The Applicability of Modern Color Differencing Equations in the Graphic Arts Industry

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Abstract

At the TAGA 2007 conference in Pittsburgh the author of this paper presented a paper about color-differencing equations and the human eye. The color test was done with inexperienced observers. One of the main results was that the DE2000 equations corresponded quite well with the perceived color differences, followed closely the $DE_{CMC2:1}$ equation.

A very similar test was carried out with experienced color observers at the IPA technical conference in Chicago in April 2008 and local print professionals in the summer of 2008. Besides having to judge a solid color chip, they were also asked to rank visual differences in four test images.

As an addition to the test carried out in 2006, the DIN99 equation was also tested to see if it relates better to the perceived color differences. Interestingly the DE2000 equation related the best with how the experienced observers perceived the color differences of the solid color patches.

Another question is how do any of the modern color-differencing equations relate to differences present between two similar images displayed on a computer screen. Due to the large number of new soft proofing systems being introduced into the graphic arts industry, test images were shown on a color-calibrated display.

Four ISO SCID images were chosen and modified in regards to lightness, chroma and hue. The images that were chosen varied in chroma from very colorful to mostly neutral colors. In the neutral colors all observers identified differences quite easily, but in the other images many observers had difficulties

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identifying slight changes in regards to lightness, but could readily identify differences in chroma and hue.

Recommendation threshold values in relation to differences in lightness, chroma and hue are listed and also which of the newer colour differencing equations relates better to the perceived color differences.

Introduction

In 1976 the CIE endorsed a color differencing equation that, for the first time, made it possible for color scientist to compare color measurement data, since the color space (L*a*b*) and illuminant (i.e. D50) and observer (2˚) were specified. The difference of ΔE of 1.0 was deemed to be the smallest color difference perceivable by the human eye.

It was soon discovered that this formula had its drawbacks. The same numerical difference did not mean the same colorimetric difference. This was particularly visible in pastel type colors.

The first attempt to rectify this problem was done by the Color Measurement Committee of the Society of Dyers and Colorists of Great Britain (Clarke, 1984) introduced the ΔE_{CMC} color differencing formula, which is based on the L*C*h*-color notation and contains weighting factors that change the size of allowable color difference and is thought to better model the way the human visual system perceives color differences. The ΔE_{CMC} formula was modeled to give the same visual difference in all regions of the color wheel with ΔE_{CMC}-value of 1.0. This was the first attempt to adjust a color difference formula to the actual perception of color differences.

In 1994 the CIE introduced the ΔE_{94}-formula (CIE, 1995). This formula, like the DE_{CMC}-formula, contains weighting factors that adjust the size of the allowable color differences depending on the location of the color in color space. Although an improvement compared to the ΔE_{ab} formula, this formula had a weakness in the blue-violet region of the visible spectrum. This formula, like the ΔE_{CMC} formula, is also based on the L*C*h*-notation of color.

Due to weaknesses in the ΔE_{94} equation in the blue-violet region the CIE DE2000 equation was introduced and published (CIE 2001). CIE DE2000 takes also the varying sensitivity in regards to lightness into consideration to determine the difference between two colors.

All these equations show the drawbacks of the L*a*b*-color space and introduce corrections to the non-uniform L*a*b*-color space. Attempts have been made in Germany to adapt the L*a*b*-color space by modifying each axis, so that the color difference formula from 1976 can be used and represents the true Euclidian difference between two points in color space (Buering, 2001).

It has to be mentioned that all ΔE equations are intended for small color differences and not for large ΔE values. Large ΔE values usually mean that the ΔE-value is larger than a value of five.

Experiments conducted to determine where the sensitivity of the human observers for certain color differences lies, depending on the location of the color in color space, were usually conducted by having observers compare solid color chips. Although this method has been used successfully it does not take into consideration that the observed color is always influenced by its surrounding colors. Out of this reason a set of test images were shown to color professionals and their judgment was required.

Experimental

For the 2007 Annual Technical Conference of TAGA a set of test colors with know color differences were prepared and shown to inexperienced observers (Habekost, 2007).

The results from the observers were entered into a weighting scale and the measured L*a*b*-readings of standard and samples correlated to the perceived differences. At that point in time the Excel-spreadsheet used for the ΔE-calculations did not contain the DIN99 formula. This is has now been corrected.

The comparison between inexperienced and experienced users usually provides interesting information on how these two different groups see color differences and if any of the color difference equations correlates better with the observed differences. This concludes the first part of the experiments.

