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# Beyond Better Pixels: How HDR Perceptually and Emotionally Affects Storytelling

By Aurora Gordon

## Abstract

*As the push for high-dynamic-range (HDR) content begins to swell, consumers may find themselves wondering what this new content offers at home, beyond gimmicks and more expensive televisions. Content creators may also find themselves wondering what this new standard offers to the stories they tell beyond yet another set of delivery specs. With the bulk of HDR demo material showcasing standalone, wow-factor wide shots designed to showcase the physical limits of dynamic range, there is a need to take a step back and examine how HDR and wide color gamut (WCG) affects an entire project: putting our brighter and better pixels in the more meaningful context of an entire story. This paper presents observations on the effect of HDR/WCG as it varies through visual styles, using examples from a one-hour medical drama, a half-hour superhero comedy, and a one-hour spy thriller. The author will use data collected from her work as a colorist on over 35 episodes of HDR content to examine the psychophysical, perceptual, and emotional impact of the deeper dynamic range and greater gamut available in larger color volumes.*

## Keywords

*Content creators, contrast ratios, HDR10, high dynamic range (HDR), home viewing, perception, standard dynamic range (SDR)-to-HDR, SDR, storytelling, wide color gamut (WCG)*

## Introduction

In 2017, the team at ArsenalFX Color worked on three first season shows that delivered a high-dynamic-range (HDR)/wide color gamut (WCG) (herein HDR) pass in addition to a standard-dynamic-range (SDR) pass: *The Tick*—a half-hour superhero comedy for Amazon,<sup>1</sup> *The Good Doctor*—a one-hour medical drama for ABC,<sup>2</sup> and *Counterpart*—a one-hour spy thriller for Starz.<sup>3</sup> These three shows had strikingly different visual styles from one another. Each

show established a first season look and also delivered HDR for the first time. As such, working on these programs set up an opportunity for a natural experiment: beyond delivery metrics, how does HDR effect different styles of stories qualitatively?

## Color Pipeline Set Up

We began setting up for these three shows' HDR delivery in March 2017, developing a lookup-table (LUT) package for 100-candela-per-square-meter (nit) delivery and 1,000-nit delivery with a consulting color scientist. These LUTs are our transforms, managing both our transfer function conversions [Gamma 2.4 to perceptual quantizer (PQ)], our top nit level (from 100 nits to 1,000 nits), and our color space conversions (from Rec. 709 to P3 or Rec. 2020).<sup>4,5</sup> We work in Autodesk Luster with digital picture exchange (DPX) sequences debayered according to the camera manufacturer's best practices.

Our log-based workflow uses our transforms as an output LUT within Luster, and, if necessary, input LUTs are applied to take our source material into our preferred working color space.

This enables us to grade all main unit and auxiliary cameras in the same sequence with a similar feel of primary controls from shot to shot. This color pipeline is depicted in **Fig. 1**.

All three of our shows were delivered in HDR10. Production was focused around our SDR passes, since this is what our shows' producers and also the majority of consumers will watch right now. Many readers may note that this is the reverse of a Dolby vision approach, which typically focuses first on the highest nit level pass. Observations on this will be given later in this paper. Our HDR passes were done on a calibrated Sony X-300, targeted to 1,000 nits.

## Esthetic Observations

Working with a color scientist in developing these LUTs made our HDR/WCG pipeline effective and predictable, and maintained fidelity to the original SDR pass.

This paper presents observations on the effect of HDR/WCG as it varies through visual styles, using examples from a one-hour medical drama, a half-hour superhero comedy, and a one-hour spy thriller.

