

Further Investigation into the Image Quality Differences between Digital Print Technologies and Traditional Offset Lithography

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Abstract

In recent years the differences in image quality of digital printers relative to offset lithographic presses have been becoming ever more subtle. In 2007 experimentation was conducted within the Print Industry Center at the Rochester Institute of Technology examining this difference. It was found that there were significant differences in perceived value of prints made on digital versus offset printing equipment with the prints on coated media made on offset equipment being generally preferred, while the prints on uncoated media made on digital printers were frequently assigned higher value. The results of this experiment were possibly compromised by the reality that there were unintended shifts in the color balance of the prints made on some of the digital equipment relative to the offset reference prints. The present study was conducted to examine the effect of these unintended color shifts, to further examine the effect of the media on the perceived image quality differences between high-end digital presses and offset lithography, and to look at the impact of the skill of the observers on the perceived image quality differences. The experimental results suggested that the color balance shift had minimal impact on the perceived image quality differences, though contrast played a significant role. The media also had a strong effect on perceived quality. Unsurprisingly, skilled observers tended to rate images more critically than unskilled participants, though this effect was only statistically significant for some of the photo-based images.

Introduction

In recent years digital “presses” have been introduced to the print market, allowing short runs of customized documents in compressed time frames. While these printing capabilities are highly valued, there were questions regarding image quality when using devices with a heritage more closely associated with office copiers than commercial lithographic printing presses. But is this guilt by association fair? The general sentiment seems to be that the quality of the images being generated on digital printing equipment has essentially reached the realm of offset. Work has been conducted by Freedman that demonstrates 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.¹⁻³ While it has been shown that it is possible to achieve image quality comparable to offset on high-end digital printing equipment, it is telling that there exists a great deal of information on “designing for digital” to optimize print quality when printing on digital equipment.

In 2007, the Print Industry Center sponsored an investigation into the image quality gap between digital print technologies and offset lithography. The results of this investigation suggest that for some of the images tested the prints provided by digital printers on uncoated cover stock were valued as highly as or even more

highly than those printed using offset lithography. The dependence on the media of the comparative difference in image quality was an interesting result that we wished to explore further.

In the 2007 experimentation, the test images contained unintended color shifts that observers were asked to disregard in making their image quality assessments. In discussions of the experimental results, concerns were expressed regarding the observers’ ability to disregard color. In these discussions, questions were also raised regarding the impact of designing images with consideration of the limitations and strengths of the specific output device and the effect of the skill of the survey participants.

The objective of this follow-on project was to further evaluate the image quality gap between digital print technologies and offset lithography, including the questions raised in the discussions, and to verify trends suggested by the initial study, with particular attention to the media used. This was accomplished in two steps; first the issue of unintended color shifts possibly confounding the results was addressed by essentially repeating the first experiment with images significantly closer in color and no longer asking observers to disregard color in making their assessments. Secondly, further testing was conducted examining additional images printed on “standard” weight media, as opposed to cover stock, which was used in the initial testing. The image set included images as used in the initial testing and images that were designed to be less stressful on the equipment being used. Participants with expertise in evaluating print images were recruited.

Understanding and evaluating digital print quality has long been an area of interest for researchers in industry and academia.⁴⁻¹⁰ While efforts have frequently been made to evaluate the measured differences in such things that pertain to print appearance as solid area density, dot gain, colorimetric values, and color gamut volume¹⁰, it is the focus of this study to evaluate actual perceived differences in quality of prints produced on high-end digital printing equipment relative to those printed via offset lithography

Experimental Methodology

Experiment I

The experimentation conducted to evaluate the effective image quality differences between offset and digital was executed in two parts, the first was essentially a repeat of the experiment conducted in the 2007 with the same image set but with prints that were significantly closer in color balance than those used in 2007.

