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## Further Investigation into the Image Quality Differences Between Digital and Offset Printing

The primary goal of this month's report, *Further Investigation into the Image Quality Differences Between Digital Print Technologies and Traditional Offset Lithography* (PICRM-2009-04), by Susan Farnand, was to follow-up on research conducted in 2007 into the image quality gap between digital print technologies and offset lithography. The 2007 results suggested that, for some of the images tested, the prints provided by digital printers on uncoated cover stock were valued as highly or even more highly than those printed using offset lithography. The dependence on the media of the comparative difference in image quality was one that required further exploration.

Additionally, 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 level of skill of the survey participants.

Therefore, the main 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 through two sets of experiments: Experiments I and II.

### Experimental Method

#### Experiment I

This experiment was essentially a repetition of the experiment conducted in 2007. It used the same image set, but the prints were significantly closer in color balance than those used in 2007.

The 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 (the images may be seen in [Appendix A of the full monograph](#)). The images represent the categories included in the 2006 Printing Industry Center research monograph *Permanence of Toner on Paper—Based on the Lifecycle of Documents* (Frey, Christensen, & Disantis, 2006): direct mail, marketing and promotional materials, business communications, and photo books.

The experiment was conducted under D50 lighting conditions in D50 viewing booths at the ImagineRIT Innovation Festival in May 2008 and in the Psychophysics Lab in the Color Science building at RIT. Twenty-one people having a variety of backgrounds



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participated. Eight females participated along with thirteen males. The age range of the participants was 15-64.

## Experiment II

The image set was expanded in this experiment. 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 the Technology Practicum course at RIT in 2007, was used. Finally, an additional category of Photos for Display was included and represented by two detailed images: "Rose" and "Flowers" (these additional images can be seen in [Appendix B of the full monograph](#)).

With the image set selected, prints were made on a sheetfed offset lithographic press in the Printing Applications Lab at RIT. These images were, as in Experiment I, used as guide prints in generating the images on the digital equipment. Prints were then made of each image on three different high-end digital presses at RIT. Three substrates were used on each device, one coated (Titan 80# gloss text) and two uncoated (80# Accent Opaque and 60# Accent Opaque). These were lighter weight papers than were used in the previous experimentation.

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 on all media as well as on all printers. Again, at the start of the evaluation of each set, the participant was told the purpose of the document.

The experiment was conducted under D50 lighting conditions in the Psychophysics Lab in the Color Science building at RIT. Twenty-seven people having varied backgrounds participated, including twenty from an undergraduate psychology course. In total, there were fifteen participants in the "Skilled" category. The remaining twelve participants comprised the naïve participant 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 around 20.

\* For each set, the print made on the offset press on the coated paper was selected to be the reference print. As in Experiment I, 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. The participants were given the following instructions: for each of the comparison prints, if the quality was sufficiently higher than the reference to justify paying more for the document, specify how much more you would be willing to pay. If the quality was sufficiently worse than the reference, tell how much less you feel it is worth. If you think the quality is essentially comparable (even if the prints looked quite different), state that it has the same 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.

## Results & Discussion

### Experiment I

For both studies, the data indicate that the offset press produced prints on coated paper that had comparable or higher perceived value (see Figures 1 and 2). This result holds up for all of the images included in the studies, on average (see Figures 3 and 5). The results for the prints made on the coated paper in the two studies are remarkably similar.