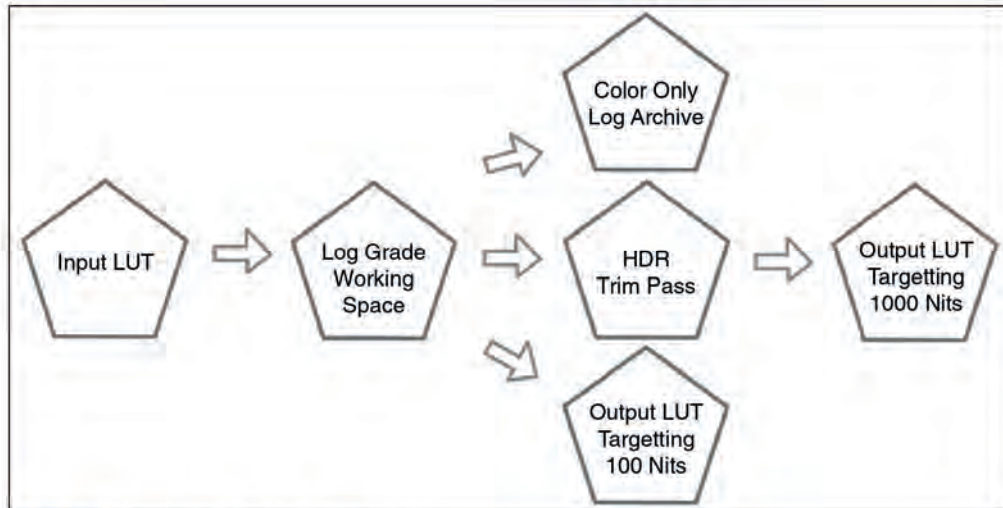


FIGURE 1. Log-based workflow diagram.

Having the math and science in our transforms carry the bulk of this work meant we could allow our HDR/WCG review to be just that—a review of information that was translated with care from the original creative intent. However, we observed some marked differences in the esthetic effect of the transform between program styles.

*The Tick* is a larger-than-life superhero satire, full of outlandish (and highly chromatic) superhero uniforms, wild and cartoony digital effects, and colorful, brightly lit evil lairs. We expected HDR and WCG to be extremely well-suited to the theatrical nature of the show, as the show contains a great variety of both brightness levels and hues. We were unsurprised by the results, i.e., the transform delivered a show that popped off the screen and was visually exciting, although the comic book source material had been given a real-life cartoony pulse.

In *The Good Doctor*, as with many hospital dramas, the setting and subject matter benefited greatly from the dramatic lighting potential in high key operating rooms and dynamic emergency vehicle lighting. It was also visually exciting, similarly to *The Tick*, but while *The Tick* featured many overall bright scenes, *The Good Doctor* featured more mid key scenes that also contained very bright highlights. These dynamic highlight benefits can also provide a challenge, i.e., managing specular hits and practical lighting that may teeter on the edge of clipping either luminance or chrominance. We knew managing these highlights with intention would give the creators and studios a piece they would be very happy with, showcasing the extended dynamic range, used in so many display device marketing materials. Once the highlights had been managed, it felt as though we were able to go deeper into the captured exposure.

With *Counterpart*, the results of the transform were more surprising. As a dark and dramatic spy thriller, this content is not necessarily what first comes to mind when trying to imagine the benefits of HDR and WCG. Yet, the moody interrogation scenes and mysterious characters

meeting in shadows expanded with new life between SDR and HDR passes. These immersive images were not as sensational as the typical HDR demo material, like a neon Ferris wheel on a pier, but the transform of this show emotionally moved both our clients and other members of the team at Arsenal.

Although both *The Good Doctor* and *The Tick* were very exciting images to look at, the change in *Counterpart* brought something different to the table. It was apparent that the scenes became more intimate through the HDR/WCG transform. This motivates to dig deeper into these shows to find quantifiable changes between our different programming styles (high, mid, and low key). As human beings are arguably the most important component of storytelling, skin tone would be the focus of this study.

### Determining Data Points

Going back to the source material, the goal was to gather stylistically representative sample points from each show across the full season. The exact same time code would be used to measure skin tone differences directly and to compare SDR with HDR.

Three frames per episode were pulled to create a manageable amount of data, at these approximate time-codes: five minutes in, at the midpoint, and five minutes from the end. For the half-hour comedy, this was adjusted to two and a half minutes in, at the midpoint, and two and a half minutes from the end.

