Detecting Appearance Changes with Spectrocolorimetry and Densitometry

Terry T. Schaeffer, Margot Healey and Chail Norton
Conservation Center, Los Angeles County Museum of Art
Los Angeles California

Abstract

Several types of ink jet prints, each containing cyan, magenta, yellow, black and grey areas, were exposed to various indoor lighting conditions that can cause fading or other appearance changes. Alterations in appearance were monitored by reflectance spectroscopy with a portable spectrodensitometer. Both CIE L*a*b* and Density T values were recorded for each measurement made during the course of the exposures. The instrument is capable of detecting trends of change in the samples before any appearance changes are noticeable by eye. The data have been evaluated to determine which system of describing appearance is more sensitive for detection of fading, for each of the colors used.

North skylight, which was filtered through window glass and thus contained a substantial component of UV A, was used to cause rapid fading of some samples. Light exposures that mimicked museum exhibition conditions - tungsten lighting filtered through UV blocking plastic glazing - were also used. As expected, the colorants were much less fugitive in these latter conditions. Most colors withstood total experimental exposures equivalent to that which would be endured over several thousand hours of gallery exhibition, before the extent of change detected was considered significant.

Introduction

Prints made by ink jet printing technologies are now recognized as fine art and collectibles, and they are a growing component of collections in museums and archives. Museum personnel responsible for paper based collections have hesitated to allow display of prints made by ink jet processes in exhibitions of normal length (up to 12 weeks for paper based Western art). Their caution has been due to reports, mostly anecdotal, that colorants such as Iris inks are extremely fugitive to light. Few reports based on appropriately controlled experiments (1) have provided information that would allay these concerns. On the contrary, conservators have observed, for example, that samples of early 1990's Iris ink jet prints left in conventional workplace lighting conditions or indirect daylight faded to an unacceptable appearance in days or weeks (2).

A more systematic investigation was needed of the effect on ink jet prints of light exposures that are likely to be encountered in museum conditions. Such a study should take into account the obligation of conservators and collections managers to address the total display lifetime of these artworks 3. The goal is to ensure that an artwork can be displayed in about 20 exhibitions, with dark storage in between them, before its appearance has changed to the extent that artistic intent is compromised.

The experiments described here represent an attempt to start addressing the concerns of collections care personnel. Light exposure regimens were chosen to mimic display conditions in homes or galleries. Sample appearance changes were monitored by the same procedure used to monitor artwork appearance in a conservation laboratory.

The data collected have permitted a comparison of the usefulness of colorimetric and densitometric monitoring to detect and interpret small appearance changes. Also, the results may be used with caution to suggest possible display lifetimes, under museum conditions and with certain assumptions, for the materials used in the experiments

Materials and Methods

Materials

Three different sets of ink jet printing ink samples were used in this study.

i) An HP DeskJet 722C printer with a three color cartridge HP C1823A recently installed was used in the normal print mode to generate approximate cyan, magenta, yellow, black and grey patches on HP All Purpose bond paper and on a commercial 100% rag paper known as "Blue Jean Bond." The cartridge contains proprietary colorants in aqueous formulations that also include 20 to 30% organic materials.

ii) Samples were taken from several different colored areas of two Iris ink jet prints that were produced in late 1990 or early 1991. Iris inks are water-based and contain dyes as colorant material. In these particular examples, the inks are printed on thick, commercially manufactured, artists' paper. The prints were sent with others to the LACMA

Conservation Center in February 1991 for informal assessment of their stability. They had been stored in the dark in archival folder stock in the paper conservation laboratory since they were received. Because no instrumental measurements were made on the prints before the current investigation began, we do not know whether the inks underwent any changes in the dark over the last decade.

iii) Cyan, magenta, yellow, black and grey color patches were printed on Royal Plush paper and on Milano Canvas with a modified Epson 9000 ink jet printer by Kevin Pontuti at Studio P. The inks used were Media Street GENERATIONS pigmented inks.

All printed samples were mounted as an artwork on paper would be, by hinging them to 4-ply archival mat board with Japanese paper and wheat starch paste. The samples were overmatted with a window mat of the same archival material, so that part of each color patch was covered and part exposed. The samples were not removed from the mat board for appearance measurements, thus mimicking the procedure used to monitor appearance changes of art objects on paper in the LACMA collections.

