

What's More Important: Color Accuracy and Contrast or Brightness in Conference Room Presentations?

A White Paper by Chris Chinnock



January, 2015

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Table of Contents

Introduction.....	3
Color Performance.....	3
Color Standards	4
What is a Color Space?.....	4
sRGB and Rec 709 color spaces	5
DCI, Rec. 2020 , and Adobe RGB Color Spaces	5
Common Causes of Incorrect Colors on a Display	6
White Point	7
How Contrast can Play a Part in Effective Conference Room Decisions	7
Measuring Contrast Ratios	7
On/Off Contrast	7
Dynamic Contrast	7
System Contrast – The Extension of the Older ANSI Contrast Measurement.....	8
Why System Contrast is Important in Corporate and Education.....	8
Brightness – Real and Perceived	10
Color Accurate, High Contrast Displays Have a Brightness Enhancing Effect Too.....	11
Experimental Set up.....	11
Experimental Results	12
Summary.....	14
Appendix 1: HC1200 Specifications	16

Introduction

Historically, the projection industry has focused on offering more and more lumens. But is this the right metric to be focused on? Maybe end users, integrators and manufacturers should focus more on the color accuracy and contrast of the projector instead of assuming that more brightness is always better. This is the question that this white paper asks. But the purpose is not to provide a definitive answer to the question, but rather, to lay out some facts and hypothesis and start an industry dialog.

This is actually a pretty important question as display makers – both flat panel and projection - need to understand what direction their products should evolve in: higher brightness or higher contrast and accurate colors. This question is perhaps most relevant to projector makers, so we will focus the discussion on that platform, although the points should apply to flat panel displays as well.

The impetus for this dialog was the release of the BenQ [Colorific HC1200](#), a projector that is optimized for color accuracy and high contrast, rather than traditional brightness measurements. The specs on this projector indicate that it can display 100% of the sRGB color gamut, offers 2800 ANSI lumens, a traditional ANSI checkerboard contrast rating of 510:1 and an on/off contrast ratio of 11,000:1. For a conference room application, is the HC1200 “better” than other popular projectors with 4,000 lumens, but with less contrast and a non standard color gamut? It is the trade offs of color, lumens, color accuracy and contrast that we are interested in exploring – not necessarily which projector to buy. That comes after one understands the trade-offs.

At the end of the paper, we will profile one set of tests done that represent one case study for a conference room set up. We encourage others to do additional studies To explore the issues, we start with background discussion on color performance, contrast and brightness, before discussing the test results.

Color Performance

Color performance refers to both the range of colors a display can produce as well as the accuracy in portraying specific colors. Color science is a complex topic and we don’t want to get bogged down in deep scientific explanation, so we will try to simplify the discussion somewhat – offering apologies to the color scientists reading this.

The place to start is the content creation process, and the easiest example is around a traditional home theater application. In the creation of Hollywood movies for example, a colorist is engaged to modify the colors of the movie or TV show to fit a certain style or look. The colors may not be accurate and may be muted or vibrant for artistic reasons. But, the colorist’s pallet is limited to a range of colors contained with the color standard for HDTV (Rec. 709). And if the display can portray this color range correctly, it will faithfully reproduce these colors, delivering the “director’s intent.”

In commercial and education settings, there are a number of other color critical needs that need to be considered. Many presentations utilize or replicate images that need to have colors that match the real world. Advertising agencies, clothing manufacturers, and hair color companies are obvious examples of the need to have color accurate displays in a presentation. Human flesh tones are perhaps the most critical to reproduce accurately, but even common items

like the tint of a blue jean or the color of a model’s hair are sensitive items that require accurate colors. If these colors are not reproduced faithfully by the display, it will be noticed.

In a conference room application, it would not be unusual for animated content or computer generated graphics to have specific colors that may not have a natural world counterpart, but one the artist has selected for a specific effect as well. Whether the artist uses static artwork or an embedded video to be played within a PowerPoint slides, the impact of color can be crucial in a decision making environment. Additionally, colors are often important to the corporate personality of the audience. Items such as embedded logos in a PowerPoint slide need to faithfully reproduce the right colors no matter how difficult they may be to reproduce on a projector or else it can distract the audience during the entire presentation. For example, if the presentation is for Coca-Cola, you better be sure that the red is the right color in both the logos and videos or the client will not be happy. And, if a person’s face looks ashen or green, or the color of the fabric you are about to order is not faithfully reproduced, no one will be happy. People are very sensitive to accurate colors – especially colors they are closely familiar with.

Color Standards

A number of color standards have been developed to help ensure that the colors created in production can be reproduced on the display. These include standards like Rec. 709, sRGB, Adobe RGB, DCI-P3 and 2020. Below is an overview of how color space and the various color standards in the industry apply to a typical conference room projector.

What is a Color Space?

