

Perceived Image Quality of Printed Fine Art Reproductions

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Abstract

A project supported by The Andrew W. Mellon Foundation, evaluating current practices in fine art image reproduction and establishing a suggested framework for art image interchange has recently been completed. To determine the image quality currently being achieved, experimentation has been conducted in which a set of objective targets and pieces of artwork in various media were imaged by participating museums and other cultural heritage institutions. Prints made from the delivered image files at the Rochester Institute of Technology on a Heidelberg Speedmaster sheetfed lithographic press and a liquid electrophotographic digital press were used as stimuli in psychometric testing in which observers were asked to evaluate the prints as reproductions of the original artwork. The results indicated that there were limited differences between perceived image quality of printed reproductions made using offset and digital technologies when the transformation of the RGB files into CMYK images was performed following the same standard procedure (ISO 12647). Additional information regarding this experiment and related work may be found at www.artimaging.rit.edu.

Introduction

Research has been conducted previously on the capture stage of the art image reproduction process in which it was found that existing capture processes were variable and that these varied processes can result in significant differences in the color appearance and image quality of digital images¹. It was of interest to understand the impact these differences are having on the printed reproductions of fine art. To explore this question, a project, sponsored by The Andrew W. Mellon Foundation, was undertaken to evaluate the perceptual image quality attained by the reproduction workflows in use today, with an emphasis on the output end of the fine art imaging workflow. As part of this body of work, cultural heritage institutions captured a variety of “artwork” targets. The resultant files were used to print images on offset lithographic and liquid electrophotographic equipment for use in psychometric experimentation. The perceived image quality attained by current cultural heritage imaging workflows in their efforts to reproduce the original artwork was evaluated.

Experimental Methodology

The experiments in this study involved creating target artwork, having participating cultural heritage institutions put this artwork through their established imaging processes, and visually assessing the renditions produced in

this exercise. The artwork used in this study included six pictorial works intended to provide a variety of images for exploring the impact of scene content and various image media while keeping the number of test stimuli manageable. All artwork was commissioned or otherwise acquired from sources that allowed for unrestricted reproductions rights. The pieces included an aquatint entitled ‘Still Life’, a platinotype print of an antique photograph entitled ‘Photograph’, an acrylic painting entitled ‘Firelight’, a watercolor entitled ‘Mountain’, and two oil paintings, ‘Daisies’ and ‘Bridge’, Figure 1. The aquatint and photograph were included to expand the range of media and to represent monochromatic art such as early photography and works on paper, which can be surprisingly difficult to reproduce. The photographic print was obtained from the collection of the Image Permanence Institute at the Rochester Institute of Technology. The ‘Daisies’ painting is a relatively light, or high-key, scene. In contrast, the ‘Firelight’ painting was commissioned to provide an original that was relatively dark overall but covering a wide dynamic range. Many paintings, especially the early Dutch masters, fit this description. The ‘Bridge’ painting was created with a mixture of blues and purples. These colors were included in the study because research has shown some blues are difficult to reproduce due to the differences in the way the camera and the human eye “see” certain blue pigments, especially cobalt blue.² At least in part for this reason, Monet’s “Waterloo Bridge” has been cited as a painting that has been difficult to acceptably reproduce. The ‘Mountain’ painting was commissioned to have the medium of watercolor represented in our image set. Again, blue and purple were featured in this work.

The artwork was circulated among participating cultural heritage institutions, which each put it through their standard imaging process. Each institution delivered digital files and information regarding its workflow. Files from eight of the institutions that contributed to the broader project were used in this digital versus offset experiment. These were primarily the institutions from the workflow study that more frequently conduct print runs of their collected works, though a few smaller institutions were included as well. The files provided were used to generate prints on a Heidelberg Speedmaster and on electrophotographic equipment at the Rochester Institute of Technology. All prints were made on NewPage Sterling Ultra 80# Matte Text paper. The offset run followed the ISO 12647 protocol. The same press operator conducted the entire offset run. Two digital print runs were conducted. In one of the runs, the RGB files were sent directly to the electrophotographic press, allowing the embedded printer algorithms to perform the transformation to CMYK. In the

experimental results, these prints are referred to as DigRGB. In the second run, the CMYK files from the offset lithographic run, transformed according to the ISO 12647 protocol, were used. In the reported results, these prints are referred to as DigCMYK. With print sets made on the offset press for each of 8 institutions plus one extra for the institution that provided two files, or 9 offset prints, along with two digital prints for each institution along with two extra for the institution providing files in multiple color encodings, or 20 digital prints, 29 reproductions were made for each piece of target artwork.

