A STUDY OF IMAGE COLORIMETRIC AND TONAL CHANGES WHEN TRANSFERRED FROM ONE IMAGING MEDIA TO ANOTHER.

PART 1

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Abstract: This work examines media, mode and raw material (medium) imposed reproduction changes through the ink on paper reproduction chain. The media change involves original images initially recorded on photocolor slide film transferred to ink on paper printed images. The images of this study have been transferred by electronic means, and printed using two different color separation techniques. One of these techniques were studied in depth, the Gray Component Replacement (GCR) technique. Several levels of GCR are discussed. The separation technique, the transfer curves, spectral sensitivities imposed by several separation devices Color Electronic Pagination Systems [CEPS] and means of printing the final images come fall under the definition of the mode. The raw material used in the printing operation are referred to as the medium . The medium independent variables of these experiments include, 3 different toner levels in the black ink, 3 different black ink density levels, and 3 different paper types.

The dependent variables studied include percent dot area, Status A transmission and Status T reflection densitometry, as well as colorimetric data indicating CIE L*a*b*, Lightness, hue angle and chroma.

INTRODUCTION

For purposes of this paper a reproduction system will be referred to by the term media, the technique of transferring that media to another is called the mode, and the materials used in the reproduction system will be referred to as medium.

The printing and publishing industry has lived through a revolution wherein the hand craftsperson has relinquished a portion of his responsibility to reproduce color images to electronics and controlled printing.

Color Electronic Pagination Systems (CEPS), which incorporate the separation steps and masking procedures are now routinely employed. Their incorporated electronics allow

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digital representation of the image. Such systems obviate the use of hand screening, and masking for color correction of the final image. Digital image manipulation also allows additional flexibility in the final printing of the image itself by the use of alternate media, separation techniques and printing medium.

Ink on paper images utilize a four color, yellow, magenta, cyan, and black printing technique. The black printer is used to improve the color reproduction of ink on paper images by changes in the color gamut or range of the dark saturated colors. The black image also provides additional sharpness and contrast to the final image.

In conventional four color reproduction the black printer is used as part of a technique called Undercolor Removal (UCR). UCR allows the removal of some color ink levels at the upper portion of the tonal range and a substitution of the colored ink removed by black ink.

During the last 10 years an alternate separation technique has been employed, that of Gray Component Replacement (GCR). Sigg (1) provided the industry accepted definition of GCR. As now accepted, GCR is a technique, in color reproduction, where in any given image location "the least predominant of the three primary printing inks is used to calculate a partial substitution for some or all of the primaries by black". A substitution of this gray component into the black printer produces print images of near equivalent visual color results to conventional printing.

The black printer in UCR and GCR is used for the same purposes. There are similar, but important differences between the resultant images from both techniques. The UCR technique only operates on gray or near neutral images, at the upper portions of the tone reproduction curve especially near the Dmax. The UCR black image is only a "skeleton black". GCR operates at a "pixel" or picture element stage of the image and is applied to the full tone reproduction range. It is sometimes called a "long black". During scanning, a computer driven system analyzes the colors in the original transparency within image areas, judges the least predominant of the three primary printing inks, calculates a partial substitution for some or all of the primaries by black on the quantities and ratios of the color inks to be used in color reproduction of that area, and implements those changes into the various color halftone separations.

Early GCR images, were not commercially acceptable. The images exhibited low shoulder contrast and the shadows were luminous, that is they looked like you could see through them. The computer programming and power available today allow scanner systems to overcome some of the early GCR difficulties. This is done with a technique called Undercolor Addition (UCA).

It was found that if additional yellow, magenta, and cyan color were added to the upper portions of the GCR color tone reproduction curves the apparent contrast and Dmax was improved, and a commercial GCR result was obtained. It is important that the quantities of the additional color (UCA) added to the image be in a ratio such that they produce a gray, if they are not, color differences will be apparent.

More than four different manufacturers make CEPS systems that allow the practice of GCR. These manufacturers utilize different approaches to produce their specific GCR effect and therefore any assessment of the color reproduction results of the ink on paper technique must consider this perturbation.

Details concerning the color spectral response of each device to the abridged spectrum provided by imaged professional transparency films are necessary for a full understanding of the characteristics of the resultant separations. Such separations determine the reproduction of the gray balance and the colors in the final result. The ink on paper reproduction system is almost infinitely flexible as to the color inks employed, especially the black ink, as well as the substrate utilized. Information concerning these variables must be factored into a color study of the repro chain.

INVESTIGATIONS and RESULTS

This work as presented is divided into three parts.

Part 1 this section will include a description of the transparency target, the original media employed for the entire study. It will also detail the investigation of the comparative spectral response of the CEPS devices. These are media and mode imposed changes.

Part 2 includes the results of a "GRATR" (5) [a "Jones" (2) type], 3 dimensional, tonal reproduction analysis technique for graphic arts images in which regression analysis is used to obtain the tone reproduction curves, and a mathematical expression was derived to describe the transfer or interaction steps. Mode imposed changes.

Part 3 details the colorimetric influence on gray images when printed with different paper stocks, different black inks at different density levels. Medium imposed changes.

Space and time limit a full coverage of the experiments leading up to the results in each of these parts the reader is referred to Fisch (3) (4) (5) (6).

Part 1 Section A
The Original Media, A Description of the Color Slide Input Target:

The 3M Color Scanner Transparency consists of three major images:

1. A 21 step Grey Balance Step Wedge
2. A set of 21 different Color Combination patches each at 3 neutral component levels or "NCL" (21x3). The colors selected were chosen from examination and measurement of actual color images sent for separation at commercial graphic arts establishments. The colors from these images therefore represent a "commercial use" spectrum and therefore, are not evenly distributed throughout the transparency spectral gamut.
3. 3 Color Primary and 2 Color Overprint Color Step Wedges.

The film used to make this target was Ektachrome Professional Film a product of Eastman Kodak.

PART 1 Section B
Mode Imposed Changes, Assessing the Spectral Distribution of the Scanner Systems.

Through the auspices of the Graphic Communication Association four of the five CEPS manufacturers agreed to separate the test transparency and produce halftone images at their optimum reproduction conditions. The same instructions regarding transparency reference points for separation where given to all the manufacturers. The images were to be separated for both conventional [280% UCR] printing as well as 50, 75, 85, and 100% GCR.

All participants established their own color aim points, using their proprietary targets, from the same, R.R. Donnelley Torrance, calibration run. Since R.R. Donnelley had agreed to provide multiple press runs, for calibration as part of the test cycle, their press conditions, inks, and paper were used as set up conditions. All of the different CEPS systems test images were simultaneously printed in the same press run. Additional press runs for the design experiments of Part 3 were made at the Rochester Institute of Technology, RIT.

Figure 1 depicts the Status A [response] transmission densities from the patches which contained the lowest NCL (neutral component level) of the selected 21 colors in the original transparency. Figure 2 depicts densities of the medium NCL patches, and figure 3 the densities of the high NCL patches.

After ink on paper printing the color reproduction of both the low and medium NCL patches were analyzed using Status T reflection densitometry. Figure 4 and 5 represent the densities reproduced by conventional and GCR printing. Only the 50%, 75%, and 100% GCR levels are depicted. These results were from images produced by participant A. The patches with the lowest NCL change least when printed by conventional and GCR processes (Figure 4). The medium level NCL images' (figure 5) exhibit large density differences between the conventional and GCR images, as well as between the different GCR levels themselves. The higher the NCL or the grayer the image the greater the GCR effect.

Figures 6 to 8 indicate film (halftone values) percent dot area vs step position, obtained from each of the four separations produced by the 3 of the 4 different CEPS systems from the lowest NCL patches. These patches were chosen since they would produce an estimate of the spectral sensitivity of the total system without the noise associated with the gray component.

The spectral response of a CEPS system is defined as the integration of image spectrum, analysis source spectral distribution, optics spectrum, photosensor filtration and spectral sensitivity as well as the computer transforms to enable color correction. These differ for each manufacturer's device. This is not surprising since each manufacturer has had to engineer the response to suit the available signal to noise ratio of his device. With no standard practice for this operation, as one might expect, each of the different manufacturers devices interpret color differently and therefore produce a difference in color reproduction.

Part 2 Mode Imposed Changes, "Jones" type gray balance tonal reproduction of the separation images for Conventional Undercolor and several levels of Gray Component Replacement.

The analysis of the gray balance [scale] images is always important since both tonal and color reproduction go hand in hand. It is particularly important in understanding the GCR process and the color reproduction capabilities produced by it. The GCR technique removes a portion of the gray component from a color image and replaces that portion removed with a portion of black ink. It is therefore not operative on a single color or two color overprint. GCR is a process that only operates on those areas composed of at least 3 colors. A four color gray image therefore is most suitable for a study of the systems characteristics.

