2011

Investigation into the perceived image quality of digital technologies for photofinishing

Susan Farnand

Franziska Frey

Mariela Rodriguez Adames

Investigation into the Perceived Image Quality of Digital Technologies for Photofinishing

By

Susan Farnand

Staff Scientist, Chester F. Carlson

Center for Imaging Science

Franziska Frey, Ph.D.

McGhee Distinguished Professor

School of Print Media

Mariela Rodriguez Adames

M.S. Graduate, School of Print Media

Rochester Institute of Technology

A Research Monograph of the

Printing Industry Center at RIT

No. PICRM-2011-04

R·I·T Printing Industry Center

An Alfred P. Sloan Foundation Center

Investigation into the Perceived Image Quality of Digital Technologies for Photofinishing

By

Susan Farnand
Staff Scientist, Chester F. Carlson Center for Imaging Science
Rochester Institute of Technology

Franziska Frey, Ph.D.
McGhee Distinguished Professor, School of Print Media
Rochester Institute of Technology

Mariela Rodriguez Adames
M.S. Graduate, School of Print Media
Rochester Institute of Technology

R·I·T Printing Industry Center
An Alfred P. Sloan Foundation Center

A Research Monograph of the
Printing Industry Center at RIT
Rochester, NY
February 2011

PICRM-2011-04

The research agenda of the Printing Industry Center at RIT and the publication of research findings are supported by the following organizations:

Table of Contents

Abstract

With the shift from silver halide film to pixels, the possibilities for photofinishing have burgeoned as well. Not much more than a decade ago, photography was a process involving the recording of images on film and the printing of these images on silver halide paper. Today the majority of images are now captured digitally, and though digital silver halide certainly remains an important player in the photofinishing market, a great many images are printed at home on ink jet printers. Images are also being printed in forms other than 4 x 6 in. prints. Electrophotographic printing technology is being used to generate photo books, cards, and calendars. In addition, wide-format ink jet and, eventually, high-speed ink jet, afford still other opportunities. It is of interest, then, to understand the perceptual image quality being achieved using the various printing technologies today.

The objective of this project is to evaluate the perceived image quality of ink jet and electrophotographic photo finishing relative to digital silver halide. Targets generated to resemble photo album pages, along with a variety of photo books, were used in this study. The observers for this project were selected to represent typical consumers rather than individuals who are more skilled in image evaluation.

The results indicate that: the observers generally found higher value in the full-size photo books and ink jet prints relative to the electrophotographic prints and the Pocket Portfolio mini photo book; that first-person images did not rank substantially differently from third-person images—at least for images that did not contain humans; and that the photo print format had a more significant impact on the assigned value than the image content.

Introduction

In 2007 and 2008, the Printing Industry Center sponsored investigations into the image quality gap between digital print technologies and offset lithography (Farnand, 2008; Farnand, 2009). The results of these investigations indicate that digital print engines can achieve a perceived level of image quality comparable to that of an offset press. These findings were in general agreement with those of Freedman, who demonstrated that higher-end digital printers such as the Kodak NexPress 2100 and the Xerox DocuColor 8000 can be set up to produce image quality comparable to that of offset lithography (Freedman, 2004; 2006a; 2006b). The results of the 2007 and 2008 Printing Industry Center work also suggest that, in selecting a printing technology, the question of quantity rather than quality should likely be the driving concern and that, if high quality images are required, attention would best be paid to the media rather than the printing technology.

The increase in image quality has allowed digital printers to penetrate markets previously closed to electrophotographic printers. The capability of printing "one-off" images has allowed the market for items such as photo calendars and digital photo books to develop. Intuitively, it seems that the representation of an image as part of a book or a photo album page, rather than a 5 x 7 in. print, may add to the perceived value of that individual image. It was the objective of this study to determine if this was indeed the case and to develop increased understanding of the factors involved.

Background

In addition to the work conducted for the Printing Industry Center, considerable work has been conducted in industry as well as academia to evaluate the image quality of digital imagery (Swanson, 2000; Gast & Tse, 2001; Shaw, 1997; International Committee for Information Technology Standards, 2004; ISO 20462; Chung & Rees, 2006a; Chung & Rees, 2006b; Xu & Kellogg, 2007). Much of this work focused on evaluation of specific image characteristics that have individually been shown to relate to visual image quality, including factors such as solid area density, uniformity, tone scale, resolution, artifacts, and colorimetric values. Certainly, an understanding of specific image characteristics is crucial for monitoring image quality and generating useful and marketable imaging products. It also is of interest to evaluate overall perceived image quality and to have an understanding of the perceived relative value of image products. This study involved just such an evaluation.

A related study was undertaken by Phillips in 2008 in which the objective was to understand the image quality of pictorial imagery in on-line digital books (Phillips, Bajorski, Burns, Fredericks & Rosen, 2010). The stimuli for this work were collected from self-publishing websites. The results showed a close relationship between the price of the book and its perceived quality, with one exception. One vendor, which produced a book that was perceived as having somewhat lower quality (though not the lowest of the books used in the study), had a price point that was significantly lower than the other vendors included in the testing. Phillips referred to the price as "game-changing". This would indicate that the price of products can not necessarily be used directly as a measure of perceived quality.

The stimuli for the present study were acquired from photofinishing websites as opposed to the self-publishing websites investigated in the Phillips study. The prices paid for the photo books in this study were comparable and considerably lower than at book publishing sites.

Experimental Methodology

This research involved conducting psychometric experimentation with stimuli consisting of prints of selected images created on digital silver halide, consumer ink jet, wide-format ink jet, and electrophotographic equipment. The first step in this process was to identify the images to be included. In this research, two image sets were used. One image set consisted of images created by two of the authors. These will be referred to as the "third person" image set. This set includes images representative of various typical consumer photographs such as children, vacation pictures, wedding pictures, and natural scenery. The other set was generated by collecting one image from each of the students in an undergraduate Digital Asset Management course in the School of Print Media at Rochester Institute of Technology (RIT). Again, an effort was made to select a variety of images to best represent the types of pictorials seen in consumer photography. This set of images will be referred to as the "first person" set, since these images were used when the students in the course served as observers and were, consequently, seeing their own images.

With the image set established, prints made on digital silver halide, ink jet, and high-end electrophotographic equipment were collected. The digital silver halide and wide-format ink jet images were purchased from the Photo Processing lab at RIT. These came in the form of 5 x 7 in. (14 x 19.6 cm) photographic prints. The ink jet images were generated on equipment available in the Image Products Lab at RIT. This included three printers—a Kodak, a Canon, and a Hewlett-Packard. The electrophotographic images were made on the Kodak NexPress in the Printing Applications Laboratory at RIT. For the electrophotographic and consumer ink jet photo album pages, two 5 x 7 in. pictures were placed on an 8.5 x 11 in. (23.8 x 30.8 cm) page with a white background. The photo books were purchased from Shutterfly, Snapfish, Kodak Gallery, and Lulu. For the full-size books, which had a format of approximately 6 x 9 in. (16.8 x 25.2 cm), one image was placed on each page. This resulted in images that were similar to the 5 x 7 in. format used for the silver halide, ink jet, and electrophotographic prints. At each of the three websites, a simple white background with a drop shadow border was selected. The books were dark gray or black hardcovers with windowed covers so that one image is seen on the front. At one site, the Pocket Portfolio format was selected. This is a soft-cover, saddle-stitched book containing full-bleed images about the size of a typical business card. All of the photo books were printed using electrophotographic equipment. Examples of the images used are shown in Figure 1.

Third-person image set

First-person image set

Figure 1. The image sets used in the study

Psychophysical experimentation was conducted with the collected prints to examine the effect or impact of the image and format differences on perceived quality among the prints created using the different technologies. To evaluate this question of impact, the observers were questioned regarding what they would be willing to pay for a given print set. The observers were shown two 5 x 7 in. prints made using digital silver halide technology as a reference. The observers were then shown the matching pair of prints for each of the other photofinishing technologies in random order. The book prints were shown as a two-page spread. The electrophotographic and ink jet prints were shown as a single print that was intended to represent a photo album page. The wide-format ink jet prints were shown as two 5 x 7 in. prints. All of the images were approximately 5 x 7 in. in size, with the exception of the Pocket Portfolio photo book, which was about the size a typical business card.