The prints were used in psychometric experiments, which followed a rank order protocol, to generate relative visual ratings of image quality. The 14 participating observers were asked to rank the prints from worst to best

representations of the original. (Because there were too many stimuli for the observers to view them all at once, the testing began by having the observers first sort the prints into piles of the better reproductions of the original, the worse reproductions, and those prints that were somewhere in-between. Then the prints within each pile were ranked. The top ranked prints from the worst pile were included with the middle pile and the top prints from the middle pile were ranked along with the better reproductions.) The original artwork was present throughout the test. The experiment took place in a viewing booth under D50 lighting conditions (correlated color temperature of 4911°K) in the Display and Perception Lab in the Color Science building at RIT. The experimental setup is shown in Figure 2.

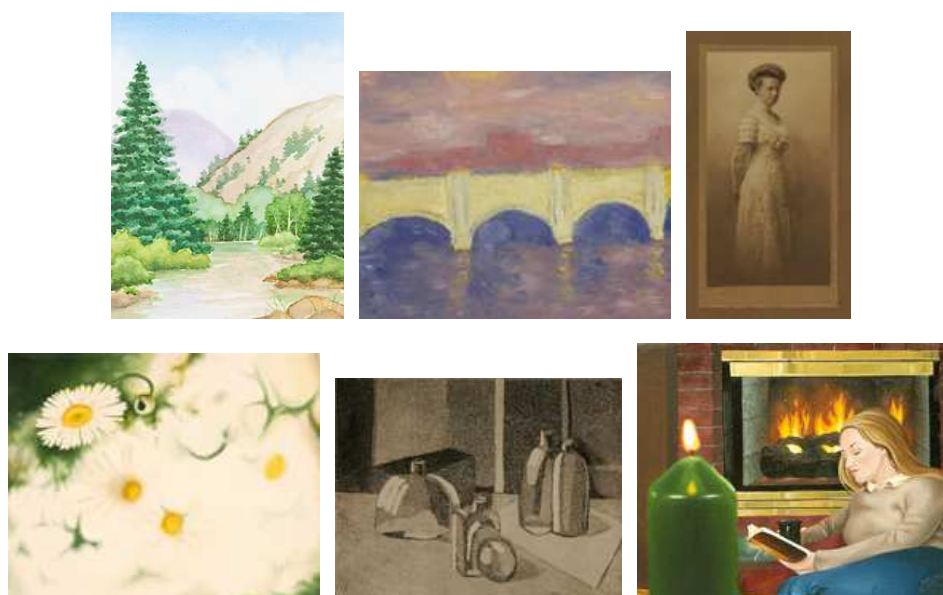


Figure 1: The artwork included in the experimentation from top left: Inspired by Monet's Waterloo Bridge, Photograph, Daisies, Mountain, Still Life and Firelight.



Figure 2: The hardcopy experimental setup.

The observers who participated in the experimentation generally consisted of individuals in the cultural heritage community. The observers included librarians, photographers, curators, art teachers, conservators, and imaging science students and staff with an interest in fine art reproduction. Observers were tested for color vision anomalies using Ishihara plates.

Once the testing was completed, the rankings provided by the observers were translated into z-scores following procedures outlined in Engeldrum⁵ and based on Thurstone's Law of Comparative Judgments – Case V⁶. In transforming from ranking to z-scores, the prints perceived to be of average quality would receive a z-score of about '0'. Prints perceived as being above average would have positive z-scores and those prints perceived as being below average would receive negative z-scores.

