E?
2. What is the difference between male and female color vision thresholds when viewing two color samples that have a color difference of approximately 1.5 Delta E's?
3. What is the difference between male and female color vision thresholds when viewing two color samples that have a color difference of approximately 2 Delta E's?
4. What is the difference between male and female color vision thresholds when viewing two color samples that have a color difference of approximately 2.5 Delta E's?
5. What is the difference between male and female color vision thresholds when viewing two color samples that have a color difference of approximately 3 Delta E's?

Delimitations

1. Age of the participant will not factor into the study.
2. Only one type of output and substrate will be used, therefore the study will not include various types of ink/toner or substrates.
3. The time of day will not be a major factor in testing the participants.
4. Subjects with corrective lens (glasses or contacts) will be given the choice to either wear the corrective lenses or remove them. Therefore corrective lens use will not factor into the study.
5. The study will be conducted within a D50 Illuminated light box, therefore the results of the study will not be applicable to any other illuminants.
6. Ethnicity of the participant will not factor into the study.
7. Metamerism will not be accounted for in this study.

Limitations

1. Responses that are untruthful will limit the outcome of the study.
2. Perfect ΔE differences between swatches cannot be made, therefore approximate ΔE differences were used for the study. (Example: 2.31ΔE rather than 2.5ΔE).

Assumptions

1. Respondents are truthful in their responses.
2. Respondents are knowingly able to make decisions
3. Respondents are willing to engage in all activities associated with the study
4. Respondents are in good health and in a responsive state at the time of participation.

Definition of Terms

1. Delta E Color Difference – The single number difference between two olors. Abbreviated as ΔE.
2. Ishihara Color Test – A color perception test for red-green color deficiency.
3. FM 100 Color Test – A color perception test with four rows of varying color hues.
4. Substrate – Base material that an object is printed on.
5. D50 Illuminant – Light source that simulates daylight at 5000 degrees Kelvin.
6. Light Box – A color controlled space.
7. L*A*B* Color Space – Digital representation of all of the colors a typical human can see.
8. Node + Chroma® Colorimeter – A device that can capture any color on a flat surface and outputs the color data in L*A*B color space.
9. Normal Color Vision – In our usage, this will be based off data collected from Pittsburg State University GIT 690 - Color Reproduction over the past few years.

Significance of the study

This study will directly affect the class in which it is being tied to (GIT 640.01 Color Reproduction) because there is a large project in this class which asks the students to create two separate printed materials that match with a tolerance of 3 Delta-E's. The results of this study may change the tolerance of that assignment, and will guide other curriculum changes in the class.

On a larger scale, this study may lead to further research in this area, which may give more information about the way in which males and females are different or similar in regards to color difference thresholds. This may help guide hiring procedures in industries that rely heavily upon accurate color vision.

Organization of the study

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Review of Literature

Introduction

Differences in color preference or discrimination between the genders has been studied since the 1800s (Nichols, 1884). Many studies link these differences to an instinctual level, referencing to a period of hunter-gather status (Stoet, 2011, Hurlbert and Ling, 2007). Hurlbert and Ling argued that females like redder colors because their visual system has been adapted to be attracted to ripe berries and fruit against a background of green foliage. Their study also found that men prefer colors in the cyan range, but there is no "hunter-gatherer" evidence to support this. Other studies focus directly on color preference, but do not look at the differences between color discrimination between the genders (Schloss and Palmer, 2010). Overall there has been a lack in research in the specific area of defining color difference thresholds between the genders.

