SURROUNDING COLOR CAN AFFECT THE MEASURED COLOR OF A SAMPLE

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ABSTRACT: The author has presented a number of papers[1-6] on the effects of lateral diffusion error (LDE) on measured reflectance values. LDE can be caused by instrument sample illuminating light laterally diffusing out of the area viewed by instrument measuring system. In a 1995 paper[4] it was shown that the color of the backing used while the sample is being measured can affect the LDE value (e. g. the LDE is higher when the sample is backed with white than it is when a black backing is used). A logical extension of this is that the color of the top surface of the area immediately adjacent to the sample area can also affect the LDE. This paper reports experimental results of a measurement program which was designed to demonstrate that the measured color of a sample can be affected by the presence of different colored areas immediately adjacent to the measured area. A typical situation in which this might occur is the measurement of small elements of a print control strip.

BACKGROUND

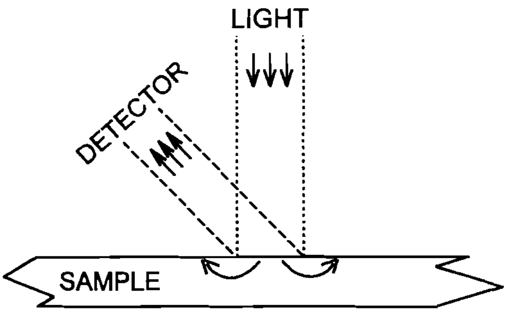

Figure 1 *Idealized 0/45 measuring configuration with the viewed and illuminated areas equal.*

In previous papers, the author has represented the lateral diffusion of light as a unidirectional diffusion of light from the illuminated area of the sample to the unilluminated surface. Figure 1 shows such a representation. Actually, after the light enters the sample, it diffuses in all directions. The arrows in figure 1 are meant to give an indication of the net result of the diffusion. In reality, some part of the light that

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diffuses out of the lighted area diffuses back into area viewed by the detector.

Figure 2 is a more detailed abstract diagram of what goes on in the sample. Some of the laterally diffused light diffuses toward the top and bottom sample surfaces and some diffuses back into the illuminated area. There are a number of physical conditions which can affect the pattern of the light diffusion and thus, the LDE. For instance, if the area illuminated on the sample is equal to, or very nearly equal to, the sample size, then some laterally diffused light will exit through the sample edges. This will reduce the amount of light that re-diffuses back into the illuminated area and thus increase the measurement error. This type of light loss error was termed "edge-loss error" in a paper by Atkins and Billmeyer[7].

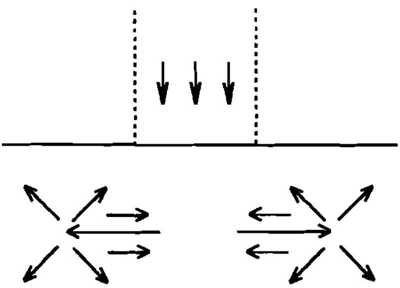

Figure 2 *A diagrammatic representation that shows that light diffuses out of the illuminated area and then diffuses back in and also toward the top and bottom of the sample.*

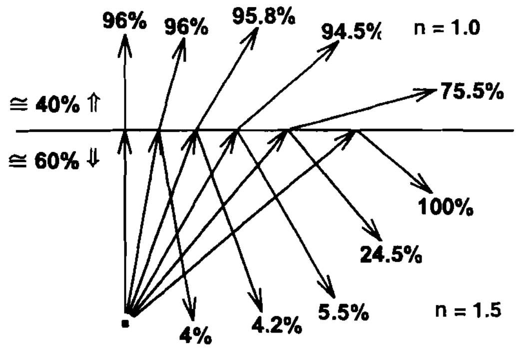

Figure 3 *When light passes through a surface, some is reflected by the surface. In the case of diffuse light going from a media with a refractive index of 1.5 (e.g. paper) to air (index of 1.0), about 60% of the light will be reflected back into the sample.*

When any portion of the diffuse flux inside the sample encounters the sample surface, more than half may be reflected back into the sample. This will happen if the sample surface is smooth, such as is the case with coated or calendered hard finish paper. Figure 3 is a representation of what happens when diffuse light passes through the sample/air interface. All light striking the inter surface at an incidence angle greater than about 42° relative to the surface normal, it is totally reflected back into the sample. Some of this reflected light diffuses back into the area view by the instrument detector. If this reflection process did not occur, the lateral diffusion error would be even greater.