Light Exposures

i) Exposure to diffuse north daylight. Mounted samples, with or without glazing, were propped at an angle on the sill of a north facing laboratory window during spring and summer. The temperature ranged from ca 70 to 75°F. Relative humidity in the laboratory is maintained at 50 ± 7%. Diffuse daylight at this location was measured periodically with an Elsec Environmental Monitor Model 764 (Littlemore Scientific Engineering). Visible light ranged from about 2150 to over 12,900 lux, depending on time of day and sky conditions. The UV A content (320 – 400 nm) of this diffuse daylight ranged from about 550 to 1450 µW/lumen. The UV A level was not obviously related to time of day. This type of light exposure would not be encountered in a museum gallery space, but is likely to be found in private homes and in businesses where ink jet printed materials are displayed.

ii) Exposure to tungsten light. Matted samples glazed with UV blocking plastic were hung in a black box on the laboratory wall. The box was located to prevent window light from reaching the samples, and was closed when the room lights were on. A tungsten flood lamp mounted in the type of can used for gallery track lighting illuminated the samples when the room lights were off. The lamp was approximately 2 m from the samples. No heating effects were observed. The illuminance at the various sample locations behind the Acrylite OP-3 UV blocking plastic glazing was measured with the Elsec 764 meter and also a Minolta illuminance meter model T1. Light levels at the locations of the different samples ranged from 625 to 675 ± 50 lux, and no UV radiation was detected by the Elsec meter. This intensity is roughly 12 times as high as the 50 lux typically used for illumination of light sensitive materials on display (4).

Appearance Monitoring

Reflectance spectra were obtained with an X-Rite Inc. Model 938 spectrodensitometer, which uses a proprietary gas filled tungsten light source and 0/45 geometry to collect reflected light. CIE L* a* and b* tristimulus values were computed by the QA Master software supplied by the manufacturer, for a D65 illuminant and a 10° observer. Also, the instrument itself was set up to display cyan, magenta and yellow density data according to ANSI Status T. These data were recorded manually for each reading.

The site that was measured on each sample was located by using a mylar template and/or crossed lines to position the target window of the X-Rite. We have found that repositioning the spectrodensitometer precisely is the largest source of reproducibility error when we are monitoring artworks. Therefore, the instrument is always repositioned for each of the three readings that comprise a measurement. The average of these readings is computed, and the standard deviations are recorded for each measurement.

Data Evaluation

Density and colorimetric values were plotted as a function of light exposure (days or lux-hours, as appropriate). This presentation makes small trends of change apparent even if the extent of appearance change is well below what is detectable by eye. Such trends may be indicative of impending unacceptable changes to an object, if light exposure is continued.

The data were evaluated for their ability to reveal small trends of change. In order to compare the usefulness of the CIE L* a* and b* numbers to that of the cyan, magenta and yellow data, the ranges of values plotted for each sample were adjusted so that the scales were similar in both cases. For example, if the tristimulus data were plotted so that full scale was 10 units – one-tenth of a total range of roughly 100 units possible - the density data were plotted with a full scale of 0.2 units. (Until very recently, it has been rare even for deep blacks to exceed density values of 2 in ink jet printing.)

The spectral output of the proprietary light source in the X-Rite spectrodensitometer is not available. However, it is known to include near UV. Thus it was necessary to ensure that repeated measurement of the same site on the printed color patches would not itself affect their appearance. This was confirmed by taping the instrument over a sample and taking a large number of readings. Pauses of several minutes were inserted between groups of five readings to ensure that heating of the instrument did not affect the measurements. No changes in the reflectance data were detected for at least 75 readings, the equivalent of 25 different measurements of the samples in our experiments.

Results and Discussion

Densitometry vs. Spectrocolorimetry: HP DeskJet Colors

A mounted set of HP DeskJet color patches printed on each of the two commercial papers was subjected to diffuse north daylight through window glass during the month of April, when days were 12 to 13 hours long. The matted samples were not glazed, so they were exposed to the high levels of UV A noted above. In these light conditions, rapid fading of colors was expected. We chose this situation to be able to observe extensive fading in a reasonable time, while comparing the usefulness of tristimulus and density values as a means of detecting change before it is noticeable to the eye.

In only 4 days slight differences were detected by visual comparison of the exposed and covered regions of the magenta patches on both papers. By nine and a half days, differences in magenta, cyan, and grey on both supports, and the yellow patch on the (blue-tinted) rag paper, were evident. After 19 days all exposed samples appeared changed with respect to the covered areas. These visual evaluations may be easier than assessing color change in an artwork, because we were able to compare exposed and covered regions of each color sample side by side. The results are much less equivocal than judging whether a particular artwork has changed on the basis of recollection of its previous appearance.

Evaluation of the graphed CIE L*a*b* and the Density T data suggests that density measurements are distinctly better than tristimulus ones for detecting small changes in the black ink before they are visually noticeable. For light colors such as the rag paper or the light grey ink, the tristimulus values are far superior. For the cyan, magenta and yellow color patches, each set of measurements provides different and useful information, before appearance changes are detectable by eye.

The rapid fading of these inks was due not only to the large quantity of light energy they received, but also to the high levels of UV A light in our Los Angeles spring sky that penetrated the window glass. These conditions do *not* represent those commonly found in museum exhibition spaces. However, they may be similar to those in homes and offices where ink jet printed materials are placed on display without any glazing or UV filters. Printers of fine art ink jet prints would be wise to encourage their clients to frame such prints with UV blocking glazing.