There are several ways to represent the color space of all visible colors. Probably the most familiar is the 1931 CIE Chromaticity diagram shown below. The horseshoe shaped area represents all the colors that the human eye can see. Interestingly, nature does not create colors to fill this horseshoe, but can be represented by an irregularly shaped circle (surface colors) in Figure 1.



Figure 1: Surface Colors within the 1931 CIE Chromaticity Diagram

sRGB and Rec 709 color spaces

The **sRGB** color space is the primary standard used in the majority of input devices, such as cameras and scanners, as well as the majority of display devices, such as computer monitors, printers, and smartphones. The **sRGB** color space uses the RGB primaries (end points of the triangle), with a specific gamma curve. The gamma is what sets the steps between gray levels. . Most internet content is rendered using the sRGB color space.

The HDTV specification for video content is represented by **Rec. 709**. **This is typically referenced in televisions and home theater projectors**, and uses the same RGB primaries as sRGB but a different gamma curve. In other words, a sRGB/Rec. 709 comparison of series of red blocks with increasing levels of brightness will show many identical levels, with only some slight difference in the darker regions

DCI, Rec. 2020 , and Adobe RGB Color Spaces

The DCI (P3) color space is used in digital cinema, while the Rec. 2020 standard is the new color space for Ultra-High Definition TVs. This is the largest color space and does the best job of showing all of the colors available in nature, plus many additional colors (neon lights, LED lights, computer generated colors, etc.). Figure 2 shows how three color standards are overlaid on the horseshoe of visible colors.

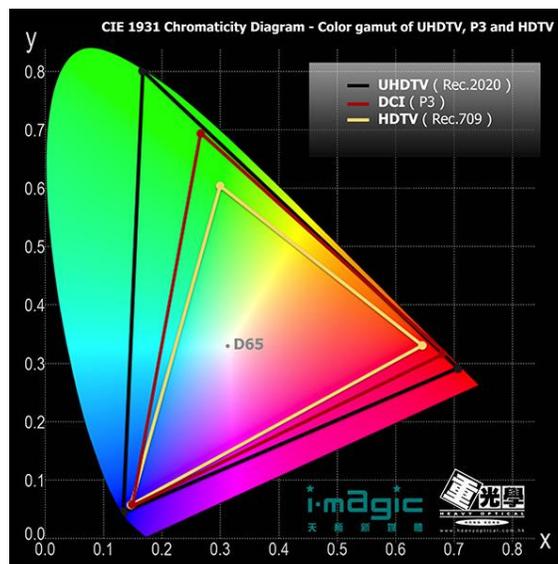


Figure 2: Various Color Standards on the 1931 CIE Chromaticity Diagram

Figure 3 shows the sRGB color space along with the Adobe RGB color space, which is popular with graphic artists. It also shows the location of a certain color, in this case, Pantone 17-5641. If you are trying to display this color on a typical sRGB standard computer monitor, you won't display it properly. Only a display designed for an Adobe RGB or DCI-P3 color space can display it properly, and are usually significantly more expensive than a standard business display using sRGB.

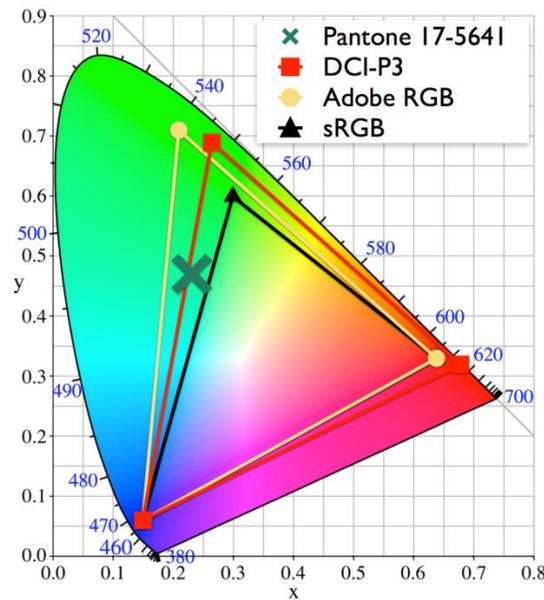


Figure 3: Displaying a Specific Color in the 1931 CIE Diagram

For conference room applications, what color spaces are important? For the majority of commercial and education projector application, the sRGB color space is the standard used with monitors, printers and on the Internet. Having this standard allows a digital photo taken in sRGB mode to be displayed on the Internet to be viewed on a monitor and show accurate colors (using the sRGB mode of the monitor) and then to print those same colors (on a calibrated sRGB printer). If a projector is used as the display, it needs to also produce accurate sRGB colors so what you see is what you get (like ordering a sweater and not being shocked at the color when it arrives). If you are going to show movies, advertisements, or videos, then Rec. 709 is needed to replicate the specific color detail the director intended

The DCI-P3 color space is used only for theatrical cinema production, so is not relevant for this market. Adobe RGB may be relevant for applications in the printing industry. It was designed to encompass all the colors achievable in CMYK color printers, but using the RGB color primaries of the display to represent these colors. The Rec. 2020 color space is coming for UHD-TV, but there is no content currently available in this color space.