These points were chosen because credits, recaps, cold opens, or teasers can sometimes begin or end a show on a different visual note, and the goal was to capture not just a mean value, but images that represented the tone and style of the show holistically. If a timecode occurred within the main titles, the sample point was rolled forward to the next shot. Four sample points that did not include any visible skin tone were discarded.

Balancing objectivity and stylistic representation was challenging. This was not completely straightforward,



FIGURE 2. Example of ROI selection for (a) the key side of the skin tone and (b) the fill side of the skin tone.

and that statistical uncertainty must be acknowledged. This procedure was designed so that the operator would be able to identify shots that were specifically not a scene from the episode, such as title sequences, without the operator injecting her personal bias when choosing which scenes were representative of the show.

Measurements were collected in nits for the most prominent talent’s face within a frame:

- SDR key side skin tone
- SDR fill side skin tone
- SDR mean picture level (MPL)
- HDR key side skin tone
- HDR fill side skin tone
- HDR MPL.

### Procedure

For the sake of this study, SDR and HDR stills were created from our log master using our 100- and 1,000-nit targeted output LUTs, respectively. This means these stills did not include our HDR trim pass information but, instead, reflected our transform process only. These stills were condensed into a sequence for ease of navigation.

An Omnitek Ultra XR scope was used to measure skin tones. First, an HDR still was selected with the scope set to Rec. 2020 Color Primaries and PQ electro-optical transfer function (EOTF). MPL was recorded, using the luminance channel of the histogram tile.

Next, the key side of the skin tone was selected as the region of interest (ROI) in as large a sample as possible, while staying on a smooth patch of skin. MPL from the ROI was recorded from the luminance channel. Care was taken to measure a diverse range of skin tones and complexions when multiple actors appeared within a frame.

With the key side ROI still selected, the scope was switched to Rec. 709 color primaries and Gamma 2.4 transfer function. Then, the SDR image of the same frame was selected and its key side mean recorded from the exact same ROI. The ROI was then moved to the fill side of the same character’s face using the same guidelines as the key side (as large of a smooth skin sample as possible), and that level was recorded for SDR. Moving back to the HDR scope settings and the HDR image,

the fill level was recorded as well for HDR. Finally, an MPL was recorded in SDR. **Figure 2** illustrates the area of a frame where skin tone measurements were taken.

### Measurements

Measurements confirm our observations of shows from brightest to darkest, in respective order: *The Tick*, *The Good Doctor*, and *Counterpart* (**Table 1**).

**Figure 3** illustrates the transformation of skin tone contrast ratios throughout the full season of all three shows, in both SDR (top row) and HDR (bottom row). On left, we see fill side skin tone measurements for SDR in **Fig. 3(a)** and HDR on the bottom of **Fig. 3(c)**. On the right, we see key side skin tone measurements for SDR in **Fig. 3(b)** and HDR on the bottom in **Fig. 3(d)**. This figure illustrates how the transform increases the contrast between the SDR and HDR passes, as bright skin tone values increase and dark skin tone values decrease.

