# Gloss Preferences for Color Xerographic Prints

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A survey was conducted to determine the level of gloss that customers prefer for xerographic color prints on various papers. Both pictorial and business graphics images were used in this survey. They were printed on two plain papers and three coated papers. The sample set consisted of six gloss levels, approximately uniformly spaced over a wide gloss range, on each of the five substrates. The sample set was evaluated by 67 observers divided into four distinct groups. The results of this survey indicate that a midrange gloss is preferred by a wide variety of observers, even when substrate gloss is low.

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## Introduction

Knowledge of the level of gloss that customers prefer on a color print is important in setting specifications for a color printer. We could find no reference to any research on this subject, except for a paper by Edinger,[1] which was limited to black-and-white images. We therefore set out to perform the required preference studies. We conducted an extensive survey to determine the level of gloss that customers prefer for xerographic color prints on various papers.

## Experimental

**Sample Preparation.** ***Substrates.*** 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 (gloss units), respectively, on the TAPPI T-480[2] (75°) gloss scale. These substrates and their gloss levels are listed in Table I.

**Table I. Substrates Used in the Survey**

| Name | Supplier | TAPPI 75° gloss |
|---|---|---|
| **Plain papers** | | |
| 4024 | Xerox | 6 |
| Laser Print | Hammermill | 12 |
| **Coated papers** | | |
| CX-1 | Fuji-Xerox | 41 |
| Alpha Gloss | Provincial Paper | 56 |
| Lustro Gloss | S. D. Warren | 76 |

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***Images.*** 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. A pictorial image, "Veggies," was therefore selected to avoid stressing these capabilities.

The business graphics image original "Benefits" was based on a Xerox publication, and it 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 they were sized to permit gloss and color measurement.

Representations of "Veggies" and "Benefits" are included in Figs. 1 and 2, respectively. These figures are included to indicate content only; note that the actual samples used were xerographic prints.

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-temperature toners allowed a wide range of gloss to be attained.

***Fusing and Gloss Measurement.*** The unfused images taken from a 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 procedure enabled smooth, high-gloss (100-gu) surfaces to be obtained.

Gloss was measured according to the TAPPI T-480[2] (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. However, because the ASTM D-523[3] (20°/60°/85° specular gloss) specification is widely used for many other applications, we have measured the gloss of the samples to this specification as well. The correlation between the two specifications is presented in Fig. 3.

For the business graphics images, gloss was measured along the colored bars. The gloss values of the single-layer colors (C,M,Y) and of the double-layer colors (R,G,B) were found to be fairly close, so the gloss of all six colors was averaged, and that average value was used to characterize the business graphics samples. The sample standard deviation was calculated for the six colors for each sample, and the mean value of this parameter for all samples was 2.8 gu. 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

**Figure 1.** A representation of the pictorial image "Veggies" used in this work.

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.

### Print Evaluation

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 to record their preferences in a table. This ranking 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 whom 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. nontechnical 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 nontechnical observers. The nontechnical 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