The participants were shown the prints in sets by image pair as shown in Figure 2. For each set, the prints made using digital silver halide technology served as the reference. The observers were told that they paid $1.50 for the reference pair of prints and were asked to determine the relative monetary value for each of the test prints. If they believed that the quality of a given test print increased enough that it would justify paying more for the document, they were asked to specify how much more they would be willing to pay. If it was slightly better than the reference print, for example, they might assign a value of $1.55. If the quality of the print decreased enough that they felt the photos would not be worth as much the reference pair, they were asked to specify how much less they would be willing to pay. For example, if they thought it was much worse, they could give it a value of $0.35. If they felt that the quality was essentially comparable—even if the prints looked quite different—they were instructed to give the same $1.50 value as the reference. They were told that they could assign any value that they wished, given that the reference prints had a value of $1.50.

Figure 2. The experimental setup used in the study

To keep the testing time manageable, each participant evaluated 3-5 image pairs. The image pairs and print sets were presented in random order, though the image pairs were selected for the "first person" set to ensure that each participant saw their own image. When the scaling of the test prints was completed, the participants were questioned regarding their decision criteria. Special attention was given to the format of the prints. The experiment was conducted under simulated D65 lighting conditions.

Primarily naïve observers were surveyed. The observers seeing the 'third-person' image set included eight students (three males and five females) from a graduate print workflow class, as well as 13 Print Manufacturers Association (PMA) 2010 trade show attendees (nine males and four females), and 15 participants in the 2010 Imagine RIT Innovation Festival (seven males and eight females). Twenty students (eight males and 12 females) from an undergraduate Digital Asset Management class evaluated the 'first-person' image set, which included the photos taken by the participating students. There was a total of 56 participants (28 males and 28 females). Most, though not all, were in their early twenties.

Results and Discussion

The experimental results are summarized in the chart in Figure 3, which shows the average value assigned, in cents, to each photo print format by each of the general groups of observers: PMA attendees, Imagine RIT Festival attendees, graduate students, and undergraduate students. For example, the Imagine RIT attendees assigned an average value of $1.50 to the wide-format ink jet prints (WFIJ), while the PMA attendees assigned an average value of $2.00 to the second photo book (Book2) prints. A few points are evident from the data depicted in this chart. First, observers generally rated the full-size photo books and ink jet prints higher and the Pocket Portfolio and electrophotographic prints lower. In evaluating this phenomenon, it is helpful to distinguish between the undergraduate student group and the other observers. As a group, the graduate, PMA, and Imagine RIT observers tended to rate the full-size photo books higher than the reference ($1.64, $1.91, and $1.60, on average, for Book1, 2, and 3, respectively). These observers tended to rate the Pocket Portfolio (Mini-book, $1.18), the electrophotographic prints (EP1 and 2, $0.89 and $0.99 respectively), and the first and third set of ink jet prints (IJ1 and 3, $1.34 each) lower than the reference value. The second set of ink jet prints (IJ2) and the wide-format ink jet prints were both scaled at about the same value as the reference ($1.57 and $1.53, respectively). The group of undergraduate observers rated the test prints significantly higher than the other observers. However, the trends among the photo print formats were similar for this group: the Pocket Portfolio received the lowest ratings ($1.27), followed by the electrophotographic prints, which received ratings essentially the same as the reference value ($1.50 and $1.46, respectively), and the full-size photo books and ink jet prints received values higher than the reference (approximately $2.10).

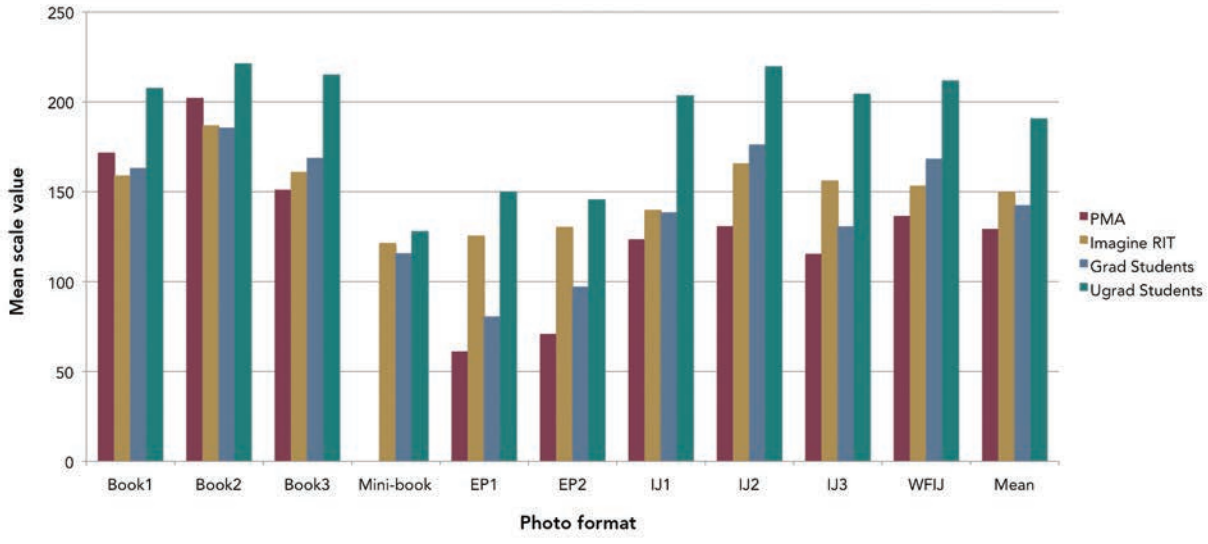

Figure 3. The mean scale values assigned to each photo print format in cents by group of observers

The graph in Figure 3 also provides information regarding the relative perception of quality for the observer groups. The undergraduate students typically assigned higher values to the prints than the other groups of observers, although all observers seemed to agree that the Pocket Portfolio prints were worth about $1.22. (There is no data for the PMA observers for this format because the author was introduced to it at the PMA tradeshow.) The remaining groups of observers were generally in agreement with one another, with a few exceptions. The Imagine RIT Festival attendees tended to assign higher values to the electrophotographic prints and the third set of ink jet prints (IJ3) than the other two groups of observers (PMA and graduate students), and the PMA group tended to assign lower values to the electrophotographic prints and the second set of ink jet prints (IJ2) than the other two groups.

The average value assigned by the individual observers participating in the study to the image pairs that they viewed is shown in Figure 4. The observers viewing the third-person set of images tended to average about $1.30-1.40 in their ratings, with a few exceptions. The observers viewing the first-person set tended to average about $1.50-1.70, with about five each significantly higher and lower and two very significantly higher. As was noted previously, the observers viewing the first-person set generally assigned higher values to the images than those viewing the third-person image set. It was of interest to determine if it was the difference in images or the difference in the observers that was driving this increase in assigned values.