Early 1990's Iris Ink Jet Prints

Matted and glazed samples of the decade old Iris prints have been exposed to the tungsten flood light on a slightly irregular light/dark schedule. On weekdays, when they are not subjected to the tungsten light, the samples remain in the closed box with a black interior. These "off" periods are usually 10 to 11 hours long. Some weekends the samples have been entirely dark, on others they have been exposed to 36 to 42 hours of constant light. This regimen is not unlike the lighting schedule that a light sensitive exhibition might endure. Usually the gallery is dark one complete day per week. And occasionally gallery lights may be left on overnight for special events or by oversight.

The simulated gallery lighting conditions have caused much slower than expected changes in the Iris inks. It must be remembered that these prints were stored in the dark for a decade before their appearance was measured. How much, if any, the inks changed during storage is unknown. We cannot say that we are detecting *initial* changes in appearance of these Iris inks due to light exposure.

Some changes have been detected by spectrodensitometry. The magenta ink demonstrated a distinct trend of density loss after approximately 114,000 lux-hours of exposure, but the change so far has been much smaller than could be detected by eye. This amount of exposure would be equivalent to about 220 ten-hour days at a gallery light level of 50 lux, if the ink obeys the reciprocity principle. The colorimetric data do not indicate the trend of magenta loss as clearly as the density values do.

The cream colored artists' paper support has become slightly lighter and less yellow in appearance, as revealed by the colorimetric data. The trend of change in density values is not as clear. In contrast, the density data clearly suggest a slight loss of cyan from the black area, whereas the colorimetric data indicate a small shift to a lighter and slightly more yellow appearance of this ink.

No particular trends of change have yet been detected in the cyan, green, or yellow inked areas of the prints. In the case of the green, unevenness of the inks and the resulting larger standard deviations in the data may be obscuring a small trend to a less yellow appearance. Poor reproducibility of the measurements on the non-uniform cyan sample area has prevented interpretation of the data collected so far for this ink.

Exposure of these Iris ink jet samples to the tungsten light continues. The small magnitude of the changes that we have been able to identify by instrumental measurements suggest that these prints could be subjected to more than twice the light exposures accumulated so far without incurring any unacceptable changes in their appearance. Provided that they obey the reciprocity principle, and that they are glazed with UV blocking plastic, these particular prints could be displayed in at least 7 exhibitions as described above, without endangering the artists' intent.

Studio P Prints with MediaStreet GENERATIONS Pigment Inks

The Studio P printed samples are being exposed to the same tungsten light regimen as the Iris prints. Exposure has caused the appearance of the Milano Canvas to shift to the blue by about the same amount as the support for the Iris prints has done, as indicated by trends in the tristimulus values and slight decreases in all three density values.

The magenta ink in the Studio P prints has shown not only a trend of magenta density loss but also a shift of tristimulus a* toward the green. The trend was detectable instrumentally after about 200 hours of light exposure under the UV blocking glazing, and continues to increase as of this writing. The data collected so far suggest that the display lifetime of this ink would be very roughly twice that of the Iris prints described above.

The changes in the Milano Canvas (that is, the color shift to the blue indicated by a decrease in b*) may be affecting the appearance of the magenta ink printed on this support. Approximately equal trends of loss in density value have been detected for this ink on both the Royal Plush Paper and the Milano Canvas. However, the tristimulus data suggest that the resulting slight color shift is not as far toward the yellow for the sample on the Milano Canvas as for the sample on the Royal Plush paper. This latter support appears so far to be more stable to light than the canvas is. None of the appearance changes have been noticeable to the eye yet.

After over 260,000 lux-hours of visible light exposure, other inks in the Studio P prints may be beginning to show trends of change that can be detected in the instrumental data. These data suggest that changes will eventually occur in inks on both the paper and the canvas supports.

The quantity of visible light that the pigmented ink samples have received so far is roughly equivalent to about 500 days of gallery exposure at 50 lux. If the inks obey the reciprocity principle and current responses continue, it can be suggested that these particular colorants on these substrates may be exhibited somewhat more than twice as long as the Iris ink jet prints before unacceptable changes will occur in their appearance.

The long term fading experiments summarized in this preprint are being continued. Further developments in the appearance changes of the samples will be presented at the NIP-16 Conference session on Image Permanence.

References

1. Wilhelm Imaging Research, Inc., "Inks and media for Iris graphics printers," and "Inks and media for desktop inkjet printers," http://www.wilhelm-research.com/ (2000)
2. V. Blyth-Hill, Personal communication. (1999).
3. T.T. Schaeffer,. Introduction, in *Possible Effects of Photographic and Reprographic Light Sources on Art and Archival Objects,* Unpublished report to The Getty Conservation Institute. (1998).
4. K.M. Colby, J. International Institute for Conservation-Canadian Group, **17**, 3-12 (1992).

Biography

Terry Schaeffer received a Ph.D. in Biophysics from UC Berkeley. After about 20 years' research on photosynthetic pigments and ion transport across mammalian cell membranes, Schaeffer entered the field of art conservation science. Over the past decade, her research has addressed the effects of light on the materials in art and archival objects.