**Mean Preference Values.** 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

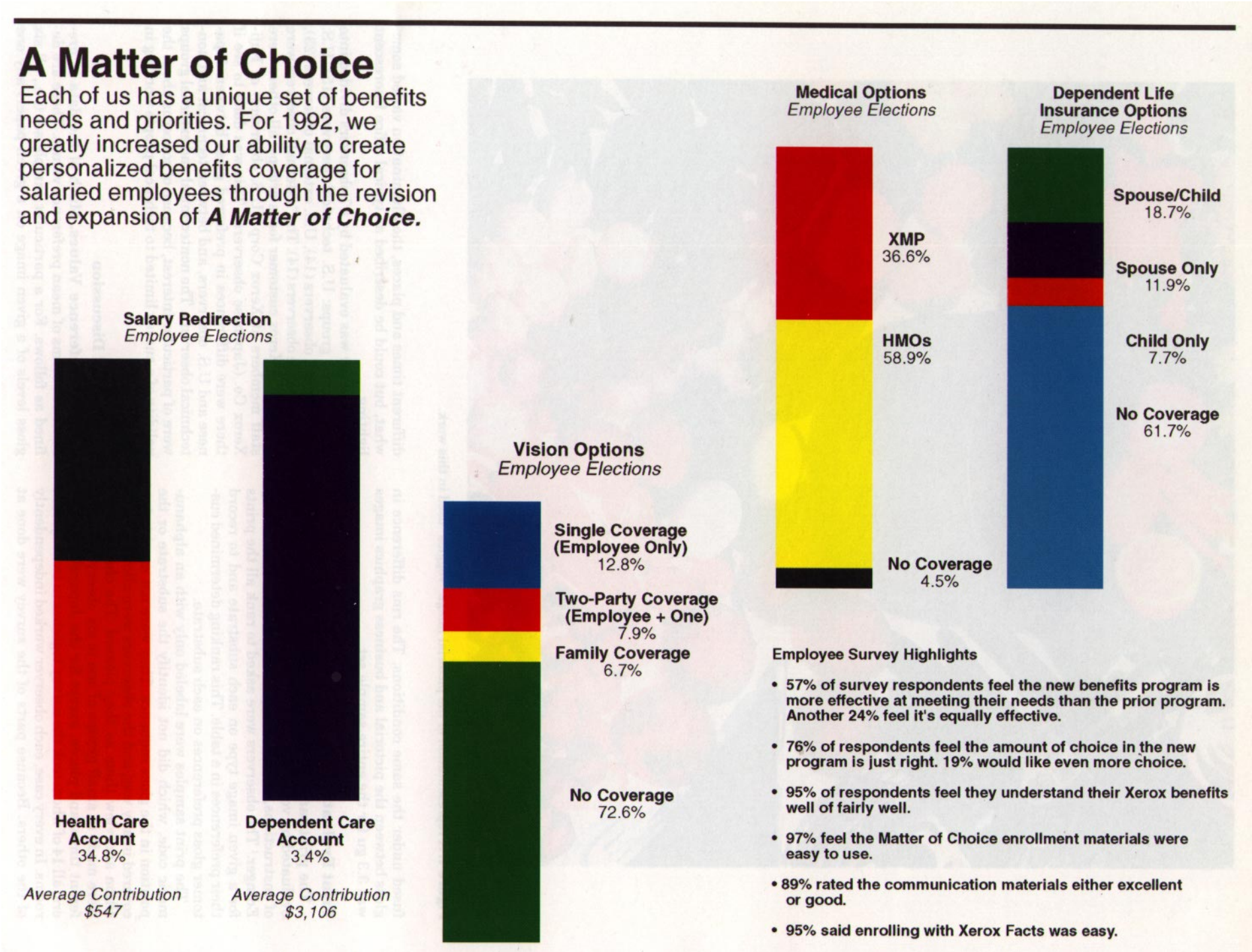


**Figure 2.** A representation of the business graphics image "Benefits" used in this work.

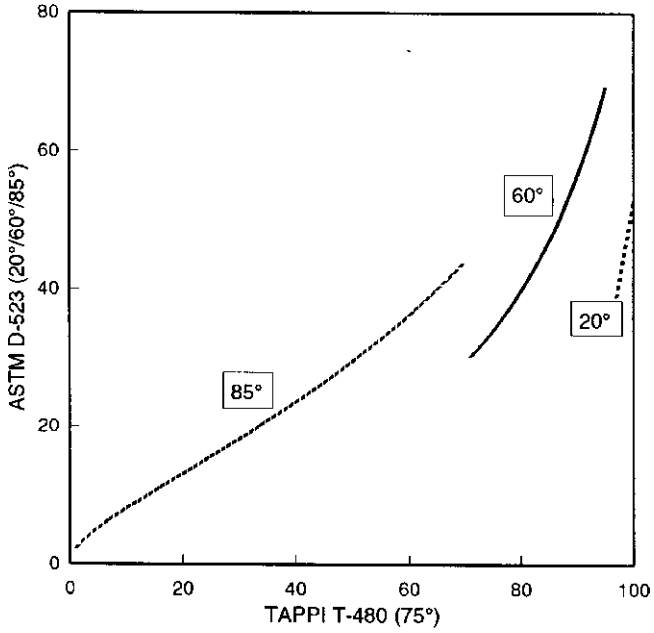


**Figure 3.** Correlation between the TAPPI T-480 (75°) and ASTM D-523 (20°/60°/85°) specular gloss specifications, for the xerographic prints used in this work.

