Review for

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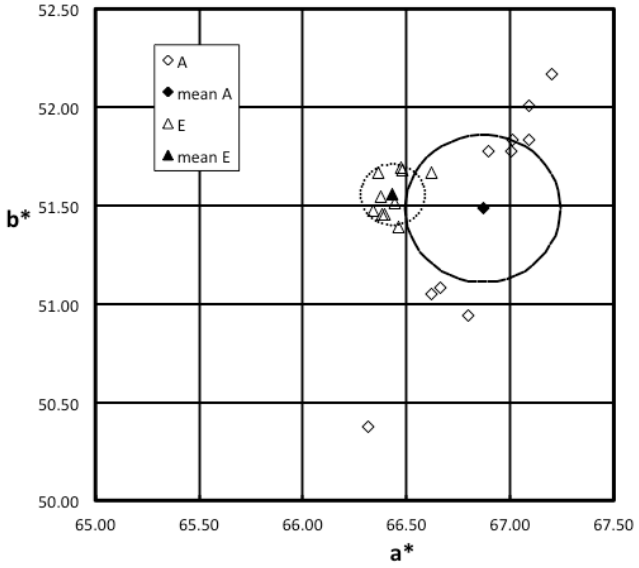
Creation of Color Analysis Target

Task C: Identify an appropriate base material for a next generation color target



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Executive Summary

In support of the digitization efforts of the Library of Congress, a solicitation, *Creation of Color Analysis Target*, was issued and subsequently awarded to Avian Rochester, LLC for the design and fabrication of a Next Generation Target (NGT) for color camera calibration. The NGT will be designed to address the shortfalls in commercially available targets. For the purposes of this project, those shortfalls are limited color gamut, and a lack of durability for typical laboratory usage. The lack of durability has a direct impact on the accuracy of the calibrated values for the target. Any physical damage to the target surface requires calibration to reassert the color coordinates for each patch, meaning the cost of operations for a target is directly tied to its durability.

The previous reports, documenting the effort in Tasks A and B of this project, proposed an initial set of colors for inclusion in the NGT. These colors considered existing color targets, color systems of historical importance, as well as the colors of historically relevant materials.

The present review addresses the requirements of Task C of the project, *Identify an appropriate base material for a next generation color target*. The goal of Task C is to evaluate a series of potential materials to be used as the supporting layer onto which the paint will be applied. The considerations for this selection are physical: after application, paint must be of uniform color and of maximum gloss.

Subsequent tasks will: identify the specific pigment systems that will fulfill the other requirements of the NGT; describe final patch production; and finally describe the production of the prototype and final NGT assemblies.

Introduction

The scope of this review is to consider the gloss and resulting paint color of various proposed substrates for the NGT painted patches. For both gloss and color, it is important that a given paint/substrate combination be uniform in both metrics. For gloss, the goal is to be the highest attainable.

The breadth of this document is therefore narrower than previous reports for this project. What follows will take the form of an experimental report.

Experimental Materials and Apparatus

A series of seven commercially-available transparency stocks were identified. These are all what would historically have been used in overhead projectors. The advent of the inexpensive digital projector has impacted the cost, variety, and availability of this type of stock. We do not claim the selection made for this review is exhaustive, but that it is representative of the available products. Table I lists the stocks used here.

Table I. Manufacture and item number of the transparency materials used for this review.

Code	Manufacturer	Type/Number
A	Kodak	ColorEdge 500
B	Precision	#10-101
C	Apollo	VCG7060E
D	TruLam	TF-LP
E	Office Depot	#753-611
F	C-Line	#60837
G	3M	CG3710

Gloss measurements were made with a BYK-Gardner micro-tri-gloss. This particular device was recently factory certified to be in good working order. It simultaneously measures 20°, 60°, and 85° gloss, all according to ASTM D523 *Standard Test Method for Specular Gloss*. Color measurements were made with a KonicaMinolta FD-7. This particular device was also recently factory certified. Color measurements were reported as CIELAB coordinates calculated using illuminant D50 and the CIE 1931 2° standard observer.

Experimental Steps and Results

The experiment requires several steps:

1. Determine the correct backing for the gloss and color measurements.
2. Measure the gloss of the bare substrates.
3. Choose an example glossy paint and identically draw down paint samples on all substrates.
4. Measure the gloss and color of the resulting paint samples.

