The Effects of Colorimetry and Spectroscopy Using the ISO M0, M1 and M2 Modes

Kaylee Flannery

Western Michigan University, kayleeflannery@yahoo.com

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THE EFFECTS OF COLORIMETRY AND SPECTROSCOPY USING THE ISO M0, M1, AND M2 MODES

by

Kaylee R. Flannery

A Project Report
Submitted to the
Faculty of The Undergraduate College
In partial fulfillment of the
Requirements for the
Degree of Graphic and Printing Science
Department of Paper Engineering, Chemical Engineering, and Imaging

Western Michigan University
Kalamazoo, Michigan
December 2014
Abstract

The use of Optical Brightening Agents (OBA’s) in printing and proofing papers has drastically increased and, while the use of OBA’s has improved the appearance for end-use consumers, it represents great challenges to those attempting to successfully color manage the print. Therefore, standards have been created in order to assist in the measurement of these papers, and can be found within ISO 13655-2009: Spectral Measurement and Colorimetric Computation for Graphic Arts Images. This newly defined measurement standard is referred to as the “M” series. While this new standard has its advantages, it also poses some disadvantages. This report will discuss the full details of the revised ISO “M” measurement modes, the dilemmas facing the comparison of values from the X-Rite eXact and i1Basic Pro 2 using the M0, M1, and M2 modes, and how to properly communicate measurements in order to minimize variations in spectral and colorimetric properties of color based upon the ΔE values.
CHAPTER 1

INTRODUCTION

The “M” Series Color Measurement Standard

Description of M0, M1, and M2 Modes

There are four modes found within the ISO 13655-2009 Color Measurement Standard: M0, M1-Part 1, M1-Part 2, and M2. These models help accurately measure the spectral and colorimetric data of print (ISO 13655-2009). The M0 measurement mode supports tungsten illumination, and maintains the practicality of instruments commonly used within the Graphic Arts industry today. At this point in time, most color measurement instruments used today align with M0, and because of that, this standard will remain the actual standard. The M1 measurement mode can be broken down into two parts. M1-Part 1 requires the light emitted by the instrument to match the CIE illuminant of D50, while M1-Part 2 simulates the effect of the D50 illumination by using U.V. compensation. M2 requires complete exclusion of any U.V. light, ignoring any effects of fluorescence (“The Color Measurement Standard for the Graphic Arts”). With the introduction of this Color Measurement Standard, printers have been able to more accurately control and communicate the spectral and colorimetric properties of color.
**Problem Statement**

While this improved color measurement standard has brought more standardization into spectral and colorimetric data within the graphic arts industry, it has introduced some discrepancies when data from multiple devices are compared. The problem with these measurement modes is that, even with a predetermined ΔE, one cannot guarantee that the colorimetric measurements taken with two instruments will agree. This can cause major issues for printers using multiple technologies.

**CHAPTER 2**

**RESEARCH GOALS**

The goal of this experiment is to evaluate the discrepancy between the measured values using two different devices that support the ISO “M” measurement conditions.

**CHAPTER 3**

**EXPERIMENTAL OBJECTIVES**

The objectives of this experiment will be, firstly, to gather spectral data (color measurements) of printed ink samples, on various substrates, using two different devices (X-Rite Exact and X-Rite i1Pro2), for each “M” mode. Secondly, the data will be statistically evaluated to determine the significant factors effecting ΔE values between the two devices,
and the three modes M0, M1, and M2. Lastly, I will provide methods, based on industry professional’s guidelines, to keep the variability of data between devices and modes to a minimum.