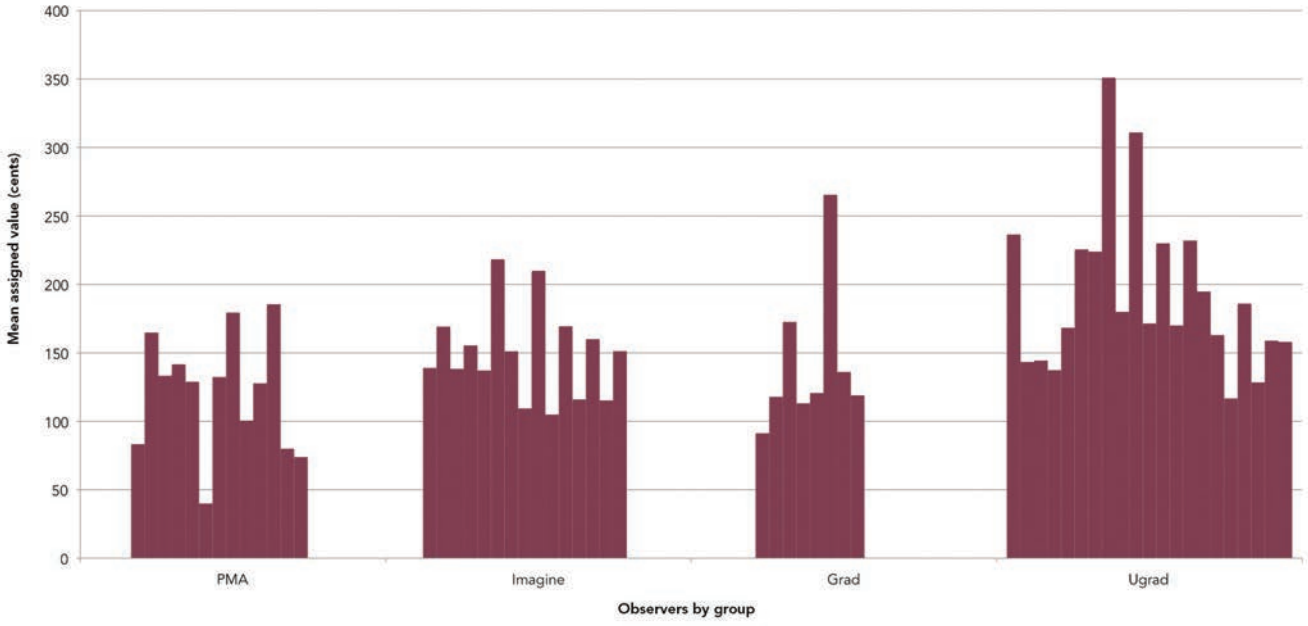

Figure 4. The average value assigned to the test images for the individual observers by group

To better understand this phenomenon, the mean values assigned by the undergraduate students to the image pair containing their image relative to the mean values assigned to the other image pairs were compared (see Figure 5). It is evident from the data in

this graph that there was generally not a significant difference between the average value assigned to the image pair containing their own print and the other image pairs. Only two observers rated "their" image pair significantly different from the others: Observers 2 and 7. In both cases, the observers rated their image pair lower, on average, then the others, and in both cases the first-person image contained humans: "Girl" for Observer 2 and "Trio" for Observer 7 (shown in the bottom row of the first-person image set in Figure 1). There was one other image containing humans, "TV" (also shown in the bottom row of the first-person image set in Figure 1). In this image, however, the people are not facing the camera. The observer who took this image, Observer 17, did not rate the image pair containing his photograph much differently than the other image pairs in Figure 5. It is possible that observers may be more discriminating when their images contain humans, especially human faces. It is also possible that the digital silver halide images provided a more pleasing rendering of images containing humans than the other photo print formats. The sample size in this experiment is much too small to provide evidence even for a general trend. This does seem, however, to be an interesting point to explore in further work.

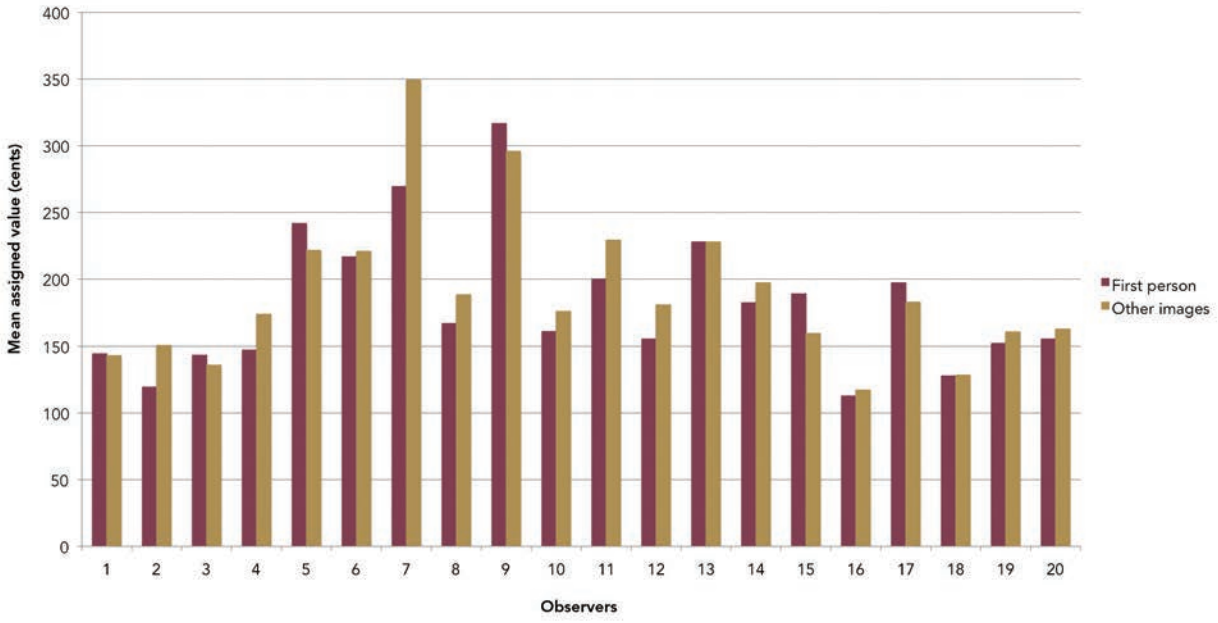

Figure 5. The mean value assigned to the image pair containing the first-person image relative to the mean value assigned to the other image pairs for each observer viewing the first-person image set

In any case, the generally higher values for the undergraduates relative to the other observers were likely not driven by the fact that the image set contained first-person images. This difference may have been the result of the undergraduates being younger than the other observers and (possibly) less experienced in image analysis than the other observers when compared to the PMA attendees and the graduate students. It is also possible that the difference was driven by a difference in the composition quality of the images. The first-person image set was created by 20 different photographers

and exhibited a range of quality. Finally, it is possible that the first-person image set contained more images that the digital silver halide process simply did not render as well as those in the third-person set. For example, this was certainly true for the "Leaves" image.

Figures 6 and 7 show the mean assigned value for each individual image pair, averaged across the photo print formats for the third-person and first-person image sets, respectively. Relative to the data in Figure 3, these figures indicate that the photo print format has a more significant impact on the assigned value than the image content. For the third-person data, only the "Babies" images were assigned a value significantly different—and in this case lower than—the mean assigned value. The "Babies" images were both indoor images of young children, and the skin tones in these images were very difficult to render in a pleasing way. The digital silver halide images were preferred over any of the other technologies; all mean assigned values for other print formats were significantly below $1.50 (see Figure 8).

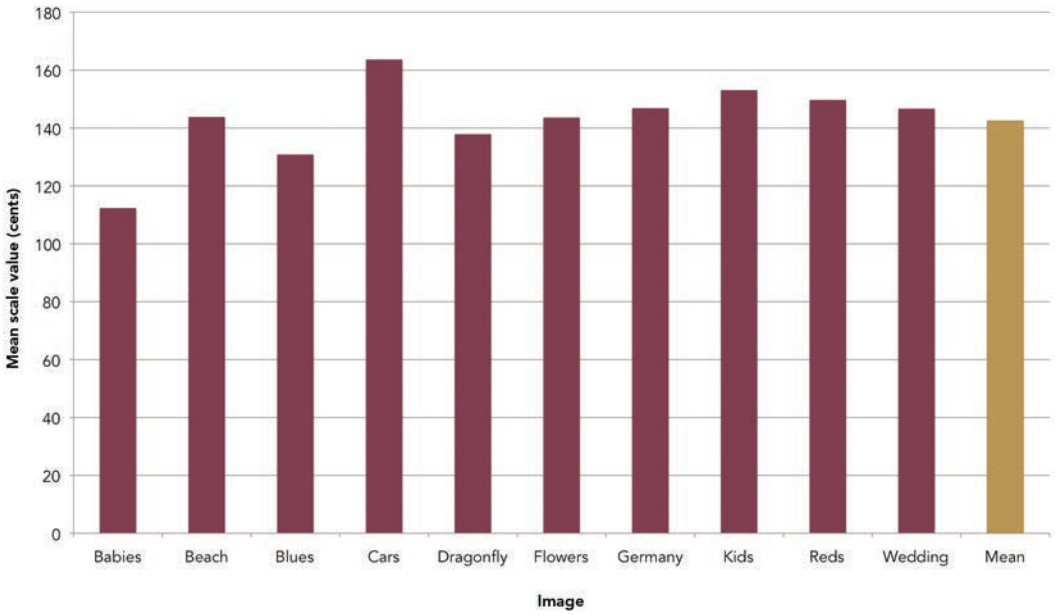

Figure 6. The mean scale value assigned to the photo prints for each of the individual image pairs for the third-person image sets