**Figure 1. Mean assigned values for the images on coated**

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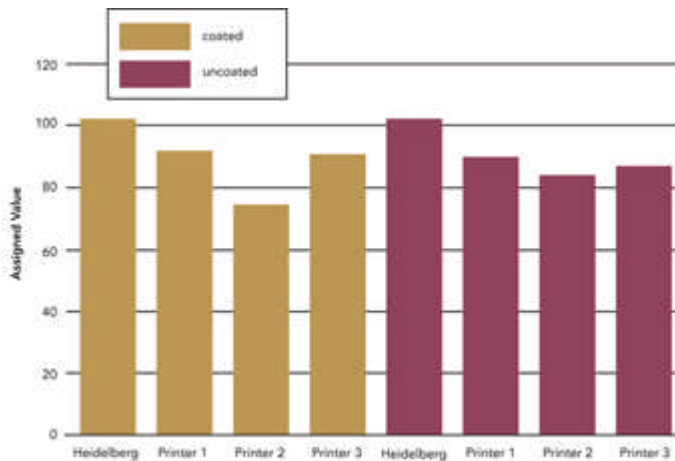
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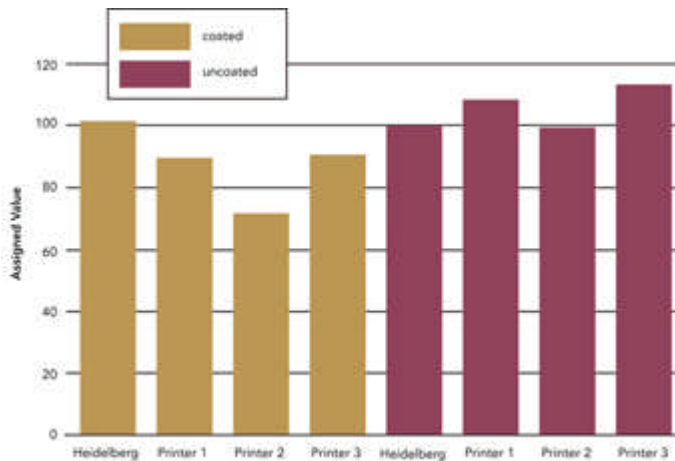
**and uncoated media for each printing device, 2008 study**

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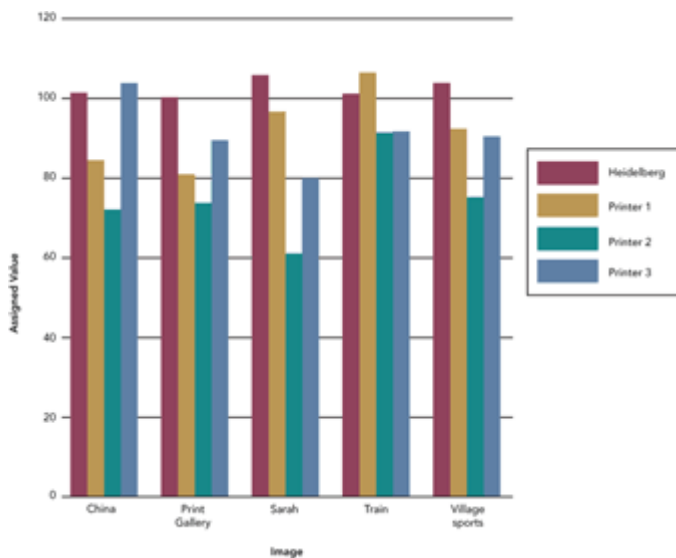
**Figure 2. Mean assigned values for the images on coated and uncoated media for each printing device, 2007 study**

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**Figure 3. Average assigned value for each image on coated media, 2008 study**

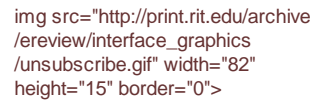
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**Figure 4. Average assigned value for each image on uncoated media, 2008 study**