CHAPTER 4

BACKGROUND

The Challenges Optical Brighteners Bring for Accurate Color Measurement

Optical Brightening Agents

Optical Brightening Agents, or OBA’s, are additives used in paper manufacturing to help the substrate appear whiter. Normally, when no agents are added to the pulp, the paper seems “yellowish” to the human eye (Herold). This is typically not desired, as graphic arts and end-use consumers associate the yellow-tint as dirty and old. Therefore, paper manufacturers add the OBA’s to the pulp in order to make the paper more visually satisfying. OBA’s work by absorbing ultraviolet light within the range of 350 to 360 nanometers on the visible spectrum, and re-emit the energy as blue light at 400 to 500 nanometers (Shi, Liu, Ni, Yuan, Zou, Zhou 2012). This phenomenon is referred to as fluorescence. The invisible U.V. light absorbed by the OBA’s can be found within sunlight and in many artificial light sources, and because of that, the appearance is not consistent under variation of light source. Since the U.V. energy absorbed by these agents fluctuates, the variability in the amount of U.V. light emitted by surrounding light sources can cause very dramatic alterations in the visually perceived color. Therefore, one needs to take
precautions when performing color measurements. When viewing a paper enhanced with OBA’s in a viewing condition where U.V. light is present, the human eye quickly adjusts to the additional blue wavelengths and our brain simply sees “bright white.” However, measurement devices, such as spectrophotometers, are not as easily deceived. They will measure the paper as being bluer than it actually is. This creates a problem because the profiling software used will adjust for the blue tint, and add excessive amounts of yellow to offset the blue measurement (“The Color Measurement Standard for the Graphic Arts”). One can imagine how this problem builds and builds as those measuring the same printed piece, in different lighting conditions with varying amounts of U.V. energy; receive different spectral and colorimetric data. In order to solve this problem, and allow for more accurate measurements, the International Organization for Standardization revised the ISO 13566-1996 standard and created the ISO 13566-2009 standard. This newly revised ISO standard clearly defines four color measurement conditions, which can be used to better calculate spectral and colorimetric properties (ISO 13655-2009).

The Detailed Description of the ISO M0, M1, and M2 Modes

M0, M1, and M2 Measurement Conditions

M0 Measurement Condition:

Until recently, spectrophotometers and densitometers have applied the use of tungsten lamps, which approximate the CIE standard illuminant A. In order to allow for consistency with this previously used standard, the ISO established the M0 measurement condition. This function supports the CIE standard illuminant A, and tungsten illumination,
and maintains the legitimacy of legacy colorimetric values. One of the disadvantages with this mode is the absence of control for the U.V. content found in the illuminant. Therefore, when a measurement is made with a tungsten illuminant, including U.V., there is no standardized way to determine how much U.V. energy is being emitted. With this shortcoming, M0 is not the best choice when papers and colorants possess fluorescent properties. However, since the majority of color measurement devices in use today align with M0, it will remain the standard for some time to come (Dautrich, 2012).

**M1 Measurement Condition:**

Measurement condition M1 was created to provide accuracy by stabilizing the interaction between the illuminant and the fluorescing properties of the substrate. In order to better define the properties of the M1 function, this measurement condition was split into two sub-sets: M1-Part 1 and M1-Part 2. M1-1 requires that the illuminant emitted from the measurement device closely resembles the CIE standard illuminant D50. By using this standardized illuminant, which contains a specific amount of U.V. energy, one can reduce variations in the measurement data. This measurement condition is commonly used in the measurement of colors when the paper possesses fluorescing properties (Dautrich, 2012). The M1-2 measurement condition allows the simulation of the effect of D50 by applying compensation to correct for the presence of fluorescence in the substrate, while conforming to the M1 condition. It is important to note that the M1-2 mode is strictly used for color measurements when the fluorescing properties of the paper need to be captured and compensated for. M1-2 should not be used when there is any trace of optical brightening agents (Dautrich, 2012).
**M2 Measurement Condition:**

The M2 measurement condition excludes the U.V. emitted from the illuminant, removing any effects of fluorescence from the measurement data. In order to remove the U.V. energy, a U.V. filter can be added to the measurement device to block this energy from the path of the illuminant. M2 can be very useful in measuring the color without letting the effects of OBA’s effect one’s measurement. With the similarities between M0 and M2, if the measured samples do not employ OBA's, the spectral and colorimetric data of the sample will be the same (Dautrich, 2012).

<table>
<thead>
<tr>
<th></th>
<th>M0</th>
<th>M1₁</th>
<th>M1₂</th>
<th>M2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Measure Effect of OBA’s</td>
<td></td>
<td>☑</td>
<td>│</td>
<td></td>
</tr>
<tr>
<td>Measure ink fluorescence</td>
<td></td>
<td></td>
<td>│</td>
<td></td>
</tr>
<tr>
<td>Measure non-OBA stock</td>
<td>│</td>
<td>☐</td>
<td>☐</td>
<td></td>
</tr>
<tr>
<td>Cut the effect of OBA’s</td>
<td></td>
<td></td>
<td></td>
<td>☐</td>
</tr>
<tr>
<td>Agree on M standard for use in exchanging data prior to measurement</td>
<td></td>
<td></td>
<td></td>
<td>When using any M standard to exchange data, it is essential to agree on a particular M standard before measuring data.</td>
</tr>
</tbody>
</table>

![Figure 1. Applications and Use of M0, M1, and M2](image)

**Devices**

Recently, more color measurement devices have been introduced to the market, which support the ICC Measurement conditions. For example, the existing X-Rite i1Pro 2 and the new spectrophotometer developed by X-Rite, called the X-Rite eXact.