Since yellow inks have average secondary absorptions, and black inks are vital to the GCR effect, much of the comments of this paper will highlight these two inks.

A study of the halftone reproduction of the gray (21) step gray wedge for the conventional and GCR separations for each of the scanner devices indicates that while there was agreement on tone reproduction curve characteristics for a conventional separation image there was disagreement on the curves for various GCR levels as well as what constituted a specific level of GCR. Comparison of the GCR images disclosed discrepancies between each of the manufacturers images. See figures 9-10.

Figure 9 compares the gray scale of the conventional process blue separation films from participants A, B, and C. There are slight differences between these three images. The curve of participant A indicates a speed difference from B and C in the straight line portion of the tone reproduction curve. The tone reproduction curves of B and C are basically congruent, with B displaying a higher shoulder contrast and Dmax. There appears to be reasonable agreement on what constitutes a conventional image.

Figure 10 compares the gray scale conventional process black separation films of participants A, B, and C. The differences here are more apparent and appear to be of relative exposure otherwise these three images appear reasonably close to one another.

Figure 11 compares the GCR process 100% level black separations of participants A and D. These curves appear quite close as well. Figure 12 compares the conventional and GCR process 50% level black separations of participants A and D. There appears to be a difference concerning the definition of the black curve of a 50% GCR image set.

Figure 13 depicts the Conventional and GCR process (50-100%) curves of the blue separation films of participant A. Figure 14 depicts the Conventional and GCR process (50-100%) curves of the blue separation films of participant B. It is evident that a smooth transition occurs at each of the GCR levels of participant B. However, participant B outputs the same curve for both a 75 and 85% GCR level. A close inspection also indicates that the between participant GCR responses are also different.

The Transparency Target
Color Patches
Status A Densitometry

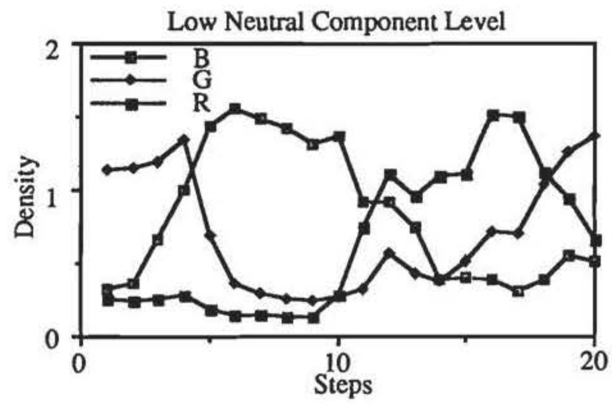

Figure 1

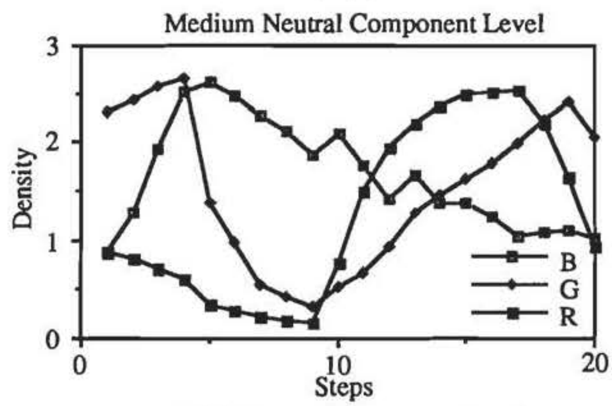

Figure 2

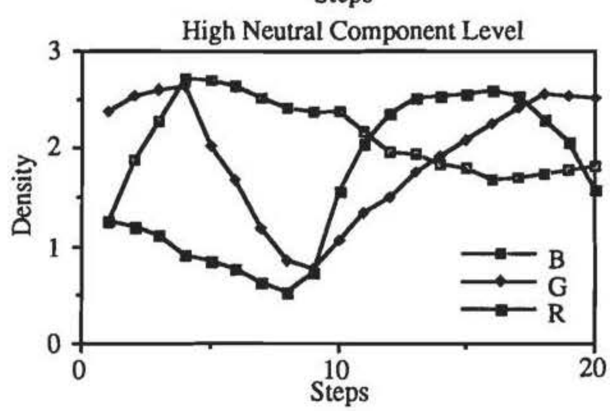

Figure 3

Printed Images of Color Patches

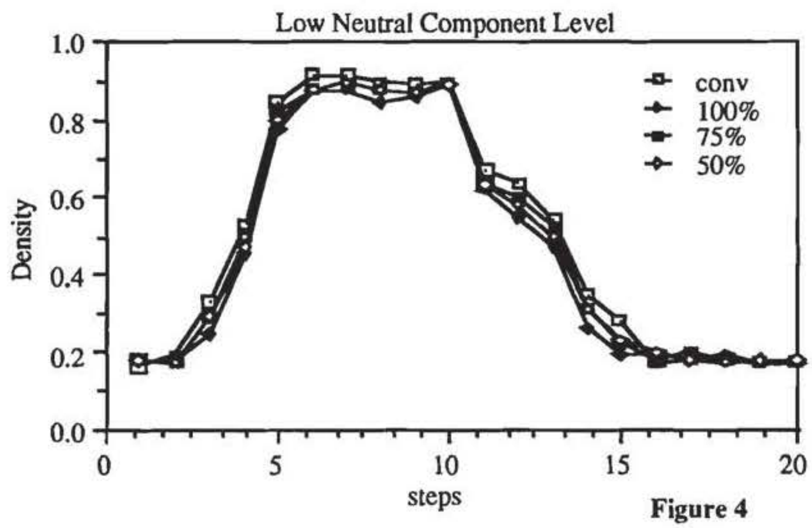

Figure 4

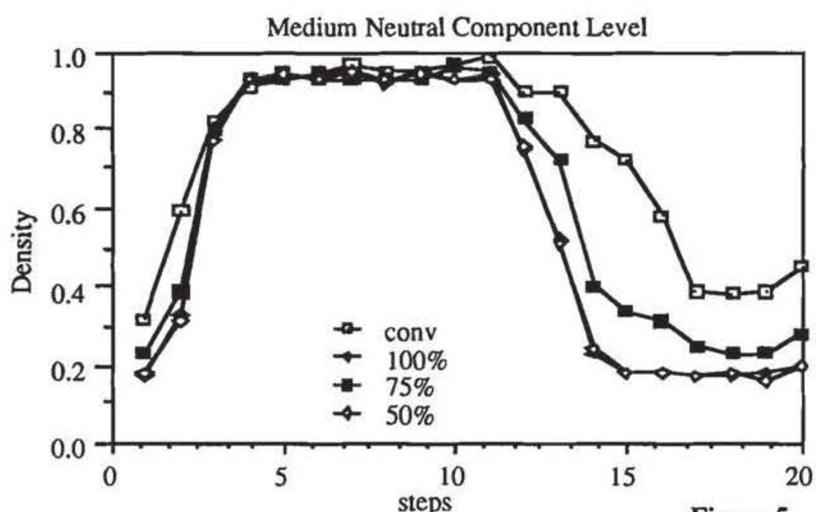

Figure 5

Density vs. Color Patch Numbers
Blue Separations Images

Relative Spectral Sensitivities from
Color Separation Images
Participants A,B,C
Low Neutral Density Component Patches