For the second part of the test reduced set of solid test colors were generated, since the observers were not only asked to rate the differences present on solid color chips, but also the difference that are present in modified SCID images.

The distribution of the solid test colors in color space can be seen in Figure 1. It was tried to have neutral colors, as well as intense color, that cover the main color centers.

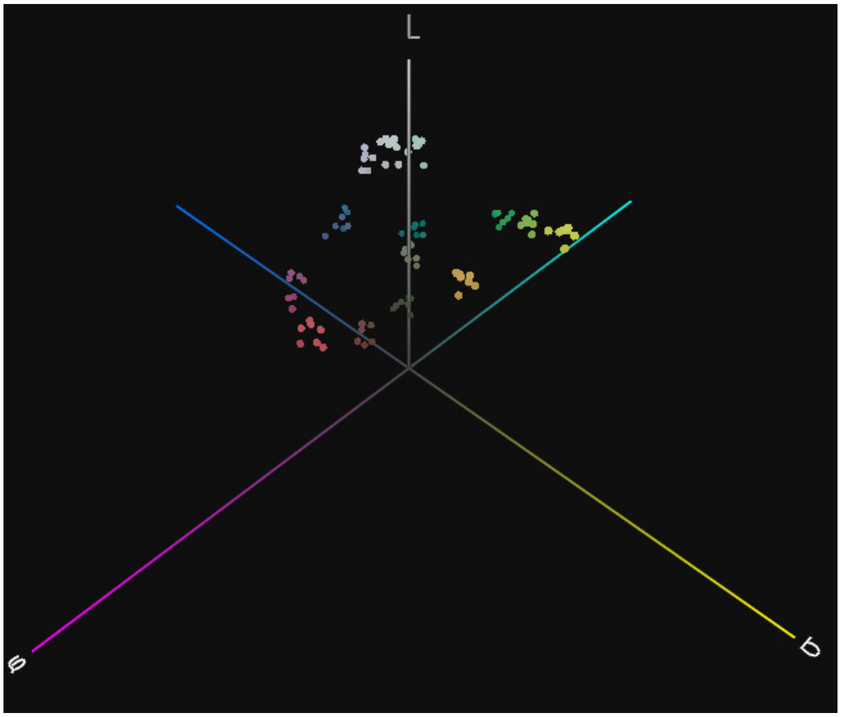

Figure 1. *Test colors used for the viewing of the test color chips.*

The test colors have been chosen to fit within the gamut of the Quickmaster DI46 printing press. Before the test colors were printed an IT8.7/4 test target was printed on press and measured to obtain the color capabilities of the press.

The L*a*b*-values of the test colours were entered into a MatLab worksheet and transformed into L*C*h*-values. These L*C*h*-values were modified in the way that color differences using ΔE_{ab} between 2 and 7 resulted. Modifications were applied to each of the three variables individually. For each standard color six variations were generated. This means that there were two variations in regards to lightness, two in regards to chroma and two in regards to hue.

The tests subjects were given these test colors and a ranking sheet (see appendix) to rank the differences. It was stipulated that the viewing of the colors took place in viewing booth, either on press or a customer viewing room, and that the light source had color temperature of 5000K. This was ensured using a Printing Industries RHEM indicator. Each participant was also given the same rating scale. The scale was as follows:

- Match
- Slightly different
- Different
- More different
- Very different

These ratings were translated into numbers from 1 (Match) to 5 (Very different) and a ranking scheme was applied to weight the given responses.

The same weighting scheme used in the 2007 study (Habekost, 2007) was applied. The ΔE-values under all five color differencing equations were plotted against the numbers obtained from the ranking scheme and the r^2-values obtained.

A typical ranking looked as shown in Table 1:

Standard 5												
	Sample 1, DEab = 3.55		Sample 2, DEab =6.64		Sample 3, DEab = 4.50		Sample 4, DEab = 5.58		Sample 5, DEab= 0.97		Sample 6, DEab = 1.64	
Match (M)	0	0	0	0	0	0	0	0	5	25	2	10
Slightly Different (SD)	5	20	0	0	4	16	0	0	6	24	7	28
Different (D)	9	27	1	3	2	6	1	3	2	6	1	3
More Different (MD)	0	0	1	2	2	4	2	4	0	0	2	4
Very Different (VD)	0	0	12	12	6	6	11	11	1	1	2	2
Score		**47**		**17**		**32**		**18**		**56**		**47**

Table 1. *Ratings and rankings of a color, DE_{ab}-values.*

The ΔE-values were plotted against the score for each sample and the r^2-values obtained. A typical plot of this can be seen in Figure 2.