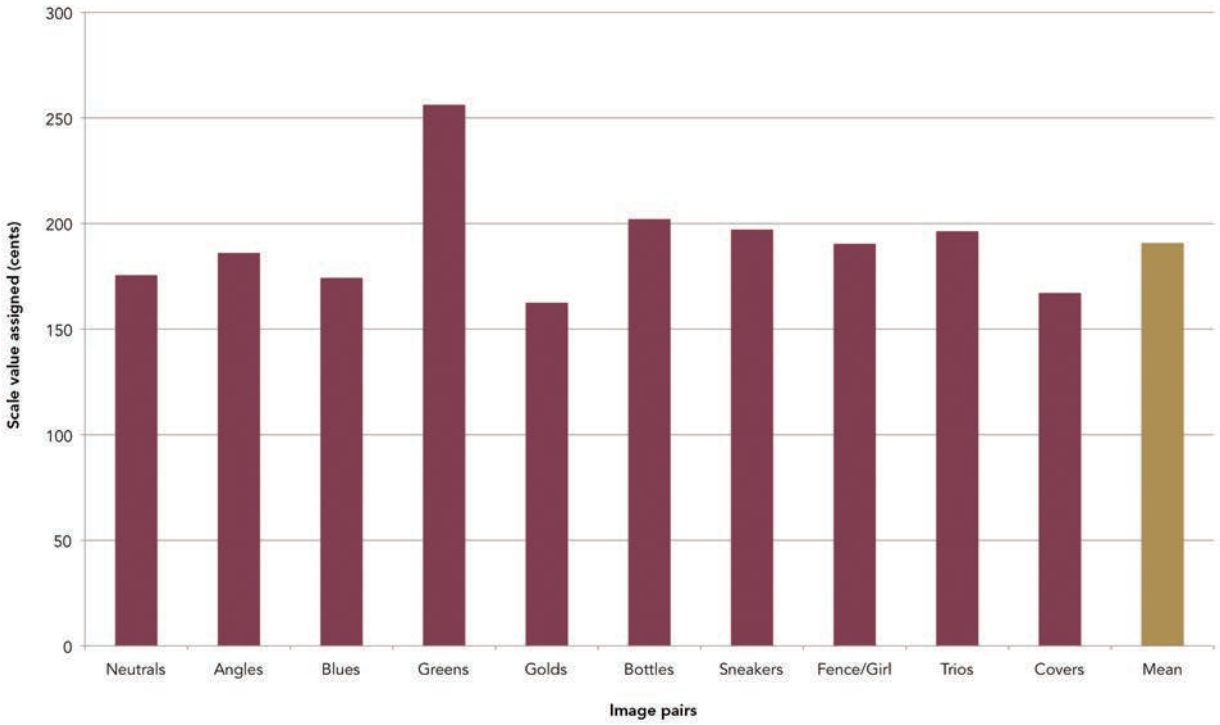

Figure 7. The mean scale value assigned to the photo prints for each of the individual image pairs for the first-person image sets

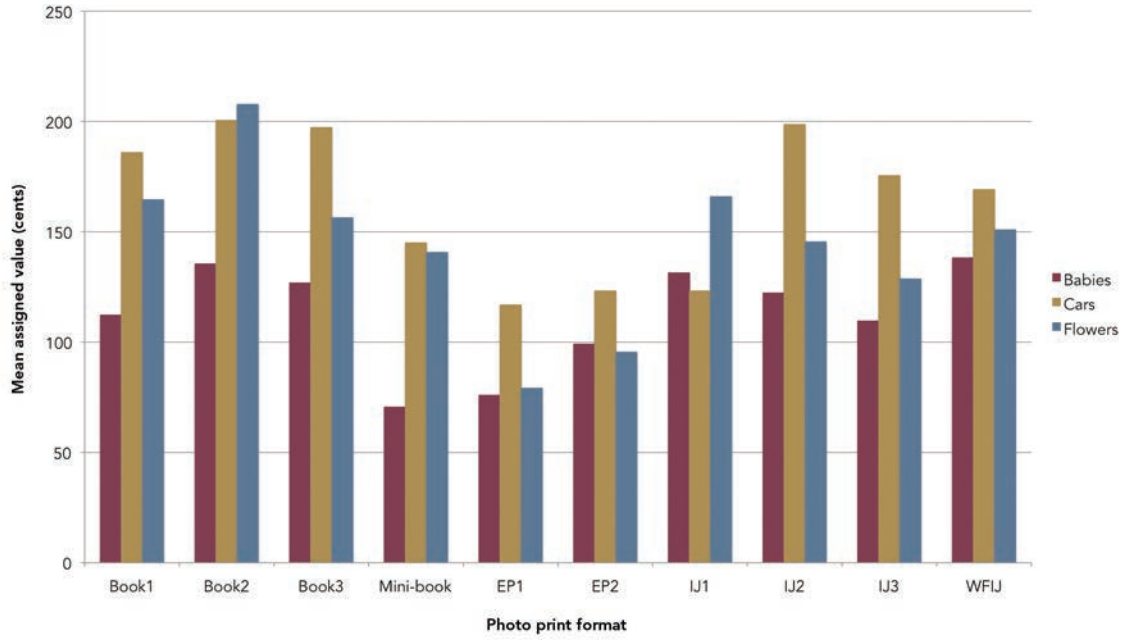

Figure 8. The mean assigned value for the "Babies," "Cars," and "Flowers" image pairs for each of the photo print formats

The "Cars" image pair generally received the highest ratings, though they were not significantly higher than the mean (see Figures 6 and 8). The results for the "Flowers" image, which were about average, are shown in Figure 8 for comparison. The "Cars" image pair included an image of a shiny, red car and an image of a black car in neutral surroundings. The red of the car in the digital silver halide print was somewhat more yellowish than in other renditions, while the neutrals in the image of the black car were somewhat cyan, as is evident in plots of the colorimetric values for the fender of the red car and a gray area of the black car (see Figures 9 and 10). The colorimetric measurements were made with an EyeOne spectrophotometer using a black backing. The data in Figure 8 show that the "Cars" image pair was assigned values higher than the reference for the full-sized photo books and most of the ink jet prints. The Pocket Portfolio received an average assigned value equivalent to the reference, while the electrophotographic prints and the first set of ink jet prints (IJ1) received values significantly lower than the reference. The neutrals for the IJ1 prints were quite green (see datapoint (-8, 8) in Figure 10). Figure 12 shows the gray and red for the digital silver halide print (center column, rows 2 and 3, respectively) relative to colors measured for images preferred over the digital silver halide print (Column 1), and rated lower than the digital silver halide print (Column 3).

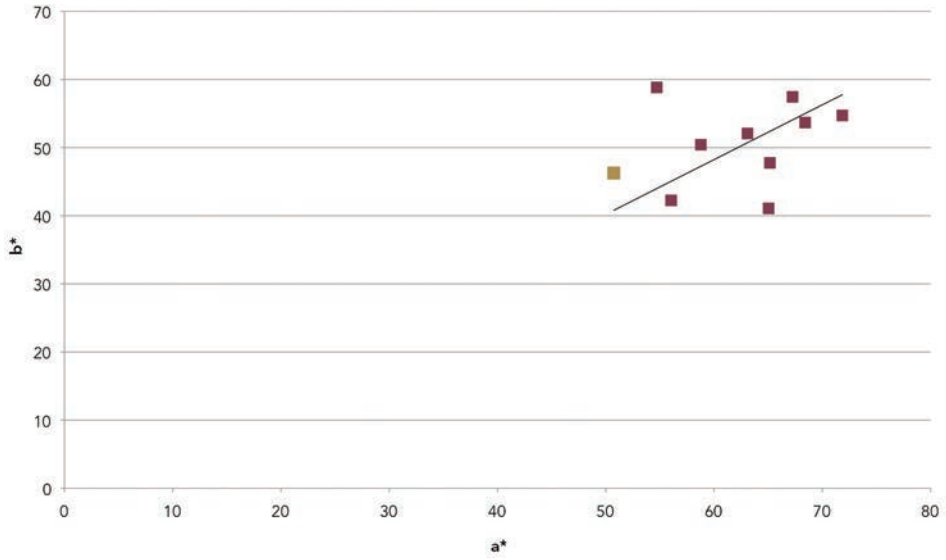

Figure 9. CIELAB colorimetric data for the fender in the red car image of the "Cars" image pair*

* The datapoint for the digital silver halide print is shown in gold on each graph.