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 4 shows the mean preference values of the pictorial image for all observers. Figure 5 shows equivalent data for the business graphics image.

The four groups (U.S. technical observers, U.S. nontechnical observers, U.S. external observers, and Japanese observers) showed very similar preferences, except that the Japanese observers generally preferred slightly higher gloss levels than the average. The differences are small

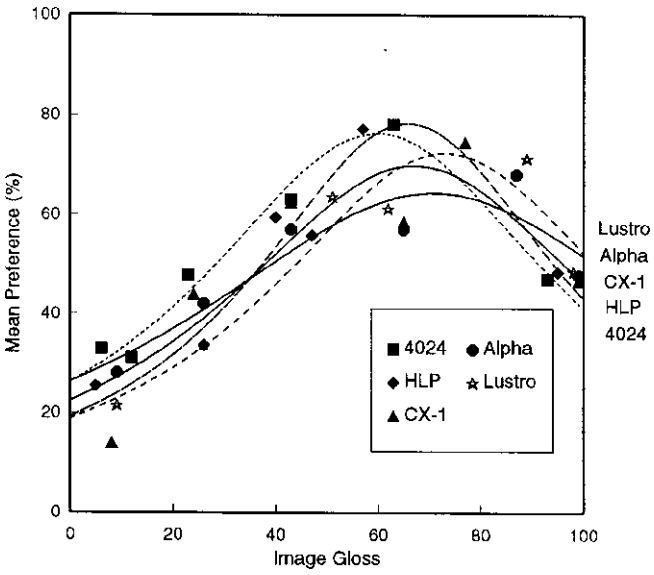


**Figure 4.** Mean preference values for the *pictorial* images as a function of image gloss on each of the five substrates.

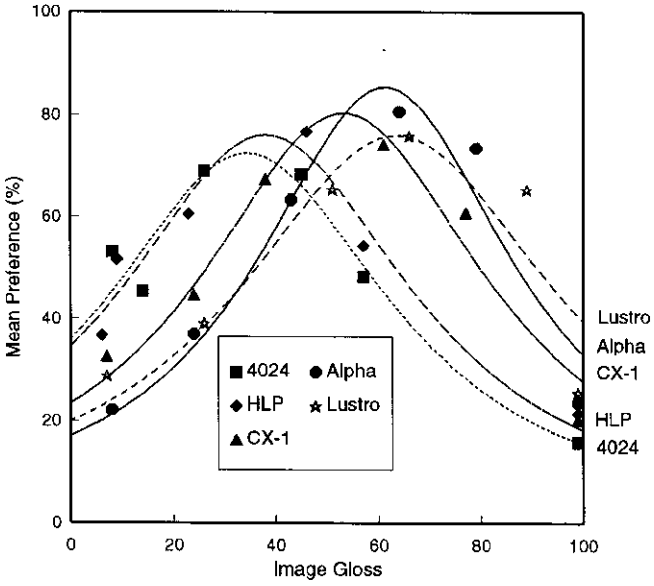


**Figure 5.** Mean preference values for the *business graphics* images as a function of image gloss on each of the five substrates.

and probably not statistically significant. Details of the preferences of the various groups are discussed later.

The smooth curves in Figs. 4 and 5 were obtained by fitting a Lorentzian peak function to the data. The Lorentzian equation is:

$$y = \frac{a}{1+\left(\frac{x-b}{c}\right)^2}, \qquad (1)$$

where $a$ is the peak height, $b$ is the peak location, and $c$ is the half-width of the curve, and in this case $x$ is image gloss and $y$ is the mean preference value. Curve fitting