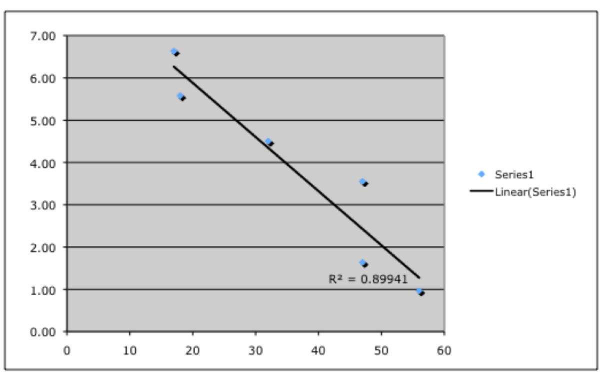

Figure 2. *Graphical representation of the data shown in Table 1.*

The r^2-values for the example given in Figure 2 varied under the five different color-differencing equations. These values were 0.899 for ΔE_{ab}, 0.827 for ΔE94, 0.926 for DE2000, 0.927 for $\Delta E_{CMC2:1}$ and 0.908 for DIN99.

The r^2-values from all the color samples and the various DE-equations were then plotted against the L, C and h values of all the colors evaluated in this study to see which color difference equations correlates well with the perceived color differences from the printing professionals.

This analysis was also repeated for the color samples used in the 2006 study (Habekost, 2007), but the DIN99 equation was also applied to see how this equation correlates with the way inexperienced color observers perceive the visual differences.

The second main part of this study ask the color professionals to look at four ISO SCID images which have been modified in a similar way like the solid color chips. The professionals were asked to write down in order which color or part of the image the noticed a color difference first, second and third.

For the analysis of the colors and their differences that observers had to find, the twelve most dominating colors were extracted from the picture using Photoshop's built-in "Indexed color"-function and the index table limit was set to 32. A typical example of this can be seen in Figure 3.

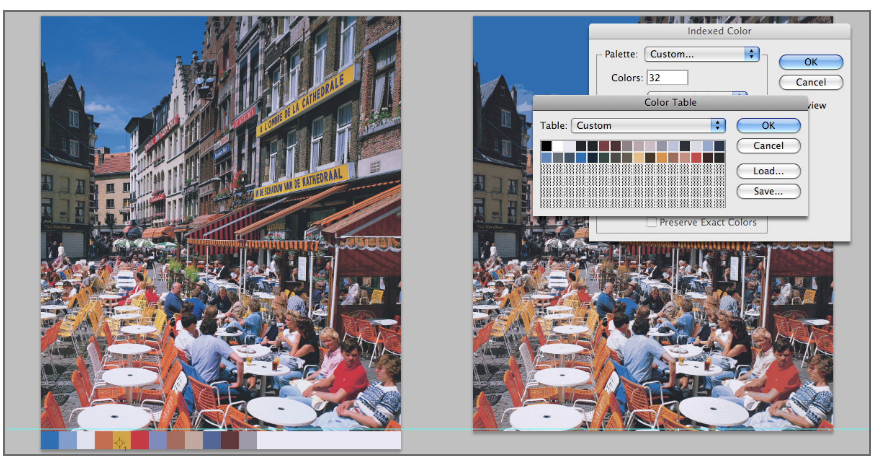

Figure 3. *SCID test images normal (left) and modified (right) with significant colors showing below.*

The significant colors were not shown to the participants, but measured later on from the screen using an Eye1iO instrument to record the difference between the standard on the left and the modified sample on the right.

The test images were shown in lighting conditions similar used to those used for softproofing solutions. The display of choice was an Apple Cinema 23" display that was calibrated before each use using Profilemaker 5.0.8 and an Eye1iO instrument.

Results

Color chips and inexperienced observers including DIN99

For the evaluation of correlation between actual measured color differences and perceived color differences the average r^2-value, the standard deviation of the r^2-values and the coefficient of variation is used. The coefficient of variation is defined as:

$$\text{Coefficient of variation} = \frac{\text{Standard deviation}}{\text{Mean}}$$

This allows comparing the data with varying means as they are generated by each entry and the color differencing equations.