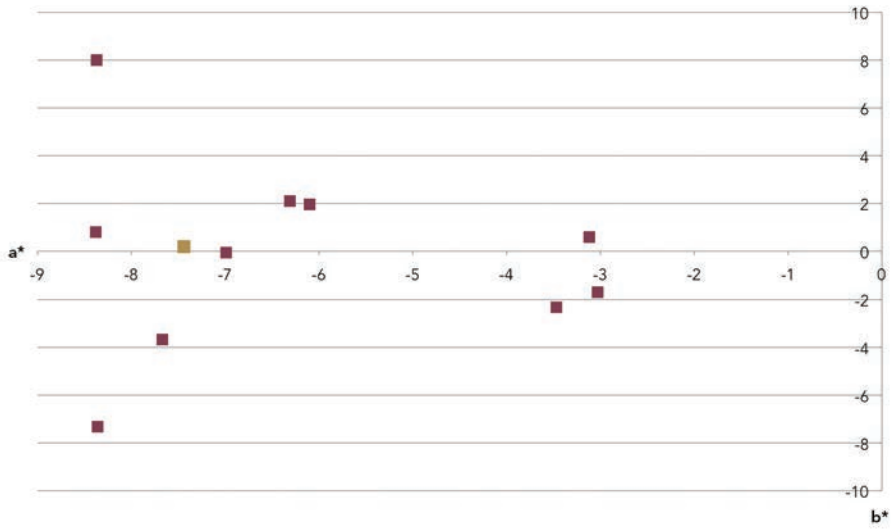

Figure 10. CIELAB colorimetric data for a neutral area of the black car image of the "Cars" image pair*

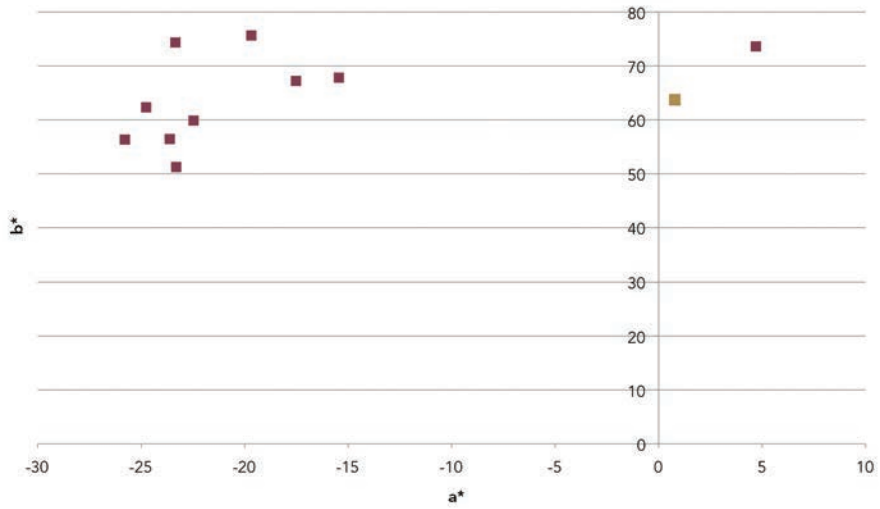

Figure 11. CIELAB colorimetric data for a central area of the leaves image of the "Greens" image pair*

* The datapoint for the digital silver halide print is shown in gold on each graph.

Figure 12. Colors as measured on the leaves image of the "Greens" image pair and the black car and red car images of the "Cars" image pair**

As with the third-person set, most of the image pairs in the first-person set were rated similarly. Only the "Greens" image pair—one of which depicts some large, green leaves and the other a waterfall—was rated significantly higher than the reference. The digital silver halide image of the leaves was considerably more yellow than all but one of the other renderings, as is evident in Figure 11 (see also the top center patch of Figure 12). The observers evidently preferred the greener rendering of the leaves.

For the first-person set, the "Golds" images had the lowest mean ratings. For this image pair, the full-size book prints did not rate as highly as they did for most of the other image pairs. This is shown in Figure 13 by comparing the ratings for the "Golds" images with the "Fence and Girl" image pair, which was the pair most representative of the mean ratings. (There is also a similar difference for the wide-format ink jet prints; however, in this one format the "Fence and Girl" image pair was significantly above the mean, while the "Golds" image pair that was more representative of the mean.) This may have occurred because one of the "Golds" images was an image of water in a headlight (see the third column of the third row of the first-person image set shown in Figure 1), the relative appearance of which may have benefited from glossier paper.

**The top row shows an area of the leaf from IJ2 (left), digital silver halide (center), and Book4 (right) prints. The middle row shows a gray from Book2 (left), digital silver halide (center), and IJ1 (right) prints. The bottom row shows a red from Book3 (left), digital silver halide (center), and EP1 (right) prints.

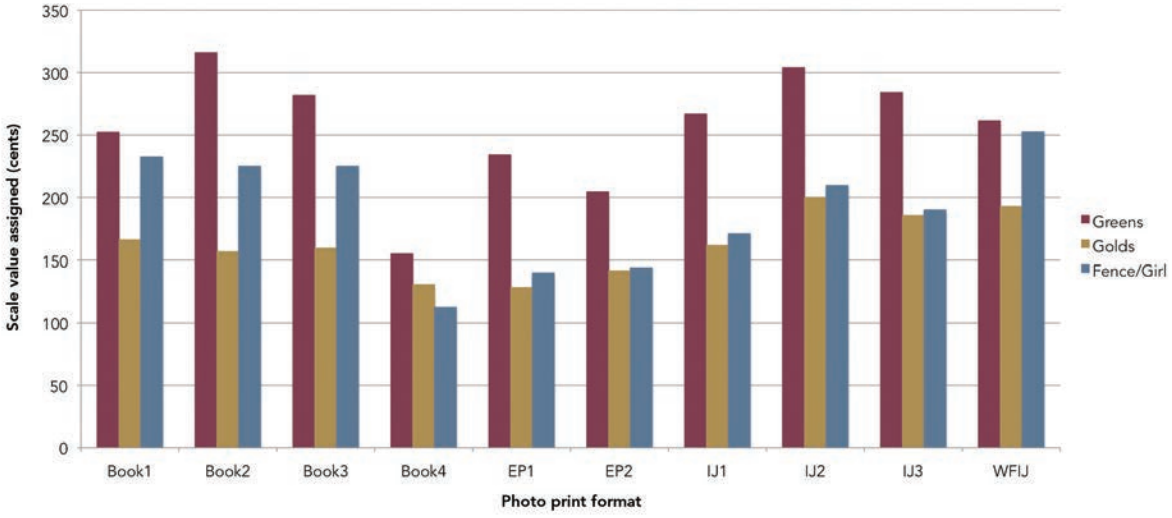

Figure 13. The mean assigned value for the "Greens," "Golds," and "Fence and Girl" image pairs for each photo print format

The substrate is a key factor for image quality. In previous Printing Industry Center studies, it was found that the choice of substrate could have a larger influence over apparent image quality than the choice of high-end printing technology (Farnand, 2008; Farnand, 2009). In this study, 20 of the 43 observers identifying particular characteristics that influenced their image quality decisions cited the paper quality as a key factor. However, the substrate in this study could not be made a constant because many of the prints were purchased from commercial websites. For the ink-jet prints, the paper recommended for each printer was used. The electrophotographic prints were made on Chorus Art 80 lb Silk Text. To better understand the differences among these papers that might impact the apparent quality of the prints, measurements of the papers were made. Colorimetric measurements, made with an Eye-One spectrophotometer using a black backing, are shown in Figures 14, 15, 16, and 17.