Blue Separations

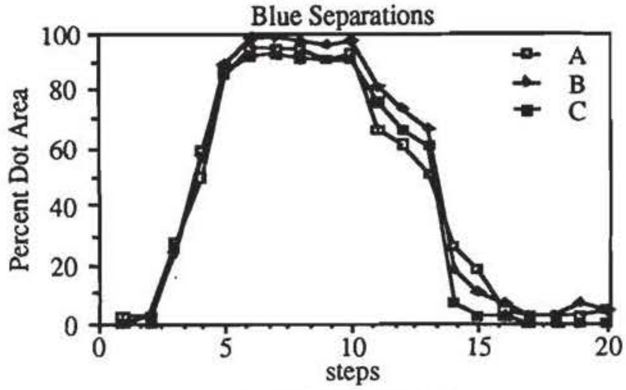

Figure 6

Green Separations

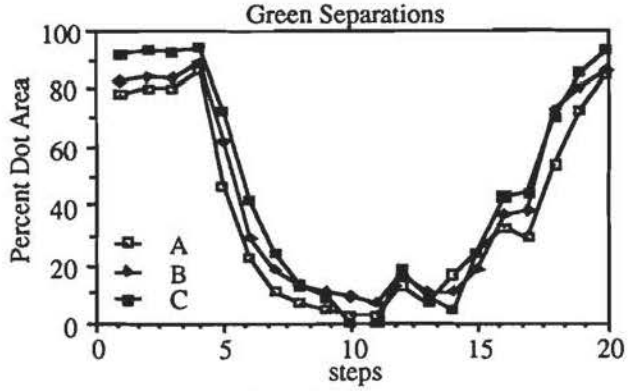

Figure 7

Red Separations

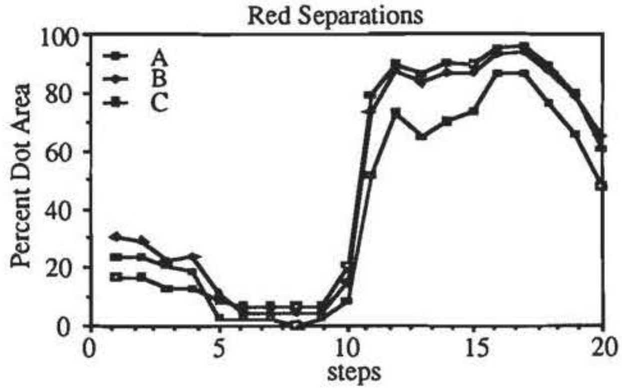

Figure 8

As demonstrated reproduction difficulties arise from the differences imposed by the equipment and techniques used by the various different CEPS manufacturers. These differences cloud an overall assessment of ink on paper color reproduction.

One manufacturers device was selected to detail the tone reproduction study. The choice was predicated on the smooth transition between the different levels of GCR and visual inspection of the gray images.

A 3 dimensional modelling technique called "GRATR" [Graphic Regression Analysis Tone Reproduction], was used for this purpose. Using the "GRATR" Model the photomechanical reproduction cycle is followed from the original transparency through electronic scanning, the separation, plate imaging, to ink on paper printing. Regression analysis is used to obtain the tone reproduction curves, and a mathematical expression was derived to describe the transfer or interaction steps.

Figures 15 and 16 depict the "GRATR" reproduction chain from the original transparency to the final ink on paper images for 3 levels of GCR and a conventional image. Two separations are depicted, the red separation, and the black separation. Various sectors include the response of the scanner, the transfer response of the contact printing action to the plate and the transfer response to the final ink on paper reproduction.

The measurement metric in the transparency section, tile 1, is Status A densitometry. The measurement parameter for the black and white separation films, plates and ink on paper images is percent halftone dot area. To facilitate an understanding of the response occurring within the CEPS system tile 2 of the diagram indicates a exponential change, density to percent dot area. Tile 3 indicates the response curve of the CEPS system. Tile 5 indicates the interaction response curve for the film plate function, and tile 8 depicts the plate to ink on paper function. It is interesting to note that there are four different scanner interactions depicted in tile 4. One for each of the processes. Tiles 5 and 8 also indicate four different functions but these overlap and appear to be one per tile. Despite differences in the techniques [GCR and UCR] the plate and ink/paper/press responses are the same. Table 1 details the mathematical expressions obtained through regression analysis of each of the transfer steps in the process. The correlation coefficients are also included to verify equation fit to the available data.