The same image set used in the 2007 experimentation, which included six images entitled “China”, “Print Gallery”, “Sarah”, “Text”, “Train”, and Village Sports”, was used in the present study

(Appendix A). The images represented the categories included in Frey's work on the Permanence of Toner on Paper were used in both experiments: direct mail, marketing and promotional materials, business communications, and photo books¹¹. The "Sarah" and "China" images represented photo book documents. The latter image included vacation-type photos, Chinese text, and copyright text. For business communications, a text and graphics document, "Text" and IS&T's NIP23 Print Gallery document were used. In the marketing and promotional materials category, a brochure, entitled "Train", created as part of a printing course at RIT from web-based material, and a mailer obtained from the Village Sports child care and sports center were used.

With the image set selected, prints were then made on the same printing equipment and the same substrates as the initial experimentation. The equipment included the Heidelberg Speedmaster 74 sheetfed lithographic press, an HP Indigo 5000, a NexPress 2100, and a Xerox iGen3 all located on the RIT campus. The images made on the Speedmaster were used in generating the prints on the digital equipment, in essence representing a set of "guide" prints.

The same substrates used in the initial experimentation were used in this experiment. Two substrates were used on each device, one coated (Titan Plus Dull *digital* 100lb. cover) and one uncoated (hp indigo printing paper 80 lb premium cover) cover stock. As in the 2007 experimentation, "text" was only evaluated on uncoated stock. With prints of five images on four printers each on two papers and one image on four printers, the complete test set consisted of 44 prints.

With the print database generated, psychophysical experimentation was conducted that examined the impact of any apparent image differences on perceived quality or value. The participants were shown the prints in sets, where a set constituted all of a given image printed on a given medium. At the start of the evaluation of each set, the participant was told of the purpose of the document. For the photo book pages, the participants were told that the prints represented photo book pages of pictures that they may have taken on vacation and were for their personal use to share with family and friends. For the Village Sports brochure, each participant was told that he or she was the owner of Village Sports and that the document was a mailer that had been commissioned to send to prospective customers. For the Train brochure, each was told that they were the owner of Georgetown Loop Railroad and that the prints represented sales brochures used to generate business. For the text document and the Print Gallery page, the participants were told that these were business communications documents that would be circulated within an office environment, maybe sent to a supervisor, and that though the main purpose of the document was to convey information, the documents still needed to be presentable.

To address the question of impact the observers were questioned regarding what they would be willing to pay for a given print. For each image on each paper, the print made on the Heidelberg Speedmaster sheet-fed press served as the reference print. When the participants were shown the reference print, they were told that they paid a dollar for this page. They were then presented with the set of comparison prints, one at a time. They were told that, for each of these prints, if the quality was enough better that it would justify paying more for the document, they would specify a value greater than a dollar. If the quality were

enough worse than the reference that they would not want to pay as much for the document as they had for the reference, they would specify a value less than a dollar, and if they thought the quality was essentially comparable, even if the prints looked quite different, they were to state that it had the same, one dollar, value as the reference. With this explanation, the first comparison print of the first set was presented and each participant proceeded through the document sets in random order.

The experiment was conducted under D50 lighting conditions. Twenty-one people having a variety of academic backgrounds participated. Eight females participated along with thirteen males. The age range of the participants was 15-64.

Experiment II

The second experiment included an expanded image set. Images lacking the known stressors, namely, uniform areas for the digital printers, were chosen to supplement the image set. Ten test images were used including five of the images used in the first experiment; "Print Gallery", "Sarah", "Text", "Train", and Village Sports". The "China" image was replaced with two other photo book images, "Munich" and "Cars". Another marketing document "Shaving", which included a significant proportion of text, and which was, like the "Train" image, created as part of a course at RIT, was used. Finally, an additional category of "Photos for Display" was included and represented by two detailed images: "Rose" and "Flowers". (Appendix B).

Prints were made on the same equipment used in Experiment I, again using the prints made on the Speedmaster as guide prints. For this second experiment, lighter weight papers were used relative to the cover stock used in the earlier experimentation. The three substrates used included one coated (Titan 80# gloss text) and two uncoated (80# Accent Opaque and 60# Accent Opaque) papers. With prints of ten images on three papers made on four printers, the complete test set consisted of 120 prints.