Common Causes of Incorrect Colors on a Display

As a general rule, content should be mastered to a specific color standard, and this standard should be best matched to the display where it is intended to be shown on. For example, TV content will be shown on a TV or tablet, so the colorist needs to render all of his colors within the Rec. 709 color space so they can be reproduced properly on a TV. That is how it is supposed to work.

But a couple of things can go wrong. First, the display may not have the capacity to properly display colors in a particular color gamut. In addition, the display that may have originally supported the color space could be have shifted and need to be recalibrated, or have aging issues that may limit its ability to display colors accurately as it did when new.

Furthermore, the display itself may not be set to the right color standard for the incoming content. For example, if the content was mastered in Adobe RGB but the display is set to sRGB mode, it will not display the correct colors – even if the display is calibrated for accurate sRGB colors. If the display can support the incoming color space, it can be switched to that gamut. If it cannot, then a transformation from the incoming color space to the display color space must be performed. The accuracy of this will depend upon the manufacturer and is not ideal for the display of color accurate information.

White Point

The white point of the display is that combination of red, green and blue light that creates white light. But white light has a “color temperature”. Movie content is typically graded and should be displayed using a D65 white point. This means the apparent blackbody equivalent of that point is a white light source at 6500 degrees Kelvin.

Some displays are tuned to high white points like 9, 10 or even 11,000 degrees Kelvin. These displays will appear distinctly bluish in their white point. Sometimes this may be preferred when showing text or PowerPoint slides with a bright white background. However, most color standards, like the ones above, call for a D65 white point.

How Contrast can Play a Part in Effective Conference Room Decisions

Contrast is a key element in image quality. It is as measure or the range of brightness levels and dark levels. High contrast allows more details to be discernible. People often believe that high contrast images have higher resolution than low contrast images. High contrast images can also take on a near 3D-like appearance, so clearly it is an important factor in image quality.

There are several types of contrast measurements, but unfortunately, these are often confused or not specified. Let’s take a look at them as each offers information about the display performance.

Measuring Contrast Ratios

On/Off Contrast

As the name suggests, this is a measure of the brightness of the projector with a full white screen at it brightest level divided by the brightness when a black screen is shown. The brightness is measured by a simple photometer in a dark room. This is often the contrast quoted on a projector spec sheet, **but it has the least meaning in terms of what to expect from image performance in a real setting**. Specs here can range from 1000:1 to more than 50,000:1 depending on the imager technology and optimization of the light path.

Dynamic Contrast

This is similar to On/Off Contrast except that a means to adjust the brightness becomes part of the measurement. In a projector, this typically means an iris is inserted in the light path that can be adjusted to vary the light delivered to the imaging panels. When fully open, the brightness level will mimic the On level from the simple On/Off contrast measurement. For the

black state measurement, the iris is closed down to limit the light. This has the effect of dramatically lowering the black level and significantly increasing the contrast. Dynamic Contrast levels can vary from 10,000:1 to 1,000,000:1.

Dynamic Contrast can be a little better at indicating the picture quality in some circumstances, such as home theater. It does not really expand the contrast in a true sense **as you cannot display the brightest white with the iris open AND the darkest black with the iris closed at the same time.**

System Contrast – The Extension of the Older ANSI Contrast Measurement

This method of contrast measurement is fairly straight forward. A 16-zone checkerboard pattern is projected onto the screen in the environment where the system will be installed and with the desired or required ambient lighting. The luminance reflected from the screen for each black and white segment is measured from several locations in the room. The contrast ratio is calculated by averaging all of the ratio measurements. Because of the requirement to measure white and black together on the same screen, the boost of mechanical aids such as an iris is removed, making this a good test to compare projectors in actual use.

Note that this procedure measures reflected light (Ft/L) and not the light coming out of the projector (lumens) — which is the way contrast is measured today by the projector makers and which was the basis for the original ANSI contrast standard, which was retired back in 2003. These contrast levels are much lower than the On/Off or Dynamic Contrast levels used in typical projector specifications. While the On/Off Contrast tells you the upper limit of contrast for the projector under test conditions where brightness can be traded for contrast, the system contrast is a highly effective way to determine actual performance when you need both brightness and contrast.

The new approach takes into account the light output and inherent contrast of the projector, but also takes into account both the size and gain of the screen, any ambient light rejecting properties of the screen, and the impact of ambient light on the resulting contrast. And, it is evaluated from several positions in the room. This is a much better representation of the actual contrast viewers will experience in real-world applications.