**X-Rite eXact:**

The X-Rite eXact is a top of the line color measurement device that enables printers to better understand, control, communicate and manage color. It is also one of the few devices
currently on the market to measure for OBAs. “The eXact fully supports all ISO Measure standards with one platform, measuring M1, through the entire visible spectrum and M0, M2, and M3 with a single pass, saving the time and aggravation of measuring each individually” (X-Rite Exact, 2014). One can alternate between the M0 and M1 measurement modes on this device by flipping the switch found on the underside of the device, in close proximity to the measurement window.

**X-Rite i1Pro:**

The i1 Pro 2 is a premier profiling device, developed by X-Rite, that features a new illuminant design which “allows for 3 standard measurement conditions (ISO 13655 M0: Tungsten; ISO 13655 M1: D50; ISO 13655 M2: UV Cut) plus Optical Brightener Compensation (OBC) without changing filters or needing a second instrument and ensures your investment well into the future” (i1Basic Pro 2, 2014).
CHAPTER 5

METHODS

Methodology and Experimental Design

In order to perform this experimentation, one must determine the variables that replicate the current printing conditions and create a randomized experimental design, which will detail the measurements to be taken. The factors essential to this design are devices, substrate, and ICC modes. The printer specifications and ink color can also enhance the experiment and add more depth to the results if time and resources allow. The devices to be used in this experiment include the X-Rite eXact and i1Pro2. Both of these instruments are able to measure with the M0, M1 and M2 ICC Modes, also variables of the experiment. The substrate variable can change depending on the printing process being tested, however, for this experiment plain, inkjet, and offset paper will be used. Once the variables have been decided, an experimental design must be created to ensure the individual is taking statistically accurate measurements; this design can be created in Minitab. Now that the variables and design have been determined, one can begin the experimentation. The first step in this procedure is to print a solid color swatch, being sure to disable any color adjustments or management. After the swatch has been produced, it is important to allow enough time for the print to dry; to ensure the most accurate results, the print must be conditioned for 24 hours in the Paper Testing lab. Next, the individual should follow the randomized design produced with Minitab, to take measurements of the sample. It is important that these measurements are recorded in order to produce the ΔE values being compared. The table below is an example of an experimental design created
for two device variables, three substrates, and three ICC Modes; a population size with 18 possible variable combinations.

Multilevel Factorial Design

<table>
<thead>
<tr>
<th>StdOrder</th>
<th>RunOrder</th>
<th>Devices</th>
<th>Substrate</th>
<th>ICC Mode</th>
</tr>
</thead>
<tbody>
<tr>
<td>15</td>
<td>1</td>
<td>2</td>
<td>2</td>
<td>3</td>
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<tr>
<td>17</td>
<td>2</td>
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<td>2</td>
</tr>
<tr>
<td>7</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>4</td>
<td>5</td>
<td>1</td>
<td>2</td>
<td>1</td>
</tr>
<tr>
<td>18</td>
<td>6</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
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<td>7</td>
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<td>8</td>
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<td>2</td>
<td>1</td>
<td>3</td>
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<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>9</td>
<td>12</td>
<td>1</td>
<td>3</td>
<td>3</td>
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<td>10</td>
<td>13</td>
<td>2</td>
<td>1</td>
<td>1</td>
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<td>1</td>
<td>1</td>
<td>2</td>
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<td>11</td>
<td>15</td>
<td>2</td>
<td>1</td>
<td>2</td>
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<td>3</td>
<td>16</td>
<td>1</td>
<td>1</td>
<td>3</td>
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<td>8</td>
<td>17</td>
<td>1</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>18</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
</tbody>
</table>

Devices
1 - eXact
2 - i1Pro 2

Substrate
1 - Plain
2 - Inkjet
3 - Offset

ICC Modes
1 - M0
2 - M1
3 - M2

Factors: 3
Number of Levels: 2, 3, 2

Figure 4. Minitab Multilevel Factorial Design

Following this experimental design will produce statistically accurate measurements. Once the measurements have been taken and delta E values are calculated, the results can be compared. The expected results for this experimentation are to observe similar ΔE values for each measurement device, within a tolerance less than observers’ ability to differentiate.