The psychophysical experimentation conducted followed the same general protocol as that in the previous experimentation, however, in this experiment, the print sets included all of the prints of a given image not just on all printers but on all media as well. Again, at the start of the evaluation of each set, the participant was told of the purpose of the document. For previously used images, the assigned purposes remained the same as in Experiment I. For the "Photo for Display" image sets, the participants were told the prints were photos for display such as posters or something that might be framed. For the Shaving document, the participants were told that this was an advertisement, maybe something handed out at the mall or available at fine salons.

The experiment was conducted under D50 lighting conditions in the Psychophysics Lab at RIT. Twenty-seven people having varied backgrounds participated including twenty from an undergraduate psychology course. Their majors ranged from Computer Science to Photography to Biotechnology. As it happened, there were a significant number of graphic design students from the class that participated in the experiment. These students were included in the expert observer category, which also included printing and imaging science graduate students and staff. The Imaging Science personnel were researchers who have worked in the area of printing. There were fifteen participants in the "Skilled" category and twelve participants in the "Naïve" category. Fifteen females participated along with twelve males.

At least one participant had a color vision anomaly; this was self-reported, so others may have been present. The age range of the participants was approximately 18-50, with the vast majority being about 20 years of age.

Results

Experiment I

The data analysis began by calculating the mean assigned value for each of the comparison prints. The consistency of the participants' responses was then evaluated by calculating the correlation coefficients of the individual responses with the mean response for each of the comparison prints. These correlation coefficients averaged about .72 and varied from .57 to .90. This compares favorably with the results from the 2007 experimentation in which the average correlation coefficient was .60 with a range of .24 to .80. All of the results collected were retained in the analysis.

The mean assigned values for the prints made on coated and uncoated paper averaged over all the image sets on each piece of printing equipment included in the experimentation are shown in Figure 1. The results are broken down by image in Figures 2 and 3 for the coated and uncoated papers, respectively. For comparison, the equivalent results for the Print Industry Center research on the differences in digital and offset print quality conducted in 2007 are included. For both studies, the data indicate that the offset press produced prints on coated paper that had comparable or higher perceived value, Figure 1. This result holds up for all of the images included in the studies, Figure 2. The results for the prints made on the coated paper in the two studies are remarkably similar. Note in Figure 2, for example, that the "China" print from Printer 3 and the "Train" print from Printer 1 were rated comparably to that from offset in both studies on coated paper. Over all the images and printers, the differences are quite subtle. These limited differences between the results for the two experiments may indicate that the unintended color shifts present in the images in the experimentation conducted in 2007 had minimal impact.

The differences were not so subtle, however, on uncoated paper, Figure 3. In the 2007 experimentation, it was found that some of the prints from two of the digital printers, especially of the photo book pages and marketing materials, were found to be of higher value than the counterparts made using offset lithography. Printer 1 or Printer 3, and often both, yielded prints that were rated more highly than the offset prints for every image tested with the exception of the Print Gallery image. For this image, the prints were considered comparable. The results of the current study were markedly different. Looking at Figure 1, it is evident that the prints made on the offset press were superior on uncoated paper as well as coated. Examining the results by image, Figure 3, there were few instances where the digital print was rated of more value than the offset print; the China print for Printer 1, possibly the Sarah print for Printer 1, and possibly the Village Sports print for Printer 3. There were also a few prints, the Train print for Printer 1, the Text print for Printer 2, and the Village Sports prints for Printers 1 and 2, which were rated comparably to the offset reference. For the most part though, the results on uncoated paper looked much more like the results from the current study on coated

paper, with prints produced by the offset press being rated as having higher perceived value relative to the digital prints, than the

