A Comparison of Color Preferences of Adults and Children

Karen M. Braun and John C. Handley
Xerox Corporation
Webster, New York

Abstract

The preferences of children and adults were compared with respect to each of the following color image quality attributes: image brightness, saturation, sharpness, color balance (+M/+G), hue rotation, and contrast. It was found that the children had no strong preferences for sharpness or contrast. There was no statistical evidence that they disagreed with adults as to the optimal level of brightness and hue rotation, although they were more widely distributed in their preferences on these two attributes. Children preferred the more saturated and less greenish choices.

Introduction

On "Bring Your Kids to Work" Day in 2001 at the Xerox Corporation Webster campus, 57 children and 34 adults performed an experiment to determine if there were systematic differences in the preference of kids and adults. Published studies on this topic are scarce,[1,2] although there have been investigations into cultural differences.[3,4] The average age of the children in our study was 10.3 (min=4, max=15), and the average adult age was 43.4 (min=35, max=62).

Observers were presented with four or five reproductions of six scenes. One attribute of each scene was modified in Adobe® Photoshop® (brightness, contrast, color balance, hue, sharpness, or saturation). Children and adults were asked to choose the reproduction they preferred for each scene.

The results of this study show a statistical difference between adults and children for particular attributes, namely saturation, sharpness, and contrast. In some cases, a clear difference in the preferred value of an adjusted attribute can be seen: adults preferred less saturation and a more greenish (rather than magenta) cast to skin tone than children. The exact magnitude of the values is not as important since the imaging path from original to reproduction will vary, including assumptions for converting unknown colorimetry to printed data. Further work in this area with a wider variety of images is warranted.

Image Preparation

Adobe® Photoshop® 4.0 was used to prepare the images for the experiment. The attributes shown in Table 1 were adjusted. Table 1 and Figs. 1-5 show the relationships between Photoshop® terms and colorimetric adjustments. These relationships were derived empirically by apply the adjustments to test targets and comparing the original to the adjusted result.

Table 1. Attributes Adjusted and Colorimetric Effect Derived Empirically.

Photoshop Attribute	Colorimetric Correlate (approx.)	Image Name
Brightness (+B)	$L^*_{out} = L^*_{in} + 0.4*B$	Fruit
Saturation (+S)	$C^*_{out} = C^*_{in} /(0.01*S+1)$	Castle
Sharpness	Unsharp masking	Birds
Color Bal. (+M/+G)	$a^*_{out} = 0.6*M + a^*_{in}$	Lady
Hue Rotation	See Fig. 4	Bridge
Contrast (+C)	$L^*_{out} = (C^*0.01+1)L^*_{in} - 0.90*C$	Tots

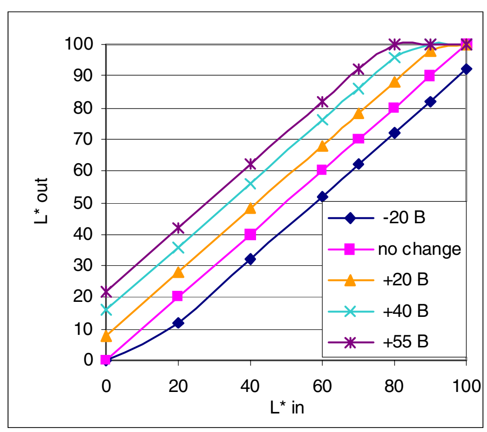

Figure 1. As "brightness" was changed in Photoshop, an additive relationship was observed on L.*

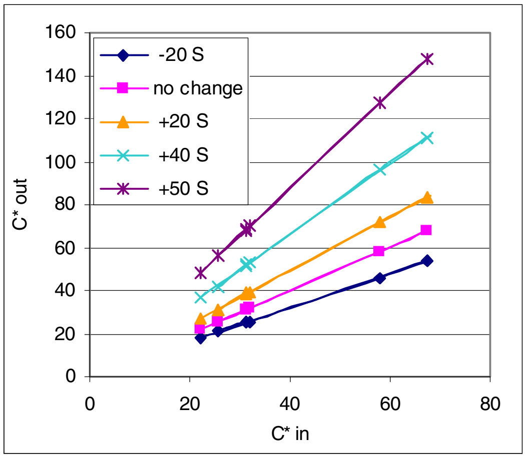

Figure 2. Adjusting "saturation" in Photoshop resulted in scaling chroma.