Color Preference between genders
The majority of studies done on the topic of color differences between genders have been focused on the physiological and psychological aspect of color preference. Hurlbert and Ling gave an explanation for human color preference based on retinal cone responses (Hurlbert and Ling, 2007). Their study focused on studying cone response to certain wavelengths. They found that both male and females preferred blue colors to yellow. They also found that there was a difference in gender preference when it came to overall preference, finding that females preferred redder colors, while males tended towards more cyan tones. Building off that research, Schloss and Palmer studied color preference in the genders, however they focused on dividing colors into the following descriptors: saturated, light, muted and dark. They found that light and muted colors were equally preferred by both genders. However, males gave saturated colors higher preference ratings than muted colors, whereas females preferred muted and saturated colors equally (Schloss and Palmer, 2010). This information helps to determine what colors should be used to test across the genders. If males and females prefer saturated colors, which can be assumed from the work done by both Hurlbert and Ling, as well as Schloss and Palmer, then the best possible response for a color discrimination test may come from using a set of saturated colors.

Psychology of color between genders
It is believed that there are a number of higher order cognitive differences between the two genders. Color lexicon indicate that females have a larger word repitoire and use more elaborate terms to describe color (Simpson and Tarrant, 1991) and they are also better at matching them from memory (Pérez-Carpinell, Baldovi, de Fez, and Castro, 1998). This ability is spread across languages and cultures (Thomas, Curtis & Bolton, 1978). It has long been believed that males have an instinct to prefer blue hues more females and females would prefer pink hues more than males. This belief is mainly rooted in cultures that define a childs gender with one of those two colors. Silver and Ferrante backed up this belief with their study in 1995. Their study found that males preferred blues more than females, and females were more likely to prefer black or pink (Silver and Ferrante, 1995). Many other studies have found that males prefer blue hues over most other hues, however the studies are not as decisive about females always preferring pink. Something that is found in the majority of the studies however is that females prefer red colors more than males. This could lead one to believe that females would prefer pink hues since pink is a less saturate version of red.

Physiological differences between the genders and color vision
Color deficiencies are more common in men than they are in women. In fact, it has been found that one in thirteen men will exhibit a color deficiency, while only one in three hundred women will have a color deficiency (Lyon, 1972). The culprit is a defective gene on the "X" chromosome. Since females carry two "X" chromosomes, it is quite rate that the defect is present on both. Males however have

only a single “X” chromosome. If the defective gene is present, they are color-blind. In the process of fertilization, the male sperm may either be of the “X” or “Y” variety. If a female is conceived, the mother contributes an “X” and the father contributes a “Y”. If a color-blind son is born, he inherited the defect from his mother, not his father (Lyon, 1972).

Color difference measurements

Color difference calculations are typically expressed in measurements referred to as Delta-E’s (ΔE). Delta E is the standard calculation metric, which correlates the human visual judgment of differences between two perceived colors. The higher the Delta E value, the further away the sampled color is from the color it is being compared with. Zachary Schuessler found that a Delta E value below 1 is not perceptible by humans. A range of ΔE 1-2 is perceptible through close observation, ΔE 2-10 is perceptible at a glance, ΔE 11-49 colors are more similar than opposite, and if the ΔE value is 100, the colors are exact opposites (Schuessler, 2014). However, there seems to be no proof of any studies being done to determine if there are different thresholds for color differences between the genders. This study will focus on that task to see if the above information about Delta E values holds true for each gender.

Summary

The review of relevant studies confirmed the initial claim that study has not been completed in the area of determining color difference thresholds between genders. While many studies have been aimed at explaining color preferences that differ between the genders, and other studies focused on the ability of each gender to pick out certain colors, they did not specifically focus on color thresholds. The work that has been done in this field can be used to guide the creation of the methods of testing for this study. For instance, finding that many males and females prefer blues and purples (Hurlbert and Ling, 2007) will help in determining the hue of the testing swatches to be used for the testing procedure. Also, findings in other studies can help to shape a timeline for this study by guiding certain times of day to complete the testing, as well as the set up of the testing facility. For instance, one study suggested for participants to avoid smoking before testing, as it will change color vision (Murray, Parry, McKeefry and Panorgias, 2012). The same study suggested testing participants in the afternoon, versus the evening or morning, and to also have them remove any tinted lenses.

