PREFERRED GLOSS LEVELS FOR COLOR IMAGES

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Keywords: Gloss, color, electrophotography, paper

Abstract: The level of gloss that customers prefer for xerographic color images was determined by means of a survey. Because of the potentially different requirements, pictorial as well as business-graphics images were used in this survey. Both of these images were printed on five different plain and coated papers. The substrate gloss, as well as the image gloss on each substrate, varied over a wide range. The results of this survey indicate that images with an intermediate range of gloss are preferred for all of these samples, and very low or very high gloss levels are clearly not preferred. Preferred image gloss correlates with image chroma.

Introduction

It is important to know the level of gloss that customers prefer on color prints, in order to set specifications for a color printer. However, little research has been done on this subject, except for a paper by Edinger (1992), which was limited to black-and-white images.

An extensive survey was conducted to determine the level of gloss that customers prefer for xerographic color prints on various papers. Because of the potentially different requirements, a pictorial image and a business-graphics image were used in this survey. Both of these images were printed on five different plain and coated papers, which covered a range of substrate gloss from 6 to 76 gu. The image gloss on each substrate varied from ~5 gu to ~100 gu. (In this paper, gloss is reported in "gloss units" on the *TAPPI* T-480 75° specular gloss scale).

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The sample set consisted of six gloss levels, approximately uniformly spaced over the gloss range, on each of the five substrates. It was evaluated by 67 observers divided into four distinct groups. The results of this survey indicate that a mid-range gloss is preferred by a wide variety of observers, even when substrate gloss is low.

Experimental Details

Five different papers covering a wide range of substrate gloss were used in this study. They included two plain papers (Xerox 4024 and Hammermill Laser Print) and three coated papers (Fuji-Xerox CX-1, Alpha Gloss and Lustro Gloss). These five papers have bare substrate gloss levels of about 6, 12, 41, 56 and 76 gu respectively, on the *TAPPI* T 480 (75°) gloss scale.

Because of the potentially different requirements, we used both a pictorial image and a business graphics image in the survey. Preliminary studies indicated that observers were very critical of imaging defects and tended to let the defects influence their selection in spite of instructions to ignore them. Contouring and improper color balance (particularly in neutrals and skin-tones) were the most difficult to eliminate consistently in xerographic prints. The pictorial image, "Veggies", was therefore selected to avoid stressing these capabilities.

The business graphics image original "Benefits" was based on a Xerox publication, and contained color bar graphs and various sizes of black text. The color bars were in saturated cyan, magenta, yellow, red, green, blue and black, and were sized to permit gloss and color measurement.

The images were made on a Xerox 5775 color copier/printer. The 5775 was used because unfused images could be easily obtained, and because the high-melting toners allowed a wide range of gloss to be attained.

Unfused images taken from the Xerox 5775 were fused to different gloss levels by varying the fusing parameters on an off-line fuser. The fused image gloss on each substrate varied from very low (~5 gu) to very high (~100 gu). All samples except one at the highest gloss were fused on a bench fuser similar to a Xerox 5765 fuser. The highest gloss samples were fused on an experimental fuser running at low speed, with the sample in contact with a plastic film. This enabled smooth, high gloss (100 gu) surfaces to be obtained.

Gloss was measured according to the *TAPPI* T 480 (75° specular gloss) specification, using a Gardner Glossgard II glossmeter. All of the gloss data presented here were measured to this specification, which is widely used in the paper and related industries.

For the business graphics images, gloss was measured along the colored bars. The gloss of all six colors (C, M, Y, R, G, B) was averaged, and that average value was used to characterize the business graphics samples. For the pictorial images, gloss was measured at two selected locations and averaged. This

average value agreed well with that for the business graphics images fused under the same conditions. The RMS difference in gloss between the pictorial and business graphics images was 3.3 gu for the entire sample set.