The results from the 2007 study plus the added results for the DIN99 equation are shown in the table below:

	r^2 ΔE_{ab}	r^2 $\Delta E94$	r^2 $\Delta E_{CMC2:1}$	r^2 DE2000	r^2 DIN99
Average r^2-value	0.818	0.851	0.877	0.883	0.872
Standard deviation	0.161	0.124	0.108	0.104	0.102
Coefficient of variation	0.197	0.146	0.123	0.118	0.117

Table 2. *Correlation values between measured and observed color differences.*

From this table is can be seen that the last three color differencing equations have a similar q coefficient of variation meaning that the dispersion of the data is similar for these equations. It can also be seen that the DIN99 equation offers a similar correlation like the $\Delta E_{CMC\ 2:1}$ equation.

Color chips and experienced observers

As described in the experimental part above a set of 14 test colors including neutral colors were chosen for this test. The results from the test have been grouped by lightness, chroma and hue.

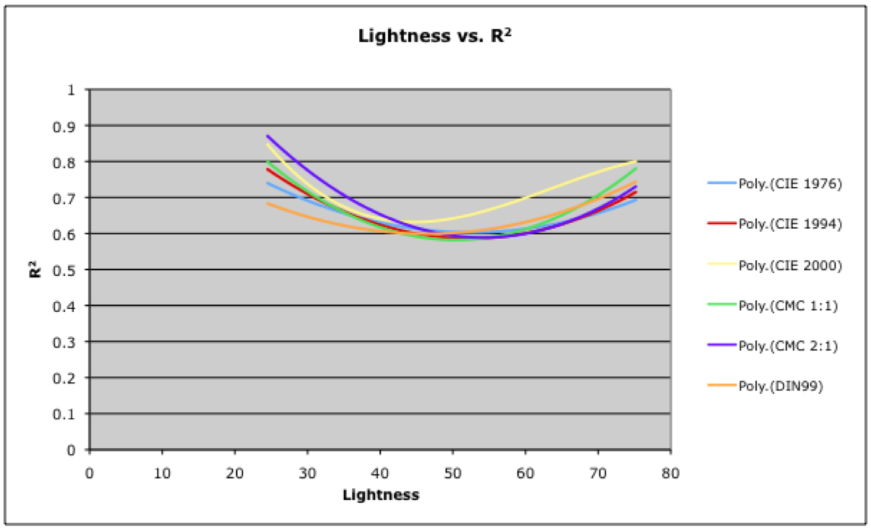

Figure 4. *Correlation of calculated vs. observed differences in relation to the lightness of values of the samples. All lines are 2nd degree polynomial.*

From Figure 4 it can be seen that the CMC 2:1 equation and DE2000 have the strongest correlation between the perceived and calculated color differences for the darker colors. However, this correlation is reduced as the lightness of the samples increases until a lightness values of about 45. After this the correlation increases again, but the DE2000 equation shows truly a better correlation than all the other equations. It is also interesting to observe that the DIN99 equation did not perform better than the DE2000 equation, although one could be under the impression that that could be the case based on the logic that went into the creation of the DIN99 equation.

The following figure shows the performance versus the chroma of the test colors.

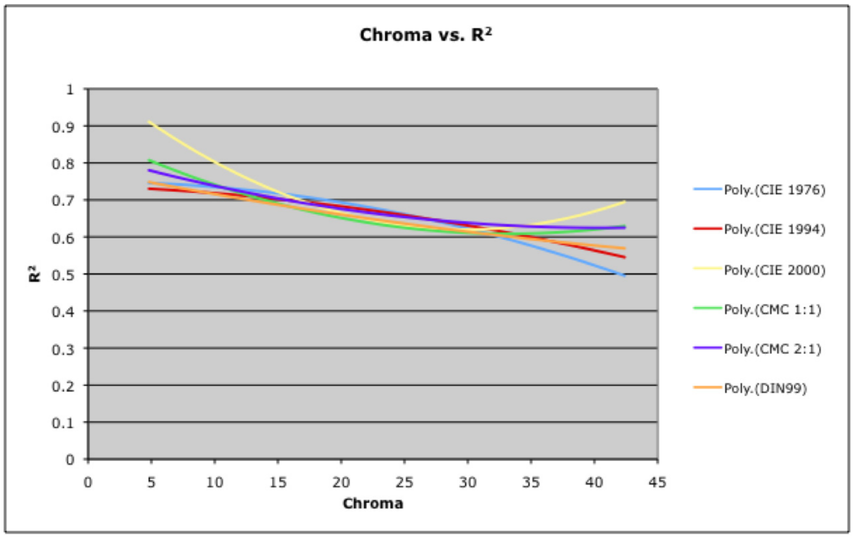

Figure 5. *Correlation of calculated vs. observed differences in relation to the chroma of values of the samples. All lines are 2nd degree polynomial.*

The interesting part of this figure is, that the DE2000 equation correlates well between the perceived differences and the calculated differences in the low chroma area from 5 to 15 (low intensity colors) and also well in the area of the high intensity colors. As could also be seen in the Figure 4 is that the CMC-equations also show a very good correlation between the perceived and the calculated color differences.