What effect does a surface layer of ink have on this internal reflection ? There will be very little reflection at the interface between paper and the ink vehicle since they both have about the same index of refraction. However, at the interface between the vehicle surface and the air, a reflection pattern similar to that of figure 3 will be present. Ink is usually made up of a mixture of a vehicle and one or more pigments. Therefore, the pigments in a colored ink can absorb much of the light before it reflects off of the vehicle/air interface. In fact, at some wavelengths, little if any light will be reflected. This lack of reflected light will decrease the amount of light that is re-diffused back into the area viewed by the detector and thus increase the lateral diffusion error at some wavelengths.

A MEASUREMENT PROGRAM

Can such a convoluted process cause a measurable difference in the reflectance of a sample surround by a colored area ? To find out, a number of patterns were generated with Corel WordPerfect Suite 2000 Presentations software and printed using a HP 855C inkjet printer. Each exhibit consisted of a 2 x 4 inch colored area (i.e. cyan, magenta, or yellow) with a circular white spot in the center. Exhibits with white spots of various diameters (i.e. approximately 4, 5, 6, 7, 8, 9, 10, and 12 mm diameter) were printed on transparent inkjet labels. The original intent was to paste these labels on various translucent plastics and papers. However, it was found that the labels would not come into complete contact with the substrate. Therefore, the patterns were printed on a number of

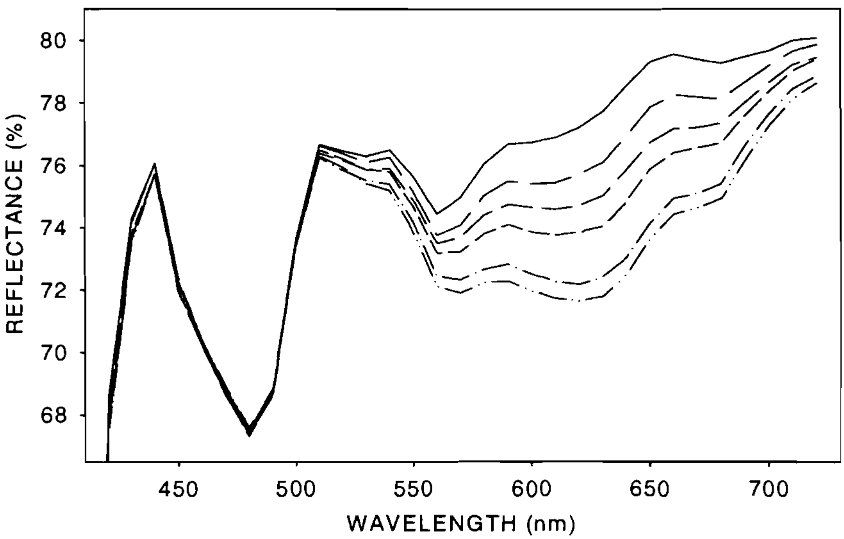

Figure 4 *Plots of the spectral reflectance of textweb paper (solid line), and white areas, surrounded by cyan (dashed lines), with diameters, top to bottom, of 10mm, 9mm, 7mm, 6mm, and 4mm.*

different paper stocks. An OEM version of the Gretag SPM-100 was used to measure the white spots in each of the exhibits. When the 3.5 mm diameter aperture plate of the instrument was carefully centered on the spot, the instrument could not view any of the surrounding colored area. Figure 4 (on the previous page) shows plots of the spectral reflectance of one set of exhibits - exhibits with a cyan surround printed on an inkjet paper used to produce proofs that simulate printing on textweb paper.