Using the existing knowledge base, the scope and structure of the current study is more easily defined.

Methods

Population

The population includes Pittsburg State University students, faculty and staff.

Sample
With a population of approximately 7,500, a convenient sample of approximately 80 will be chosen to participate in the study. The number of the sample is lower than would be traditionally chosen because of the nature of the testing. Each participant will be asked to complete three tests that will total approximately thirty minutes.

Survey Instrument

There will be three different survey instruments used for the study. Participants must first pass two color vision tests to assure that they are not color deficient, and to assure that they have normal color vision. Normal color vision will be measured by a Farnsworth-Munsell 100 (FM 100) color acuity test. Normal color vision will be defined as a total error score between 20 and 100 on the FM 100 test. This range of acceptable total error score was determined by the makers of the FM-100 test to be a determinate of normal color vision.

Instrument #1: Ishihara Color Blindness Test
The Ishihara Color Blindness Test is the industry standard instrument to test for color deficiencies. The test consists of a number of colored plates. Each plate contains a circle of dots appearing randomized in color and size (Kindel, 2013). Within the pattern are does which form a number or shape clearly visible to those with normal color vision, and invisible to those with a red-green color vision defect. If a subject fails pass the Ishihara test, they will be excluded from the study as their view of color differences could be potentially skewed compared to individuals with normal color vision.

Instrument #2: Farnsworth-Munsell 100 Color Acuity Test
The FM 100 color acuity test is used to measure an individuals color vision. The test is used to separate persons with normal color vision into classes of superior, average and low color discrimination and to measure the zones of color confusion of color defective people. The test consists of 4 rows of colored caps. On each row the colored caps are similar hues that vary slightly from one another. The participant is asked to place the caps in order from one hue to the next. This test will be used in this study in order to validate the results from the Ishihara test and also to exclude those participants that score outside of the 100 total error score threshold. The 100 total error score (TES) is being used as a threshold due to the fact that Farnsworth-Munsell identified that 68% of the population fall within a TES of 20-100, while 16% of the population has superior discrimination and falls within the 0-20 TES range and the rest of the population falls outside of the 100 TES range and are considered to have a color deficiency.

Instrument #3: Color Difference Threshold Test

This final test will be the main instrument used to gather data for the study. While the first two tests were simply qualifiers to make sure that the participants had normal color vision, this final test will be administered to find if participants of different genders are able to differentiate between similar swatches at differing color difference values. These values are classified as Delta-E values and will be measured by a Node+Chroma® colorimeter device.

Using Adobe InDesign (Creative Cloud Version), color swatches were created that was three inches wide by three inches tall. This size was used in order to give enough space to take random color readings with the Node+Chroma® for generalization purposes. It was also found to be a convenient size for judging color samples from an approximate distance of one foot. The distance between the subject and the sample needs to be held constant in order to get generalizable results. The measurement of one foot was used simply because it was deemed to be a comfortable viewing distance compared to the size of the swatches and viewing booth. The distance was measured from the edge of the viewing booth to the approximate plane of the subject's eyes for consistency.

Two sets of color tests were chosen for the test. The colors chosen to test individuals were in the hue designation of blue and red. Blue and red were chosen based upon a previous study done by Hurlbert and Ling that found a preference for blues across both genders and a preference for reds or pinks across both genders.

A control blue swatch was created with the CMYK values of: Cyan = 100%, Magenta = 50%, Yellow = 0% and Black = 0%. A control red swatch was also created with the values of: Cyan= 0%, Magenta = 100%, Yellow = 75% and Black = 0%. From the control, four more swatches were created for each color. These four swatches would need to have an approximate color difference from the control of 1.5ΔE, 2.0ΔE, 2.5ΔE and 3.0ΔE.