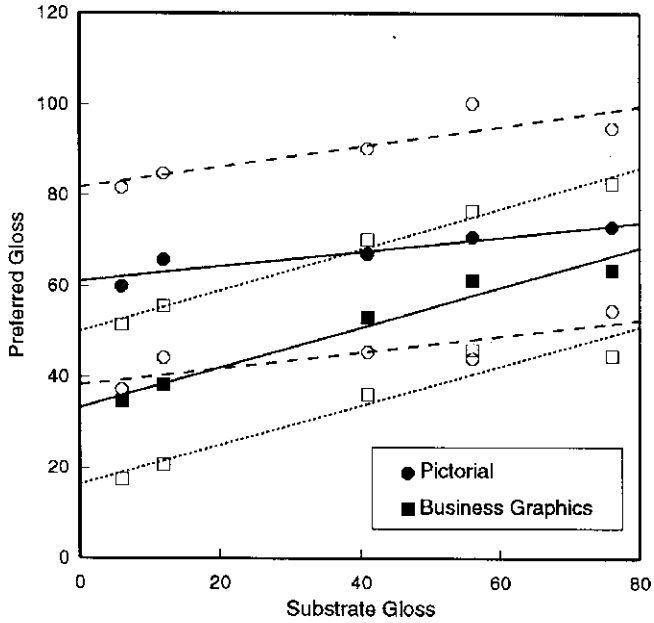


**Figure 6.** Dependence of preferred gloss on substrate gloss. The solid lines represent the peak preferred gloss and the dotted lines represent the spread at 80% of the peak preference value.

was done with Table Curve 2D software (from Jandel Scientific), which permits many equations to be fitted and ranked very quickly. The Lorentzian equation was selected because it consistently provided a good fit to the data.

**Dependence of Preferred Image Gloss on Substrate Gloss.** The data in Figs. 4 and 5 show that the gloss preferences are very broad, indicating that there is no strong preference for a particular gloss level, but very low or very high gloss samples are clearly not preferred. The peak preference is near the middle of the gloss range, and increases slightly with increasing substrate gloss.

The dependence of preferred image gloss on substrate gloss is shown in Fig. 6, which is a plot of image gloss corresponding to the peak mean preference value for each paper (parameter $b$) against the bare paper gloss. The two solid lines represent the variation of preferred image gloss with substrate gloss for the pictorial and the business graphics images, respectively. In addition, the dotted lines indicate image gloss values at 80% of the peak mean preference value, representing the width of the distributions. These values are computed from:

$$x' = b \pm c\sqrt{\frac{(1-f)}{f}}, \qquad (2)$$

where $x'$ is the desired width; the parameters $b$ and $c$ from Eq. 1 are the peak location and half-width, respectively; and the peak fraction $f$ is set to 80%. Equation 2 can be derived from Eq. 1.

Figure 6 shows 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 1:10. For the business graphics images, the slope is higher, about 1:2 overall.

In Fig. 6, 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.

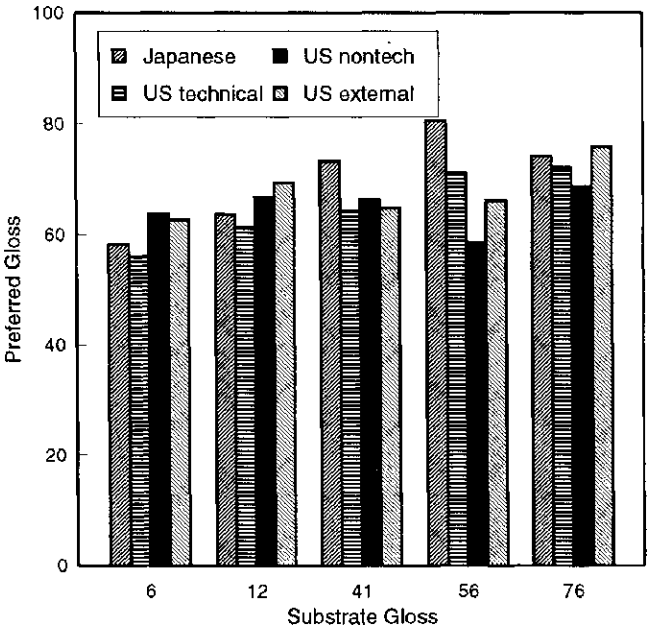


**Figure 7.** Dependence of preferred gloss on substrate gloss, comparing data for each of the observer groups, for the *pictorial* images.