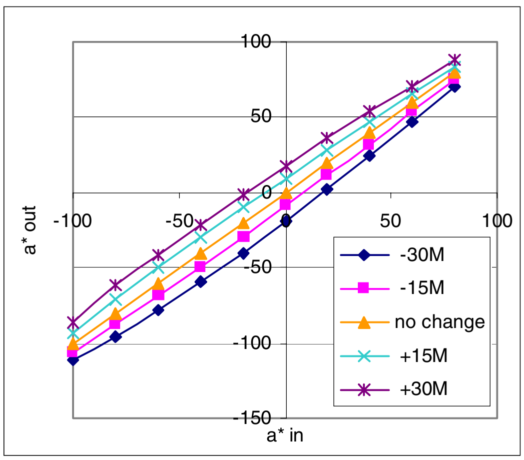

Figure 3. As color balance is varied, approximately an additive constant is applied to a. This plot is for L*=50 because the color balance was only applied to the midtones. The amount of the shift to a* falls off as L* goes away from L*=50.*

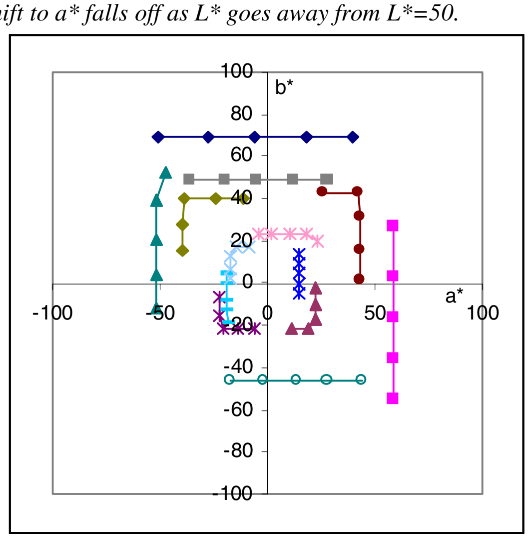

Figure 4. Photoshop 4.0 has a non-linear relationship between "hue rotation" and CIELAB hue. The x-axis is a and the y-axis is b*. Each line represents a random color adjusted by –30, -15, original, 15, and 30 units of hue rotation.*

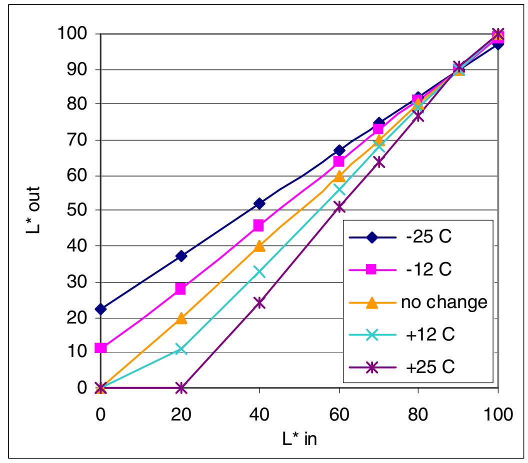

Figure 5. As "contrast" was changed in Photoshop, an effect was seen on the slope of the input to output lightness.

For the Birds image, sharpness was modified using the "unsharp mask" filter, and the amount was varied to 100%, 200%, and 500%. "Radius" and "threshold" parameters were not changed or recorded.