The correlation between observed and calculated differences in relation to the hue of the test colors is shown in the following figure.

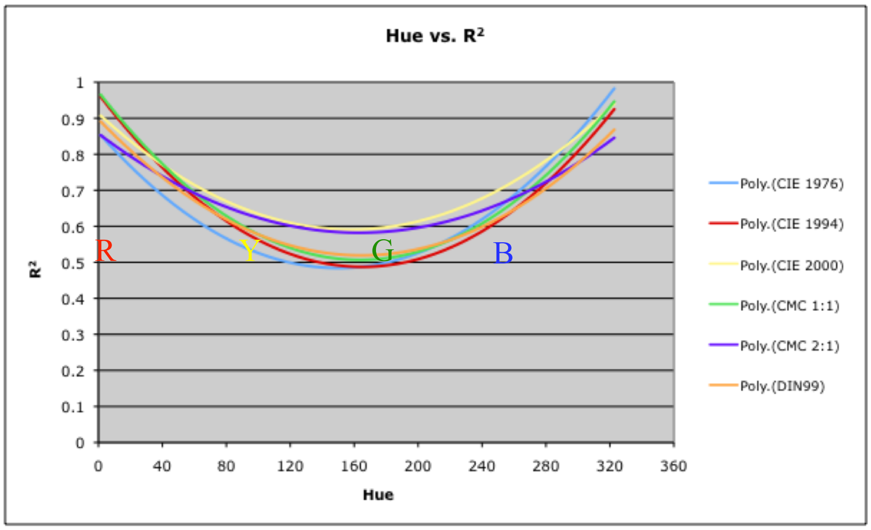

Figure 6. *Correlation of calculated vs. observed differences in relation to the hue of values of the samples. All lines are 2^nd^ degree polynomial.*

The figure gives an interesting insight on how the perceived and the numerical differences correlate. The CMC equations surpasses the correlation between the perceived and the calculated differences of the DE2000 equation in the reddish area of the tested colors, but for the majority of the tested colors the DE2000 equation shows a definitely better correlation.

From these three figures it can clearly be observed that the DE2000 equation performs quite well in regards to the lightness, chroma and hue of the tested colors and their perceived differences. This is an important finding of this test especially if the connection between this test and the test with the inexperienced users is drawn. In both cases it was the DE2000 equation that gave the best results in regards present and perceived color differences.

In an extension of the work done with the inexperienced users it was also tried to optimize the weighting factors of the DE2000 equation (Habekost, Rohlf, 2008). The result of this work was that it was best to leave the weighting factors at their default values of 1.

Perceived color differences in images

Looking at solid color chips and judge any perceivable differences and looking at images to judge differences are not too separate things, but different factors come into play when two images are being compared. Not only are surrounding colors a possible influence, but also the image content itself can have an impact on how easy or difficult it might be to detect any differences. The images that were shown to the experienced color observers ranged from very colorful to very neutral in color. The changes applied to all images were very similar, yet it sometimes the observers had no difficulties detecting any changes, sometimes the images were considered being very similar. One challenge for the color professionals was to pinpoint which color they saw first, since most of them started to adjust the ink zones of a printing press in their head to compensate for the differences they perceived. The test images are shown in the figure below.

Figure 7. *Test images with color patches of most frequent colors.*

Results from the Street Café image

Figure 8. *Street cafe image with relevant test colors below.*

The first changes shown to participants were changes in lightness. Although DE_{ab} differences of 1.84 to 6.54 were present none of the participants recognized them. This can possibly be attributed to the “busy” image where the eye is easily distracted and does not focus on one part of the image in particular to notice any differences.

The second sets of changes were related to the chroma or Intensity of the colors. The changes applied to the colors translate into a color difference of DE_{ab} of around 2 and 5.

Most observers noticed the changes in the colors dark blue and dark orange.

The values for these changes are listed in the table below:

	ΔE_{ab}	ΔE94	DE2000	$\Delta E_{CMC\ 2:1}$	DIN99
Dark Blue	1.77	0.63	0.47	0.77	0.55
Dark Orange	1.44	0.48	0.49	0.61	0.45

Table 3 DE-values in relation to chroma of the most noticeable color changes

These differences were detected by 30% of the participants.