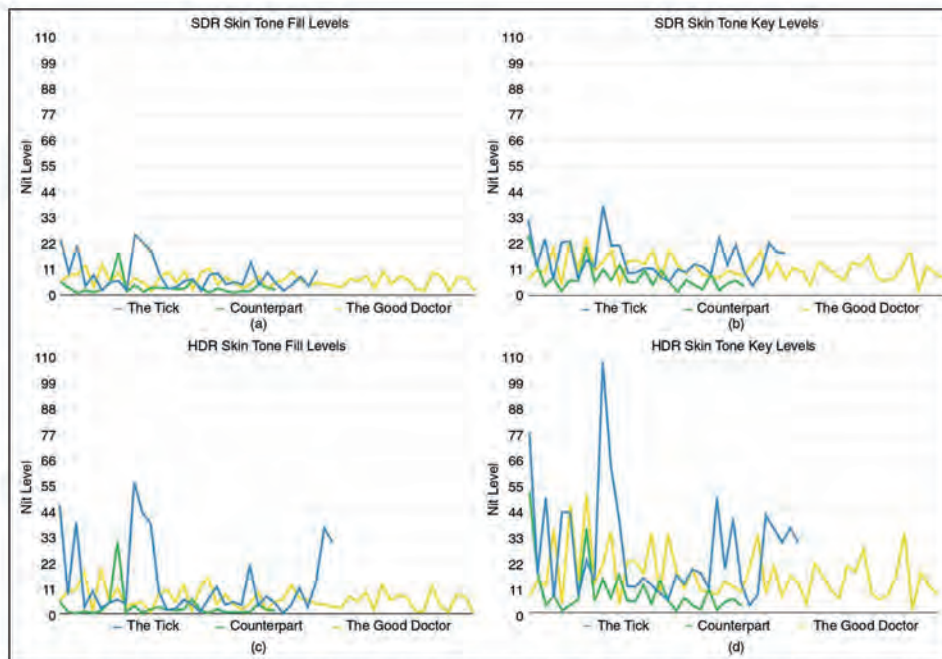
### Contrast Ratios

As colorists, more so than overall picture level, contrast ratios are important to us. Contrast ratios indicate tonality within a picture, rather than a blanket average across a shot. In other words, contrast ratios give us context for brightness values. This is meaningful in determining the original creative intent.

We expected a greater contrast ratio in *Counterpart*, the show we would nominally describe as more low-key and

**TABLE 1. Skin tone averages from all three productions, values are listed in units of cd/m<sup>2</sup>.**

	<i>The Tick</i>	<i>Good Doctor</i>	<i>Counterpart</i>
SDR average fill side skin tone	8.6	6.4	3.4
HDR average fill side skin tone	12.0	6.5	2.8
SDR average key side skin tone	15.3	11.6	7.7
HDR average key side skin tone	27.5	16.8	9.3



**FIGURE 3.** Illustration of (a) and (c) the key side and (b) and (d) the fill side of skin tone throughout the season of all three shows, for SDR (top row) and HDR (bottom row), in  $\text{cd}/\text{m}^2$ .

darker than either *The Good Doctor* or *The Tick*. Averaging key to the fill side of skin tones for all three shows, it was indeed true that, in both SDR and HDR, *Counterpart* had the highest average contrast ratio of key side to fill side, at 2.3:1 average for SDR and 3.3:1 in HDR.

## Reading Results

### Dark Matters

As shown in **Table 2**, MPL for all three shows went down from SDR to HDR, despite the fact that all three shows were targeted for 1,000 nits. As the MPL for all three shows declined between SDR and HDR, this indicates that, no matter what the style of programming, generally there is more dark material than light material in a show. As far as MPL, this darker material is numerically more influential than very high nit level highlights, in addition to being esthetically consequential. While the procedure in this paper relied on scopes

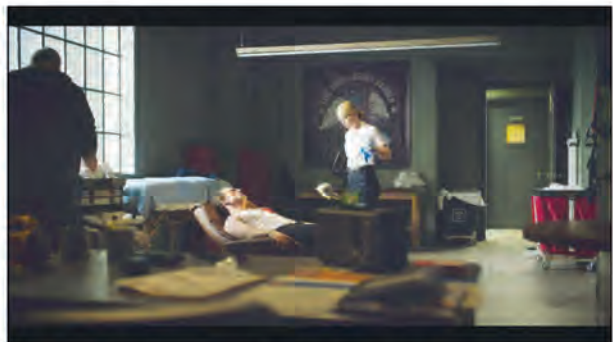
to measure nit levels, greater accuracy and information could be obtained through utilizing a spectroradiometer for precise measurement of physical light levels.

The changes observed in dark picture values are not discussed in HDR specifications or guidelines with nearly as much frequency as discussion of top target nit levels, but it could provide a wealth of new benefits for skin tones and darker material if studied further. For example, within this study, the shot with the greatest contrast ratio in SDR is different than the shot with the greatest contrast ratio in HDR. In SDR, the image with the greatest contrast ratio (**Fig. 4**) features a very strong highlight coming in through a window of a dark room and illuminating the key side of the talent's face.