Analysis

Each subject was asked to chose the rendition he or she preferred. Out of all treatments, a subject chose one. Each choice was assumed to be independent. We model the choice behavior for a population as a multinomial distribution. Let the number of treatments be *m*, the number of presentations be *N*, and X_i be the random variable modeling the number of times treatment *i* was chosen. For a fixed population and a fixed print/adjustment pair, the probability of the choices is multinomial

$$P(X_1 = x_1, \ldots, X_m = x_m) = \frac{N!}{x_1! \cdots x_m!} p_1^{x_1} \ldots p_m^{x_m} \qquad (1)$$

where $\sum_{i=1}^{m} x_i = N$, $0 \le x_i$, for $i = 1, \ldots, m$, $\sum_{i=1}^{m} p_i = 1$, and $0 \le p_i$ for $i = 1, \ldots, m$. Parameters $\{p_i\}$ are the probabilities of a random member of the population choosing treatment *i*. Note that since the parameters sum to one for a particular image, there are only *m*-1 true parameters. The response to each image *v* (one of Fruit, Castle, Tots, Lady, Birds, Bridge), for each population, Adults or Kids, is characterized the choice probability vector $\mathbf{p}_{A,v} = (p_{1,A,v}, \ldots, p_{m,A,v})$ for adults and $\mathbf{p}_{K,v} = (p_{1,K,v}, \ldots, p_{m,K,v})$. We wish to investigate the following: do the populations exhibit the same choice behavior (test $\mathbf{p}_{A,v} = \mathbf{p}_{K,v}$ for all images *v*, versus $\mathbf{p}_{A,v} \ne \mathbf{p}_{K,v}$ for some image *v*). We also look at each image to see how the two population differs.

Analyses are based on likelihood procedures.[5] There are two populations (Kids or Adults), six image/adjustment pairs *v*, and for four of the images, there are four true parameter values and for the other two, three true parameter values. In each case, the maximum likelihood estimates of the parameter values are the number of times treatment i is chosen divided by the number times the particular image was presented to the population.

There is a multinomial outcome for each population and image. The log likelihood of this outcome is computed using the natural log of Eq. (1),

$$l(\mathbf{p}) = \log(N!) + \sum_{i=1}^{m} [x_i \log(p_i) - \log(x_i!)] \quad (2)$$

Table 2. Counts, Maximum Likelihood Estimates, and Log Likelihoods, *l*, for "Kids" Population.

Image	1	2	3	4	5	*N*	*l*
Fruit	2 0.04	6 0.11	13 0.23	20 0.36	15 0.27	56	-7.11
Castle	4 0.07	9 0.16	16 0.29	14 0.25	13 0.23	56	-7.49
Birds	11 0.20	16 0.29	11 0.20	18 0.32	-	56	-6.00
Lady	6 0.11	20 0.36	20 0.36	10 0.18	-	56	-5.82
Bridge	15 0.26	19 0.33	11 0.19	5 0.09	7 0.12	57	-7.50
Tots	8 0.14	9 0.16	14 0.25	15 0.26	11 0.19	57	-7.70

Table 3. Counts, Maximum Likelihood Estimates, and Log Likelihoods, *l*, for "Adults" Population.

Image	1	2	3	4	5	*N*	*l*
Fruit	0 0.0	2 0.06	5 0.15	24 0.71	3 0.09	34	-4.37
Castle	2 0.06	11 0.35	12 0.35	8 0.24	1 0.03	34	-5.89
Birds	2 0.06	8 0.24	11 0.33	13 0.38	-	34	-4.93
Lady	1 0.03	5 0.15	23 0.70	4 0.12	-	33	-4.19
Bridge	5 0.15	21 0.62	7 0.21	0 0.0	1 0.03	34	-4.40
Tots	2 0.06	14 0.41	13 0.38	2 0.06	3 0.09	34	-5.88