Preference Survey

The print samples, prepared as described above, were evaluated by volunteer observers following a written set of instructions, which was patterned on a list used by Edinger(1). The observers were asked to rank all the prints for a given image type on each substrate, and record their preferences in a table. This determined customer gloss preferences on each substrate.

The print samples were labeled only with an alphanumeric code which did not identify the substrate or the position in the gloss sequence. They were not mounted or covered in any way, and the observers were allowed to position and view them as they pleased. The observations were made in small groups of one to six observers at different times and places, except for the Japanese observers, all 14 of which took the survey together in two adjacent rooms. In every case, each observer worked independently of the others. Because parts of the survey were done at different times and places, the illumination varied somewhat, but could be described as typical office fluorescent lighting.

The survey was evaluated by 67 observers divided into four distinct groups: U.S. technical observers (15), U.S. non-technical observers (14), U.S. external observers (23), and Japanese observers (14). The "external" observers were members of Xerox customer focus groups; all others were staff members at Xerox Corp. (U.S. observers) or Fuji-Xerox Co. (Japanese observers). This was done to see if there were differences in preferred gloss between Japanese and U.S. observers, and between technical and non-technical observers. The non-technical and external groups were of particular interest, because of concerns about the validity of a survey limited to technical people working in this field.

Results and Discussion

Much of the data is presented in terms of Mean Preference values. These are defined as follows. For a particular sample set (i.e., all six gloss levels of a given image on a given paper) any one observer ranks the samples from 1 through 6, with 1 being the most preferred gloss level. These rankings are converted to Preference values, the highest ranked sample having a Preference value of 100% and the lowest ranked sample having a Preference value of 0. The Mean Preference value is defined as the mean of the Preference values quoted by all observers, or by a particular observer group, for a given sample.

Figure 1 is a three-dimensional plot of the Mean Preference values of the pictorial image for all observers, as a function of image gloss and substrate gloss. Figure 2 shows equivalent data for the business graphics image.

The four groups (U.S. technical observers, U.S. non-technical observers, U.S. external observers, and Japanese observers) showed very similar preferences. Details of the preferences of the various groups are discussed later.

The surfaces in Figures 1 and 2 were obtained by fitting a three-dimensional function to the data. In an earlier analysis (Swanton and Dalal, 1996) it was shown that, for any given substrate, the dependence of Mean Preference value on image gloss could be well fitted by a Lorentzian peak function:

$$z = \frac{a}{1+\left(\frac{x-b}{c}\right)^2} \tag{1}$$

where the constants a, b and c are the peak height, peak location, and half-width of the curve, while the variables x and z are the image gloss and Mean Preference value, respectively. For the different substrates, the constants a and c were found to remain essentially fixed, whereas the constant b varied approximately linearly with substrate gloss y. Therefore, the following three-dimensional function was used in this work:

$$z = \frac{a}{1+\left(\frac{x-(b_0+s\cdot y)}{c}\right)^2} \tag{2}$$

where the constants b_0 and s are the intercept and slope, respectively, of the peak location $b(y)$.

Three-dimensional curve fitting was done with *TableCurve 3D* software from *Jandel Scientific*. Values of the constants a, b_0, s and c for the two images are listed in Table 1, together with the correlation coefficients.

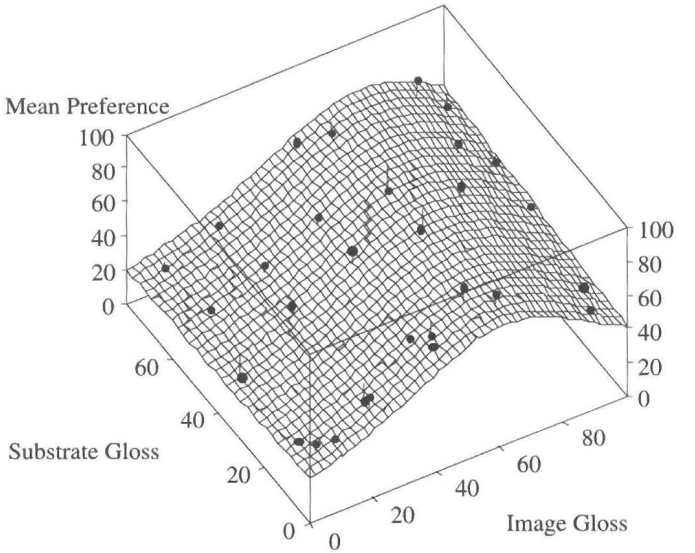

Figure 1: Mean Preference values for the pictorial images as a function of image gloss and substrate gloss.