In HDR, the image with the greatest contrast ratio (**Fig. 5**) features a character sitting in deep shadow, with mid to low key illumination on the key side of the

**TABLE 2.** Contrast ratios and MPL for all three productions, values are listed in units of  $\text{cd}/\text{m}^2$ .

	<i>The Tick</i>	<i>Good Doctor</i>	<i>Counterpart</i>
SDR Key to Fill Contrast Ratio	1.8:1	1.8:1	2.3:1
HDR Key to Fill Contrast Ratio	2.3:1	2.6:1	3.3:1
SDR Mean Picture Level	5.4	6.0	2.8
HDR Mean Picture Level	4.2	4.5	1.5



**FIGURE 4.** Dot preparing to perform hush-hush medical triage on a thug in *The Tick*.



which has already been photographed. This has benefits on an emotional and storytelling level.

### Greater Representation

Stories are being told from more diverse perspectives than ever before. This gives viewers the opportunity to see themselves reflected not only emotionally on the screen but also physically. Being able to push skin tones out of the 18% gray box is incredibly inspiring and exciting; it will allow us to physically see the differences between more and more different skin tones and complexions, celebrating differences while remaining flattering. This will help ensure diverse casts, such as the one in **Fig. 8**, will be captured true to life.

It is imperative moving forward that we include greater samples of skin tones in technical evaluative materials.

### Enhancing Psychophysical Concepts

Light, dark, and chromatic adaptation are already used and manipulated in SDR. Moving to HDR and WCG magnifies these already understood appearance phenomena.

For example, going from a dark interior to a bright exterior can cause some mild annoyance to a viewer, but on a physical level, we dull our visual sensitivity with the increase in brightness from scene to scene. In HDR, this may enable us to use light adaptation to create more exciting and surprising reveals of characters and plot points.

Dark adaptation is the inverse of the above, and results in increased sensitivity when viewing darker scenes. That extra sensitivity can also be used as a narrative device. When watching longer dark scenes in a dark viewing environment, a viewer's increasing sensitivity can allow subtleties to be slowly revealed, aiding in dramatic tension.

Although chromatic adaptation is a complex mechanism, the basic idea is that the eye's cones become saturated in the dominant color channel during prolonged exposure, and the brain becomes acclimated to a higher level of saturation. That acclimation creates a new normal level of color in the brain. After prolonged periods of exposure to yellow, for example, neutral gray will appear blue.

Therefore, if we have a scene biased very warm and bright, followed by a cool scene, this shift will feel more



**FIGURE 8.** A scene from *The Good Doctor*, with five different skin tones.

dramatic because our eyes have become adapted to the warmth, and a cool afterimage may remain. This can be used to help a viewer truly feel a difference in locations. The viewer will adapt, allowing what appeared at first as an extreme color palette to once again appear neutral. With HDR and WCG permitting a deeper and more intense expression of color, this allows for a deeper and more intense level of these phenomena as well.<sup>8</sup>

### Allowing SDR and HDR to Help Each Other

Very reliably, the first thing a client will do upon viewing an HDR version of a show for the first time is ask to bring the highlights down. Very bright highlights are distracting and make the surrounding areas appear darker. Therefore, often the request is made to step down the highlights and bring the focus back to the talent's faces.

Oftentimes lurking in those highlights, whether it be a wrinkle in a cyclorama out a set window, a gel inside a flashing ambulance light, or gaseous fall off within a fluorescent light fixture, is something distracting that competes for attention. It is not that these impurities were not present in initial capture and mastering at 100 nits; the top end of the image was simply too compressed for us to read them.