Using a collective theory from previous studies, the saturation of the color was manipulated in order to achieve the various color differences. A swatch would have incremental amounts of yellow added into it in order desaturate the blue or it would have cyan added to desaturate the red. A sample would be printed, then the Node+Chroma® device would be used to determine color differences between the control and each desaturated swatch. Because of the variability of paper fibers, each swatch was tested ten times in different areas and an average color difference was calculated.

The characteristics of the final swatches chosen are documented below.

Swatch	Cyan Value	Magenta	Yellow	Black Value
Red 1.5ΔE				
(Actual 1.67ΔE)	4%	100%	75%	0%
Red 2.0ΔE				
(Actual 2.16ΔE)	5%	100%	75%	0%
Red 2.5ΔE				
(Actual 2.31ΔE)	6%	100%	75%	0%
Red 3.0ΔE				
(Actual 2.92ΔE)	7%	100%	75%	0%
Blue 1.5ΔE				
(Actual 1.51ΔE)	100%	50%	3%	0%
Blue 2.0ΔE				
(Actual 2.02ΔE)	100%	50%	6%	0%
Blue 2.5ΔE				
(Actual 2.3ΔE)	100%	50%	10%	0%
Blue 3.0ΔE				
(Actual 2.85ΔE)	100%	50%	12%	0%

The target and the actual ΔE values differ slightly on some swatches, and the difference is more pronounced on others. Achieving a perfect ΔE value was found to be nearly impossible. Instead, close approximations had to be made. Because these are approximations, this is a limitation of the study.

Once the swatch values were identified, they were arranged in InDesign to put four swatches on an 11x17" sheet. These swatches were arranged in such a way that they would create two separate pairs of swatches. In each pair there would be a control and one of the swatches that would have a color difference from the control. There was also one pair that was both controls with a negligible color difference (defined as a 0.7ΔE value or lower). The paper used was 11x17" coated white gloss 70# book. The swatches were printed and trimmed in half because there were two sets of swatches on each 11x17" sheet. The swatches were side-by-side, touching and parallel to each other in order to minimize any color infiltration from the paper or surrounding elements.

Administering the Instruments

Instrument #1: Ishihara Color Blindness Test

The Ishihara Color Blindness Test was the first to be administered, as it was familiar with most participants and the quickest of the three tests. Participants were asked to view each swatch in the Ishihara book in the D50 light booth and give a response. The book was held and controlled by the administrator, not the participant. The responses were recorded on the testing sheet and the administrator determined if the participant passed or failed the Ishihara. If the participants failed the Ishihara, they were disqualified from continuing in the study.

Instrument #2: FM 100

Participants were given instructions how to complete the FM 100, and shown the area in which they could stand to complete the test. Participants were given time to arrange the swatches as they desired and the administrator would score the results in the FM 100 software. A total error score would be created from the software and the Total Error Score would be recorded on the scoring sheet. If the subject score over 100, they were disqualified from continuing in the study.

Instrument #3: Color Difference Thresholds Test

The final instrument was the color difference thresholds test, and participants were asked to stay in the same position as they were in for the FM 100 test. This test was also administered in the D50 light booth. For this test, the administrator instructed the participant that they would be viewing two swatches at a time. The participant was simply to answer the question “do the two swatches match?” with a Yes or No response. The administrator then recorded the responses.

The swatches were randomized in order to limit participants guessing. The administrator kept a key with the order to make sure that every participants saw the swatches in the same randomized order.

Data Analysis and Findings

Once all of the data was collected, it was processed in SPSS to find the frequency and the data was also analyzed using a Chi-Square goodness of fit test. This test was chosen to determine if the sample data matched the population. Below are the results of the analysis.

