Human Gloss Perception of Unprinted Inkjet Media

Cheryl Cheng, Michelle Oakland, and Douglas Bugner; Eastman Kodak Company; Rochester, NY/USA

Abstract

In an effort to better understand human gloss perception of unprinted inkjet media, a study was conducted to correlate psychophysical results with objective gloss measurements via a mathematical model. This study made use of currently available inkjet media samples covering a wide range of perceived gloss, including "matte" papers. Thirty observers ranked the unprinted samples in order of decreasing gloss. Concurrently, the samples were measured for various objective values, including specular gloss, distinctness of image (DOI), and haze. The results were used to calculate a metric for perceived gloss, known as the perceived gloss index (PGI).

Introduction

The overall goal of this study was to better understand the correlation between objective and subjective evaluations of gloss by determining which measured parameters best correspond to consumer perception. The cost and ease of tests were also considered. Several previous studies have dealt with the perception of gloss; however, the paper industry has shifted more towards coated papers, with a greater variety of gloss levels: matte, satin, semi-gloss, and super gloss. In addition to the changes in the media industry, new instruments and test methods have arisen that may be more useful in measuring the perception of gloss. To validate and expand on the conclusions of earlier studies, this study incorporated a larger number of coated samples, both porous and swellable papers, a larger range of gloss, and new equipment and techniques.

Background

In addition to color and other image quality characteristics, an important attribute of media is its perceived gloss. Although there are many "gloss" measurements, none of them singularly predict human perception. Common measurements are specular gloss, distinctness of image, haze, and angular dependence of reflection.

Specular gloss is often used as a value of gloss. The measurement is made where the angle of detection (from the normal) is equivalent to the angle of incidence [1]. This angle varies by measurement device; common angles are 20º, 60º, and 85º.

Another value important to inkjet media is distinctness of image (DOI) [2]. DOI is the sharpness, or distinctness, of a reflected image on the media surface. A high DOI is indicated by a clear reflection. It is calculated based on the specular gloss and the gloss measurement slightly off specular.

Haze indicates the spread of light around the specular. Typically, surfaces with low haze appear glossier, because the light is not spread over the surface. Haze is calculated by measuring the specular gloss as well as the light at an angle a few degrees from the specular.

The angular dependence of reflection is a plot of the reflectance measured as a function of angle. Both the angle of incidence and the angle of detection are varied. On a perfectly matte surface, the reflected light is constant, regardless of angle. However, a large amount of light at an angle of detection equal to the angle of incidence, along with low light at other angles, indicates a glossy surface. The plot for a semi-glossy surface would fall between these two.

In an unpublished internal study, a model was developed using specular gloss (20º) and DOI after a variety of these objective measurements were evaluated [3].

The scope of the study explained in this paper expanded on prior work. Because the market has tended towards coated papers, this study included coated papers not previously considered, which provided a better understanding for the formulation of new inkjet media. The objective was to create a model that would describe perceived gloss as a function of gloss measurements that are easily attained.

Design of Experiment

In order to compare measured gloss-related values to gloss perception, it was necessary to obtain and correlate objective measurements with psychophysical study results. The media selection, objective measurements, and psychophysical study design are discussed below.

Media

The selection of papers used in the study was based on a variety of factors, including production type, coating type, surface material, and preliminary 20º and 60º specular gloss measurements. In order to get a range of these factors, 38 media types were selected for this study. The chosen subset of media spanned a wide range of perceived gloss, from super glossy papers down to true matte papers (Table 1). The samples used in this study were all unprinted.

An issue to consider was the discrepancy between perceived gloss and a commonly used metric, specular gloss. One known instance of this is Canon Photo Paper Pro, which has relatively low specular gloss values but appears highly glossy to the average consumer. The reverse may occur as well; optical matte and satin papers are frequently perceived as low gloss, as expected, but they measure relatively high specular gloss values. Several media of this type were chosen as well.