While the plots of the spectral curves do show the differences caused by the nearby solid color areas, they do not give an indication of the color differences. Figure 5 plots as points the Clab* color differences between the paper with no surround and the curves in figure 4 and a line which is a three parameter fit to the differences. Note that the point plots of the color differences do not track well. This is the result of the center of the instrument aperture not being coincident with the center of the white areas when some of the measurements were made. The aperture plate of the Gretag instrument often hides the edges of the white area on the paper when measurements are made.

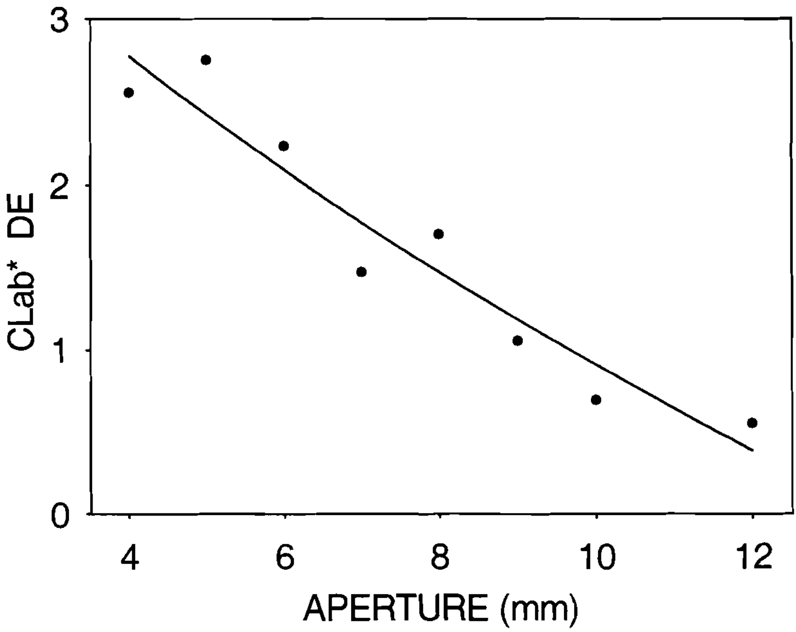

Figure 5 *Plot of the Clab* color difference between the paper measured inside an area surrounded by a large cyan coated area and paper without a color surround. See text for details.*

Color difference plots for three other papers are below and on the next page.