For the hue of the colors changes up to a DE_{ab} of seven were applied.

The same two colors as listed above were noticed, but the observers detected a third, yellowish color showing a noticeable difference. In regards to the hue changes more drastic color changes were necessary. The table below lists the measured color differences:

	ΔE_{ab}	ΔE94	DE2000	$\Delta E_{CMC\ 2:1}$	DIN99
Dark Blue	4.99	3.06	3.07	3.41	2.90
Dark Orange	6.57	3.88	4.41	6.16	2.70
Mustard Yellow	7.21	3.93	4.87	5.04	3.62

Table 4. *DE-values in relation to hue of the most noticeable color changes.*

These changes were detected by 60% of the participants.

Here are the L*a*b*-values of the colors listed in Tables 3 and 4.

Dark Blue: L*: 45.3, a*: –3.53, b*: –41.89
Dark Orange: L*: 55.40, a*: 32.89, b*: 32.73
Mustard Yellow: L*: 69.85, a*: 9.18, b*: 54.50

From this picture and the changes applied to it, it is interesting to notice that changes in lightness were not very noticeable by the observers although quite larger changes were applied. In regards to chroma changes the participants noticed ΔE-values of around 0.5 using the newer equations. For the hue changes ΔE-values in the range of 3 to 5 from the newer equations were noticed. The observers seem to be most sensitive in regards to changes in chroma and less sensitive in regards to changes in hue.

Results from Fruit Basket image

The fruit basket image is a well know test image in the industry. The changes applied to this image were very similar to ones applied to the Street Café image. The results are little bit different than before.

Figure 9. *Fruit basket test image with relevant test colors shown on the side.*

The observers did not detect small changes in lightness. The DE_{ab} was between 1.8 and 2.7. Larger changes in lightness were noticed.

The values for these changes are listed in the table below:

	ΔE_{ab}	ΔE94	DE2000	$\Delta E_{CMC\ 2:1}$	DIN99
Red	4.91	4.90	4.72	2.29	4.79

Table 5. *DE-values in relation to lightness of the most noticeable color changes.*

In regards to chroma the observers noticed smaller changes. The blue of the napkin and the red of the apples and peppers were detected.

The table below lists the measured color differences:

	ΔE_{ab}	ΔE94	DE2000	$\Delta E_{CMC\ 2:1}$	DIN99
Blue	2.31	0.95	0.64	1.10	0.79
Red	2.44	0.62	0.63	0.84	0.61

Table 6. *DE-values in relation to chroma of the most noticeable color changes.*

Although the colors in this test image are quite bold it took more drastic changes for the observers to notice a difference in regards to hue changes.

The table below lists the measured color differences:

	ΔE_{ab}	ΔE94	DE2000	$\Delta E_{CMC\ 2:1}$	DIN99
Red	5.29	2.60	2.79	3.29	1.71
Yellow	8.73	5.46	6.55	6.66	5.05

***Table** 7. DE-values in relation to hue of the most noticeable color changes.*

Here are the L*a*b*-values of the colors listed in Tables 5 to 7.

Red: L*: 48.56, a*: 60.89, b*: 31.81
Blue: L*: 41.38, a*: –9.91, b*: –41.75
Yellow: L*: 84.71, a*: 2.53, b*: 39.30

An image with more intense colors, but less detail seems to get the observer more focused and able to realize changes. It was interesting to observe that for this image small changes in hue were noticed, but larger changes in lightness and hue were required.

As before with the "Street Café" image the observers seem to be more sensitive in regards to chroma changes when a ΔE-value of around 1 using the newer color differencing equations was visible. In regards to the lightness an ΔE-value of around 4 was noticed. The results for noticeable hue changes are not that surprising since the human eye is not so sensitive when it comes to changes in the yellow colors.

Results from Musicians image

The “Musicians” image is also well known in the industry. This image shows an interesting combination of blue colors and various skin tones that pose challenges for accurate color reproduction.

Figure 10. *Musicians picture with relevant test colors shown on the side.*

As before changes in lightness were shown to the participants first. The results for these changes are shown below.

	ΔE_{ab}	ΔE94	DE2000	$\Delta E_{CMC\ 2:1}$	DIN99
Medium Blue	2.10	2.08	1.91	1.06	2.07
Dark Blue	5.21	5.18	4.18	2.94	5.66
Black	5.44	5.42	4.18	2.94	5.66
Dark Red	5.37	5.34	4.25	3.05	5.89

Table 8. *DE-values in relation to lightness of the most noticeable color changes.*

As can be expected it takes a bit more drastic changes in regards to lightness for them to be observable. It is interesting to notice that the changes were detected in darker colors and that a DE_{ab} of around 5 is necessary so it can be observed. These changes were observed by 26% of the participants in this study.