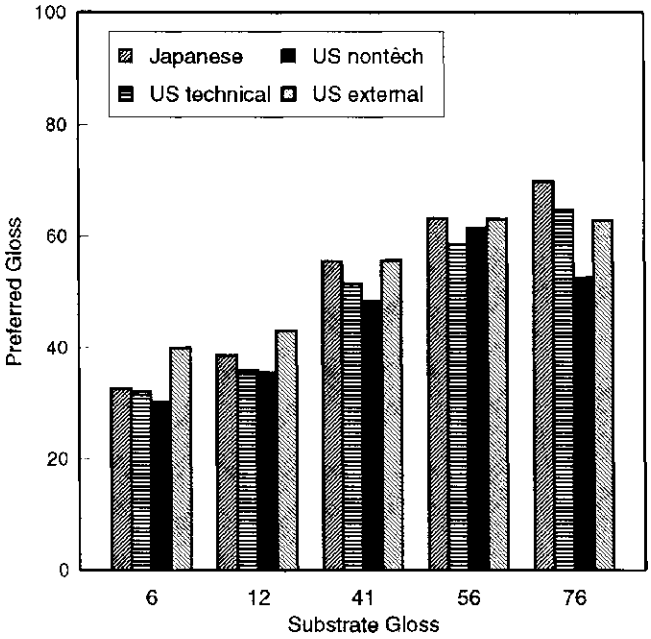


**Figure 8.** Dependence of preferred gloss on substrate gloss, comparing data for each of the observer groups, for the *business graphics* images.

**Differences Between Observer Groups.** The preferences of the various observer groups are compared in Figs. 7 and 8 for the pictorial and business graphics images respectively. The agreement between the four observer groups is very good in both figures.

**Discussion of Gloss Preferences.** 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)

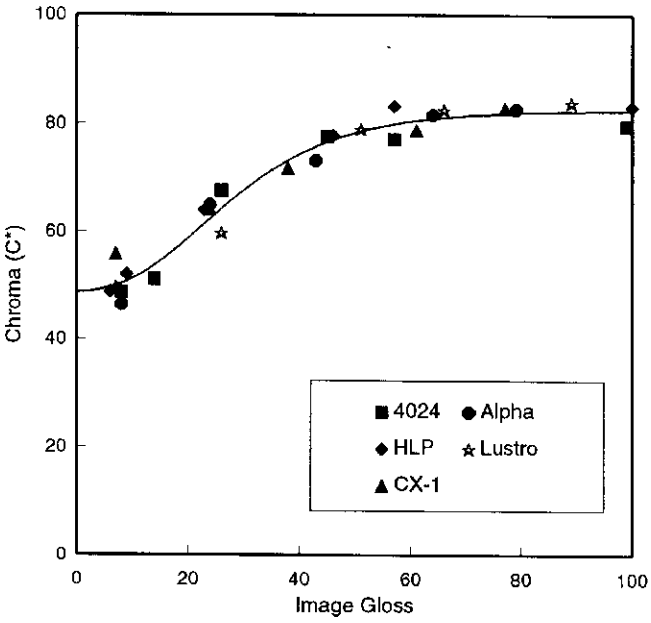


**Figure 9.** Dependence of image chroma on image gloss for the saturated blue area of the business graphics images. Color measurement conditions: 0∞/45∞ geometry, D50 illuminant, 2∞ observer.

increases with increasing gloss. It does so rapidly at low gloss, but eventually levels off. A "nuisance factor" (which includes enhanced defect visibility as well as poor readability due to glare) also increases with increasing gloss, presumably without leveling 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. Figure 9 shows how image chroma (of the saturated blue area from the business graphics images) varies with image gloss. The chroma increases with gloss and eventually levels off, as expected. There is a very large change in chroma over the gloss range, from about 50 CIELAB units at low gloss to about 80 CIELAB units at high gloss. The chroma change is smaller for the other colors, but still significant.

Chroma reduction at low gloss is due to "dilution" of the color by diffuse surface-reflected white light. Consequently, low lightness (L*) and high chroma (C*) colors, such as the saturated blue discussed here, are most affected.

The nuisance factor cannot be quantified as readily as the image chroma, but we speculate that it 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 (Fig. 6). Presumably the slope of the preferred image gloss for a given image is not limited to one of these two values and can vary depending on the image content.

Another factor to consider in the lower preferred gloss for business graphics images is the presence of sharp edges between solid areas and bare paper, which 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.

## 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 paper only, where the preferred gloss range is about 20–50 gu. These gloss values correspond to mean preferences at or above 80% of the peak preference.
3. The preferred image gloss increases slowly (1:10) with substrate gloss for the pictorial images, and more rapidly (1:2) for the business graphics images. The preferred image gloss values for the two types of images converge at high gloss. Substrate-matching 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 occurring near those gloss levels where chroma starts to level off.

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## References

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