Why System Contrast is Important in Corporate and Education

The new Projected Image System Contrast Ratio (PISCR) standard that was developed by InfoComm is key in ensuring that a meeting room delivers an effective image - a system evaluation that includes the projector, screen, ambient light and even the room itself.

The standard specifies four minimum system contrast levels depending upon the needs of the end user. Note that any of these applications can occur in a conference room. As shown in Figure 4, they are:

- Passive/Informational Viewing requires a minimum contrast ratio of 7:1.
- Basic Decision Making requires a minimum contrast ratio of 15:1.
- Critical Decision Making requires a minimum contrast ratio of 50:1.
- Full Motion Video requires a minimum contrast ratio of 80:1

Viewing Category	Minimum System Contrast Ratio	Viewer's Requirements	Environment Example Characteristics	Examples
Passive Viewing	7:1	<ul style="list-style-type: none"> • Images and text distinguishable from background • Passive engagement with content • Assimilation and retention of detail not required • Informal viewing of video and data 	<ul style="list-style-type: none"> • May have little control of ambient light • Ambient light may be high • Task lighting may not be ideal • Windows may have insufficient blinds or curtains • May be reflective surfaces (e.g., furniture) • Projector light output may be inadequate 	Retail stores, family (TV) rooms, presentations of non-critical or informal information
Basic Decision Making	15:1	<ul style="list-style-type: none"> • Actively engaged with content • Assimilation and retention of detail • Images and text are legible to the extent that basic decisions can be made • Decisions based on content itself, not resolution of detail 	Improvements relative to the above category are often in evidence	Information displays, presentations containing detailed data and images (e.g., classrooms, boardrooms, multipurpose rooms, product illustrations)
Analytical Decision Making	50:1	<ul style="list-style-type: none"> • Images and text contain finest detail • Assimilation, retention and analysis of finest detail • Analytical image assessment • Mission-critical image displays • Professional analysis of detail 	<ul style="list-style-type: none"> • Highly controlled environment • Controlled ambient light • Focused task lighting • No ambient light directly affecting screen, black-out window treatments 	Engineering and architectural drawings, electrical schematics, forensic evidence, failure analysis, photographic evaluation (e.g., courtrooms, medical galleries)
Full Motion Video	80:1	<ul style="list-style-type: none"> • High level of engagement with content • Films below movie theater distribution standard 	Precisely controlled ambient light	Controlled viewing environment (e.g., home theater, business screening room, broadcast post-production)

Figure 4: PISCR Minimum Contrast Levels

The specified minimum contrast ratios above were developed with the input and support of a whole team of contributors including display chip manufacturers, screen manufacturers, and subject matter experts from both the commercial and home theater sides of the display industry. The minimum contrast levels are a consensus after a long series of tests.

While the contrast specification numbers are lower than what is found on projector marketing spec sheets, it does an excellent job of **indicating how important native contrast is in decision making**. For example the **need for increased contrast for “Critical Decision Making” is over three times that needed for “Basic Decision Making”**.

Consequently, if a projector model with lower native checkerboard contrast is placed into a “Critical Decision Making” environment, then either the ambient light has to be reduced, or a more expensive screen with higher contrast needs to be installed to enable the projector to be effective enough to meet the standard. In a typical corporation where each conference room can be the location of thousands of decisions, the ability for a projector to support higher native checkerboard contrast levels can enable easier viewing for better decision making with less impact to either meeting environments or having to purchase more expensive screens.

Brightness – Real and Perceived

Technically speaking, brightness is what we perceive, whereas luminance is what we measure. While both terms are typically used interchangeably, there is a difference – especially when you have wide color gamut displays.

Luminance is typically measured with a luminance meter and measures the power of the light. Normally, it is white light that is measured, as with the contrast measurements, but one can also measure colored light as well. All projector makers specify their luminance as a white light value at its peak output (maximum lumens). This luminance level can also be affected by the color temperature of the display. Projectors will generally have lower luminance when they have a D65 white point as opposed to a 8000, 9000 K white point or higher. Sometimes this difference is significant, but the color temperature for the luminance measurement is rarely specified. Some manufacturers of projectors also specify “color lumens”, which measures luminance with all-red, green and blue screens.

When the projector illuminates a screen, light is reflected back to the eye where it’s “brightness” is perceived. This brightness depends on the size of the screen illuminated – the bigger the screen, the lower the light per unit area and the lower the brightness. It also depends upon the “gain” of the screen and your position relative to the center of the screen.

The impact of color saturation in perceived brightness is well known and called the Helmholtz-Kohlrausch (HK) effect. According to Wikipedia, the HK effect “is an entoptic phenomenon wherein the intense saturation of spectral hue is perceived as part of the color’s luminance. This brightness increase by saturation, which grows stronger as saturation increases, [so it] might better be called chromatic luminance.”