For example, early in the season on *The Good Doctor*, I noticed, in our HDR, passes that the gaseous fall off within fluorescent tubes in the hospital hallway was distracting within the newly enlarged color volume. Although this was at first trimmed in HDR only, as the season progressed I was able to identify where this might happen in SDR, adjust a highlight roll-off, and then push the image back up to the desired peak brightness. This resulted not only in a cleaner HDR image but also a better SDR image.

### Why Preference for SDR Priority?

#### Our Viewers

The majority of our viewers continue to either primarily or even exclusively view SDR displays. Although we are now seeing more clients and content creators monitoring HDR final delivery, and even on-set monitoring in HDR, it currently holds true that our SDR pass will garner a lot more eyeballs than our HDR pass. While we want to strive for the Icarian principle of future-proofing, it is critical we allow our paying viewers to determine the speed at which we focus on HDR over SDR. Meanwhile, extending images from more limited rules to more expanded rules also offers us an advantage.

#### Our Clients

HDR and WCG breath color and dynamic range into images in a way that is visually striking and emotionally moving. However, showing this version to our clients first means that in most cases, they will never be happy with SDR again. This is a disservice to the work. Viewing these transforms as an expansion of our work in SDR will allow us to serve both passes. This is very important to consider while we are in the transition period of getting clients and viewers equipped to view HDR regularly.



**FIGURE 5.** Howard sipping whiskey and contemplating two worlds in *Counterpart*.



**FIGURE 6.** The very large man going through some very crazy stuff in *The Tick*.

talent's face. Images are represented in this paper in SDR, due to physical limitations.

This effect of transforms from SDR to HDR in high key tonalities versus low key tonalities could also be examined on a psychophysical level, through the application of Stevens' Power Law.<sup>6</sup> These natural laws have already been studied and applied to perceptual uniformity in the work of Borer, Cotton, and Wilson through hybrid-log-gamma (HLG) transfer function, but further discussion and understanding of these laws would benefit the creative process as well.<sup>7</sup>

Although it carries statistical uncertainty, attempting to quantify and categorize these esthetic changes can help serve as a jumping-off point for not only designing future dynamic range transform processes but also for helping filmmakers and technicians alike understand how larger color volume can become used in practical, everyday production as a part of film language.

#### **Transforms Have Esthetic Consequences**

Studying a transform change alone without including trim pass changes reveals that there are different benefits and esthetic consequences simply by the design of a LUT, depending on overall program tonality (high, mid, or low key). The transform's translation of content is also influenced by the content itself. This substantiates the common feeling from many colorists: that material will need to be trimmed according to the program style, not just technical targets. In general, colorists and show creatives want the transformed version of a show to be representative of the original creative intent, but we value the human element that allows us as artists to do what an automaton cannot: prioritize what was most important about the original exposure and fully utilize our enlarged color volume to then explore and push that specific visual idea.

#### **Immersion Comes in More than One Flavor**

Immersion is often thrown around as an HDR buzzword and accompanying examples of HDR demo material point toward extremely bright images with great dynamic range. There is no rule that images must be a certain nit level in order to qualify as immersive. In fact, most skin tones recorded in this study are lower than

a traditional 50% exposure. An image that dedicates more range to seeing deeper into shadow detail can be equally engaging.

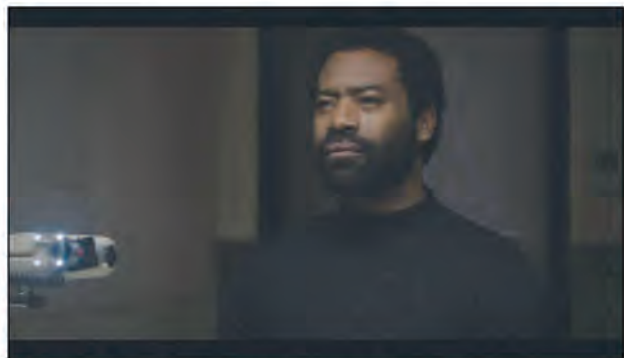
In the context of measuring these SDR-to-HDR changes, I began to think of immersion as having two axes: excitement and intimacy. The following guidelines are helpful in determining what sort of trim to make.