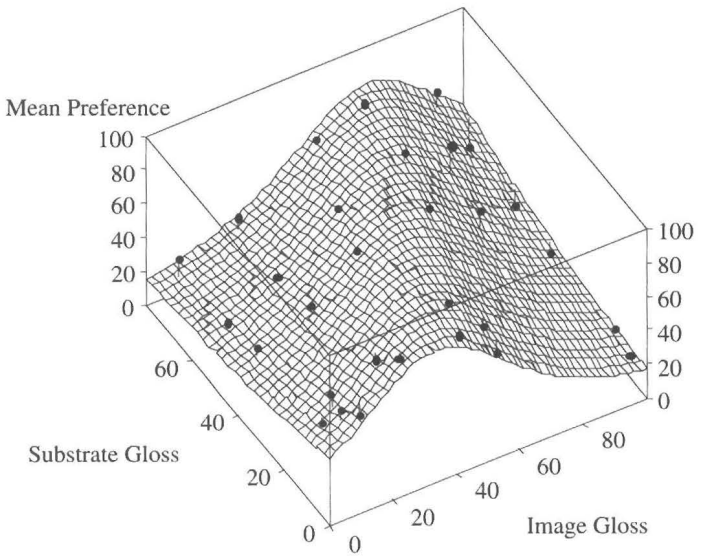

Figure 2: Mean Preference values for the business graphics images as a function of image gloss and substrate gloss.

Parameters	Pictorial Images	Business Graphics
Peak Height a	71.0	77.9
Intercept b_0	61.0	33.2
Slope s	0.158	0.454
Half-width c	46.2	34.2
Correlation coefficient r^2	0.854	0.875

Table 1: Three-dimensional curve fitting parameters.

Figure 3 is a contour plot of image gloss against substrate gloss for the pictorial images, and Figure 4 is a similar plot for the business graphics images. Figures 3 and 4 are essentially top views of Figures 1 and 2 respectively, which show the dependence of preferred image gloss on substrate gloss more clearly. The solid lines represent the variation of peak preferred image gloss with substrate gloss. The dotted lines are the contours of the surfaces at 90%, 80%, 70% and 60% of the peak Mean Preference value. The contours at 80% of the peak Mean Preference value are emphasized by dashed lines.

Figures 3 and 4 show that the dependence of preferred image gloss on substrate gloss for the pictorial images is significantly different from that for the business graphics images. For the pictorial images, the preferred image gloss is almost independent of substrate gloss, with a slight positive slope of about 0.16, while for the business graphics images the slope is higher, about 0.45. The slope is the constant s in Equation 2 and Table 1.

In Figures 3 and 4, note that images with a wide range of gloss, from about 40 to 80 gu, would have high Preference values (~80% of peak value or higher) for most of these samples. The clear exceptions are the business graphics images on plain papers only, for which a gloss range of about 20 to 50 gu would lie within this Preference band.

The preferences of the various observer groups are compared in Figures 5 and 6 for the pictorial and business graphics images respectively. The agreement between the four observer groups is very good in both figures.