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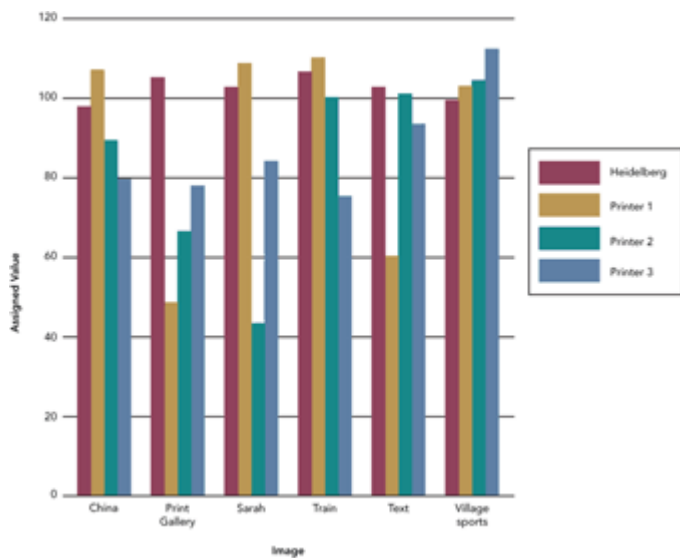
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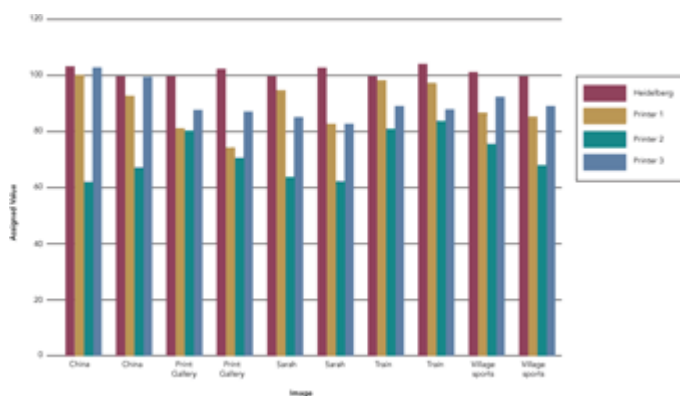
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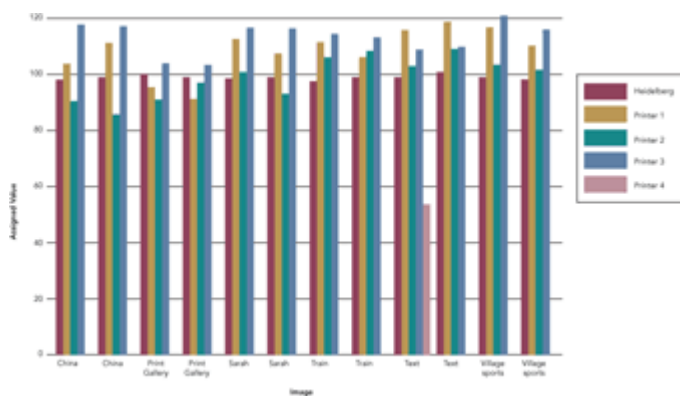
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**Figure 5. Average assigned value for each image on coated media, 2007 study**  
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**Figure 6. Average assigned value for each image on uncoated media, 2007 study**  
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The differences were not so subtle, however, on uncoated paper. 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 (see Figure 6). Printer 1 or Printer 3—and often both together—yielded prints that were rated more highly than the offset prints for every image tested with the exception of the "Print Gallery" image.

However, 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 (as shown in Figure 4), there were few instances where the digital print was rated of greater

value than the offset print. For the most part, however, 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 results of the 2007 experimentation for uncoated paper.

How did this occur? There were several differences between the two experiments, including different sets of observers and different physical viewing environments, although both experiments took place in D50 viewing booths. However, 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. With the digital prints used in the current study much more closely resembling the reference print, the resultant variability in assessed value was significantly lower.

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 seem to have been affected as well. By making these aspects of the digital prints more like the offset prints, any advantage that they may have provided 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 original question under investigation in Experiment I was what the effect of the unintended color shifts present in the images in the experimentation conducted in 2007 had on the results obtained. Looking at only the coated results, we see that the impact of the color shift on the experimental results was minimal, though the variability in the data was reduced. The uncoated results, however, illustrate the importance of contrast and gloss on perceived image value. The changes in these attributes makes it difficult to know what impact the color shift alone had on relative perceived quality of the uncoated prints.

It is fortunate, perhaps, that the experiments were conducted in the order they were, because the effect of the paper, which was a key result in the experimentation conducted in 2007, was not obvious in Experiment I of the current study. However, as Experiment II will show, this factor is indeed relevant and important to consider.

## **Experiment II**

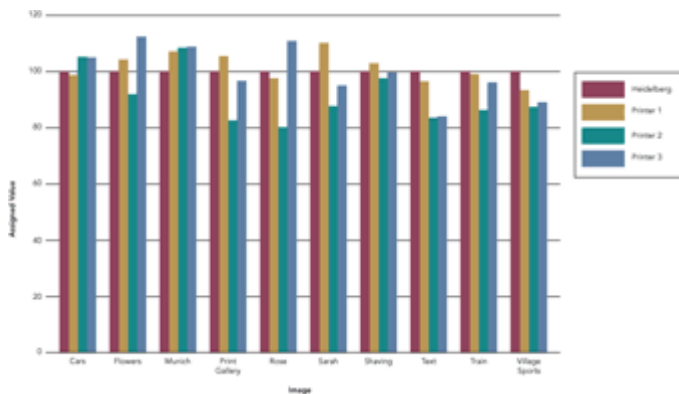
The mean assigned values for the prints of each image on each type of paper included in the experimentation are shown in Figures 7-10. A key difference between this experiment and the previous studies is that, in this experiment, the image on coated paper was used as the reference print for all renditions of that image on all of the three media. Interestingly, there are several prints from Printers 1 and 3 on coated paper (as shown in Figure 7) that were rated more highly than the offset reference and