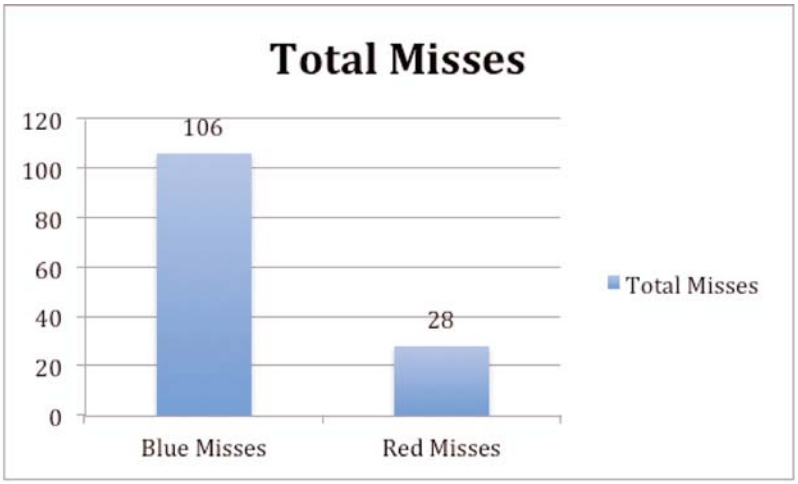
Male vs. Female

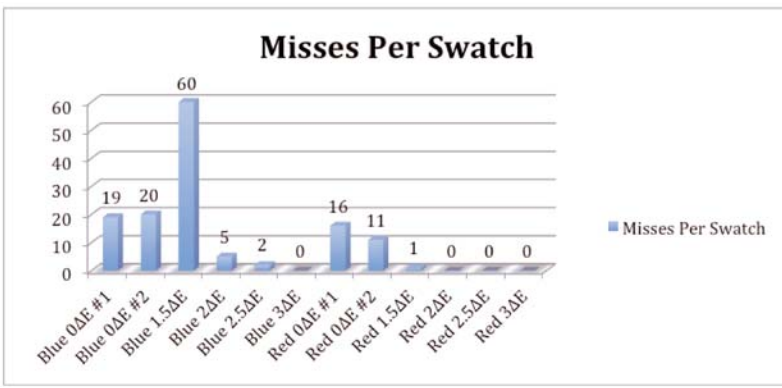
The study was able to collect information from 86 total participants. Of those participants, 38 were male (44%) and 48 were female (56%). Males responded incorrectly 64 times out of the total of 134 misses for a rate of 1.68 misses per male participant and 48% of the total misses. Females responded incorrectly 70 times out of the total of 134 misses for a rate of 1.46 misses per female participant and 52% of the total misses.

Red vs. Blue Swatches

Of the 134 total misses, participants responded incorrectly with red swatches 28 times and 106 times with the blue swatches.

The swatch with the most misses was the 1.5ΔE Blue swatch. This swatch received 60 misses, which translates to 48% of the total misses by participants. Overall, 68% of participants missed the Blue 1.5ΔE swatch. The chart below illustrates the breakdown of misses per swatch. Note that the following swatches had zero misses: Red 2ΔE, Red 2.5ΔE, Red 3ΔE, and Blue 3ΔE. Also, note that blue and red each had 2 control swatches.





Pearson Chi-Square Test

When applying the Pearson Chi-Square Test to the valid cases (swatches where participants missed at least one response), given a signifi cance level of a=0.05, the following results were generated.

Crosstab					
	Gender	Total			
	Male	Female			
Red Control	Right	Count	31	39	70
		Expected Count	30.9	39.1	70.0
	Wrong	Count	7	9	16
		Expected Count	7.1	8.9	16.0
Total	Count	38	48	86	
	Expected Count	38.0	48.0	86.0	

Red Control #1 (0ΔE)
Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.002a	1	.969		
Continuity Correctionb	.000	1	1.000		
Likelihood Ratio	.002	1	.969		
Fisher's Exact Test				1.000	.597
Lin -	.001	1	.969		
N of Valid Cases	86				

In the case of the Red Control, p=.597 which is larger than the significance level of 0.05, therefore the null hypothesis is accepted. The conclusion is that there is not enough evidence to suggest an association between gender and color difference threshold differentiation when viewing two red swatches with 0ΔE color difference.