Toner Reproduction Curves - % Dot vs. Gray Scale Step

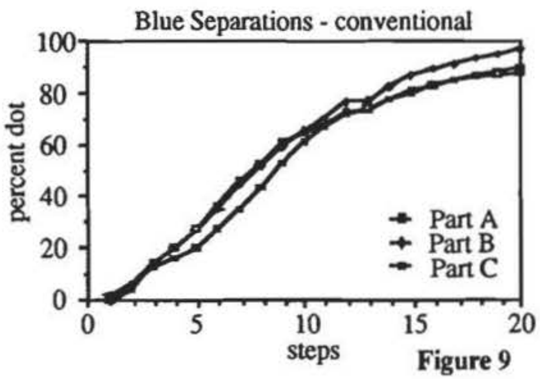

Figure 9

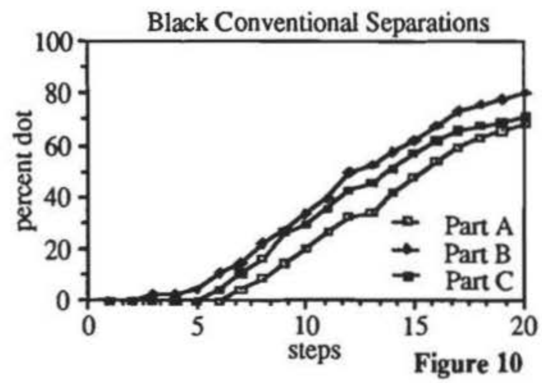

Figure 10

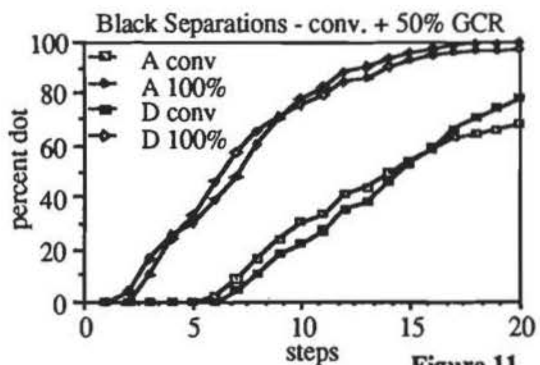

Figure 11

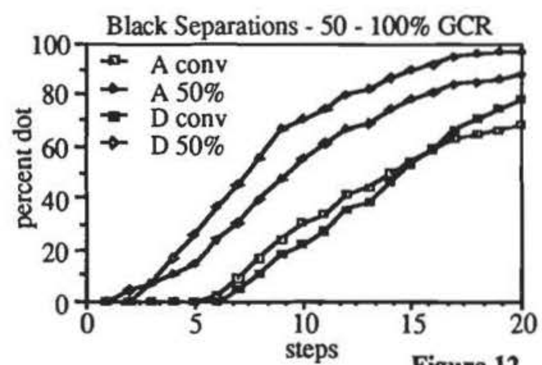

Figure 12

Blue Separation Films
Comparison of GCR and Conventional
Images From

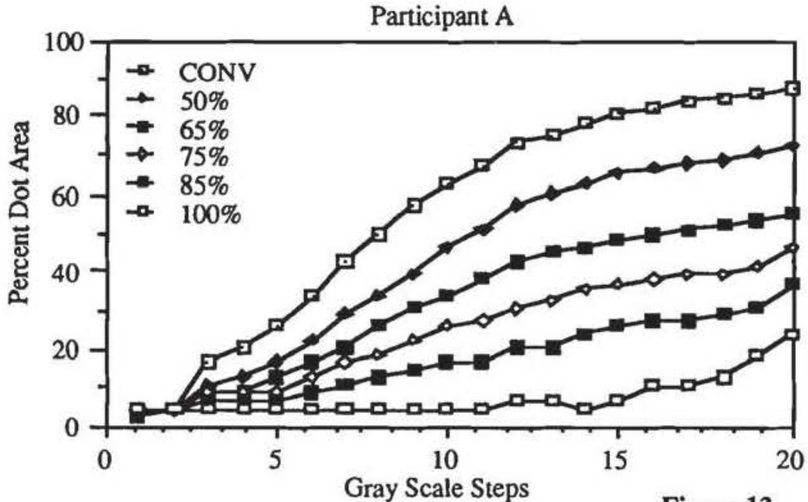

Figure 13

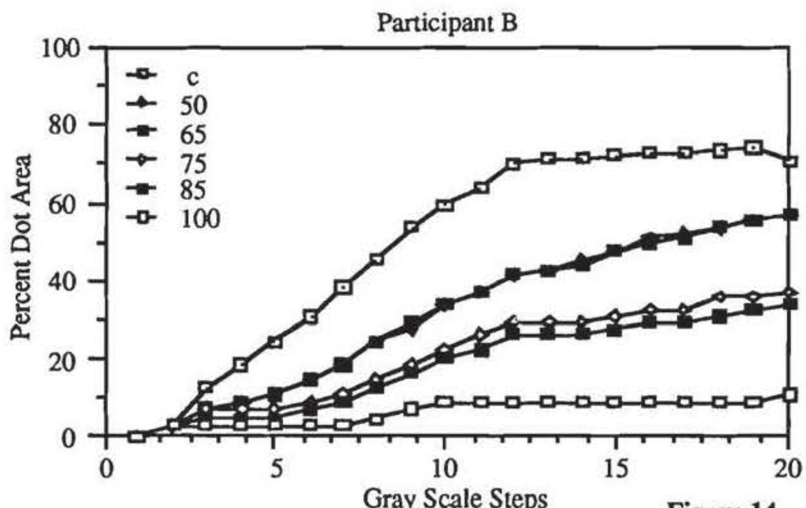

Figure 14

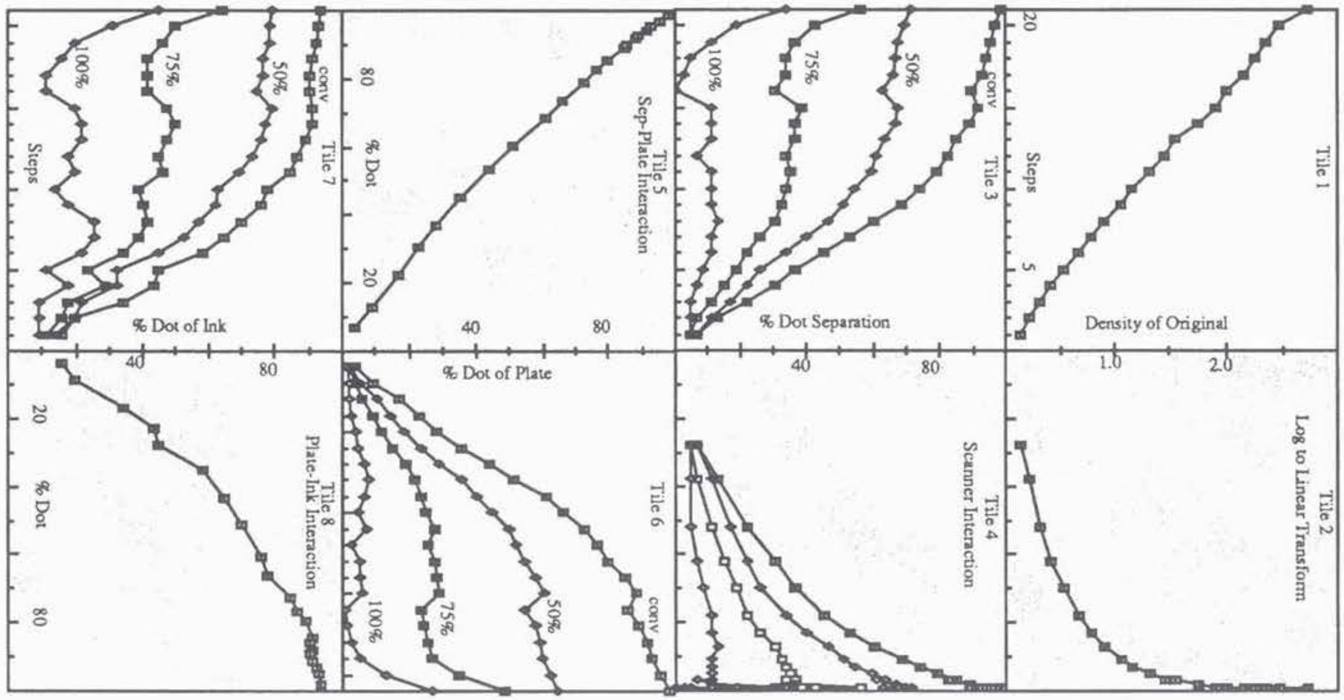

Figure 15

A 'GRATR' Model Representation of the Conventional , 50%, 75%, 100% GCR/UCA
Web Offset Printing Process Red Separation, Cyan Image

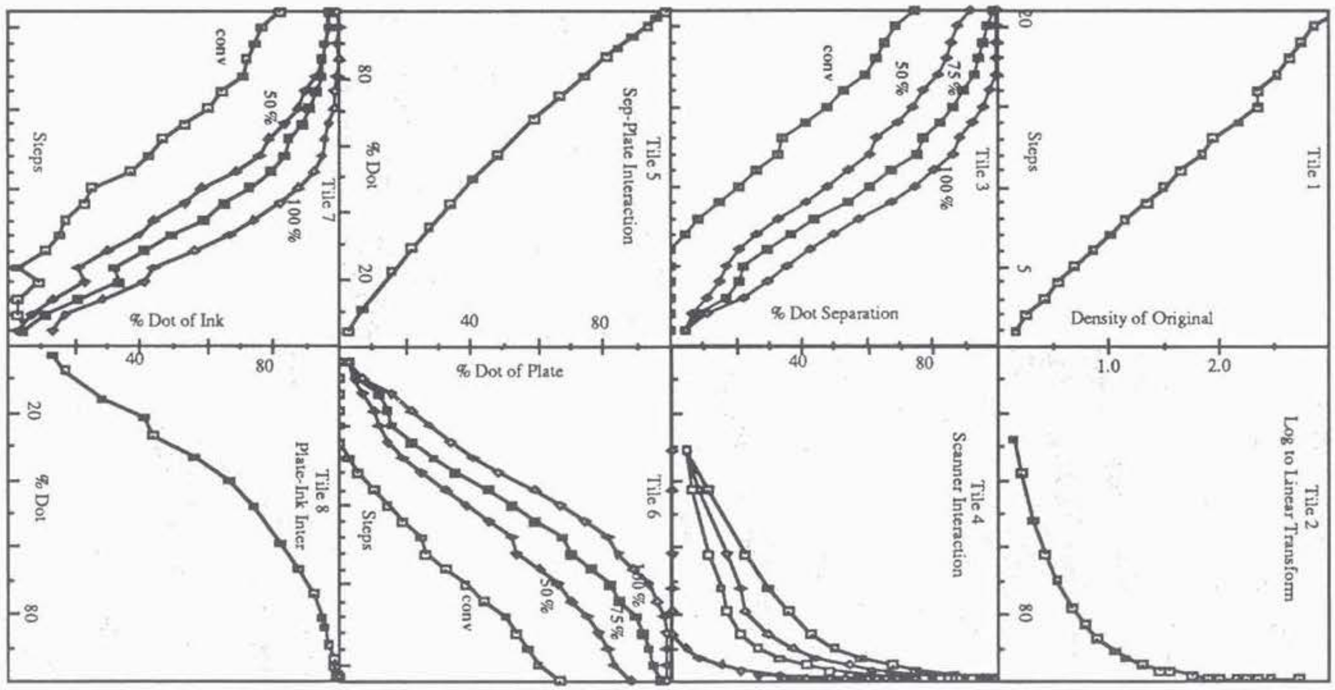

Figure 16

A 'GRATR' Model Representation of the Conventional, 50%, 75%, 100% GCR/UCA

Web Offset Printing Process   Black Separation

Table 1

Equation	R^2
CYAN	
SCANNER INTERACTION	
Conventional Image	
$y = -62.241 + 3.9305 X - (6.6086 * 10^{-2}) X^2 + (4.2656 * 10^{-4}) X^3$	$R^2 = 0.997$
SEPARATION TO PLATE	
$y = -0.41155 + 0.67068X + (2.6667 * 10^{-3})X^2 + (6.1643 * 10^{-6}) X^3$	
$R^2 = 1.00$	
PLATE TO INK-ON-PAPER	
$y = 7.7135 + 1.7097 X - (1.0653 * 10^{-2}) X^2 + (2.1832 * 10^{-5}) X^3$	$R^2 = 0.997$
BLACK	
SCANNER INTERACTION	
100% GCR	
$y = 1.4480 * 10^{(1.8079 * 10-2) X}$	$R^2 = 0.976$
SEPARATION TO PLATE	
$y = 4.2507 * 10^{-2} + 0.6261 X + (3.6648 * 10^{-3}) X^2$	$R^2 = 1.000$
PLATE TO INK-ON-PAPER	
$y = 5.9188 + 1.7172X - (6.5116 * 10^{-3}) X^2 - (1.3366 * 10^{-5}) X^3$	$R^2 = 0.998$

REGRESSION EQUATIONS for TILES 4, 5, and 8

Part 3 Medium Imposed Changes, The Colorimetric Influences on the Test Images When Printed on Different Paper Stocks, with Different Black Inks, at Different Black Ink Density Levels, Using the Conventional and the 50, 75, and 100% GCR Separations.

Part 3 General

It should be noted that trapping effects may also cause individual area color differences in offset printing. Trap values indicate how well one ink adheres to a wet already printed ink during the printing process. Color changes always occur when one ink is unable to fully transfer or adhere on top of another already printed ink. In a three or four conventional print job one always knows the color print sequence of the total picture and how that relates to color reproduction. One ink "color" layer of an otherwise 3 ink color image may be absent in a GCR image because it contributed most or much of the gray component of the total color image. Therefore the color ink layer sequence of a GCR produced image will be different for different portions of that image. The differences in trapping between the same pictures produced by GCR and conventional imaging sequence produce many of the differences in color reproduction we associate with GCR. A definitive study of the colorimetric changes due to trapping influences is beyond the scope of this paper.