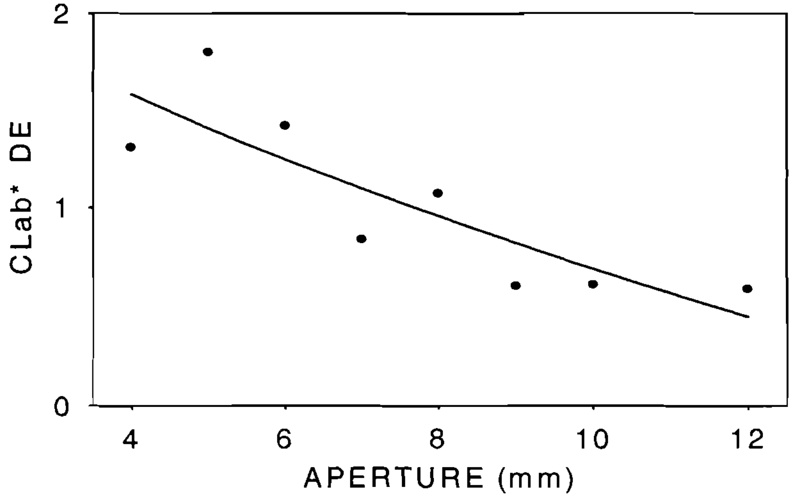

Figure 6 *DuPont/Epson inkjet proofing paper over white with cyan surround.*

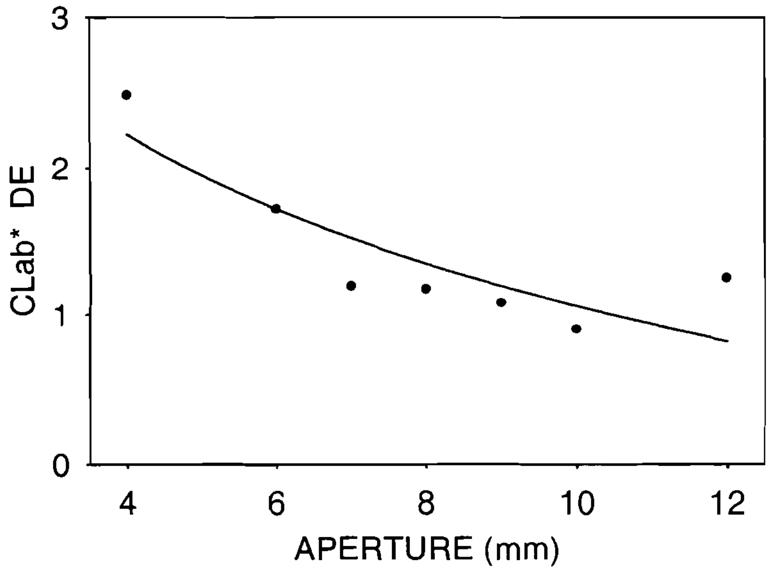

Figure 7 *Hewlett-Packard glossy photo paper over white with cyan surround*

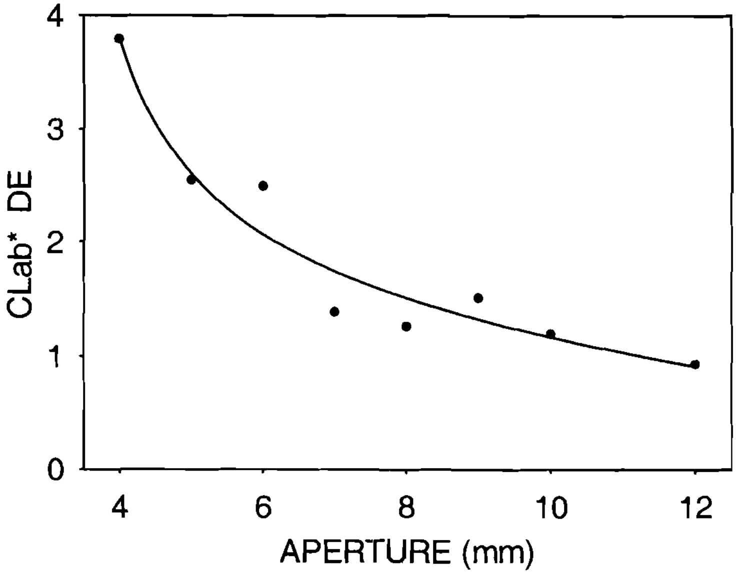

Figure 8 *Copier paper over white with cyan surround.*

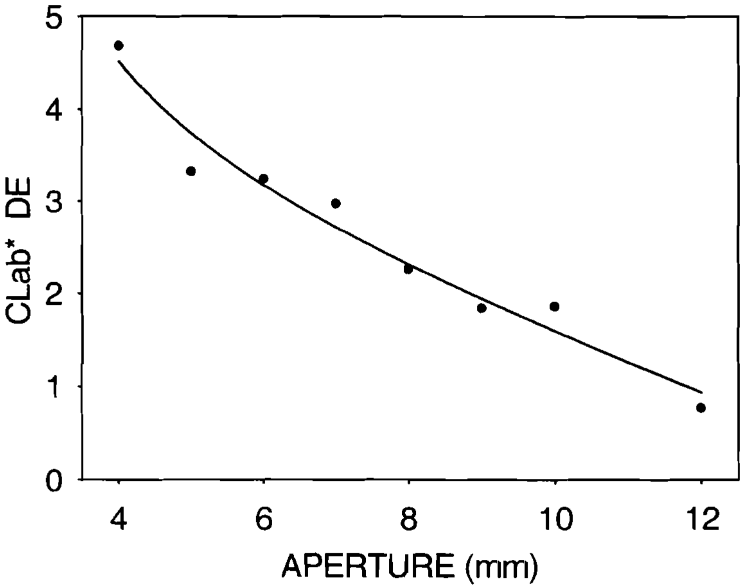

Figure 9 *Copier paper over white with magenta surround.*

DISCUSSION

Sometimes, the printer did not print the white circular areas on the exhibits as perfect circles. Also, the magenta ink from the printer often splattered on to one edge of the white area. This splatter was observable as very small dots when observed with a 9X linen tester magnifier. However, no splatter was observable with the cyan ink. Observational difficulties made it impossible determine if the yellow ink had splattered. To avoid errors caused by splatter, with the exception of the data in figure 9, only cyan surround exhibits were evaluated. Figure 9 presents data for a magenta surround. Note that the color difference for the 4 mm white area with magenta surround is about one delta-E greater than it is for the cyan surround (Figure 8).

The exhibits were also measured with an X-rite 938 instrument. These measurements also indicated an effect cause by the color surround. The data is not presented here because, with the exhibit configurations, only four measurements were available from each substrate type (i.e. the 938 view aperture is 8 mm in diameter so only the exhibits with 8, 9, 10, and 12 mm white areas could be measured). The lateral diffusion error is both a function of the difference between the illumination and view apertures and to a lesser extent the actual size of the apertures[6]. In the case of an instrument arrangement where the illuminated and viewed areas are identical such as is shown in figure 1, when the diameter of the apertures is doubled, the LDE will be reduced by approximately 50%. This appears to be so also for the surround color effect. The regression fits to the data in figures 5, 6, and 7 each give a color difference at 12 mm which is roughly one third of that at 4 mm.

In this initial effort, black was purposely not used as a surround color. Initially it was recognized that if black was used, reflectance differences caused by surface defects, sample non-uniformities, and instrument drift could not be distinguished from value changes caused by surrounding black areas. The use of colored surround insured that the surround effects could be distinguished from simple level changes. As it turned out, level changes did not cause a problem.