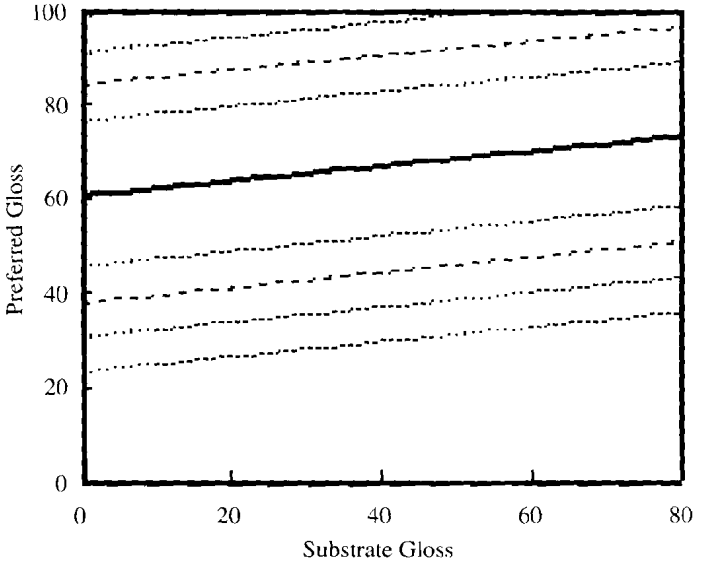

Figure 3: Contour plot of the dependence of preferred image gloss on substrate gloss for the pictorial images. Contours at peak (solid line) and 10% decrements (dotted lines)

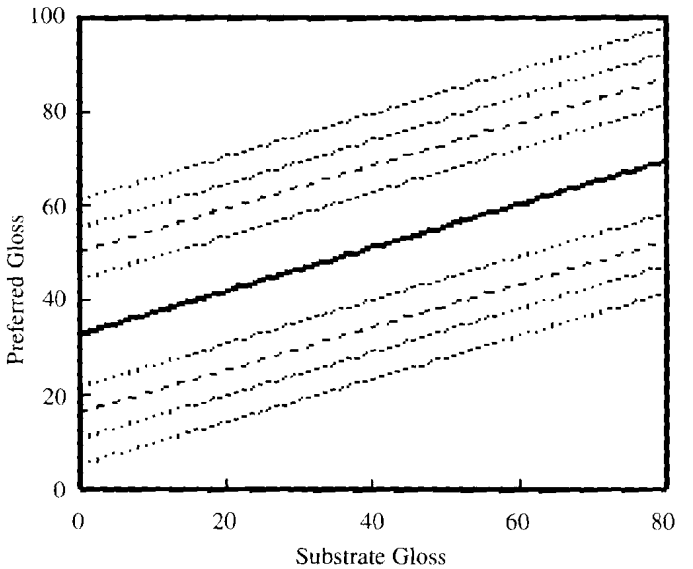

Figure 4: Contour plot of the dependence of preferred image gloss on substrate gloss for the business graphics images. Contours at peak (solid line) and 10% decrements (dotted lines)

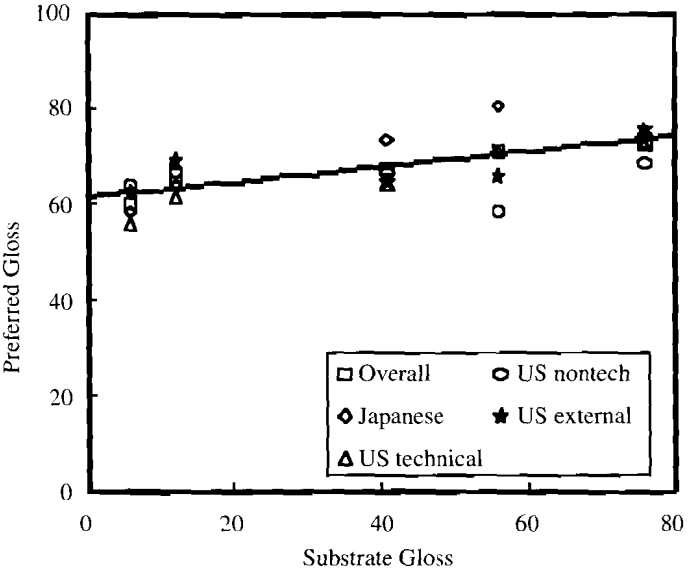

Figure 5: Dependence of preferred gloss on substrate gloss, comparing data for each of the observer groups, for the pictorial images.