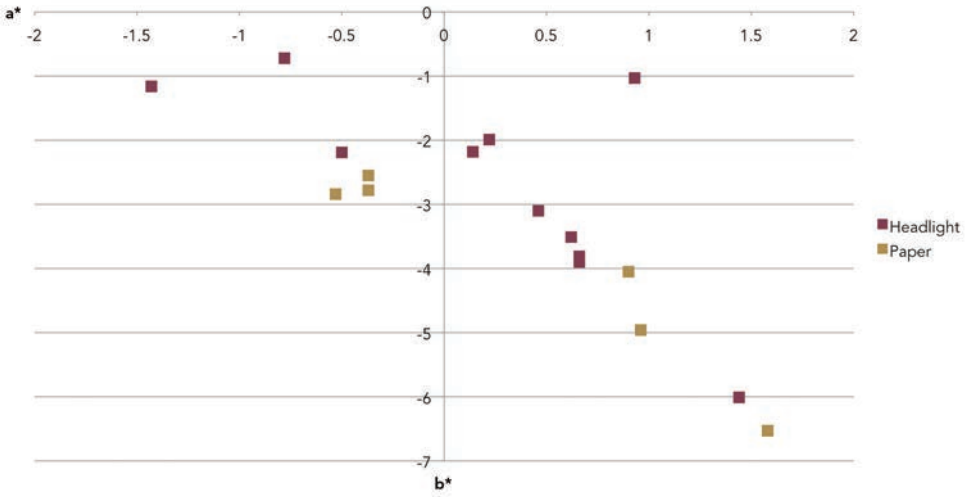

Figure 14. CIELAB a* and b* colorimetric data for white areas of the first-person image sets, where available

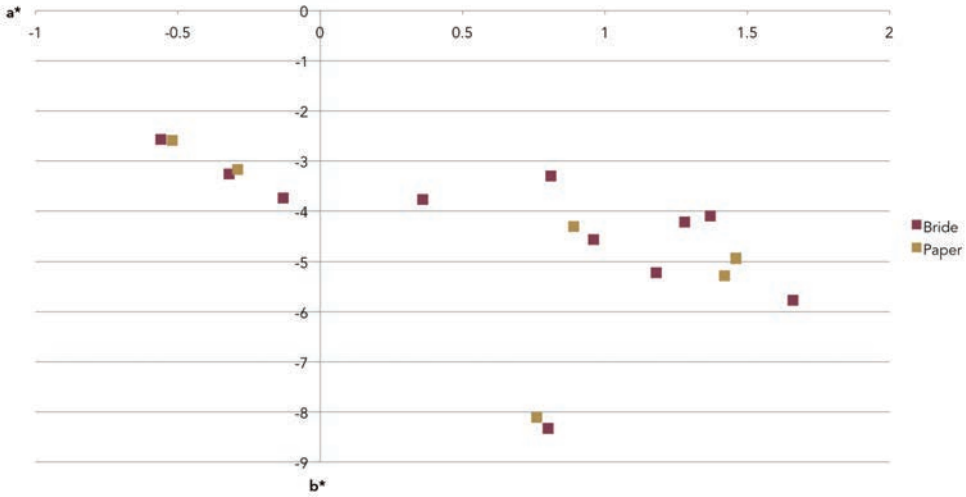

Figure 15. CIELAB a* and b* colorimetric data for white areas of the third-person image sets, where available

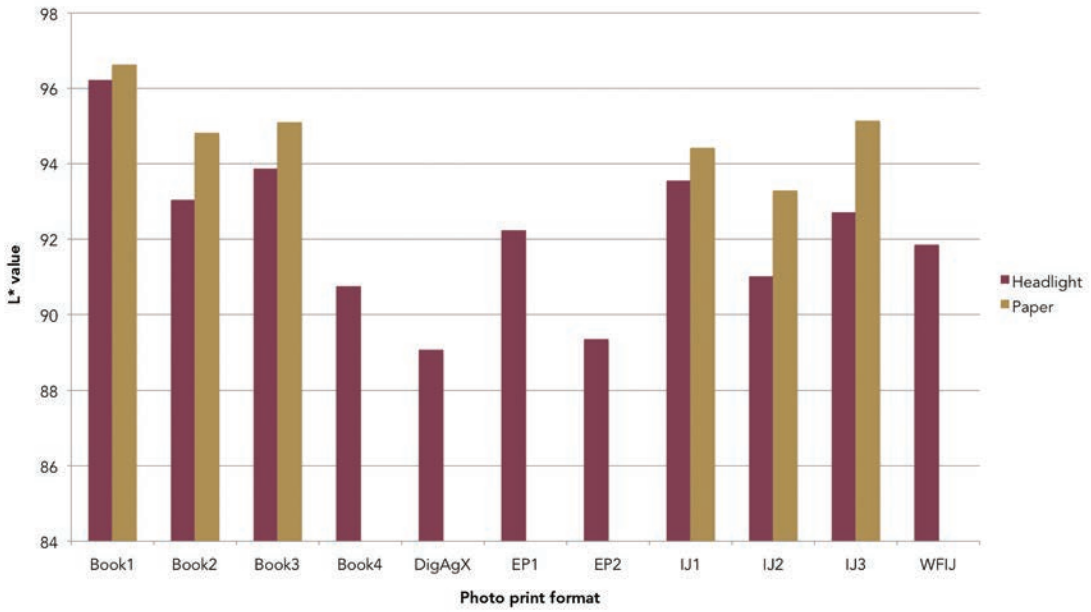

Figure 16. CIELAB L* colorimetric data for white areas of the first-person image sets, where available

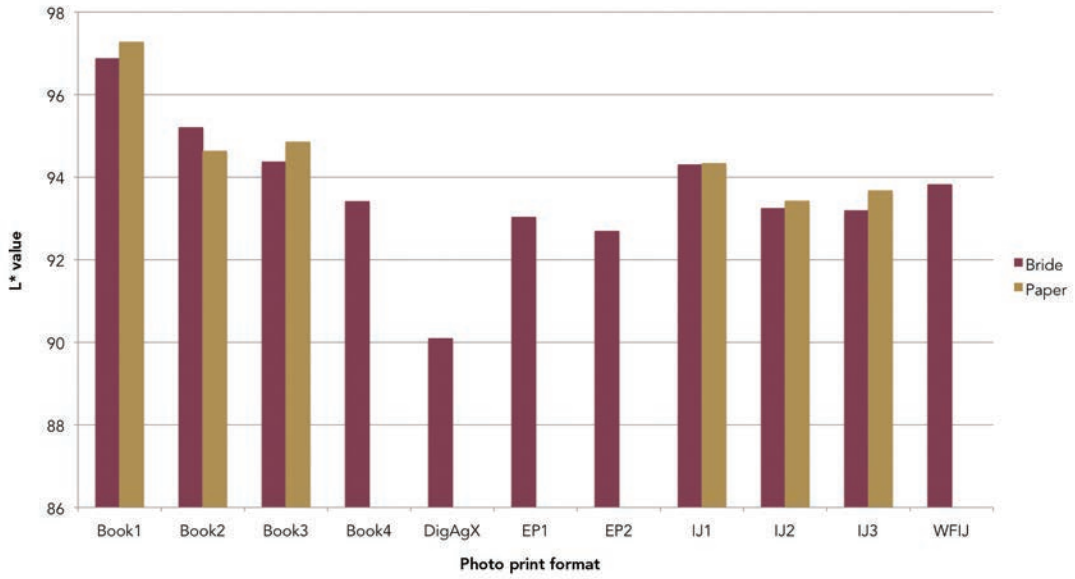

Figure 17. CIELAB L* colorimetric data for white areas of the third-person image sets, where available