An exciting immersive image will have a combination of high luminance and high chrominance, which evokes a flood of visual information. This concept is illustrated in this scene from *The Tick* (**Fig. 6**) featuring the very large man going through some big changes. The diodes in the TV will be physically excited, as will the cones in the eye of the viewer.

An intimate immersive image will have a large portion of the image's exposed value dedicated to a relatively small range of natural stops. This concept is illustrated in the following shot (**Fig. 7**) from *Counterpart*, of Shaw interrogating Howard. In HDR, viewers are more able to feel the dark surrounding him, and experience the isolating nature of this dark interrogation room. It can be described as visual breathing room.

#### **Benefits of Better Pixels**

Although marketing materials would tout the sudden inclusion of more stops of information and more colors, we are not actually increasing the captured data by scaling our scenes to HDR/WCG at 1,000 nits and beyond; we are using a better display case for that information,



**FIGURE 7.** Shaw interrogating Howard in *Counterpart*.

## Our Ideas

Recently, a cinematographer I was working with pushed me to bolder color passes by constantly questioning, “What’s the idea?” This question sets a very healthy frame of mind; if he could not tell by looking at the image what tone was intended, an audience would not be able to either. As an episodic show carries on the course of its run, and increasingly more parties add windows and isolations, it is not unheard of to flatten out a picture trying to make all parties happy. As far as the cinematographer, director, and creators are concerned, we should commit to the idea photographed.

This logic can be carried on to color space. Beginning with a very large color gamut and dynamic range means, we can massage every part of the frame to utilize every step of contrast, but perhaps lose track of what the original creative idea was. If we are able to commit to the esthetic idea in a smaller box (and due diligence has been done in setting up a color pipeline), then when we expand that image we can hope to see a faithful representation of that original idea in a bigger, more expansive palette.

It is my observation that the SDR to HDR transform begins on a much more decisive visual note for this reason. We can go beyond a better, brighter HDR pass: we can learn from it, and scale our experience back down to SDR as well, for as long as our viewers need us to do so.

## Conclusion

An SDR and color mapping transform will have a distinct esthetic effect depending on the tonality of the show. Study of this tonality and technical analysis of light levels within the relationship of a specific show or shot could assist in designing transforms that result in technically sound and improved image capture, but also repeatable and reliable creative looks as well. In particular, in the creation and representation of darker material, a carefully designed transform could assist in an image’s consistent representation within the myriad of home viewing options, faithful to original creative intent. Contrast within dark values should be further studied, as the material studied in this paper suggest the prevalence of dark scenes in a variety of different content types, and also darker values will provide greater representation of differing real-world skin tones. Technical evaluative materials should be developed for more inclusivity of varying skin tones and complexions. A collaborative relationship between color scientist and colorist can help develop multiple options for translating SDR to HDR that are not only technically well measured to hit specifications, but measured for general esthetic goals.

As we move from an SDR-predominant viewership to a more even split, and eventually HDR dominance, we must let viewers dictate how fast we reprioritize HDR over SDR. These improvements will help bring HDR from an extra deliverable to a storytelling technique, serving many different stories and many different perspectives as a creative choice rather than a mandated file.

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## About the Author



**Aurora “Rory” Gordon** is a senior colorist at Arsenal, Santa Monica, CA. She has a life-long passion for the science and art of image capture, which has taken her from makeshift basement darkrooms in her home state of Oklahoma to the Munsell Color Laboratory, Rochester Institute of

Technology, Rochester, NY, where she earned a BFA degree in film production, and to Hollywood, where she has worked steadily for the last nine years. She has worked on 20 shows as a colorist, executing many different styles and always working in support of the choices made by the show’s creative team—from cinematographers, to directors, to producers. She has completed about 100 episodes of high-dynamic-range (HDR) content, including both HDR-10 and Dolby Vision. Gordon lives in Los Angeles with her partner James Gibson and two cats. In her spare time, she enjoys making hand-painted wood clocks, messily cooking, and doing lazy yoga.

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