Each row of these two tables corresponds to a multinomial outcome having probability distribution shown in Eq. (1). Figures 6-11 show graphs of the estimated parameters with approximate 95% confidence intervals. Confidence intervals were computed using a likelihood ratio.[5] This procedure is preferred.[6] A 95% approximate CI is

$$\{p : -2[l(\hat{p}_1,\ldots,\hat{p}_{i-1},p,\hat{p}_{i+1},\ldots,\hat{p}_m) - l(\hat{p}_1,\ldots,\hat{p}_m)] \le \chi_1^2(\alpha)\}$$

where $\alpha = 0.05$ and $\chi_1^2(0.05) = 3.842$. (This holds for parameters in the interior of the parameter space [0,1]; CI's for estimates $\hat{p}_i = 0$, on the boundary of the parameter space, cannot be determined by likelihood methods.)

To test whether the two populations are indeed the same, we need estimates and log likelihoods from the pooled data as shown in Table 4.

Table 4. Counts, Maximum Likelihood Estimates, and Log Likelihoods, *l*, for Pooled Population.

Image	1	2	3	4	5	*N*	*l*
Fruit	2 0.02	8 0.09	18 0.20	44 0.49	18 0.20	90	-7.66
Castle	6 0.07	20 0.22	28 0.31	22 0.24	14 0.16	90	-8.38
Birds	13 0.14	24 0.27	22 0.24	31 0.34	-	90	-6.66
Lady	7 0.08	25 0.28	43 0.48	14 0.16	-	89	-6.32
Bridge	20 0.22	40 0.44	18 0.20	5 0.06	8 0.09	91	-8.09
Tots	10 0.11	23 0.25	27 0.30	17 0.19	14 0.15	91	-8.55

According to likelihood modeling theory, were the two populations the same, the pooled log likelihood should differ little from the sum of the individual log likelihoods. Letting l_{pooled}, l_{Kids}, and l_{Adults} denote the appropriate log likelihood values, the test statistic for overall identity of the populations is $U_{overall} = -2(l_{Kids} + l_{Adults} - l_{pooled}) = 51.25$. Under the null hypothesis that the populations are the same, the test statistic is asymptotically distributed chi-square with 22 degrees of freedom (there are 4+4+4+3+3+4 = 22 parameters for each population, so there are 22+22-22 = 22 for the test statistic). The *p*-value for this statistic is 0.0004 < 0.05, by which we reject the null hypothesis that the populations are equal. We perform the analysis image-by-image in Table 5 to see if there are any exceptional cases.

In Table 5, Fruit and Bridge exhibit marginal evidence of equality, but none of the six images exhibits *strong* evidence of equality.

Table 5. Image-by-image *p*-values for Test of Equal Parameters. Bold Indicates When the Null Hypothesis That the Populations Are Equal Was Rejected.

Image	*p*-value
Fruit (brightness)	0.11
Castle (saturation)	**0.04**
Birds (sharpness)	**0.04**
Lady (color balance)	0.06
Bridge (hue rotation)	0.11
Tots (contrast)	**0.04**
Overall	0.0004

We also investigated whether kids preferences are "noisier" than adults. Specifically, we ask how preferences of kids and adults differ from a uniform response ("don't care"). To do this, we construct a likelihood ratio statistic to test whether the observations differ from uniform ($p_i = 1/m$ for $i = 1, \ldots, m$). The statistic $U = -2(l_{uniform} - l_{fit})$ is asymptotically chi-squared distributed with m-1 degrees of freedom, where l_{fit} is the last column of Tables 2 and 3 (the maximized log likelihood) and $l_{uniform}$ is the log likelihood

$$l_{uniform} = \log(N!) + \sum_{i=1}^{m} [x_i \log(1/m) - \log(x_i!)]$$

for each observation. Table 6 shows the results for each image.

Table 6. *p*-values for Tests for Uniformity. Numbers in Bold Indicate Cases where Uniformity Is Not Strongly Rejected (p < 0.05).