The same four color separation images used in parts 1 and 2 were used for these designed experiments.

The color and surface characteristics of the paper used in printing a given commercial job or set of tests has a great influence on the colorimetric attributes of the resultant images. This design, a 3x3x3x4, included 3 different paper stocks, 3 different toner levels in the black ink at, 3 different ink solid densities for the 4 different processes.

Theoretically, the computation of the gray component to be removed from the 3 or 4 color image assumes the black ink to be neutral. However, the CEPS system can be programmed to remove "non achromatic" black quantities as well depending on the colorimetric properties of the black ink used.

There are however, no neutral black inks. In black and white printing so called "toners", i.e. Reflux Blue, are added to a black ink to improve customer color acceptance of the images. These same black inks are also used for color reproduction. Since the separator may have no knowledge of the print shops specific black ink many normally assume a "neutral" black in the computations regarding ink color. Unless specified, a printer uses the black ink of his shop. Therefore different "color" blacks can be used between shops or over a period of time in a single shop. As indicated CEPS systems operators can correct for printing conditions when they are allowed to participate in the full reproduction chain.

The independent variables of this experiment include the 21 step gray scale in the test transparency, 3 levels of Gray Component Replacement (GCR) [50, 75 and 100%].and the Conventional Under Color Removal [UCR] 280% Total Area Coverage images. A detailed description of the independent variables follow. The dependant variables studied include D50, 1931 2° observer CIE L*a*b*, Lightness, hue angle and chroma colorimetric data. The images were analyzed using a GRETAG SPM100 0/45 Reflection Spectrophotometer.

Detailed description of the independent variables

PAPER:

3 types of Paper stock were provided by Boise Cascade, Boise Cascade Grade 4 50 Pound Oxford High Gloss, Boise Cascade Grade 5 45 Pound Oxford Pub Text, and Boise Cascade Grade 4 45 Pound Oxford Dependoweb.

Spectrophotometric curves for the papers used are reproduced as Figure 17. The CIE L*a*b* values for these papers can be found in Table 2.

Table 2

Papers	L*	a*	b*
low	90.91	-0.78	1.81
medium	86.38	-0.31	2.73
high	90.59	0.44	0.71

INK:
3 black inks for this experiment were provided by the Flint Ink Company, a black ink with no toner, a medium (or normally) toned black ink, and a black ink with a high toner level. The CIE L*a*b*values for these inks can be found in Table 3.

Table 3

Ink Toners	L*	a*	b*
no	21.01	1.73	4.75
med	20.34	0.02	-0.23
high	21.08	-0.73	-0.77
Torrance	21.72	-0.61	-0.66

Figure 18 depicts the spectrophotometric curves of a the inks as well as that for a commercially used (Donnelley Torrance) black ink. The Torrance sample was included since the original scanner set up to make the separations used data from this ink.
None of these inks are gray or neutral.
INK SOLID DENSITY:
Each of the paper types, and black inks with different toner levels were printed at 3 different black ink solid densities to obtain Status "T" Reflection Optical Densities of 1.6, 1.8, and 2.0.

Part 3 Section A
Media, Mode and Medium Imposed Changes, Colorimetric Study of gray scale reproduction (a 3x3x3x4x21 Designed Experiment)

This section of the paper compares the colorimetric results [in terms of dot area coverage] of the the 21 step gray scale in the test target resultant from printing the same images used in Part 2.

The designed experiment that produced this data was a 3x3x3 (medium) x21 (media = 21 steps) x4 (mode) experiment which when analyzed (Lightness, hue angle, and chroma) consisted of 2268 data points. In the interest of parsimony steps 1 and 2, 5 and 6, 15 and 16, and 20 and 21 were combined in pairs to form "pseudo replicates" for each design point. These correspond to average tonal values of 25% for combined step 2, 50% for combined step 3, 75% for combined step 4 and 100% for combined step 5. Steps 1 and 2 contain data measuring paper and small dots up to about 20%.

Colorimetric Response due to Media and Mode Changes

Difficulties arise when trying to investigate affects caused by the media alone without realizing the interactions between the two other factors in the study, that is the interactions of Media, Mode and Medium. For this reason designed experiments were used. The details of the effects of these are to be found under the medium affects section.

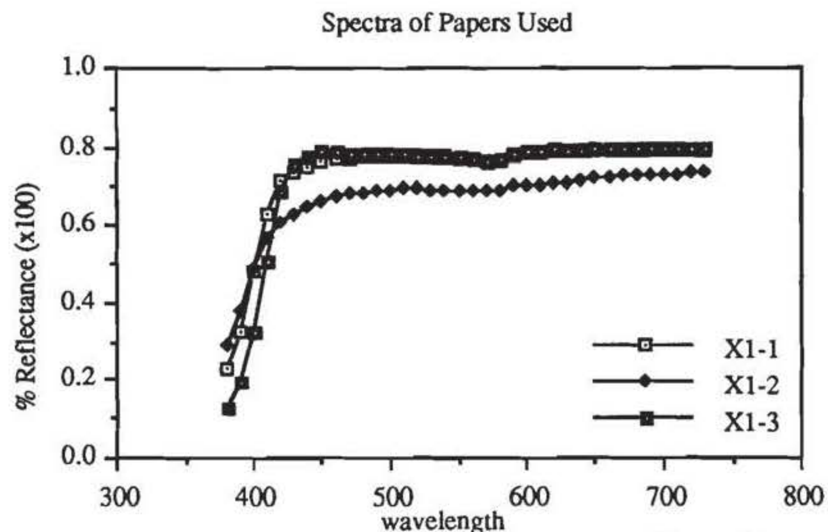

Figure 17

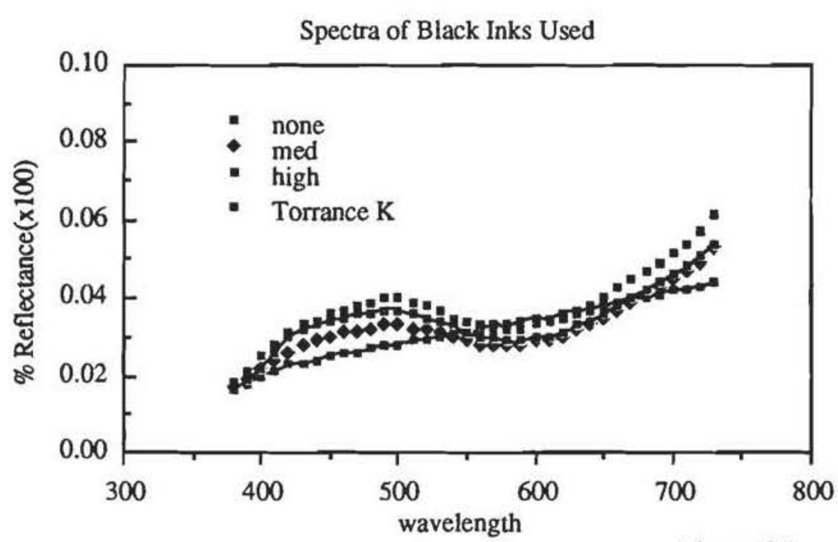

Figure 18

Colorimetric Response due to Medium Changes

It should also be noted that nominal gray images are very sensitive to imposed color changes. Hue angle values from such changes can be quite high. Visual assessment of such values therefore are compulsory.

1. Paper Type Changes

Lightness

In the Conventional process changes in paper type effect Lightness at the toe of the tone reproduction curve [paper and small dot areas]. As the paper is covered by ink (dot area increases) Lightness diminishes. The changes occur through out the halftone range. The Lightness changes correlate with the paper properties. Figure 19, 20, 21, 22.

In GCR printing the same change in paper stock produces a larger Lightness change. This affect is at a minimum at the 100% GCR.

hue angle

In the conventional process changes in hue angle as a result of paper changes are statistically significant in the paper and small dot areas. In the GCR process the same change effects the tonal scale from the paper level to the 25% dot areas.

The fact that a "nominal" neutral component is removed from the image and is replaced with a toned black ink may account for the effect. It should be noted that such small dots do not normally overlap and the inclusion of a "colored" black dot at a different screen angle to the color removed may affect hue angle values.

chroma

There is no change in chroma response to paper type changes [for the papers studied] in both the conventional and GCR processes.

One must remember that the changes reported are derived from instruments. The paper appearance, color and physical properties, do have a psychophysical effect that is non instrumentation in nature. This is especially true when one considers the stock effects the "white point" of the image.