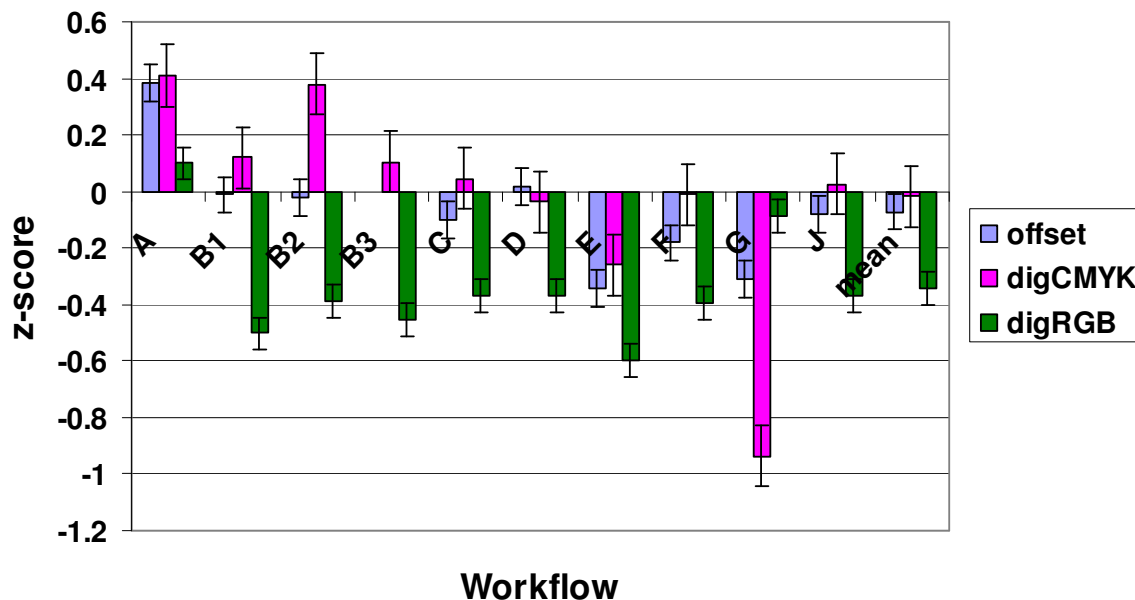


Figure 3: Z-scores generated from the ranking of the prints by workflow. There was no offset print generated for Workflow B3.

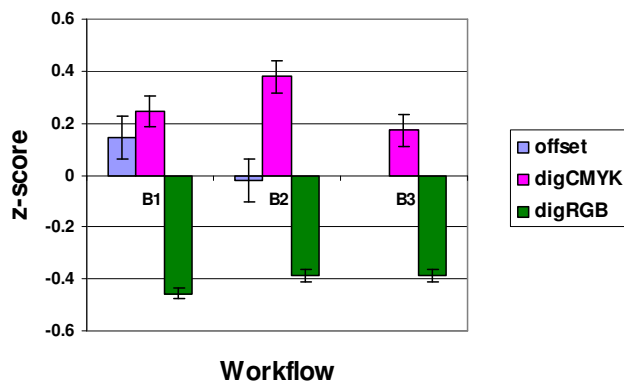


Figure 4: Ranking results expressed in terms of z-score values for the three workflows from Institution B with the results for *Still Life* excluded

Experimental Results

The experiments yielded comparative ranking results for the prints made using offset and digital printing for six pieces of artwork, Figure 3. The results averaged over all of the artwork show that the digital prints made using the transformation algorithms embedded in the printer (digRGB) performed worse than the prints made using offset lithography. This was true for all of the workflows except G. The difference in Workflow G was that it

produced a slightly greenish offset lithographic print, whereas the transformation from RGB to CMYK as executed by the digital printer algorithms tended to produce slightly reddish prints. For Workflow G, this resulted in a print that was perceived to be statistically better than the offset print. With the remainder of the workflows, the DigRGB prints were considered too red or too warm.

When the transformation from RGB to CMYK was executed following the ISO 12647 standard procedure (DigCMYK), the opposite result occurred. The DigCMYK prints were generally ranked comparably to the prints made using offset lithography for most of the workflows. Again, Workflow G was ranked differently from the other workflows. Since Workflow G produced greener offset prints than other workflows, the DigCMYK prints for this workflow were considered rather ghastly in appearance, consistently receiving below average rankings. The DigCMYK prints for Institutions A and B2 and the offset lithographic prints for Institution A were considered to be the best, when averaged over all six pieces of artwork. It is important to note that there was no *Still Life* aquatint print for Workflow B2. The other prints for Institution B (B1 and B3) did not rank particularly well for the aquatint. Therefore, if a print of this piece had been included for B2, its overall average might have been somewhat lower. Indeed, an analysis of the average for the three workflows without the aquatint shows that the ranking results for B2 were still higher than those for B1 and B3, but by a lesser margin, Figure 4.