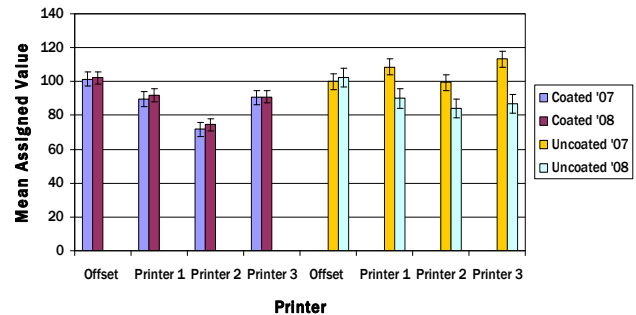


Figure 1: Mean assigned values for the images on coated versus uncoated media for each printing device for the experiments conducted in 2007 and 2008.

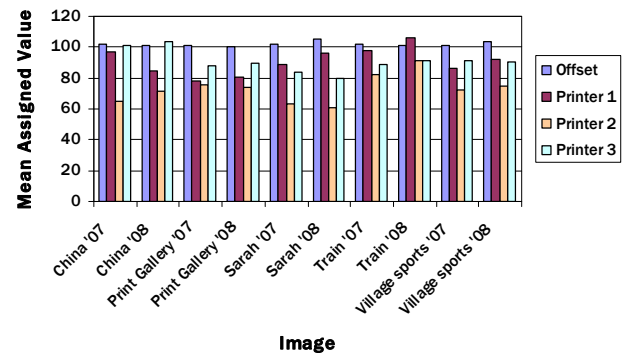


Figure 2: The average assigned value for each image on coated media.

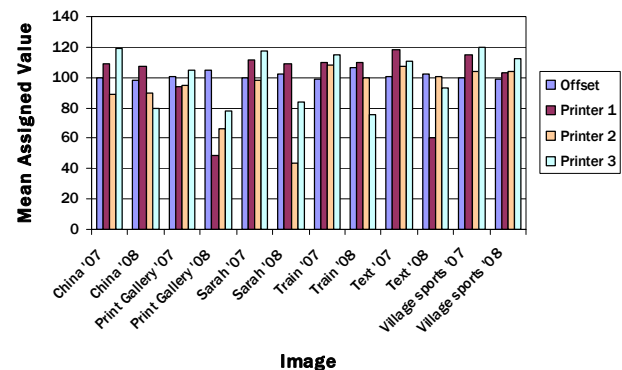


Figure 3: The average assigned value for each image on uncoated media.

results of the 2007 experimentation on the uncoated paper. Note the relative drops in perceived value, between the two studies, for Printer 3 for the China, Sarah, and Train images, for the Text image for Printer 1, and for the Print Gallery image for all of the printers. Only the Village Sports image produced similar results in both studies on the uncoated paper.

So, what happened? There were several differences between the two experiments. There were different sets of observers and the viewing environments were different, though both experiments took place in D50 viewing booths. But, probably the most important difference between the two was that the digital prints were different. Recall that for the present study, the offset print on each media was used as a “guide print” for the digital print runs to remove the impact of color balance shifts in the print value assessments. Making the digital prints look like the offset prints had important consequences. For one thing, it reduced the variability in the assessed values. In the 2007 experimentation it was found that, as the difference from the reference print increased, so did the variability in how the participants valued those prints; some thought the differences were inconsequential, some found they added to the value, while others occasionally felt the differences rendered the prints worthless. With the digital prints used in the current study much more closely resembling the reference print, there was greater consistency in the relative impact of those differences as indicated by the higher average correlation coefficient between individual and the mean responses for each comparison print cited earlier.

Another, perhaps more important, consequence of using the offset prints as guide prints is that this may have impacted the advantages seen by the digital presses. In the 2007 study, the offset prints were generally preferred over the digital prints on the coated paper. Using the offset print as a “guide print” then entailed little risk. However, for the uncoated media, the offset print was not always the most preferred. The contrast and overall gloss level of the digital prints were cited as the image attributes that led many participants to rate the digital prints more highly than the offset prints. Although the intent of using the offset print as a “guide print” was to verify the color balance, the contrast and gloss were affected as well. By making these aspects of the digital prints more like the offset prints, any advantage that they may have provided by these attributes was lost. The differences that remained were the uniformity issues and reduced quality text and line reproduction on the digital prints.