2. Ink Toner Changes

Lightness

In the conventional process and in the 50% GCR images ink toner level changes produce no or little change in CIE Lightness. See figures 23 and 24.

In the 75 and 100% GCR levels the Lightness change due to ink toner is statistically significant. Ink toner changes affect different potions of the halftone reproduction scale differently. See figures 25 to 26. At the 75% GCR level changes in ink toner change produce a Lightness effect which starts at the 25% and extends to the 100% dot area levels. At 100% GCR the change in Lightness is more dramatic and starts at the paper plus small dot levels.

Toner Reproduction Curves - % Dot vs. Gray Scale Step

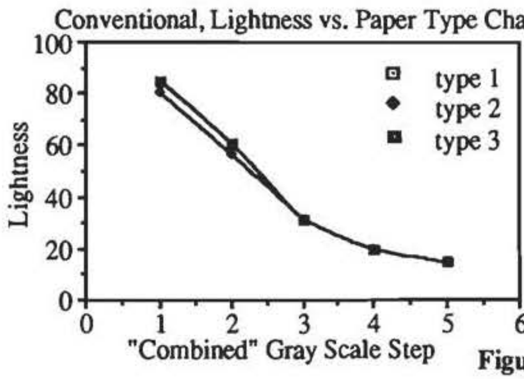

Figure 19

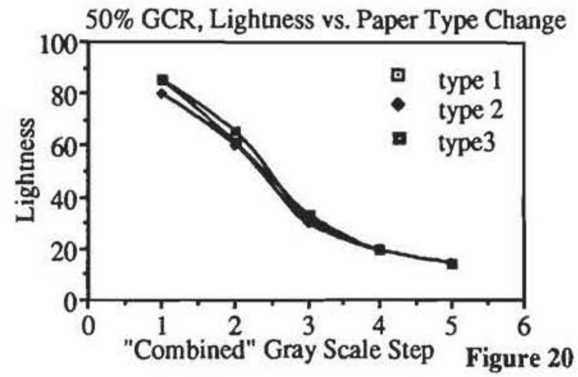

Figure 20

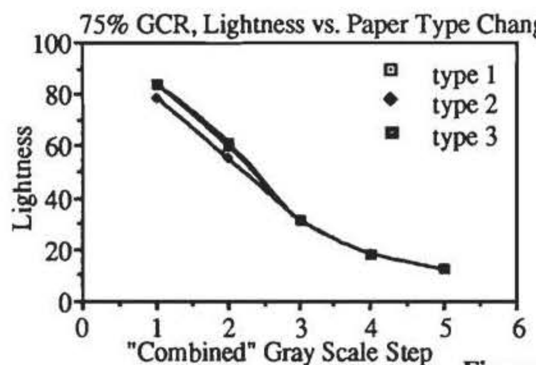

Figure 21

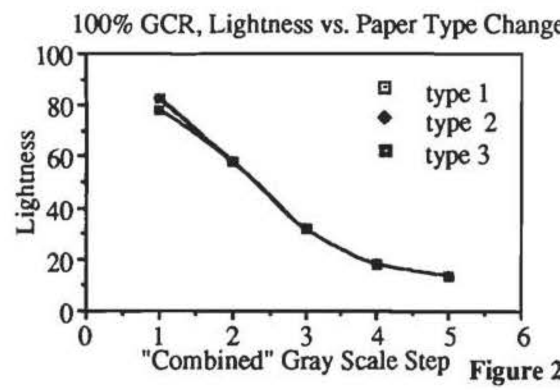

Figure 22

Toner Reproduction Curves - % Dot vs. Gray Scale Step

Conventional, Lightness vs. Ink Toner Level Change

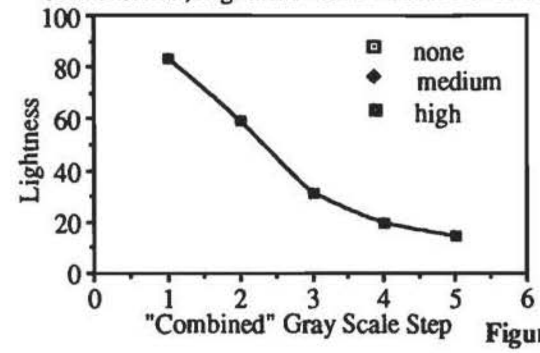

Figure 23

50% GCR, Lightness vs. Ink Toner Level Change

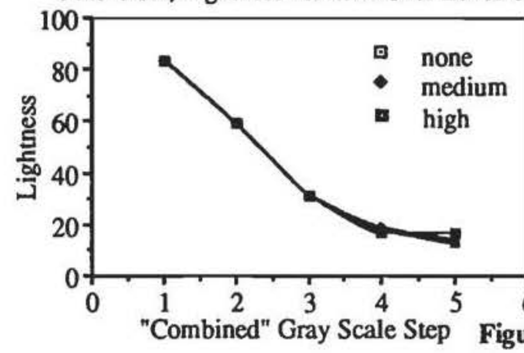

Figure 24

75% GCR, Lightness vs. Ink Toner Level Change

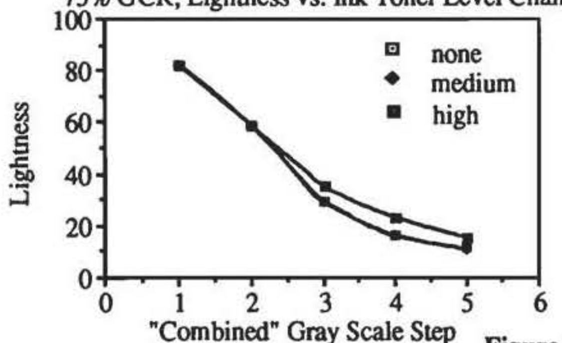

Figure 25

100% GCR, Lightness vs. Ink Toner Level Change

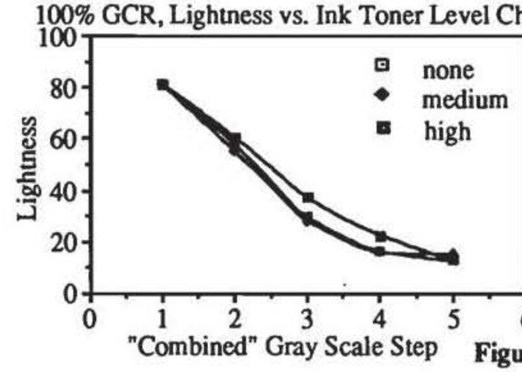

Figure 26

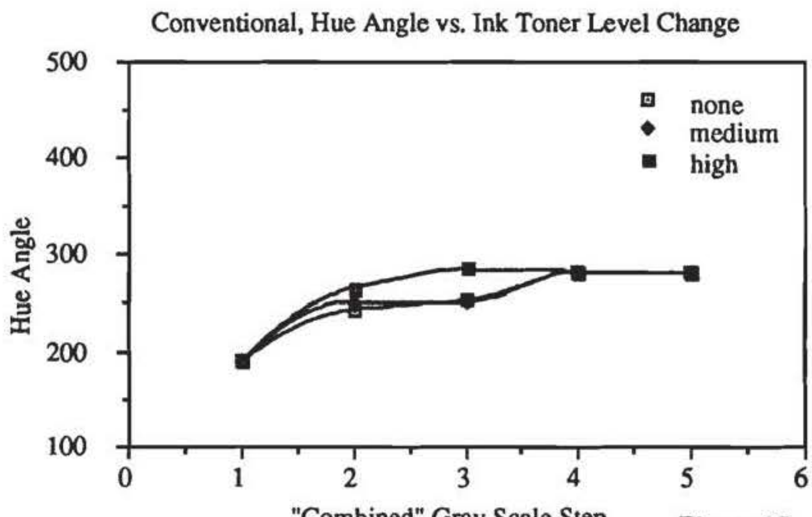

Figure 27

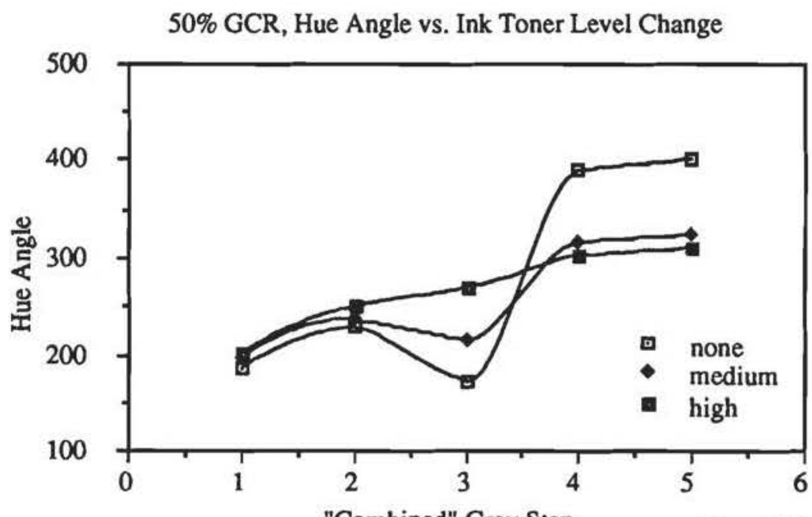

Figure 28

The change is different for two of the three ink toner levels. There is no statistically significant Lightness [change] difference between the no toner and medium toner samples. Medium and no toner inks produce smaller changes in Lightness than high toner inks.

hue angle

In the conventional process, changes in ink toner level produce statistically significant changes in hue angle, figure 27. The change in color per ink toner level changes at a rapid rate from the paper plus small dot areas up to a 25% dot area level. At 25% dot area the high toner level ink proceeds asymptotically to 100% dot area, however, the no toner and medium toner ink chroma response plateaus from the 25 to the 50% dot area rises at the 75% tone and then proceeds in an asymptotic nature to Dmax.