CONCLUSIONS

The measurement of white areas surrounded by color on inkjet media does not give a good indication of what may be experienced when measurements of a color control strip printed on a variety of printing papers. However, the results of this study do show that surrounding color can change the measured color of a sample. Knowing this, a more definitive measurement study can now be mounted.

The author has told a few of his color knowledgeable friends the results of this study and they all have said that the results were obvious. Obvious or not, no one has seemed concerned enough to find out the extent of the problem.

FURTHER STUDIES

To further evaluate the extent of this problem, exhibits need to prepared using typical printing media and processes. Exhibits prepared with press runs would be ideal for this purpose, but prohibitively costly. The use of exhibits made using transfer proofing products such as duPont Waterproof® or Imation Laser MatchPrint® and a variety of printing papers would certainly produce more representative data than the five year old inkjet printer used for the present work.

The exhibits used in this study, consisting of white areas within colored surrounds, served to illustrate the effects of surrounding color on color measurement. However, exhibits made up of a colored areas printed within colored surrounds would give results nearer to real world situations. Previous experience[2] would seem to indicate that a yellow sample area surrounded by magenta or cyan might give a maximum errors.

The centering of the instruments on the sample area will remain a problem as long as the instruments are positioned by hand. The author has a three axis mensuration stage in his lab which is hardware and software interfaced to move four different instruments over proof exhibits. There are two possible ways in which this stage might be used to get well centered measurements of the sample areas. In one method, the stage positioning set-up reticle and TV system could be used to determine the position of the centers of each sample areas. These coordinates could then be programmed into the software to set the measuring apertures of each of the four instruments down exactly on the center of each sample area. An alternative method would be to do a grid of measurements with points 0.1 mm or so apart over each sample area. The spectral curves of each of the grid point could then be examined and the point with the maximum reflectance at a selected wavelength could be selected a the center point.

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