In other words, the more saturated the colors, the brighter they appear. Figure 5 from Wikipedia shows this effect. The top and bottom rows all have squares with the same luminance. The gray squares on the bottom are all perceived as the same brightness (so not distinguishable or visible) while the colored squares are perceived to be quite different in brightness.

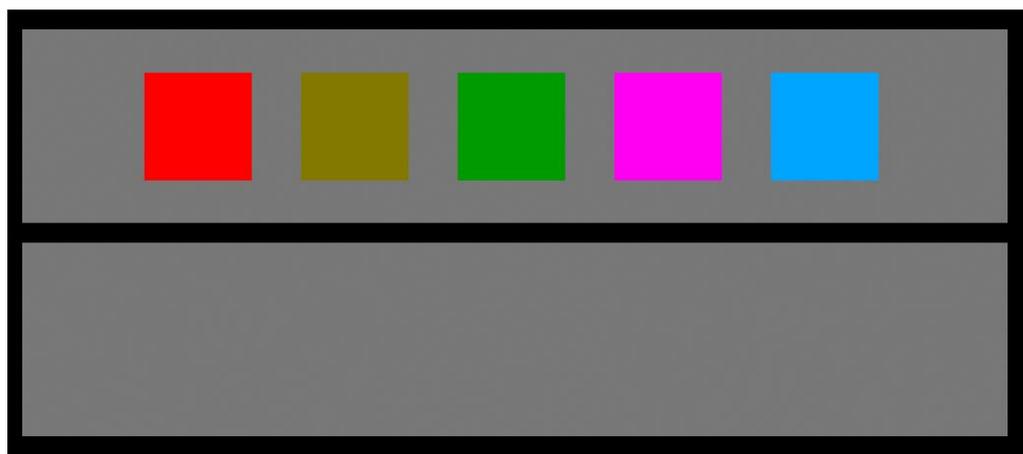


Figure 5: The HK Effect Visualized

Color Accurate, High Contrast Displays Have a Brightness Enhancing Effect Too

Our theory is that displays that have accurate colors that meet a specific standard which have high contrast will appear brighter than displays that have inaccurate colors and/or lower contrast. If this is true, it also means that simply looking at the standard brightness specification for a projector may not be the best indicator of final image quality.

Appendix 1 provides the full specifications for the new BenQ HC1200 projector. This is a single chip DLP projector that has 1920x1080 resolution and uses a single 310W lamp to achieve 2800 ANSI lumens, and is rated at 510:1 ANSI contrast and an on/off contrast ratio of 11,000:1.

BenQ believes this projector offers some advantages over other competitive models such as:

- Color accurate sRGB gamut out-of-the-box
- Stable white point
- Stable colors and color accuracy
- Higher Checkerboard Contrast for improved System contrast ratings
- Same or better perceived brightness than 4,000 lumen competitors

To better quantify these value propositions, BenQ performed some testing. The details are presented here and we invite industry to perform similar tests to better understand the important aspects of image quality.

Experimental Set up

- Three projectors were tested: BenQ HC1200; a Top Selling 4000 lumen model using 3LCD technology and a Top Selling 4000 lumen model¹ using DLP technology
- All featured identical unity gain, matte white screens
- Room ambient was “dim” although not specifically measured
- 18 static images were presented to each projector (Figure 6)
- A BenQ Model PG2410PT G7 Certified color accurate monitor was calibrated to the sRGB color space and positioned between each projector to act as a reference image when judging color accuracy
- Respondents were asked to judge which projector image was brighter (or if they were the same)
- Respondents were asked to judge which projector image seemed more [color] accurate (or if they were the same)
- 42 people participated in the survey

¹ *Top Selling 4000 lumen class DLP projector model – InFocus IN3138HD*

Top Selling 4000 lumen class LCD projector model – Epson 1940W

Both projectors were ranked in the top six best selling projectors rated 4000 lumens or higher in the December 2014 US Distribution Sell Through report from Pacific Media Associates

- The manufacturers or model information of each display were not identified

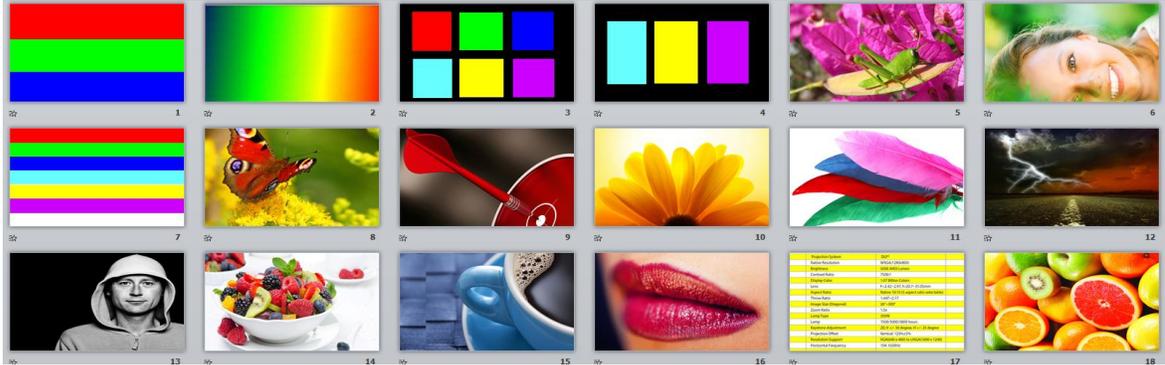


Figure 6: Some of the Test Images Used

Experimental Results

The ANSI checkerboard system contrast of each projector was measured in the dim room.