Table 1: Media Samples

Manufacturer	Media
Canon	Glossy Photo Paper
Canon	High Gloss Photo Film
Canon	Photo Paper Plus Glossy
Canon	Photo Paper Pro
Epson	DURABrite Ink Glossy Photo Paper
Epson	Glossy Photo Paper

Epson	Premium Glossy Photo Paper
Felix Schoeller	Image Plus Pro Glossy
Felix Schoeller	UltraFoto Glossy
Ferrania	Optijet
FujiFilm	Premium Inkjet Paper Glossy
HP	Everyday Semi-Gloss
HP	Premium Glossy Photo Paper
HP	Premium Matte
HP	Premium Plus Matte
HP	Premium Plus Photo Paper Glossy
Ilford	Galerie Professional Inkjet Photo Range Smooth Gloss Paper
Ilford	Galerie Professional Inkjet Photo Range Smooth High Gloss Media
Ilford	Galerie Professional Inkjet Photo Range Smooth Multi-Use Paper
Ilford	Galerie Professional Inkjet Photo Range Smooth Pearl Paper
Ilford	Inkjet Photo Paper Heavyweight Semi-Matte
Ilford	Printasia Premium Photo Glossy Paper
Jet Print Photo	Multi-Project
Jet Print Photo	Portrait Studio Satin
Jet Print Photo	Professional Photo Paper
Kodak	KODAK Picture Paper
Kodak	KODAK Production Poly Poster Glossy / 7 mil
Kodak	KODAK Premium Picture Paper
Kodak	KODAK Premium White Film / 5 mil
Kodak	KODAK PROFESSIONAL Inkjet Photo Paper, Gloss Finish
Kodak	KODAK PROFESSIONAL Inkjet Photo Paper, Lustre Finish
Kodak	KODAK Ultima Picture Paper, Glossy
Kodak	KODAK Ultima Picture Paper, Satin
Konica	QP Photo Quality Inkjet Paper
Konica	QP Professional Photo Glossy
Office Max	Premium Glossy Photo Paper
Royal Brites	High Gloss Photo Paper
Royal Brites	Inkjet Glossy Paper

Objective Measurements

The objective measurements included in this study were

- Specular gloss at 20º, 30º, 60º, 85º
- Haze at 2º, 15º
- Distinctness of image (DOI)
- Angular dependence of reflectance

These measurements were taken in both the long (MD) and short (CD) directions for each sample, using three devices: a BYK-Gardner micro-TRI-gloss glossmeter (20º, 60º, 85º gloss), a Tricor Model 807A DOI/Haze Meter (30º gloss, 2º, 15º haze, DOI), and a Murakami goniospectrophotometer (angular dependence of reflectance). Each measurement on the glossmeter and hazemeter was taken three times and averaged; the measurements on the goniospectrophotometer were taken once each at incident angles ranging from –20º to 80º.

Psychophysical Study Stimuli

Prior experience with psychophysical testing had suggested that a study with 40 to 100 evaluations would be the most appropriate amount: fewer than 40 judgments would not be worth the time spent in judging the samples and more than 100 would be too tiring for the judges. With only 38 selected media types, many were duplicated to create nine test groups of seven samples each, for a total of 63 samples. A sample pool of this size was small enough to avoid placing strain on the participants but large enough for accurate statistical analysis.

The 38 media types were initially ranked in order of decreasing gloss, as perceived by the author. The first seven samples in this initial ranking comprised the first sample group (Group A). The second sample group (Group B) included the bottom samples from Group A as well as the next few in the initial ranking, and so on. Each sample group, A through I, overlapped with the preceding and/or following groups.

The samples were trimmed to 4" × 6", the typical size for a consumer print. These were then mounted on 5" × 7" gray foamcore to minimize any potential for bias based on factors such as manufacturer's backprint, stiffness or weight.

Participants

This gloss perception study was completed internally, with thirty participants selected as a representative of typical consumers. The group of volunteers provided a mix of males/females and glossy/matte-preferrers. The volunteers had no experience judging gloss, so they were not familiar with the visual characteristics related to typical gloss measurements. They were not vision-screened.

Psychophysical Study Setup

The study was completed at a viewing table with D5000 lighting. The participants were given one lettered group of seven samples at a time and asked to rank each group from most glossy to least glossy. They were not given a definition of gloss. They were allowed to view the samples at any angle, as a consumer would. They were instructed to ignore dust, scratches, and paper color. The order of the groups presented, as well as the samples within each group, was randomized for each individual.