The comments made by the participants as they made their assessments support this assertion. The most common print attribute cited as important in their quality decisions was uniformity, which was mentioned for all of the images except the Text document and the Village Sports brochure. For the Text document, text and line quality was the most common attribute mentioned. This was a factor for the Print Gallery page as well. And, related to this, sharpness was the most frequent attribute cited for the China print. For the Village Sports brochure saturation was mentioned most often with gloss being mentioned on occasion as well. In the 2007 experimentation, lack of uniformity was the most common complaint for the prints made using digital equipment, with concerns regarding text and line quality ranking second. In this earlier work, however, many participants preferred the higher contrast of the digital printer output, especially for the photo book pages and marketing material on the uncoated media. Although there were few comments specific to gloss, higher gloss could have added to the higher contrast and the higher color saturation, which appealed to many participants. In the current study, the comments regarding contrast, saturation, and gloss were largely absent with the exception of the Village Sports and Train brochures.

Experiment II

As in Experiment I, the mean value assigned to each comparison print was calculated, and the correlation coefficients of the individual responses with the mean response for each of the comparison prints were determined. These correlation coefficients were similar to those resulting in Experiment I, with an average of about .74 and a range varying from .56 to .84. All of the results were retained in the analysis.

The mean assigned values for the prints of each image made on each piece of printing equipment included in the experimentation are shown in Figures 4-6 on each media, with Figure 4 showing the coated paper, Figure 5 showing the #80 uncoated paper, and Figure 6 showing the #60 uncoated papers. A key difference between this experiment and the previous studies is that, in this experiment, the image on coated paper was used as the reference print for all renditions of that image on all of the three media. Interestingly, there are several prints from Printers 1 and 3 on coated paper, Figure 4, that are rated more highly the offset reference and many that were rated equivalently to the offset reference. Only the Village Sports brochure and possibly the Text reference prints were consistently rated higher than the digital comparison prints. In contrast, almost none of the prints on uncoated media were rated higher than the reference print, which

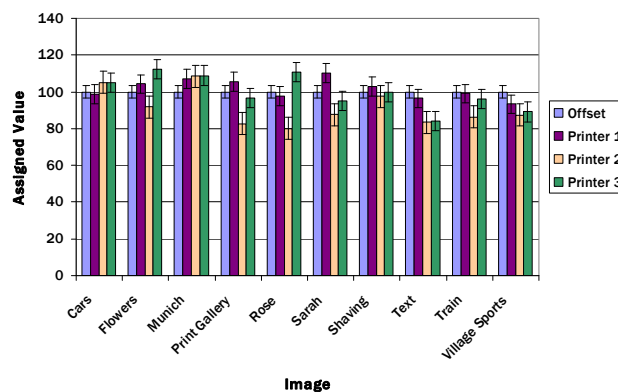


Figure 4. The average assigned value for each image on coated media by printing device.

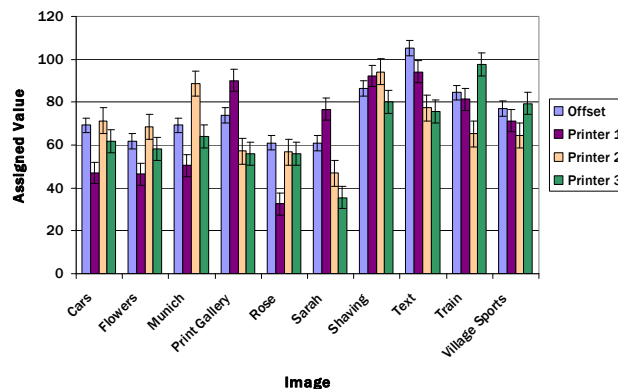


Figure 5. The average assigned value for each image on 80# uncoated media.