Results:

- Top Selling 4000 Lumen Class 3LCD: ~10:1
- Top Selling 4000 Lumen Class DLP: ~30:1
- BenQ HC1200: ~30:1

The manufacturer rated lumen specification of each projector was:

- Top Selling 4000 Class Lumen 3LCD: 4,200 lumens
- Top Selling 4000 Class Lumen DLP : 4,000 lumens
- BenQ HC1200: 2,800 lumens

The results of the question about perceived brightness are shown in Figure 7.

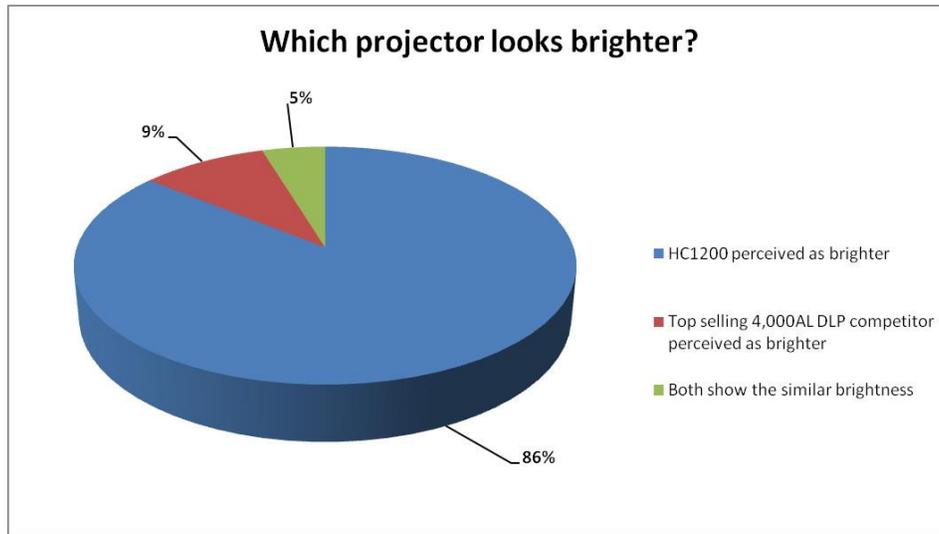


Figure 7: Brighter Projector Results

Even though the BenQ projector has a significantly lower lumen specification, it was judged to be brighter than a popular projector with rated specifications nearly 50% higher. Why is that? We think it is the color accurate nature of the display since the other top selling DLP projector had similar contrast.

The color gamut for each projector (out of the box) was also measured. The results are shown in Figure 8. Note that the BenQ projector is closest to the Rec 709/sRGB color gamut whereas 4000 Lumen DLP projector model is short in the green and off in the blue. The 4000 Lumen 3LCD unit actually has green and red primaries that are outside the Rec. 709 triangle.