In the various GCR processes the change in hue angle per change in toner level is more distorted. At 50% GCR the high toner level ink has a more linear response to the ink toner induced hue angle change, figure 28. Both the 75% and 100% GCR levels exhibit an unusual hue angle response per dot area increase.

In summary ink toner level changes do effect the colorimetric properties of printed Y,M,C, K images, the effect is more pronounced in higher GCR levels. This is to be expected since a "nominally computed" neutral ink is being replaced by a colored black ink.

chroma

There is a statistically significant interaction between paper type and ink toner level for this attribute. In the conventional process the change in chroma due to ink toner level is seen at all halftone levels. The high toner level ink exhibits a shallow elliptical response. A sudden rise from the paper to 50% dot area, followed by a slight plateau from 50 to 75% dot areas, followed by a decline from the 75 to 100% dot areas.

The medium toner level is preferred. Its response while not linear is flatter than the high toner level ink. The images with this toner level exhibit higher chroma values at the smaller dots and lower chroma value at dot areas from 75 to 100% dot area coverage. The rate of change of the no ink toner level image appears similar to the medium toner level curve, it however produces lower chroma values and exhibits a greater change (lower chroma) from the 25 to 50% dot areas than the medium ink (figure 29). In the GCR process, at the 50% GCR level, the change in chroma per change in dot area is somewhat similar to that of the medium and no ink toner levels of the conventional process. The medium ink produces a more linear chroma response than the other two (figure 30). At 75 and 100% GCR the response from all three inks are distorted (figures 31 and 32).

3. Ink Solid Density Changes

Lightness

In the conventional process there is a small but significant change in Lightness due to changes in ink solid density. The change is especially notable at the 75 and 100% dot area levels, figure 33.