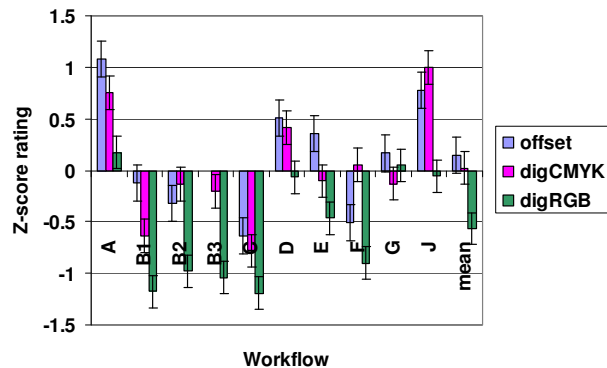


Figure 5: Ranking results for the 'Daisies' oil painting

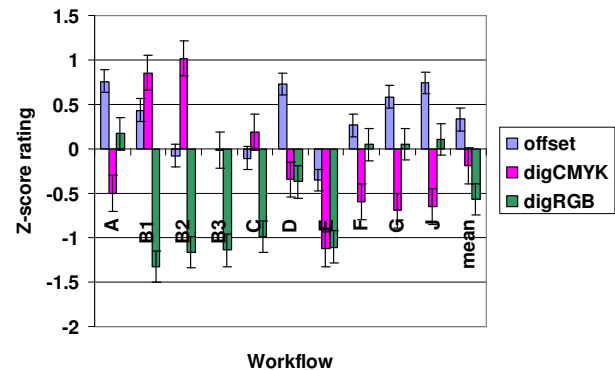


Figure 6: Ranking results for the 'Photograph' platinotype print

An analysis of the results for the individual pieces of artwork showed some image-dependent differences in performance. The *Daisies* painting was the one piece of artwork for which the DigCMYK version of Workflow G was ranked about average, Figure 5. In this case, the slight green cast did not detract as much as it did for the other paintings and more neutral pieces. For both *Still Life* and *Daisies*, Workflow J performed better than with the other images, while Workflows C, B1, B2, and B3 had more difficulty with these images than with others. These pieces of art were less chromatic than the remaining images, with the exception of *Photograph*. For *Photograph*, Figure 6, the prints made using offset lithography generally did better, although the DigCMYK prints for workflows B1 and B2 were ranked highest, on average. For the more chromatic pieces—*Bridge*, *Firelight*, and *Mountain*—Workflows C, B1, B2, and B3 performed much better than the others.

Conclusion

In summary, the electrophotographic digital press generally produced prints that were perceived as comparable in quality to or slightly better than those printed using offset lithography if the conversion from RGB to CMYK was done prior to printing. This result was image-dependent, with the offset prints ranked higher than the digital prints for the platinotype photographic print. This result also varied across institution, with the DigRGB prints for Institution G generally being ranked as better reproductions than offset or DigCMYK; the DigCMYK prints being ranked best, on average, for workflows B2, B3, and E; and offset and DigCMYK being ranked comparably for the remaining institutions.

Acknowledgments

The authors wish to thank The Andrew W. Mellon Foundation for supporting this work and the participating cultural heritage institutions and observers for taking the time to help make this project a success.

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Author Biography

Susan Farnand received her BS in physics from Cornell University and her Masters in Imaging Science from the Rochester Institute of Technology. After beginning her career at Eastman Kodak, she moved to RIT where she works as a Research Scientist in the Center for Imaging Science. Her research interests include image quality, human vision and perception, and color science. She is a member of IS&T and serves as an Associate Editor for the Journal of Imaging Science and Technology, and has served as co-chair of the IQSP conference at EI and guest editor for the Journal of Electronic Imaging.