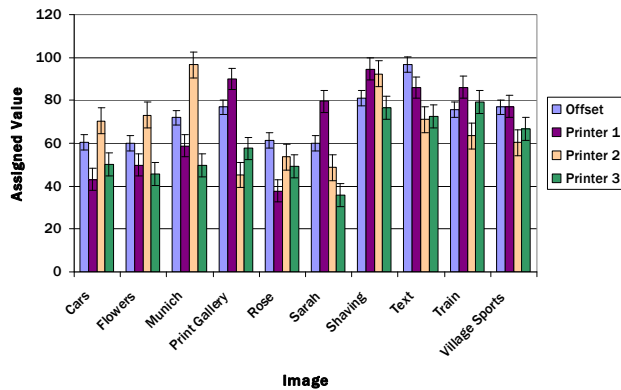


Figure 6. The average assigned value for each image on 60# uncoated media.

was on coated stock. Only the Text print made on the 80# uncoated paper on the Heidelberg press was rated more highly than the reference (value of 100), Figure 5. Only the Train print made on Printer 3 on the 80# uncoated paper, Figure 5, and the Munich print made on 60# uncoated paper, Figure 6, were rated comparably to the reference print, though the Text print made on Printer 1, the Shaving prints made on Printers 1 and 2 on 80# and 60# uncoated paper, the Text print made on the Heidelberg press, and the Shaving prints made on Printers 1 and 2 on were close.

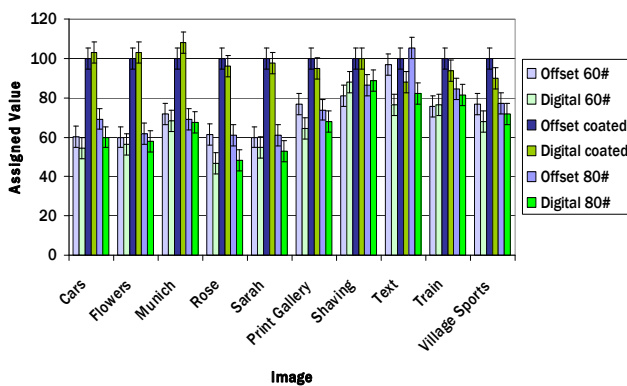


Figure 7. The average assigned value for each image by media.

The mean assigned value for each image is shown in Figure 7 for each paper on the offset press and averaged over the digital presses. Clearly, there is a significant difference in the perceived quality of the prints on coated media relative to uncoated media. For all of the photo images, Cars, Flowers, Munich, Rose and Sarah, the ratings on coated paper stand significantly taller than those for the uncoated media. Even for the Print Gallery image, which includes a picture of a young girl, shows a substantial difference between the coated and uncoated media. Only for the Text image, which is the only image with no photo content at all, shows a larger difference between print technologies than between media. The response data are shown averaged over all of the images by media for each printer in Figure 8. While each of the digital printers had lower rated prints for some of the images on

one or two of the media used, the overall digital results were essentially comparable to the offset results. The one medium where offset appeared to have a slight advantage is the 80# uncoated paper. It is evident from the data shown in this graph that the media had a far greater effect on perceived value than the print technology on average.

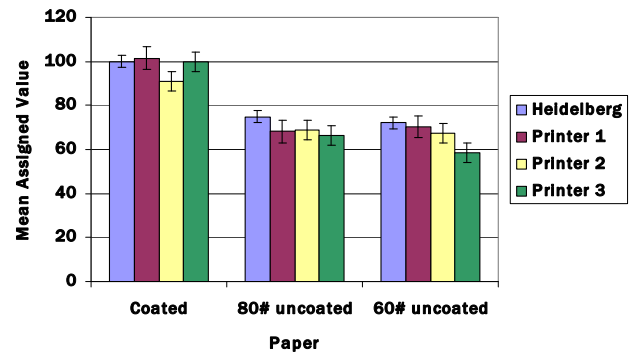


Figure 8. The average assigned value for each media and printer, averaged over all images.