Calculations for Perceived Data

The rankings from the psychophysical study were converted to just noticeable difference (JND) values using the methods described in ISO 20462 to reduce rank order data to paired comparison data and infer an interval scale of JND from the proportions matrix. Each group of seven samples was analyzed independently, and a list of JND values corresponding to each sample in the group was calculated. The JNDs of duplicate samples were expected to be similar; therefore, the JNDs within each group were shifted to match those of the repeated samples in the preceding group. The range was then adjusted so that the least glossy sample had a value of 0. The scale, however, was unchanged. The resulting values are referred to as the perceived gloss index (PGI) values.

Evaluation

As expected, directionality was negligible; it was not necessary to take measurements in both the long and short directions. For these models, only measurements taken in the long (MD) direction were used.

One model that was investigated used the previous recommendation of 20º specular gloss and DOI [3]. While this provided a decent model, it involved two different measurement instruments (glossmeter for 20º gloss, hazemeter for DOI). To simplify the testing necessary to support a given model, three more models were created; each used only the measurements taken by an individual instrument. Again, all three returned decent models, with the hazemeter and goniospectrophotometer providing better models than that obtained with the combination of 20º gloss and DOI measurements. Of these four models, the hazemeter provided the best model with relatively quick and cost-efficient measurements. To examine possible improvement to the model, the hazemeter measurements were combined with those of the glossmeter and then the goniospectrophotometer to create two new models. While this does improve the model somewhat, the improvement is not enough to warrant the additional cost of measurement.

Within the measurements taken by the hazemeter, the 30º specular gloss and 15º haze values exhibit a hyperbolic relation. Because one term can be used to calculate the other, only one is necessary for use in the model. For simplification purposes, the 15º haze value was dropped, resulting in the recommended model for determining consumer perception based on objective values.

Results and Verification

The recommended model uses only measurements made on the Tricor hazemeter.

$$\begin{aligned} PGI = {} & 5.013 + 0.00796\,(30º\ \text{gloss}) + 0.0261\,(DOI) \\ & - 0.0780\,(2º\ \text{haze}) + 0.00361\,(30º\ \text{gloss})\,(2º\ \text{haze}) \\ & + 0.000335\,(2º\ \text{haze})^2 \end{aligned} \quad (1)$$

As expected, the amount of perceived gloss increases with increasing specular gloss and DOI. With low specular gloss, perceived gloss decreases with increasing 2º haze, which is expected as well.

The hazemeter measurements are quick and easy to obtain, with the operator pressing one button and obtaining results in less than four seconds. In comparison, the goniospectrophotometer takes approximately fifteen minutes per sample. The slight correlation improvement does not warrant the time differential.

Figure 1 indicates the correlation between the PGI as determined by the psychophysical study and the best model for PGI using the recommended measurements.

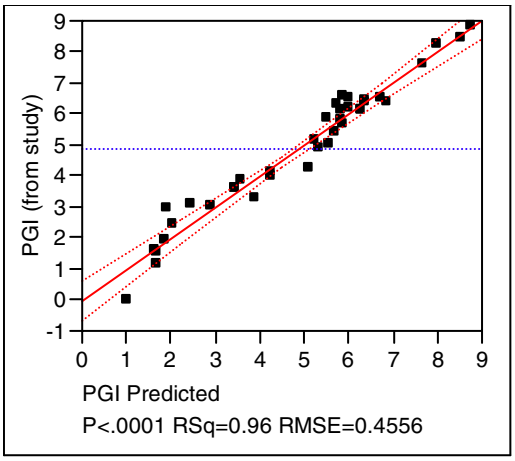

***Figure 1**. PGI vs. PGI predicted from recommended model*

An alternate model uses only measurements made on the Gardner glossmeter, which is more commonly available in testing labs than the Tricor hazemeter. Although the correlation for this model is not as high, it provides an adequate estimate for perceived gloss. This is shown in Figure 2.

$$\begin{aligned} PGI = {} & 0.317 + 0.280\,(20º\ \text{gloss}) - 0.00610\,(60º\ \text{gloss}) \\ & + 0.0230\,(85º\ \text{gloss}) \\ & - 0.00229\,(20º\ \text{gloss})\,(60º\ \text{gloss}) \end{aligned} \quad (2)$$