Red 1.5ΔE
Crosstab

Gender	Total				
	Male	Female			
Red 1.5	Right	Count	38	47	85
		Expected Count	37.6	47.4	85.0
	Wrong	Count	0	1	1
		Expected Count	.4	.6	1.0
Total	Count	38	48	86	
	Expected Count	38.0	48.0	86.0	

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.801a	1	.371		
Continuity Correctionb	.000	1	1.000		
Likelihood Ratio	1.176	1	.278		
Fisher's Exact Test				1.000	.558
Lin-	.792	1	.374		
N of Valid Cases	86				

In the case of Red 1.5ΔE, p=.558 which is larger than the significance level of 0.05, therefore the null hypothesis is accepted. The conclusion is that there is not enough evidence to suggest an association between gender and color difference threshold differentiation when viewing two red swatches with 1.5ΔE color difference.

Blue Control #1 (0ΔE)
Crosstab

Gender	Total				
	Male	Female			
Blue Control	Right	Count	29	38	67
		Expected Count	29.6	37.4	67.0
	Wrong	Count	9	10	19
		Expected Count	8.4	10.6	19.0
Total	Count	38	48	86	
	Expected Count	38.0	48.0	86.0	

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.100a	1	.752		
Continuity Correctionb	.003	1	.956		
Likelihood Ratio	.100	1	.752		
Fisher's Exact Test				.798	.476
Lin -	.099	1	.753		
N of Valid Cases	86				

In the case of the Blue Control 0ΔE, p=.476 which is larger than the significance level of 0.05, therefore the null hypothesis is accepted. The conclusion is that there is not enough evidence to suggest an association between gender and color difference threshold differentiation when viewing two blue swatches with 0ΔE color difference.

Blue 1.5ΔE
Crosstab

Gender	Total				
	Male	Female			
Blue 1.5	Right	Count	10	16	26
		Expected Count	11.5	14.5	26.0
	Wrong	Count	28	32	60
		Expected Count	26.5	33.5	60.0
Total	Count	38	48	86	
	Expected Count	38.0	48.0	86.0	

Chi-Square Tests

Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	
Pearson Chi-Square	.495a	1	.482		
Continuity Correctionb	.218	1	.640		
Likelihood Ratio	.499	1	.480		
Fisher's Exact Test				.637	.321
Lin-	.489	1	.484		
N of Valid Cases	86				

In the case of Blue 1.5ΔE, p=.321 which is larger than the significance level of 0.05, therefore the null hypothesis is accepted. The conclusion is that there is not enough evidence to suggest an association between gender and color difference threshold differentiation when viewing two blue swatches with 1.5ΔE color difference.

Blue 2ΔE
Crosstab

Gender	Total				
	Male	Female			
Blue 2	Right	Count	35	46	81
		Expected Count	35.8	45.2	81.0
	Wrong	Count	3	2	5
		Expected Count	2.2	2.8	5.0
Total	Count	38	48	86	
	Expected Count	38.0	48.0	86.0	

Chi-Square Tests

	Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)
Pearson Chi-Square	.538a	1	.463		
Continuity Correctionb	.073	1	.787		
Likelihood Ratio	.534	1	.465		
Fisher's Exact Test				.651	.389
Lin-	.532	1	.466		
N of Valid Cases	86				

In the case of Blue 2ΔE, p=.389 which is larger than the significance level of 0.05, therefore the null hypothesis is accepted. The conclusion is that there is not enough evidence to suggest an association between gender and color difference threshold differentiation when viewing two blue swatches with 2ΔE color difference.