Image	Kids *p*-value	Adults *p*-value
Fruit (brightness)	0.0003	0.0000
Castle (saturation)	**0.0526**	0.0010
Birds (sharpness)	**0.4387**	0.0002
Lady (magenta-green)	0.0087	0.0000
Bridge (hue rot.)	0.0190	0.0000
Tots (contrast)	**0.5124**	0.0001

Uniformity is strongly rejected (< 0.05) for all images for adults, and for Fruit, Lady, and Bridge for kids. The kids population appears to be significantly ambivalent with respect to sharpness and contrast.

Results

Figures 6-11 show the percentage of times that each group chose a given reproduction. Three hypotheses were tested and the captions indicate the results. (1) First, are the two groups significantly equal from each other? A *p*-value of less than 0.05 indicates that this hypothesis should be rejected. In three cases, equality was rejected (Castle - saturation, Birds - sharpness, Tots - contrast) and in the other cases, it was accepted marginally. (2) The second hypothesis tested is that the kids essentially gave uniform results across the choices. Again, for Castle, Birds, and Tots, the children were found to give results that did not differ significantly from uniform. Castle was marginal in this regard. (3) The adults were never found to give uniform results, indicating again that the adults and children were quite different in their responses.

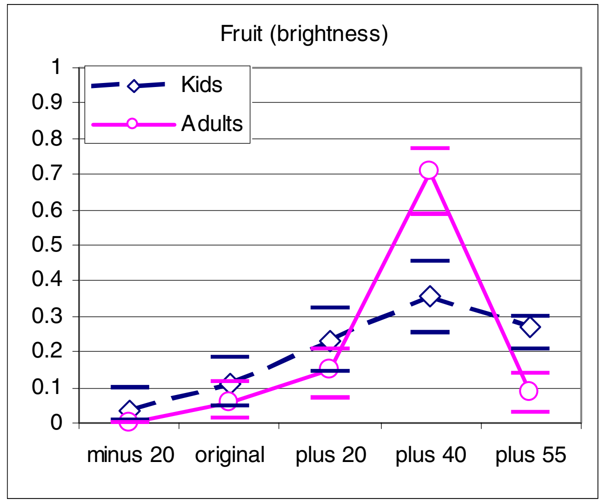

Figure 6. Results for Fruit image. Equality of the two populations is not rejected.

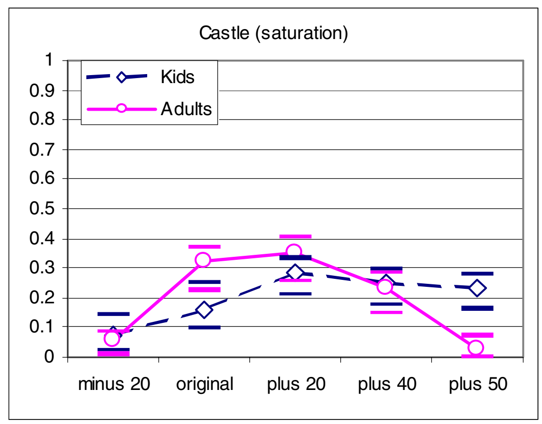

Figure 7. Results for Castle image. Equality of the two populations is rejected.

Figure 8. Results for Birds image. Equality of the two populations is rejected. The response of the children was not significantly different from uniform.

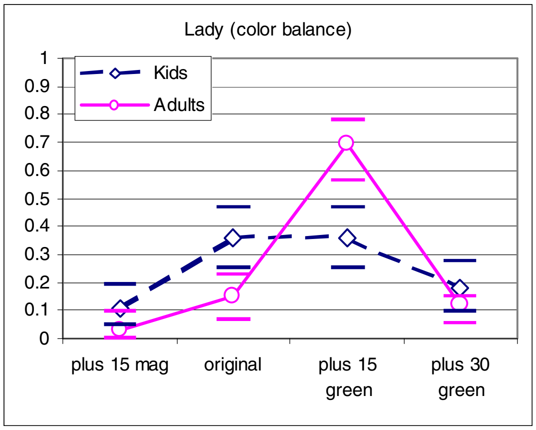

Figure 9. Results for Lady image. Equality of the two populations is not rejected.