The results were also examined as a function of the skill of the participants, Figure 9. The people participating in the experiment included several Graphic Design and New Media students, printing students, faculty, and staff; photography students, and Imaging Science students and staff with printing experience. These were grouped into the skilled category. All others were grouped into the naïve category. The average assigned value for each image for each group of participants was determined. The results for the two groups were highly correlated with a correlation coefficient of about .92. The difference between the skilled and naïve participants was then calculated (naïve – skilled). All the differences are positive, indicating that the skilled observers were more critical in general than the naïve participants, which is to be expected. However, only the Flowers, Sarah, and, possibly the Rose print had statistically significant differences between the skilled and naïve observers with the skilled observers being more critical than the naïve participants.

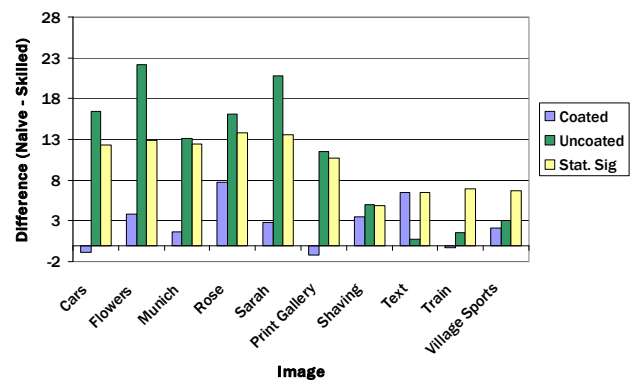


Figure 9. The difference in the average values assigned by skilled versus naïve participants for each image. The columns on the right for each image indicate statistical significance..

Conclusion

As was stated in 2007, it is important to remember that prints were made on only one offset press and only one machine for each of three different high-end digital printer vendors. Different results may be obtained using different equipment or even the same equipment run by different people or on different days. Drawing conclusions from this work must be done with a fair bit of caution. What we were really looking for is a better understanding of the existing trends. In this experimentation, it was found that the offset press produced prints on coated and uncoated paper that had comparable or higher perceived value for the images tested. This is a different result from that obtained in 2007, when, on uncoated media, some of the prints from two of the digital printers, especially of the photo book pages and marketing materials, were found to be of higher value. As in 2007, participants generally liked the uniformity and high quality lines and text of the offset prints. However the higher contrast of the digital prints that they tended to prefer on the uncoated paper, at least for some applications, was missing from the prints made on uncoated paper for this experiment. The digital prints on uncoated paper went from being comparably rated or slightly preferred in 2007 to receiving lower ratings in the present testing.

These results are in general agreement with Chung and Rees findings that offset printing image quality issues tend to be related to materials problems, such as lower contrast on uncoated paper, while image quality issues for digital printing equipment tend to involve technical limitations of the equipment, such as uniformity issues and weaker lines and text.¹²

While the results on uncoated paper were dramatically different in the two studies, the results on coated paper were nearly equivalent year to year. This may serve as evidence that the observers in the earlier experimentation were able to ignore the unintended color balance shifts, since this was the main difference between the prints used in the two experiments.

The effect of media was overwhelming in Experiment II. In this experimentation, the impact of the media was much greater than the impact of the print technology, overall.

Another result of Experiment II was that skilled observers tended to be more critical of image quality, especially for photo book pages and what were termed “photos for display”, than observers less familiar with image evaluation.

In general, this body of experimentation over the past two years can be taken to support the assertion of those who claim that, in deciding which print technology to use for a given print job, quantity may be a more important consideration than image quality. If 10,000 prints are needed, lithography is still the right choice, if only 100 or maybe 1,000 prints are needed, or if personalized prints would provide some advantage, digital presses would be the right tool for the job. These results also suggest that, if high image quality is imperative for a given print job, you would do well to spend some time and a great deal of care in the selection of the media; there may be no more important choice.

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