Blue Control #2 (0ΔE)
Crosstab

Gender	Total				
	Male	Female			
Blue Control	Right	Count	27	39	66
		Expected Count	29.2	36.8	66.0
	Wrong	Count	11	9	20
		Expected Count	8.8	11.2	20.0
Total	Count	38	48	86	
	Expected Count	38.0	48.0	86.0	

Chi-Square Tests

Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	
Pearson Chi-Square	1.236a	1	.266		
Continuity Correctionb	.730	1	.393		
Likelihood Ratio	1.229	1	.268		
Fisher's Exact Test				.310	.196
Lin-	1.221	1	.269		
N of Valid Cases	86				

In the case of the Blue Control #2 0ΔE, p=.196 which is larger than the significance level of 0.05, therefore the null hypothesis is accepted. The conclusion is that there is not enough evidence to suggest an association between gender and color difference threshold differentiation when viewing two blue swatches with 0ΔE color difference.

Red Control #2 (0ΔE)
Crosstab

Gender	Total				
	Male	Female			
Red Control	Right	Count	33	42	75
		Expected Count	33.1	41.9	75.0
	Wrong	Count	5	6	11
		Expected Count	4.9	6.1	11.0
Total	Count	38	48	86	
	Expected Count	38.0	48.0	86.0	

Chi-Square Tests

Value	df	Asymp. Sig. (2-sided)	Exact Sig. (2-sided)	Exact Sig. (1-sided)	
Pearson Chi-Square	.008a	1	.928		
Continuity Correctionb	.000	1	1.000		
Likelihood Ratio	.008	1	.928		
Fisher's Exact Test				1.000	.588
Lin-	.008	1	.928		
N of Valid Cases	86				

In the case of the Red Control #2 0ΔE, p=.588 which is larger than the significance level of 0.05, therefore the null hypothesis is accepted. The conclusion is that there is not enough evidence to suggest an association between gender and color difference threshold differentiation when viewing two red swatches with 0ΔE color difference.

Conclusions and Recommendations

Based on the resultant data, it can be concluded that there is not enough evidence to suggest an association between gender and color difference threshold differentiation when viewing two swatches either red or blue in hue with varying color differences from 0ΔE to 3ΔE.

These findings show that males and females observe color differentiations similarly, at least within the blue and red range. These findings also suggest that acuity of color vision can solely be based upon the color the viewer is observing. The study showed that participants overwhelmingly had a more difficult time discerning color differences in the blue swatches compared to the red swatches. This directly impacts the printing industry. Currently there are different standards for acceptable color difference tolerances depending on the business. This study could help to adjust those standards if they are too loose or too tight. How the study impacts the industry depends on the specific output process and tolerances used by a business.

Recommendations for Further Research

One subject that could be studied further is the impact of yellow upon blue swatches and overall color acuity. The researchers created the blue swatches by changing the amount of yellow, which is the opponent color of blue. Because yellow is among the most difficult colors for humans to discern, it would make sense that changes in the amount of yellow present in a swatch would create a difficult situation for participants to discern color changes.

This study focused on determining color difference thresholds between two swatches that were directly next to one another. In many real world examples of determining color differences however, two samples may not be directly next to one another. For this reason, a study that used similar swatches to those used for the current study, but focused on the correlation between the distance of the swatches and the acuity of the participant would be of value. This would determine if participants can accurately detect color differentiations between color samples that are varying distances apart from each other. The impact of such a study would validate or dispute the findings of the current study and help to understand the relationship to product placement in the printing industry.

This study could also be expanded to include more color swatches for the same test. This would generalize the results to a broader range of colors. And lastly, the study could be expanded to a different target population to see if there is a correlation between color difference thresholds and age, ethnicity, or any other demographic.

Conclusion

This study found that there is no difference in the way males and females see differentiations in color, but the study was limited. In the future, the study should be expanded to include different color swatches, varying distances between swatches and a broader range of age and possibly skill level in the participants.

The results of this study can possibly help determine tolerance levels for the printing industry, especially when considering red and blue color differences. The results can also help to dispel any myths about male versus female color vision differences as they pertain to color differences.

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