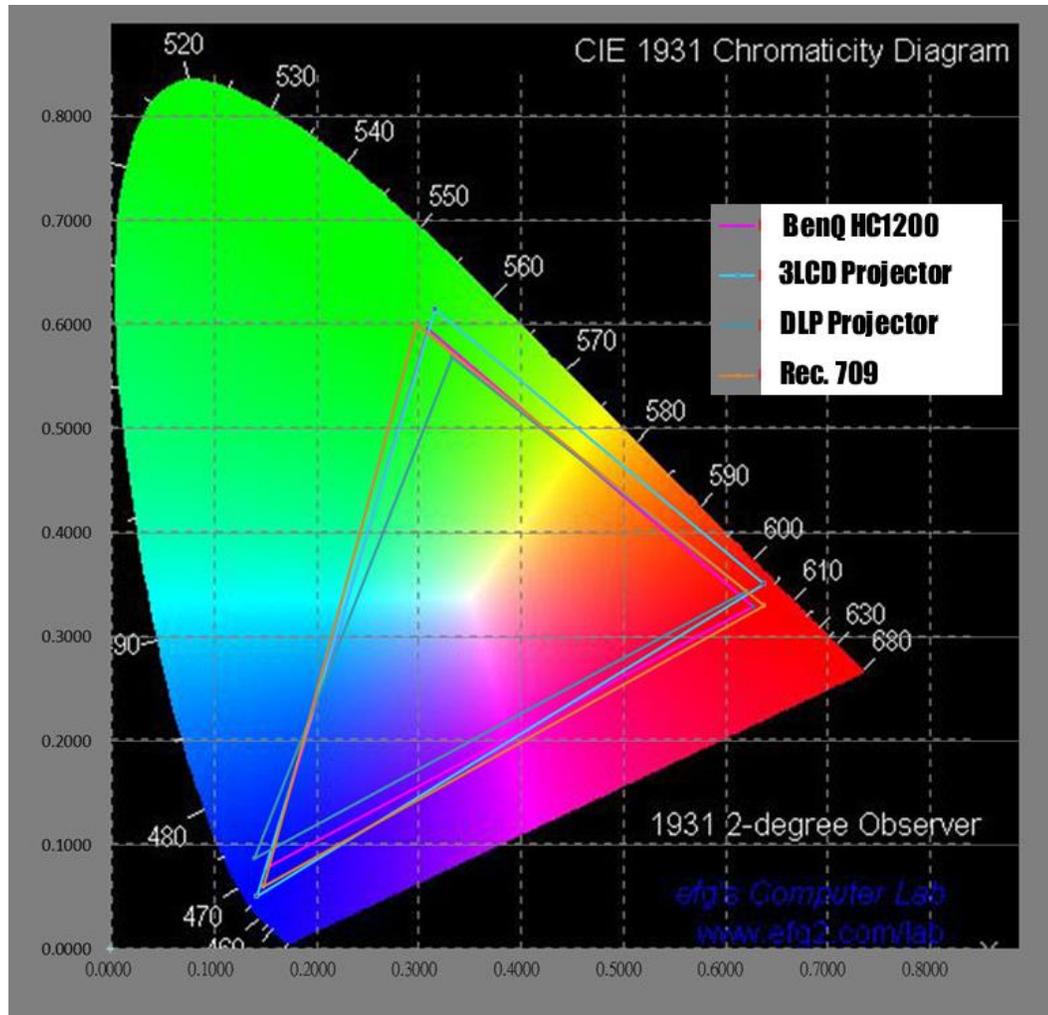


Figure 8: Measure color gamuts for the tested projectors

One might think that more color is better, but since content is typically not mastered for these wide color gamuts, the display must decide how to map these colors to the wider color gamut space. If not done well, viewers may perceive a problem.

The results of the survey for color accuracy are shown in Figure 9. This data reveals that the BenQ projector was perceived as having more accurate colors than the 4000 lumen 3LCD projector. It was closest to the reference sRGB color image thus providing the best match to the content shown on the color correct monitors.

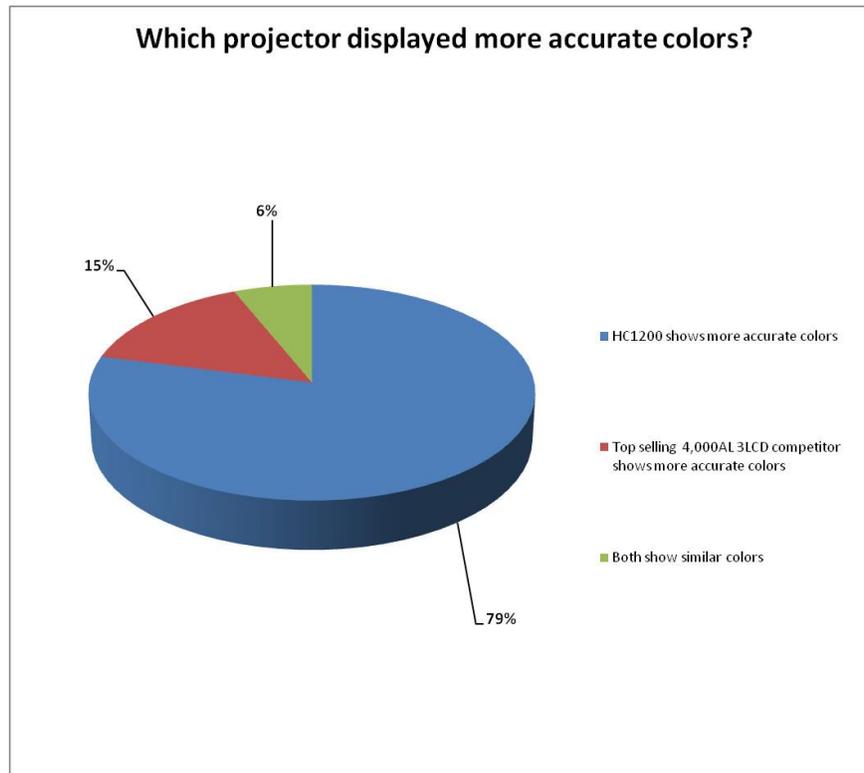


Figure 9: Accurate Color Results

These test results find that that higher contrast and color accuracy can produce an image that is preferred by those surveyed. It also indicates that a **projector with lower lumen specifications with high contrast and accurate colors can look as bright as projectors with higher lumen specifications, but less accurate colors.**