many that were rated equivalently to the offset reference. This is somewhat surprising, given the results from the 2007 experimentation and Experiment I. One difference between the studies was that the present work used a lighter weight coated paper than was used in the previous experimentation.

In contrast to this, almost none of the prints on uncoated media were rated higher than the reference print, which was on coated stock.

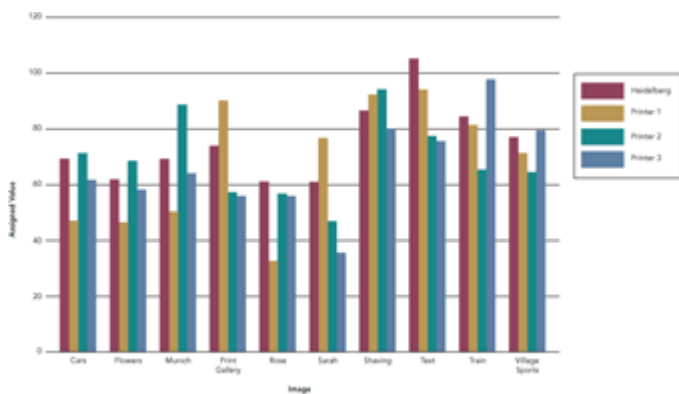
**Figure 7. Average assigned value for each image on coated media by printing device**

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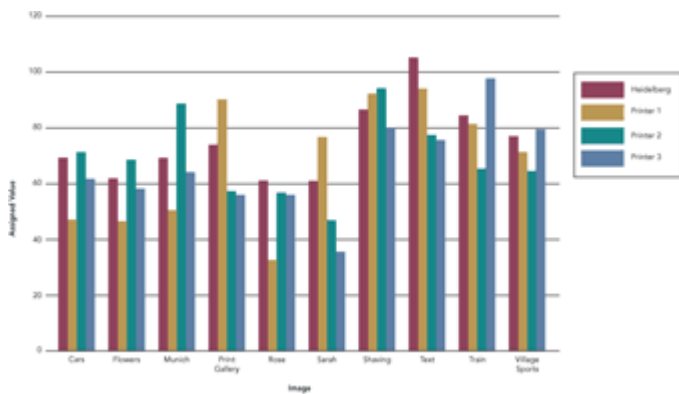
**Figure 8. Average assigned value for each image on 80# uncoated media**

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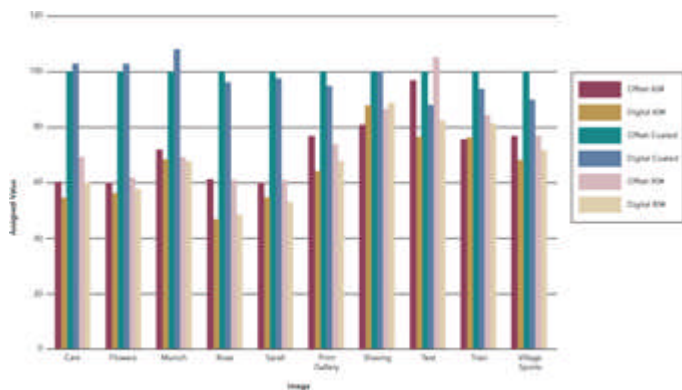
**Figure 9. Average assigned value for each image on 60# uncoated media**

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**Figure 10. Average assigned value for each image by media**