The axes in Figures 14 and 15 represent the reddish- greenish (a^*) and yellowish-bluish (b^*) components of the measured colors. Figures 16 and 17 show the L^* (lightness) values. Figures 14 and 16 show the values for the first-person set. Measurements were made on a specified area of the "Headlight" image that was consistently the whitest and on the paper itself, where available. Figures 15 and 17 show the values for the third-person image set. In this case, measurements were made on a specified area of the "Bride" image that was most consistently white, as well as the paper itself, where available. The measurements indicate that the paper used for full-size photo books tended to be slightly bluer than other papers. The data points for these books in Figures 14 and 15 are clustered in the area of about an a^* value of about 1 and a b^* value of -4 to -5. A color having a positive a^* value and a negative b^* value would be reddish-bluish. In this case, the relatively small values would indicate that the papers had a slight violet-blue tinge. This makes sense because studies have indicated that people prefer a slightly bluish white (Judd, MacAdam & Wyszecki, 1964). To achieve a preferred white, most papers used in printing use optical brighteners (Axiphos GmbH, 2001). The bluest papers in the study were those used for Book1 in the first-person set, which had an a^* value of 1.4 and a b^* value of -6, and the IJ3 print paper in the third-person set, which had a^* and b^* values of about .5 and -8, respectively. These prints were not rated significantly different from others of the same format, indicating that the paper whites were not different enough to have an appreciable effect on the quality ratings assigned.

Figures 16 and 17 show the L^* information, which is a measure of lightness, for each of the print formats. Higher numbers represent higher lightness. The Book1 paper, then, had the highest lightness of the papers used in the experiment. While it could not be measured directly, it appears from the measurements made in the "Bride" and "Headlight" images that the digital silver halide paper had the lowest lightness level. The data depicted in these graphs suggest that the measurements made in the "Bride" image were statistically indistinguishable from those made on the bare paper itself and, consequently, may be used as a reasonable estimation of the lightness of the paper when no margin areas are present. In contrast, the white area measured in the "Headlight" image was consistently lower in lightness than the bare paper, though not always statistically so. The higher lightness level for the full-size photo books (especially Book1) and the lower lightness level for the digital silver halide prints may have impacted the relative perceived quality of the images in these formats. This is especially true for images like those in the "Cars" and "Wedding" image pairs, which may have been positively impacted by the higher lightness level, as well as the "Babies" images, which may have been negatively impacted. While the lightness and color of the paper may have contributed to the relative perception of quality, it was likely not a dominant factor. This is so because the Book1 and digital silver halide prints were never at opposite ends of the rating scale (though for the "Babies" images, it was close).

Gloss may have had a more significant impact. The gloss measurements, made with a Color Control Systems glossmeter, are shown in Figures 18 and 19. As is evident from this data, the papers used for the prints in this experimentation exhibit a wide range of gloss values. Also, as with the colorimetric measurements, the measurements made

in margin areas where no image is present are generally not statistically different from those made in image areas, indicating that the image area measurements can serve as reasonable approximations of the gloss value of the paper when a margin area is unavailable. The wide range of gloss values for the papers used for the different print formats is generally not reflected within format type, such as ink jet or full-size book. The relatively high gloss values of the ink jet prints, however, could serve as a partial explanation to the significant difference in perceived quality between the ink jet prints and electrophotographic prints, which both used a two-photo format. To properly characterize this effect, further testing with controlled substrates would be required.

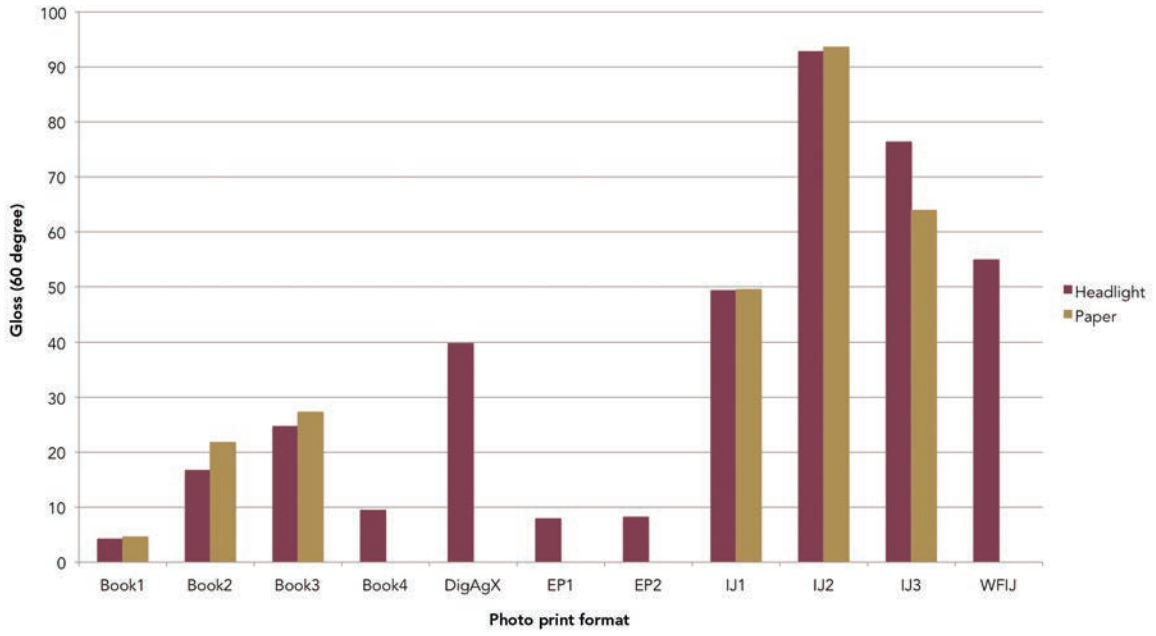

Figure 18. Gloss data for white areas of the first-person image sets and the paper white, where available

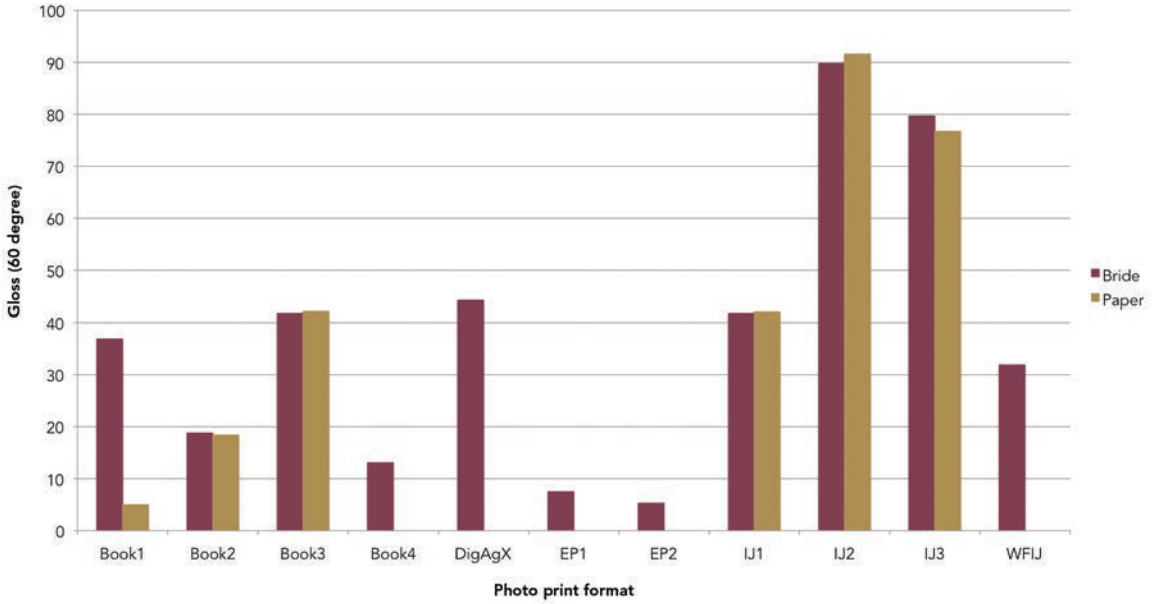

Figure 19. Gloss data for white areas of the third-person image sets and the paper white, where available

The gloss data suggests that gloss was an important factor in image quality assessment. The observers' qualitative assessments support this data. After completing the print ratings, the observers in the study were asked to comment on the print characteristics that influenced their quality ratings. The resulting data are shown in Figure 20. Twenty of the 43 observers identifying particular characteristics that influenced their image quality decisions cited the quality of the paper or the gloss level as something that mattered most in making their quality assessments. This was an especially important characteristic for the graduate group of observers. This group also cited sharpness and color as factors of interest. Indeed, color was a key characteristic for all of the observers. The color of the prints was the characteristic most often identified as important in quality decisions, with 30 observers mentioning this attribute. It was also an especially dominating factor for the undergraduate group of observers, with 17 of 20 observers mentioning color.