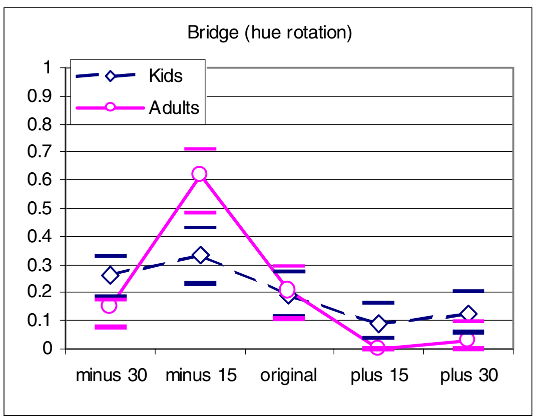

Figure 10. Results for Bridge image. Equality of the two populations is not rejected.

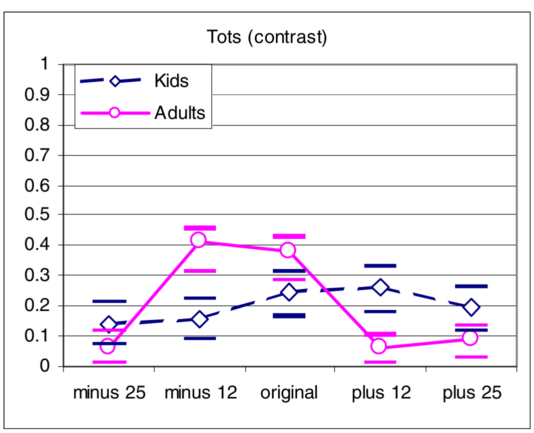

Figure 11. Results for Tots image. Equality of the two populations is rejected. The response of the children was not significantly different from uniform.

The children's results were more widely distributed across the range of reproductions. Adults preferred the given scenes with less saturation and a more greenish (rather than magenta) cast to skin tone than adults. The children were ambivalent to changes in sharpness and contrast. Adults preferred the sharpest images that were provided. The peak value when brightness was varied was about equivalent between the groups, as was the peak when color balance of the sky was varied. In both those cases, the children had a flatter distribution.

Table 7. Summary of Hypothesis Tests and Conclusions. (m) Indicates That the *p*-value was Marginal. No Entry Indicates the Populations Results Were Not Uniform for the Particular Image.

Attribute (Image)	Kids = Adults?	Kids uniform?	Adults uniform?	Result
Brightness (Fruit)	=			No diff.
Saturation (Castle)	≠	Yes (m)		Kids: more saturated
Sharpness (Birds)	≠	Yes		Kids: no pref.
Color Bal. (Lady)	= (m)			Adults: greener
Hue Rot. (Bridge)	=			No diff.
Contrast (Tots)	≠	Yes		Kids: no pref.

Conclusions

Children and adults were shown to give statistically different responses for their preference of color reproduction. Children were found to be ambivalent to contrast and sharpness, and were also found to prefer more chromatic images. These results were only obtained from one image each and are very likely image dependent. Further research might indicate how to adjust images for these preferences. It is significant to find that the preferences statistically differ between the two populations.

Color imaging software, computer games, and website are being designed for children. Several companies are marketing computer peripherals to kids, including laptops and printers. Color reproduction modified for the specific preferences of children might be valuable in these applications.

References

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Biography

Karen Braun received her B.S. degree in physics from Canisius College and her Ph.D. in imaging science from Rochester Institute of Technology. Her work at Xerox Corporation focuses on color reproduction and color perception. Karen has published numerous journal articles and co-authored Recent Progress in Color Science. She is a board member of the Inter-Society Color Council, an active member of IS&T, and a technical committee member for the IS&T/SID Color Imaging Conference.