Toner Reproduction Curves - % Dot vs. Gray Scale Step

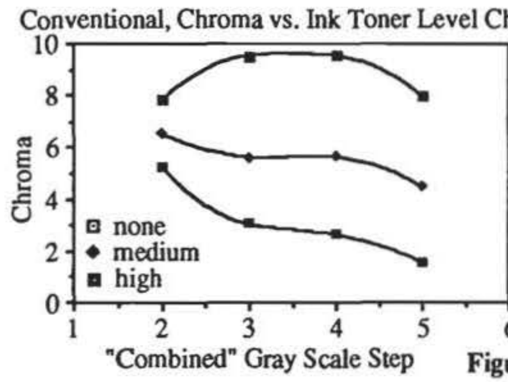

Figure 29

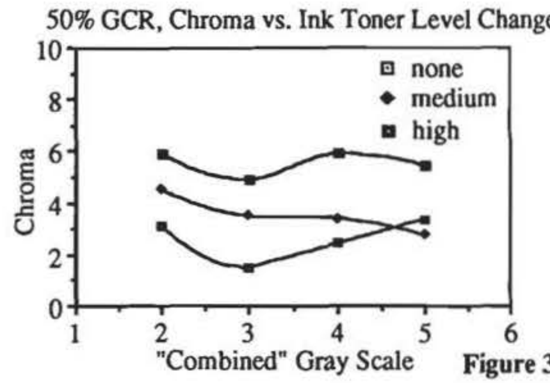

Figure 30

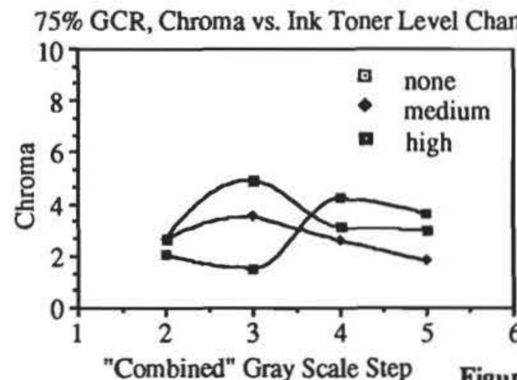

Figure 31

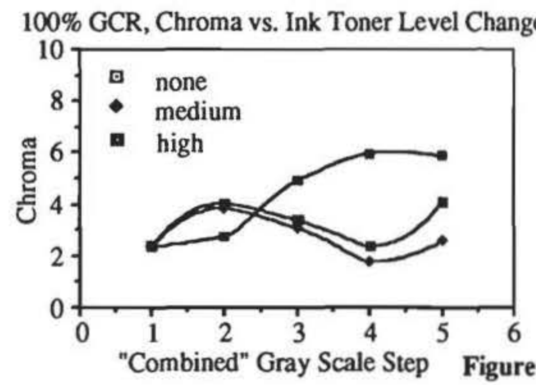

Figure 32

Toner Reproduction Curves - % Dot vs. Gray Scale Step

Conventional, Lightness vs. Ink Solid Density Change

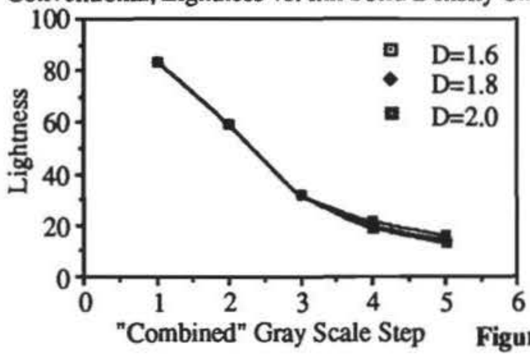

Figure 33

50% GCR, Lightness vs. Ink Solid Density Change

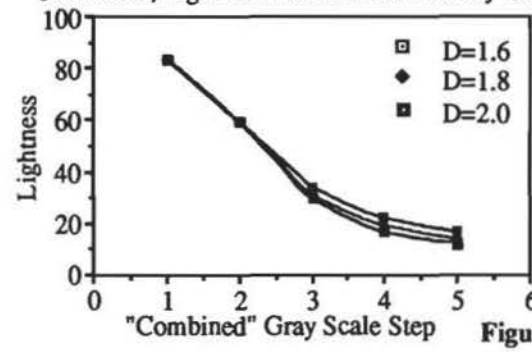

Figure 34

75% GCR, Lightness vs. Ink Solid Density Change

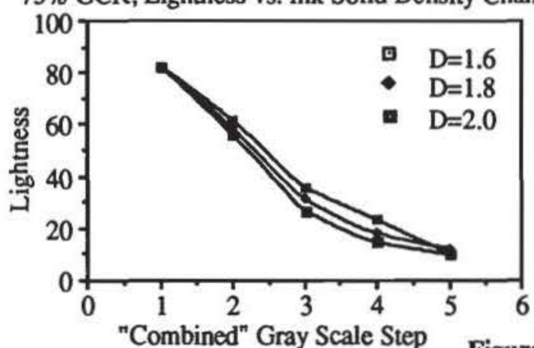

Figure 35

100% GCR, Lightness vs. Ink Solid Density Change

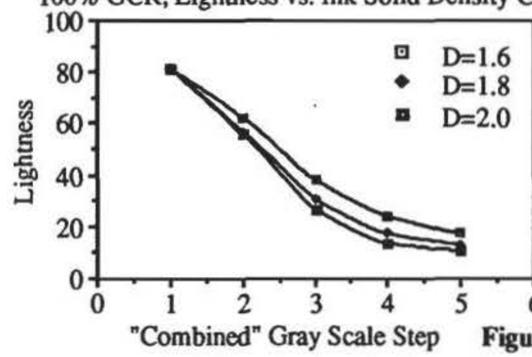

Figure 36

75% GCR, Chroma vs. Ink Solid Density Change

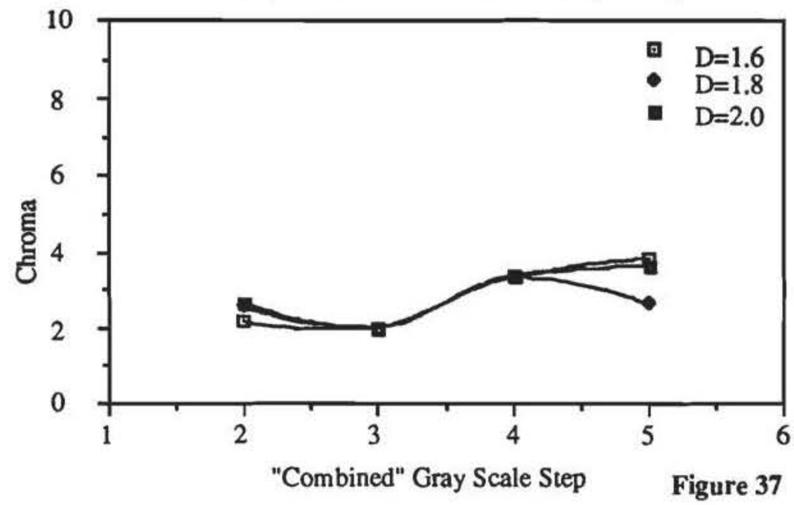

Figure 37

100% GCR, Chroma vs. Ink Solid Density Change

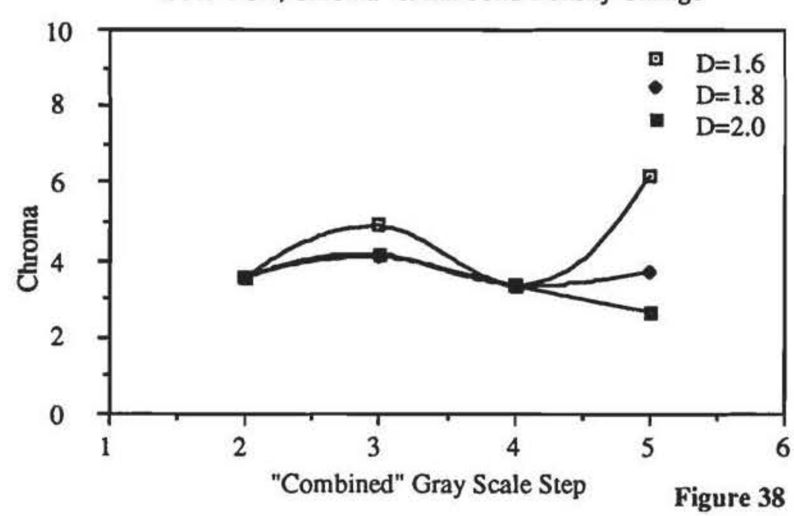

Figure 38

Changes in Lightness due to ink solid density change are more pronounced for GCR images. The change is most apparent at 50% GCR and occurs from the 25% dot area to Dmax (figure 34). At the 75% GCR level the effected area extends from above the 25% dot area level to the Dmax, figure 35. At 100% GCR the affected area extends from the paper level to Dmax, figure 36. Such changes lower the contrast of the image. At 50% GCR this appears as a shoulder contrast effect. At higher GCR levels the effect is overall contrast. In all cases the lower the ink solid density the lower the contrast. This piece of work may give credence to the craftspersons claim that a higher black Dmax (ink solid density) should be used in the GCR process.

hue angle

No significant response in hue angle is evidenced with changes in ink solid density for either the conventional or the GCR process levels.

chroma

No statistical change is evidenced in the conventional and 50% GCR images. The chroma response from different black ink densities are similar at the conventional and 50% GCR levels. A chroma change is evident in the higher GCR processes. The extent of the change depends on the amount of GCR. Some distortion of the response curves appear at 75% GCR at the Dmax level (figure 37). At 100% GCR the response curves change radically from the other GCR levels. The non linear effects of ink solid density at 100% GCR for the lowest ink solid density are very apparent. See figure 38.

CONCLUSION

MODE RELATED AFFECTS

1. RELATIVE SPECTRAL SENSITIVITY

As one might expect, each of the different manufacturers scanning devices analyze color differently and therefore produce a difference in color reproduction.

2. TONE REPRODUCTION

It is interesting to note that there are four separate [different scanner] interactions depicted in tiles 3,4, 6, and 7 of the GRATR diagram. One for each of the GCR levels and one for conventional imaging processes. Each of these tiles relate to a step in the reproduction process. Tiles 5 and 8 indicate one interaction per tile in reality there are four overlapped interactions per tile. In its 3 dimensional form the GRATR diagram would have made this very apparent. Despite differences in the techniques [GCR and UCR] the plate and ink/paper/ press responses are the same indicating no tone reproduction differences in the steps of separations to a plate (contact printing and separation plate responses) or the press/ paper/ ink action can be attributed to differences in UCR-GCR techniques.

MEDIUM RELATED AFFECTS

Difficulties arise when trying to investigate affects caused by the medium alone without realizing the interactions between the two other factors in the study, that is the interactions of Media, Mode and Medium. For this reason designed experiments were used.

Gray Scale Colorimetric Response To:

Paper Type Change

Lightness

In the Conventional process changes in paper type effect Lightness at the toe of the tone reproduction curve [paper and small dot areas]. As the paper is covered by ink (dot area increases) Lightness diminishes. The changes occur through out the halftone range. The Lightness changes correlate with the paper properties. In GCR printing the same change in paper stock produces a larger Lightness change. This affect is at a minimum at 100% GCR.

hue angle

In the conventional process changes in hue angle as a result of paper changes are statistically significant in the paper to small dot areas. In the GCR process the same change effects the tonal scale from the paper level to the 25% dot areas.

chroma

There is no change in chroma response to paper type changes [for the papers studied] in both the conventional and GCR processes.

Ink Toner Change

The lack of a colorimetric specification on an ink color set for the offset process complicates matters. This is especially true for black inks. The saving grace of the system is the psychophysical human interface that interprets the images. Seen alone without reference most sets of images appear satisfactory. This however does not mitigate the need for standards involving ink colors, tonal response and raw materials.

Lightness

In summary ink toner level changes affect the colorimetric properties of the gray scale. In the conventional process the rate of change in hue angle per ink is rapid rate from the paper plus small dot areas up to a 25% dot area level. At 25% dot area the high toner level ink proceeds asymptotically to 100% dot area, however, the effect is more pronounced in higher GCR levels. At high levels of GCR the change distorts the reproduction curve. This is to be expected since a "nominally computed" neutral ink is being replaced by a colored black ink.

chroma

There is a statistically significant interaction between paper type and ink toner level for this attribute. In the conventional process the change in chroma due to ink toner level is seen at all halftone levels. The high toner level ink exhibits a shallow elliptical response. The medium toner level while not linear is flatter than the high toner level ink. The rate of change of the no ink toner level image appears similar to the medium toner level curve, it however produces lower chroma values and exhibits a greater change (lower chroma) from the 25 to 50% dot areas than the medium ink. In the GCR process, at the 50% GCR level, the change in chroma per change in dot area is somewhat similar to that of the medium and no ink toner levels of the conventional process. At 75 and 100% GCR all three inks are unacceptable.

Ink Solid Density Change

Lightness

In the conventional process there is a small but significant change in Lightness due to changes in ink solid density. The change is especially notable at the 75 and 100% dot area levels. Changes in Lightness due to ink solid density change are more pronounced for GCR images. The change is most apparent in GCR. At 50% GCR this appears as a shoulder contrast effect. At higher GCR levels the effect is apparent at all tonal levels (general contrast). In all cases the lower the ink solid density the lower the contrast. This piece of work gives credence to the craftsman claim that a higher black Dmax (ink solid density) should be used in the GCR process.

hue angle

No significant response in hue angle is evidenced with changes in ink solid density for either the conventional or the GCR process levels.

chroma

No statistical change is evidenced in the conventional and 50% GCR images. The chroma response from different black ink densities are similar at the conventional and 50% GCR levels. A chroma change is evident in the higher GCR processes. The extent of the change depends on the amount of GCR. Some distortion of the response curves appear at 75% and 100% GCR where the response curves change radically from the other GCR levels. The non linear effects of ink solid density at 100% GCR for the lowest ink solid density is very apparent.

While the flexibility of medium which can be employed in the ink on paper process is one of its greatest benefits it also presents a large the disadvantage when one attempts to define the process. Standardization, a growing trend in the graphic arts will no doubt limit the flexibility. The trick however will be to promote flexibility and standards harmony.

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