Step 1: Substrate backing

To consistently evaluate the set of substrates, a series of backings were analyzed to determine the one resulting in the most uniform gloss. Since the transparency stock is obviously very transmissive, the possibility exists for the backing behind the stock to affect the gloss measurements. Likewise for the paint measurements in step 4: if the paint/substrate combination is not completely opaque, the backing will influence the color.[†] Once the uniformity of the measurements is established and a consistent backing material is defined, all subsequent measurements will be made (for bare or painted stock) on that backing. The assumption is that if the measurements of one stock over the backing are uniform, any non-uniformity found later can be attributed to the stock or paint.

To find the optimum backing, the gloss of a sheet of stock A was measured with replicates over several different

[†] The final paint selection and ultimately patches in the NGT are expected to completely hide the background. The possibly lack of complete hiding in this experiment was due to the desire to simplify the test, and further, is not expected to affect the color or gloss results significantly.

materials. These were: 8 sheets white office paper (matte); wooden tabletop; 50 sheets of stock A; 5 sheets of glossy office paper; and black cardboard (matte). The results are in Table II.[‡]

It is clear that the white matte office paper results in the most uniform gloss. In particular, the 60° gloss measured identically across the sheet. For all further measurements the samples will be backed by the same eight sheets of office paper.

Table II. Gloss results from Backing Experiment (Step 1, above)

	Gloss Measurement			**scaled z-score (100σ/μ)**		
Backing	**20°**	**60°**	**85°**	**20°**	**60°**	**85°**
8 sheets white office paper (matte)	116	128	99.5	**0.98**	**0.00**	**0.31**
	118	128	100			
	116	128	99.6			
	117	128	99.3			
	115	128	100			
Wood tabletop	119	137	100	1.75	1.86	0.55
	119	139	100			
	124	143	100			
	121	140	99.5			
	122	143	101			
50 sheets of stock A	292	218	101	4.55	0.82	0.55
	292	221	101			
	298	221	100			
	316	223	100			
	279	220	100			
5 sheets stock H (glossy paper)	119	143	99.5	1.61	0.31	1.00
	120	143	102			
	117	143	100			
	122	143	100			
	118	142	101			
black cardboard (matte)	113	125	100	4.03	0.67	0.68
	104	124	100			
	106	125	98.6			
	102	126	99			
	104	126	100			

Step 2: Bare Substrate Gloss

For this step, two sheets of each substrate type were measured 10 times across the sheet. It was noted that the slight texturing of some of the substrates resulted in different gloss when the instrument was rotated 90°. Therefore gloss measurements were made in both in portrait and landscape directions.

Table III summarized the bare substrate gloss results. Two metrics are shown for each substrate type: overall average gloss, and the absolute difference between portrait and landscape measurement. The preferred substrate will have high mean gloss, and the low sensitivity to instrument orientation. According to the results in Table III, there is

[‡] The use of standard deviation divided by the mean is a common statistical technique sometimes referred to as "z-score." It is useful to compare the distributions of data that are not all on the same scale. In this case they are further multiplied by 100 to keep the numbers in a useful range.

no clear winner. Substrate C, however has the highest mean gloss and the lowest orientation sensitivity to 60° gloss, which , by ASTM D523 recommendations, is the most relevant gloss geometry for this application.[§]

Table III. Results of gloss measurements of bare substrates.

Substrate ID	overall mean gloss			|portrait - landscape|		
	20°	60°	85°	20°	60°	85°
A	114.3	131.2	100.1	0.7	6.9	0.7
B	98.7	130.8	91.9	6.7	7.3	2.7
C	**177.7**	**168.8**	**103.4**	4.2	**0.7**	1.0
D	166.7	161.8	101.9	3.5	2.0	0.0
E	100.0	121.2	91.7	0.8	8.5	1.5
F	130.1	150.4	100.2	5.5	9.9	1.7
G	150.3	152.3	105.9	3.2	3.1	0.9

Step 3: Draw down example glossy paint

A glossy exterior latex paint was selected that is a reasonable example of the ultimate target paint for the NGT. The specific paint was Sherwin-Williams All-Surface Enamel, an exterior acrylic latex gloss product. (Note that the final selection of the coloring system is the goal of Task D of this project.) For each substrate type, two sheets were used for paint draw downs: one that was previously measured in Step 2 for gloss, and one additional sheet. To achieve (near) complete hiding, the draw-downs were completed in three passes: 0.003", 0.006", and 0.012". Between each paint application the samples were allowed to dry. To speed the drying process a small hot air blower was used.

To facilitate consistent draw downs, a BYK-Gardner byko-drive was used. This device holds the substrate down with a vacuum platen and pushes the draw down bar across the surface at a uniform velocity. This eliminates the human factor and contributes significantly to uniform and high quality drawdowns.