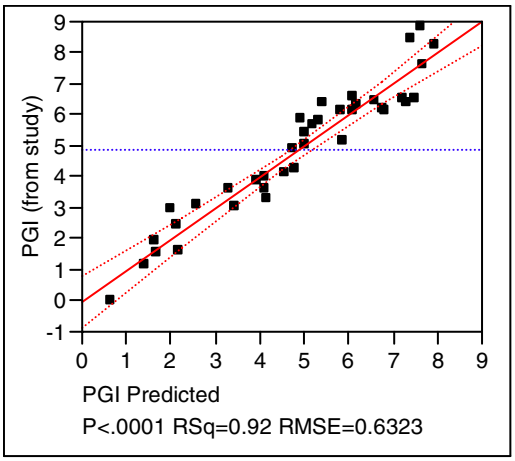

***Figure 2.** PGI vs. PGI predicted from alternate model*

For comparison purposes, Figures 3 and 4 indicate the relation between PGI and previously used gloss measurements: 20º specular gloss (Figure 3) and DOI (Figure 4).

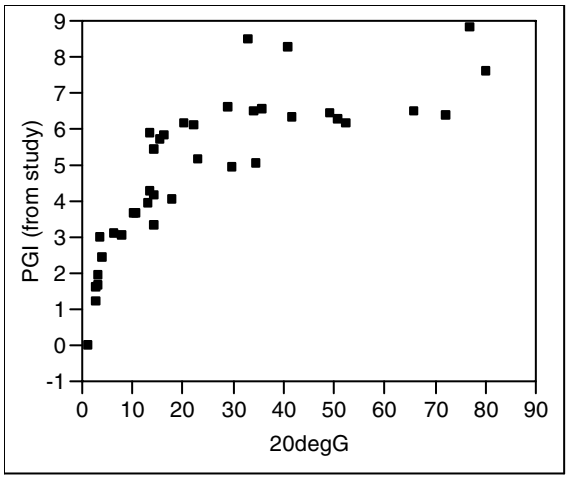

***Figure 3**. PGI vs. 20º Gardner gloss*

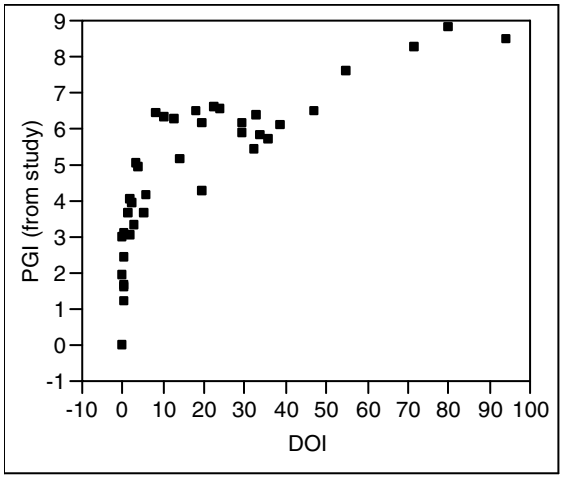

***Figure 4**. PGI vs. DOI*

The recommended model was then verified by judging papers not previously examined. Because a large portion of available media was included in the test set, most of the samples in verification are older, less common media. This sample of twenty media was ranked in terms of the authors' gloss perception. The recommended model values were measured on the hazemeter to calculate the PGI value for each media sample.

Of the twenty media tested, several samples did not fit the exact rankings as determined by these PGI calculations. However, those samples are off by less than 1–1.5 PGI, which is within the expected variability of the model (RMSE = 0.456). Therefore, this model can still be considered a good fit.

Conclusion and Future Work

The set of media used in this study ranges from very glossy to very non-glossy; the corresponding PGI values serve as a basis for determining the perceived gloss for unprinted samples. Gloss perception can best be modeled with values measured by the hazemeter: 30º specular gloss, distinctness of image, and 2º haze. These measurements can then be converted to PGIs and compared to the scale determined by the 38 tested media: 0 (very non-glossy) to 9 (very glossy).

Future work will expand on this study, looking into consumer gloss preference and acceptability, as well as printed gloss.

References

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Author Biography

Cheryl Cheng received her B.S.E. and M.S.E. degrees in chemical engineering from the University of Michigan. She is currently a Development Engineer at Eastman Kodak Company in Rochester, NY.