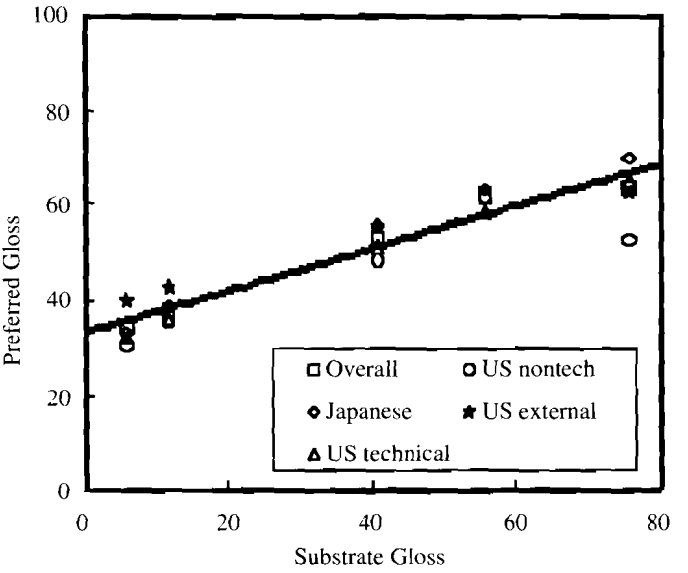

Figure 6: Dependence of preferred gloss on substrate gloss, comparing data for each of the observer groups, for the business graphics images.

From the survey we have learned which gloss level the observers preferred, but not exactly why they preferred it. Our view of this issue is as follows. Image chroma (i.e., color saturation) increases with increasing gloss, rapidly at low gloss but eventually levelling off. A "nuisance factor" (which includes enhanced defect visibility as well as poor readability due to glare) also increases with increasing gloss, presumably without levelling off. We believe that observers trade off these two effects. Low gloss levels give inadequate image chroma. However, once maximum chroma is reached, further increase in gloss increases the nuisance factor without a corresponding gain in chroma. Observers therefore avoid both extremes in gloss.

Image chroma can be directly measured. It increases with gloss and eventually levels off, as shown in Figure 7 for the saturated blue area from the business graphics images on Lustro Gloss paper. Image chroma was measured in CIELAB units, with 0°/45° geometry, D50 illuminant and 2° observer The chroma changes from about 50 CIELAB units at low gloss to about 80 CIELAB units at medium gloss, and then levels off.

Figure 8 shows how Mean Preference varies with image chroma for the same images. Mean Preference increases as chroma increases, and drops when chroma levels off. Note that chroma remains constant for the last three points in Figure 8, but the gloss continues to increase.

The nuisance factor cannot be quantified as readily as the image chroma, but is related to the microgloss structure of the images. At equivalent high gloss, large solid areas look more grainy or mottled on plain papers than on the glossy coated papers. This effect is more visible in the business graphics images, which have large uniform solid areas, than in the "busy" pictorial images. Correspondingly, a lower image gloss is preferred for the business graphics images than for the pictorial images, particularly for the rougher (lower substrate gloss) plain papers. This contributes to the large difference in slope between the pictorial and business graphics images (Figures 3 and 4).

The preferred gloss on plain paper is lower for business graphics images, probably because the presence of sharp edges between solid areas and bare paper makes the gloss difference very apparent if high gloss images are printed on low gloss paper. This effect is mitigated in pictorials, which are likely to have more gradual transitions between full coverage and bare paper. Considerations of glare and readability, presumably more important for business graphics, might also play a role.