Summary

The impact on color in presentations has been well documented by the University of Minnesota (and others²), and the new system contrast specifications highlight the role of contrast in the corporate decision making process. The new BenQ projector is a unique product that is focused around the paradigm of color accuracy and higher native contrast, but at the cost of lower specified lumen rating. Yet despite the lower lumen specifications, the projector was perceived as bright as a top selling model with brightness specifications that were 50% higher and also perceived as more color accurate than a top selling model when setup to the industry

² *The Importance of Color in Business Presentations*

<http://soappresentations.com/the-importance-of-color-in-business-presentations/>

Expert Color Choices for Presenting Data

<http://www.stonesc.com/pubs/Expert%20Color%20Choices.pdf>

Principles of Color Management

http://www.hutchcolor.com/PDF/Principles_6.pdf

standard sRGB color space that is used in virtually every other monitor, printer, or smartphone output device typically deployed in a corporate environment.

Given the affordable nature of this new projector (with a street price under \$1500), can the ability to deploy high contrast color accurate projectors into conference room and education areas where there is high ambient light impact effective decision making and improve the effectiveness of the projector system environment? We call on industry to continue additional tests to validate these results and help focus developers on those aspects of image quality that have true meaning to the end user.

Appendix 1: HC1200 Specifications

Projection System	DLP
Native Resolution	1080p (1920 x 1080)
Brightness* (ANSI Lumens)	2800 ANSI Lumen
Contrast Ratio	11000:1
sRGB Color Space Coverage	100%
ANSI (Checkerboard) Contrast	510:1
Display Color	1.07 Billion Colors
Lens	F=2.42~2.97, f=20.7~31.05mm
Aspect Ratio	Native 16:9 (5 aspect ratio selectable)
Throw Ratio	1.398~2.09
Image Size (Diagonal)	26" ~ 300"
Zoom Ratio	1.5x
Lamp Type	310W
Lamp Mode (Normal/Economic/SmartEco/Lamp Save/LumenCare)*	2000/2500/3000 hours
Keystone Adjustment	1D, Vertical +/- 40 degrees
Projection Offset	Vertical: 130% ±5%
Resolution Support	VGA(640 x 480) to UXGA(1600 x 1200)
Horizontal Frequency	15K-102KHz
Vertical Scan Rate	23-120Hz
Interface	Computer in (D-sub 15pin) x 2 HDMI x 2 Monitor out x 1 Composite Video in (RCA) x 1 S-Video in x 1 Audio in (Mini Jack) x 1 Audio in (L/R) x1 Audio out (Mini Jack) x 1

	<p>Speaker 5W x 1 LAN(RJ-45) x1 USB (Type B) x 1 DC 12V Trigger (3.5mm Jack) x 1 RS232 (DB-9pin) x 1 IR Receiver x2 (Front+Rear)</p>
Dimensions (W x H x D mm)	<p>360.1x119.9x259mm (include feet) 360.1x114.8x259mm (exclude)</p>
HDTV Compatibility	480i, 480p, 576i, 576p, 720p, 1080i, 1080p
Video Compatibility	NTSC, PAL, SECAM
3D Support and Compatibility	<p>Frame Sequential: Up to 60Hz 720p Frame Packing: Up to 24 Hz 1080p Side by Side: Up to 24Hz 1080p Top Bottom: Up to 60Hz 1080p</p>
Weight	8.14 lbs (3.7 Kg)
Audible Noise (Normal/Economic Mode)	38/33 dBA (Normal/Economic mode)
Power Supply	AC100 to 240V, 3.8A, 50 to 60 Hz
Power Consumption	370W(Normal), 300W(Eco), Standby<0.5W
On-Screen Display Languages	<p>Arabic/Bulgarian/ Croatian/ Czech/ Danish/ Dutch/ English/ Finnish/ French/ German/ Greek/ Hindi/ Hungarian/ Italian/ Indonesian/ Japanese/ Korean/ Norwegian/ Polish/ Portuguese/ Romanian/ Russian/ Simplified Chinese/Spanish/ Swedish/ Turkish/ Thai/ Traditional Chinese (28 Languages)</p>
Picture Modes	Dynamic / Presentation / sRGB / Cinema / (3D) / User 1 / User 2
Accessories (Standard)	<p>Carry bag Power Cord (by region) Remote Control w Battery VGA cable User Manual CD QSG Lens Cover Warranty Card (by region)</p>
Accessories (Optional)	<p>Spare Lamp Kit P/N:5J.J8805.001 Ceiling mount kit P/N: 5J.J4N10.001 Carry bag P/N: 5J.J4R09.001</p>