Step 4a: Gloss measurements of paint on substrate

Table IV shows the gloss measurements of the painted substrates. There are two important conclusions from these measurements: first, the total gloss range is very small, meaning that the paint effectively masks any surface differences between the various substrates. Given the first, the second is not surprising: there is essentially no longer any difference seen by rotating the measurement device. Consider that substrate F has amongst the highest in the right three columns of Table III, yet it has the lowest average difference in the right three columns of Table IV.

Table IV. Results of gloss measurements of painted substrates.

Substrate ID	overall mean gloss			|portrait - landscape|		
	20°	60°	85°	20°	60°	85°
A	23.2	59.4	87.7	0.1	0.1	0.3
B	22.8	60.0	88.8	0.2	0.5	0.2
C	22.9	59.9	88.8	0.2	0.5	0.1
D	22.4	59.7	88.0	0.3	0.3	0.6
E	22.9	60.0	88.6	0.1	0.4	0.6
F	**23.2**	**60.3**	**89.0**	**0.1**	**0.3**	**0.0**
G	23.4	60.6	88.8	0.3	0.7	0.4

Step 4b: Color measurements of paint on substrate

Table V shows the *Mean Color Difference from the Mean* (MCDM) for each substrate. This metric is an indication of the color uniformity across each respective painted area. It is a three-step calculation:

[§] ASTM D523 states: "The 60° geometry is used for intercomparing most specimens and for determining when the 20° geometry may be more applicable." Further, 20° gloss should be considered when 60° gloss is greater than 70, and 85° gloss when 60° gloss is lower than 10.

1. Calculate the mean L*, a* b* for each substrate. (MCD*M*)
2. Calculate the color difference between each measurement and the mean from step 1. (M*CD*M)
3. Average these color differences for MCDM. (*M*CDM)

Table V shows that with respect to color uniformity, substrate E performs the best, followed closely by substrate G. Note that even the greatest MCDM (substrate A at 0.37) is still indicative of a small range of colors.

Table V. Results of color measurements of painted substrates.

Substrate ID	Mean Color			MCDM
	L*	a*	b*	
A	40.5	66.9	51.5	0.37
B	40.5	67.1	52.0	0.22
C	40.4	67.0	51.8	0.25
D	40.5	67.2	52.0	0.20
E	**40.1**	**66.4**	**51.6**	**0.16**
F	40.4	67.1	52.0	0.31
G	40.2	66.8	52.0	0.18

A more visual representation of MCDM is shown in Figure 1. Open triangles are individual measurements from substrate E. The filled triangle is the mean color for substrate E. The dashed circle is centered on the mean color of E, and has radius of its MCDM. As noted above, even the apparently dispersed data from substrate A are still reasonably clustered from a perceptual sense; all but one of the measurements are well below a color difference of 1.0 from the mean, indicating the visual difference is quite small.

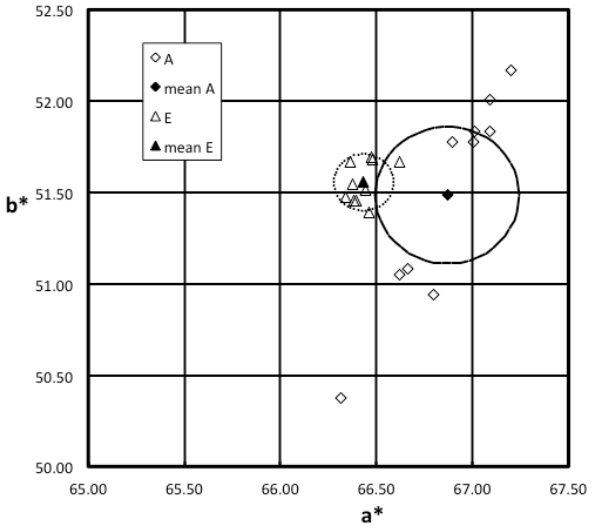

Figure 1. Distribution of colors of two substrates, A and E. Open symbols are individual measurements; filled symbols are the mean color; the radius of the circles is the MCDM. Lower MCDM indicates a more tightly clustered (and therefore repeatable) set of measurements.

Conclusions

A set of experiments were performed to evaluate the gloss and color uniformity of a series of clear transparency stock. While the gloss measurements on the bare substrate did show a substantial variation across the substrate types, these differences were masked once the substrate had paint applied. Painted substrates performed much more similarly in color and gloss. It is the conclusion of this review that the final substrate selection be deferred and

reported with the results from Task D: *Identify and test an appropriate color pigment system*.

After selection of the pigment system, which will be based on gloss and attainable color gamut, a subset of transparency stock will be re-evaluated using the newly-defined pigment system.