Timetable

The procedures for this experiment can all be completed onsite with no necessary outsourcing for analyses. Therefore, assuming the necessary devices and variables are
present at the time of experiment, the experimentation is solely dependent on the individual's time schedule. A general breakdown of the time for each operation goes as follows:

- Determine variables and create multilevel factorial design: 1 Hour
- Print swatch and condition in paper testing lab: 25 Hours
- Measure swatch according to full factorial design and enter into Excel: 10 min/measurement
  - 18 possible combinations: 2 hours
- Record data and calculate ΔE values: 1 hour
- Compare and analyze data: 2 hours

Total time needed for experimentation: 31 hours

CHAPTER 6

FUNDING

The funding required to complete this experimentation is dependent on whether or not the company in focus currently owns the X-Rite eXact and i1Pro 2. If the company does not own these instruments, funding must be acquired to obtain them. Additionally, the labor and use of equipment will require funding. This may vary from plant to plant, but should remain low as the experiment is only proposed to take five hours of the company's time.
FACILITIES AND EQUIPMENT

Facilities

This experiment does not require any external use of facilities, as the processes can be completed anywhere assuming the appropriate equipment is provided. The facility can be internally located within the company performing this experiment.

Equipment

In order to complete the procedures outlined in this experiment, the company must obtain key equipment. First of all, the X-Rite eXact and X-Rite i1Pro are essential to this experimentation. Assuming the company is a fully functioning printer, these two devices should already be in-house. If not, one can purchase both of these devices from X-Rite, and receive them within a few weeks. Another necessary piece of equipment is the printer and appropriate ink. The printer outlined in this experiment is an HP Color LaserJet CP2025, and the ink selected is Magenta. This equipment can vary depending on the resources available. Finally, software can play a role in the procedures outlined for this experiment. Minitab can be helpful for creating a statistically acceptable factorial design, while Microsoft Excel can ease the process of calculating the ΔEs of each measurement.
BUDGET

The budget for this experiment remains minuscule if the company currently owns the X-Rite eXact and i1Pro 2, as these are the most costly aspects to the budget. However, there is a high probability that the company has already purchased and is currently making use of the majority of equipment needed for this project. Therefore, it is expected that the budget will come in significantly lower for fully functioning printing facilities. The image below provides a detailed breakdown of all the potential expenses, and therefore the maximum budget needed to complete these procedures.

<table>
<thead>
<tr>
<th>Budget of Experiment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Personnel</td>
</tr>
<tr>
<td>Labor $10/hour $310</td>
</tr>
<tr>
<td>Materials</td>
</tr>
<tr>
<td>Ink $24.99</td>
</tr>
<tr>
<td>Substrate $25</td>
</tr>
<tr>
<td>Equipment</td>
</tr>
<tr>
<td>X-Rite eXact $7,000*</td>
</tr>
<tr>
<td>X-Rite i1Pro 2 $1,259.00</td>
</tr>
<tr>
<td>Minitab $1,495</td>
</tr>
<tr>
<td>Microsoft Excel $60</td>
</tr>
<tr>
<td><strong>Total Budget</strong> $10,173.99</td>
</tr>
</tbody>
</table>

*Approximation

Figure 5. Budget of Experiment
CHAPTER 9

CONCLUSION

After performing the methods outlined, and obtaining results of the ΔE values, one can determine the feasibility and significance of comparing measurements between the eXact and i1Pro 2. Since both instruments employ identical light sources and detectors, and are calibrated to a (standardized) white tile, the ΔE values should only vary based on random statistical variations, and small systematic errors inherent between devices. However, as this has only been stated by X-Rite, and no data has been released to support the claim, this experiment will help the printer identify the level of variance, and its statistical significance. Therefore, following the project, the individual will have data to provide a confidence interval providing statistics printers may use to understand the significance of comparing measurements made between these testing devices.
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ISO. "Graphic technology -- Spectral measurement and colorimetric computation for graphic arts images." ISO 13655:2009 (n.d.).


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