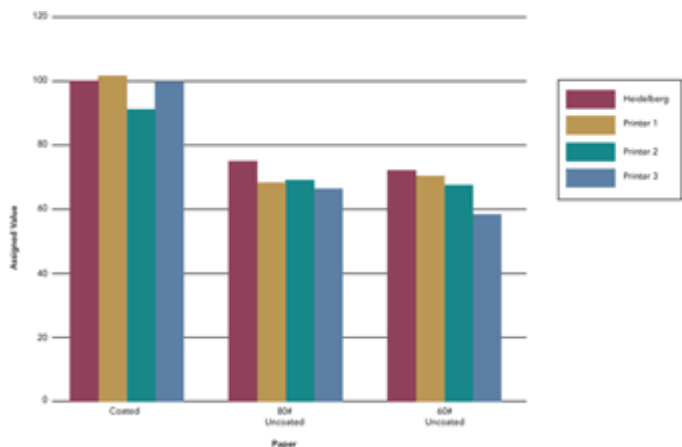
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Clearly, there is a significant difference in the perceived quality of the prints on coated media relative to uncoated media. The mean assigned value for each image is shown in Figure 10 for each paper on the offset press and averaged over the digital presses. For all of the photo images, the ratings on coated paper were significantly higher than those on uncoated media. Even the “Print Gallery” image, which includes a picture of a young girl, shows a substantial difference between the coated and uncoated media. Only the “Text” image (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 and by printer in Figure 11. From this graph, it is evident that the media had a far greater effect on perceived value than the print technology, on average.

**Figure 11. Average assigned value for each media and printer, averaged over all images**

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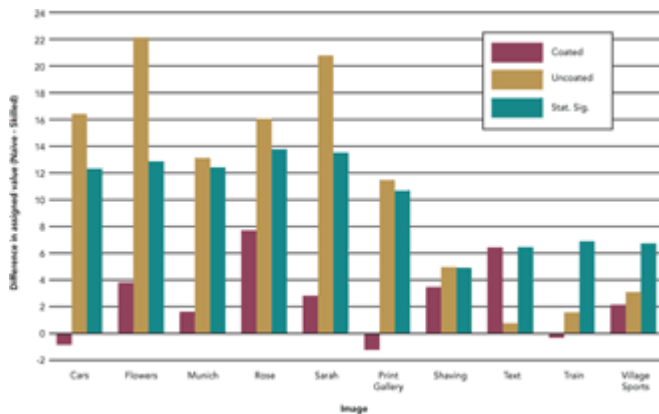
The results were also examined as a function of the skill of the participants. The people participating in the experiment included several graphic arts students, faculty, and staff; photography students, and imaging science students and staff with printing experience. These were grouped into the skilled 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, and the relationship was highly linear with a slope slightly greater than 1 and an offset of about 29, indicating a systematic difference between values given by skilled and naïve participants. This difference 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.

When the results are examined by paper, however (see Figure 12), significant differences are seen for almost all of the images. There are significant differences for all of the photo images and the Shaving image on uncoated paper and for the text image on coated paper. The only images that do not have a statistically

significant difference between skilled and naïve observers are Train and Village Sports.

**Figure 12. Difference in the average values assigned by skilled versus naïve participants for each image on coated and uncoated paper\*\***

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\*\* The statistically significant bar shows the level needed for the difference to be statistically significant.

In Experiment I, the attribute most frequently mentioned as important in assessing the quality of the images was uniformity. In this experiment, uniformity was much less frequently mentioned. For Experiment II, the most common attribute mentioned as important in quality decisions was contrast. Other relevant attributes in this experiment were saturation, gloss, paper quality, sharpness, and text and line quality.

## 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 are really looking for is a better understanding of existing trends. In Experiment I, 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' (2006) 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.

While the results on uncoated paper were dramatically different between the experiment conducted in 2007 and Experiment I of the present study, 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.

In Experiment I, the overall results on uncoated paper were similar to those on coated stock. The effect of media was not obvious as it was in the 2007 experiment. The effect of media was, however, quite obvious in Experiment II. In this experimentation, the impact of the media was much greater than the impact of the printing technology, overall. The prints made using offset lithography and those made on the digital printers, on average, were comparable in image quality on both coated and uncoated papers.

## References

Chung, R., & Rees, M. (2006). *A survey of digital and offset print quality issues* (PICRM-2006-04). Rochester, NY: Printing Industry Center at RIT.

Frey, F., Christensen, H., & Disantis, N. (2006). *Permanence of toner on paper—Based on the lifecycle of documents* (PICRM-2006-05). Rochester, NY: Printing Industry Center at RIT.

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