The next sets of changes were in relation to chroma. The results are shown in the table below.

	ΔE_{ab}	$\Delta E94$	DE2000	$\Delta E_{CMC\ 2:1}$	DIN99
Skin medium	4.47	4.43	3.76	1.93	3.69
Dark Red	5.52	2.09	2.22	2.50	2.19
Dark Blue	7.96	2.68	3.01	3.29	2.57

Table 9. *DE-values in relation to chroma of the most noticeable color changes.*

Although the changes in regards to chroma needed to be a bit more intense for observers to notice them it is interesting to notice that a skin color was noticed first. It also has to be mentioned that not many participants detected these changes. Only 26% of the observants noticed the changes listed in Table 9. The change present in the dark blue was noticed by 40%.

The last set of changes was applied to the hue of the image. The results are shown in the table below.

	ΔE_{ab}	$\Delta E94$	DE2000	$\Delta E_{CMC\ 2:1}$	DIN99
Dark Red	2.83	1.80	1.72	2.01	1.17
Skin medium	2.19	1.42	1.51	1.98	0.94

Table 10. *DE-values in relation to hue of the most noticeable color changes*

From Table 10 it can be seen that smaller DE-values were noticed in comparison to the chroma changes listed in Table 9. These changes were noticed by 33% of the participants.

The composition of the "Musicians" image seem to make observers more aware of small color differences since small differences in lightness and hue were detected, while a bit more drastic chroma changes had to be present to be observable. The percentage number of participants noticing the color changes does not mean that the others did not notice any changes at all. They noticed changes in other colors.

For lighter colors a ΔE-value of approximately 2 seems to be noticeable when the lightness values had been modified. For darker colors an average ΔE-value of 5 was observed. Chroma changes were detected when an ΔE-value of almost 4 was present. Hue changes were noticed with an average ΔE-value of 2.

Here are the L*a*b*-values of the colors listed in Tables 8 to 10.

Medium Blue:	L*: 41.64, a*: –8.25, b*: –44.86
Dark Blue:	L*: 35.68, a*: –3.54, b*: –28.20
Black:	L*: 17.20, a*: –0.30, b*: –2.97
Dark Red:	L*: 34.86, a*: 35.52, b*: 8.41
Skin Medium:	L*: 65.28, a*: 25.65, b*: 17.04

Results from Drinks image

The "Drinks" image is also a well know test image in the industry. Since it is composed mainly of neutral grey colors it is to be expected that the participants will detect smaller changes since a slight color imbalance in the grey colors will be noticeable.

Figure 11. *Drinks image with relevant test colors shown on the side.*

The first sets of changes were applied in regards to the lightness values of the image. The results are listed in the table below.

	ΔE_{ab}	ΔE94	DE2000	$\Delta E_{CMC\ 2:1}$	DIN99
Medium Grey	2.24	2.21	2.05	1.56	2.24

Table 11. *DE-values in relation to lightness of the most noticeable color changes.*

The medium grey color represents the background of the image, which represents almost half of the image. This change was noticed by 40% of the study participants. One would think that more observers would notice this difference. Even if the DE-values were increased to a value of around 5 it were again only 40% of the participants who noticed this difference.

The next step was to show the participants the picture were the chroma was altered. The color differences can be seen in the table below.

	ΔE_{ab}	ΔE94	DE2000	$\Delta E_{CMC\ 2:1}$	DIN99
Medium Grey	2.65	2.21	2.32	2.94	1.71
Off-White	5.01	3.66	4.02	4.54	3.00

Table 12. *DE-values in relation to chroma of the most noticeable color changes.*

This change in the medium grey was observed by 87% of the participants, and the change in the off-white was observed by 80% of the participants. Although this might be encouraging results one has to keep in mind that these two colors make up the majority of the image.

The results for changes in regards to hue changes were skewed since the color changes applied to the color of the drink in the glass were larger than normal. The next noticeable color change observed was again in the background grey.

	ΔE_{ab}	ΔE94	DE2000	$\Delta E_{CMC\ 2:1}$	DIN99
Medium Grey	1.04	0.94	1.29	1.26	0.93

Table 13. *DE-values in relation to hue of the most noticeable color changes.*

It is interesting to see such a small change was noticed and that all color differencing equations give similar values.