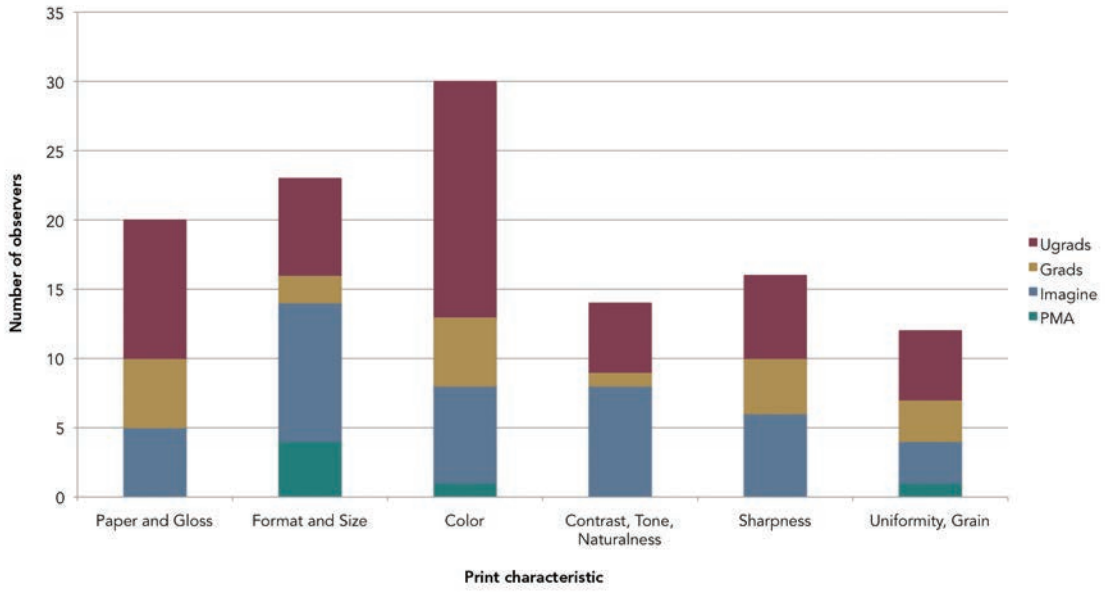

Figure 20. Number of observers citing various print characteristics as important in their ratings of print quality

After color, the print attribute most often identified as important in quality decisions was format, including print size. Format had a particular influence for the Imagine RIT Festival attendees, with two-thirds of these observers considering it important. Of the 23 observers citing format, nine commented that they preferred the full-size books, one liked the photo-album-style pages with two images per page, and, though several observers stated that they felt that the small size of the Pocket Portfolio correlated to lower value, one was enthusiastic about this format, remarking that she liked the portability of this mini-book. This qualitative data generally reflects the quantitative data shown in Figure 3, though from this data, it might be expected that more observers would have identified the two-photo album page format as preferable. It is possible that the electrophotographic prints reduced the number of people identifying this format as their favorite. It is also possible that observers did not have a specific appreciation for the consumer ink jet pages, although they liked the quality of these images.

Conclusion

As has been the case in past Printing Industry Center studies examining digital versus offset printing, it is important to remember that prints used as stimuli in this experiment were made on a limited set of machines. Different results may be obtained using different equipment or even the same equipment run by different people or on different days. Making definitive statements based on this data would not be prudent; however, a few general statements of relative perceived quality may be made. In this study, it was found that observers generally assigned higher values to the full-size photo books and ink jet prints relative to the electrophotographic prints and the Pocket Portfolio mini photo book. The ink jet prints may have ranked significantly above the electrophotographic prints due to the heavier weight and the substantially higher gloss of the substrates.

The group of undergraduate observers rated the test prints significantly higher than the other observers, who were generally in agreement with one another. The data indicate that this difference was likely not due to the fact that the image set contained first-person images. This difference may have been the result of the undergraduates being younger and less experienced than the other observers, or it may have been that the first-person image set contained more images than the third-person set for which the digital silver halide process simply did not render as well as other print processes.

The final result of this study was that the photo-print format had a more significant impact on the assigned value than the image content, though there were one or two image pairs that were rated significantly different among the two image sets. When this occurred, the images involved had significant levels of memory colors, including skin tones and foliage.

References

Axiphos GmbH. (2001, August). *Reviewing the concept of paper brightness.* Retrieved from http://www.axiphos.com/BrightnessReview.pdf

Chung, R., & Rees, M. (2006a). Digital print quality—First year review. Unpublished manuscript, Printing Industry Center at RIT.

Chung, R., & Rees, M. (2006b). Bridging traditional and digital printing standards. In *Test Targets 6.0* (pp. 37-41). Rochester, NY: RIT School of Print Media.

Farnand, S. (2008). *Minding the gap: Investigation into the image quality differences between digital print technologies and traditional offset lithography* (PICRM-2008-08). Rochester, NY: Printing Industry Center at RIT.

Farnand, S. (2009). *Further investigation into the image quality differences between digital print technologies and traditional offset lithography* (PICRM-2009-04). Rochester, NY: Printing Industry Center at RIT.

Freedman, H. B. (2004). Production color xerography matches offset printing quality – Xerox's groundbreaking high density multibeam digital color printing systems. *Technologe Watch.* Vol. 9, Fall 2004.

Freedman, H. B. (2006a). Kodak NexPress digital color printing – Offset quality and enhanced screening technology create new market opportunities. *Technologe Watch.* Vol. 11, Fall 2006.

Freedman, H. B. (2006b). Matching electrophotographic color printing to offset lithography – Color measurement targets perform magic. In *Test Targets 6.0* (pp. 33-36). Rochester, NY: RIT School of Print Media.

Gast, G., & Tse, M. K. (2001). A report on a subjective print quality survey conducted at NIP16. *IS&T's NIP16: International Conference on Digital Printing Technologies: Vol. 16* (pp. 723-727). Springfield, VA: The Society for Imaging Science & Technology.

International Committee for Information Technology Standards. (2004). *What is INCITS?* Retrieved from http://www.incits.org

ISO 20462 -- 1-3:2005 Photography—Psychophysical experimental methods for estimating image quality.

Judd, D. B., MacAdam, D. L., & Wyszecki, G. (1964, August). Spectral distribution of typical daylight as a function of correlated color temperature. *Journal of the Optical Society of America, 54(8),* 1031-1036.

Phillips, J.B., Bajorski, P., Burns, P.D., Fredericks, E.P., & Rosen, M.R. (2010). Comparing image quality of print-on-demand books and photobooks from web-based vendors. *Journal of Electronic Imaging, 19(01),* 011013-011013-17.

Shaw, R. (1997). Image quality considerations for printing digital photographs. *IS&T's NIP 13: International Conference on Digital Printing Technologies: Vol. 13* (pp. 562-565).

Swanson, T. W. (2000). Digital image quality: What is it and how is it measured? *IS&T's Eleventh International Symposium on Photofinishing Technologies: Vol. 11* (pp. 11-13). Springfield, VA: The Society for Imaging Science & Technology.

Xu, R., & Kellogg, H. P. (2007). Print quality of dry-toner color electrophotography for production printing and comparison to offset printing. *IS&T's NIP23: International Conference on Digital Printing Technologies and Digital Fabrication 2007: Vol. 23* (pp. 378-381).

Rochester Institute of Technology
College of Imaging Arts and Sciences
55 Lomb Memorial Drive
Rochester, NY 14623
Phone: (585) 475-2733
http://print.rit.edu