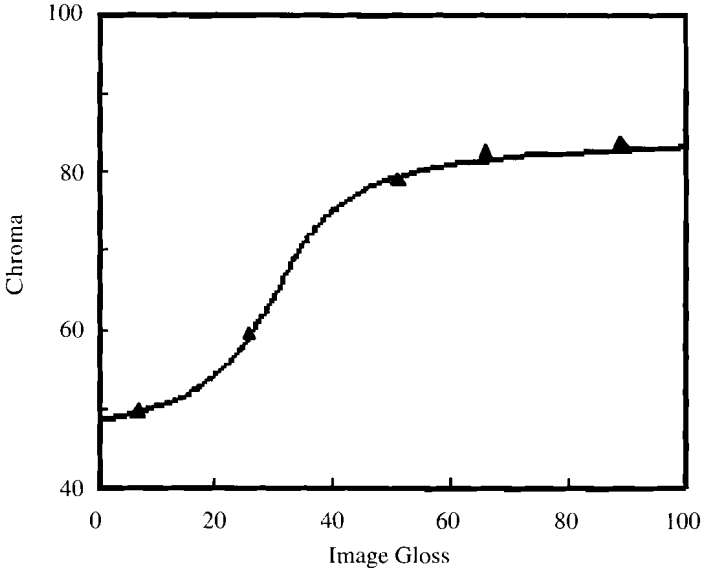

Figure 7: Dependence of image chroma on image gloss for the saturated blue area of the business graphics images on Lustro Gloss paper.

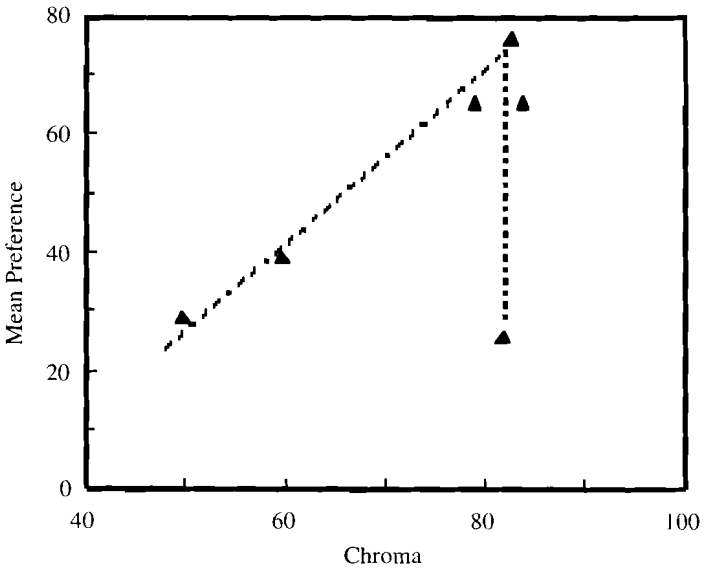

Figure 8: Dependence of Mean Preference on image chroma for the samples in Figure 7.

Conclusions

The overall conclusions from this survey are as follows:

1. Mean Preference curves are very broad, but very low or very high gloss samples are not preferred.

2. The preferred gloss range is about 40~80 gu for all cases, except for business graphics on plain papers only, where the preferred gloss range is about 20~50 gu. These gloss values cited correspond to Mean Preferences at or above 80% of the peak Preference.

3. The preferred image gloss increases relatively slowly (slope $s = 0.16$) with substrate gloss for the pictorial images, and more rapidly ($s = 0.45$) for the business graphics images. The preferred image gloss values for the two types of images converge at high gloss. Substrate-matching gloss, where image gloss is equal to paper gloss, is generally not preferred on low gloss substrates, even for the business graphics images.

4. Image chroma increases with gloss and eventually levels off. This variation is compatible with the preferred gloss for pictorial images, with the peak preferences occuring near those gloss levels where chroma starts to level off.

Acknowledgements

The authors are very grateful to all the volunteer observers who took the time and effort to carefully evaluate the sixty samples in this survey, and to G. Link for administering the survey to the external observers. We would also like to thank S. Blaszak and K. Natale for help with the preliminary survey and color measurements, D. Green for providing the pictorial image, and K. Moore for creating the business graphics image.

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