Here are the L*a*b*-values of the colors listed in Tables 11 to 13.

Medium Grey: L*: 37.19, a*: –0.80, b*: –4.67
Off-White: L*: 84.72, a*: 1.95, b*: –8.07

Conclusions

The solid color chip experiment carried out with experienced color observers confirmed that the DE2000 equation correlates quite well in the numerical expression of color differences in relation to the perceived color differences. The experiment carried out in 2006 with inexperienced color observers and experienced color observers in 2008 show that the latest color differencing equation seems to work well in this regard. It was a surprise to see that the DIN99 equation did not fare any better or worse than the other newer color differencing equations.

The results from the test with the images were a bit disappointing. The professionals were not as sensitive when it came to images as one could assume, since they need to look at images every day. Most of the time everyone detected changes in a different color. Only when large changes were present they all identified the same color(s).

None of the newer color differencing equations stood out by resulting in the lowest DE-numbers independent of the colors being shown, relating to a just noticeable difference. Hue changes were detected more readily than chroma and lightness changes. This is in line with common knowledge on how humans notice color differences.

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Appendix

Notes on MatLab Execution

Based on the original work, the following is a summary of the commands executed and the description of each.

Producing the Variants

```
i4L2P = varylch(i4,1,2); i4L5N = varylch(i4,1,-5);
i4C2N = varylch(i4,2,-2); i4C5N = varylch(i4,2,-5);
i4H2N = varylch(i4,3,varyimg(i4s,3,-2));
i4H5N = varylch(i4,3,varyimg(i4s,3,-5));
```

These commands call the custom function “varylch” for image file named “i4” (one of the samples, and setting the change for (1) lightness, (2) chroma, (3) hue with the given values. Only for hue, the change value is obtained from another custom function “varyimg”, which uses the trail and error method to reach a target ΔE value using “i4s” (small thumbnail file) and trying change for (3) hue by –2 and –5 (ΔEs).

This was repeated for each image in the set to produce the 6 changed variants.

Saving the Variants as Lab Files

```
imwrite(i4,'output/i4.tif','tif','ColorSpace','icclab'); …
imwrite(i4H5N,'output/i4H5N.tif','tif','ColorSpace','icclab');
```

This command saved each image back to the disk for use with InDesign.

Producing the Results Table

This table is a more accurate version for hue difference. The values collected in MatLab before (ΔE_{Final}) excluded the patches. For lightness and chroma this would have no implications on the numbers. However for hue, as explained previously, each colour is affected differently and thus average would shift. So, $\Delta E_{Patches}$ is added to the table to prove that the patches selected are representative of the overall image to a large degree and is the ΔE_{ab} of the patches area only for each image, since the numbers are close to those for the overall image. ΔE_{Trial} is the thumbnail.

	Aim	ΔE_{Trial}	ΔE_{Final}	$\Delta E_{Patches}$	Iteration #	Hue
Market Place	ΔE(H-)2	1.98	2.22	2.67	15	–0.132
	ΔE(H-)5	5.01	5.64	6.79	24	–0.336
Drinks	ΔE(H-)2	2.01	2.10	3.10	17	–0.285
	ΔE(H-)5	5.03	5.25	7.7	26	–0.726
Musicians	ΔE(H-)2	1.98	2.04	1.77	22	–0.093
	ΔE(H-)5	4.95	5.08	4.41	22	–0.233
Fruit Basket	ΔE(H-)2	1.95	1.96	1.83	15	–0.088
	ΔE(H-)5	4.96	5.00	4.65	24	–0.224

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Date:

	LU	LV	CU	CV	HU	HV	Where did you notice a difference
Street Café							
							First
							Sescond
							Third
							Fourth
							Fifth
							Sixth
Fruit Basket							
							First
							Sescond
							Third
							Fourth
							Fifth
							Sixth
Musicians							
							First
							Sescond
							Third
							Fourth
							Fifth
							Sixth
Party Scene							
							First
							Sescond
							Third
							Fourth
							Fifth
							Sixth

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Colour differences can be expressed as:
Match
Slightly different
Different
More Different
Very Different

Date:

	Sample 1	Sample 2	Sample 3	Sample 4	Sample 5	Sample 6
Standard 1						
Standard 2						
Standard 3						
Standard 4						
Standard 5						
Standard 6						
Standard 7						
Standard 8						
Standard 9						
Standard 10						
Standard 11						
Standard 12						
Standard 13						
Standard 14						