A Study on User Preference Towards HDR Format Decoding Strategies in Smartphones.

Thibault Cabana*, Pooshpanjan Roy Biswas*, Adrien Carmone*, Paul Bernardi*, Eloi Zalczer*, Frederic Guichard*

***DXOMARK, Boulogne-Billancourt, France**

Abstract

HDR videos can be encoded in a variety of formats with dynamic metadata, the most popular of which are Dolby Vision, HDR Vivid and HDR10+. In this paper, the decoding strategies of these three encoding options are subjectively analyzed in order of their preference in smartphones by performing a psychophysical experiment in a laboratory environment. Three different smartphones were used to display the videos encoded in the three formats respectively. Ten different video sequences were used which ranged from having outdoor, indoor, studio, night-time and skin tones content. The preference experiment was also done for all these videos under four illumination conditions: dark, ITU standard (lowlight), indoor and outdoor (overcast day). Thirty-one observers having different levels of experience in psychophysical experimentation participated in the study. Qualitative analysis of the observer response was also done using several questions pertaining to a chosen response of the observers. It was found that the decoding of Dolby Vision encoded HDR videos by smartphone A was the most preferred strategy for the majority of scenarios. The statistical significance of the preference across different categories of observers was also accomplished in this study.

Keywords

HDR, dynamic metadata, Dolby Vision, HDR10+, HDR Vivid, smartphones, user preference, ambient illumination.

1. Introduction

HDR content mastered on a display can be encoded for reproduction on different mediums using a variety of formats. There are several of such encoding formats possible that are based on the difference in the choice of the bit depth as well as the electro-opto-transfer function (EOTF). On the basis of an EOTF, HDR encodings can be broadly classified into Hybrid Log Gamma (HLG) and Perceptual Quantizer (PQ) based HDR formats. The PQ EOTF was standardized by the SMPTE ST2084 and since then several formats have emerged using this as an EOTF, for example, HDR10, HDR10+, Dolby Vision, and HDR Vivid (Dolby, 2014; HDR10+, 2017; HiSilicon, 2021) . Dolby Vision can be encoded with a bit-depth of 10 or 12 bits, while formats such as HDR10, HDR10+ HDR Vivid, and HLG are 10-bit formats. Dolby Vision also have a profile (8.4) that used the HLG instead of the PQ as the target EOTF. Therefore, it should be noted that Dolby Vision can be encoded using either the PQ or HLG curve as an EOTF.

HDR videos can also be differentiated with the choice of static or dynamic metadata. Static and Dynamic metadata both encompass the chromaticity coordinates of the RGB primaries, white point chromaticity, and the minimum/maximum luminance (MinDML & MaxDML) for the mastering display. Additionally, they incorporate the Max Frame-Average Light Level (MaxFALL), representing the highest average brightness per frame in the specified program/sequence, and the Max Content Light Level (MaxCLL), which specifies the luminance of the brightest pixel. HDR10 is a static metadata based HDR encodings, while HDR10+, HDR Vivid and Dolby Vision use dynamic metadata. HLG on the other hand has no requirement for a metadata, as the transfer function is on relative scale, rather than absolute. Static metadata does not change over the entire course of the video, while dynamic metadata has more flexibility. Using this flexibility, metadata can be set on a frame-by-frame basis of the video. It should be noted that the dynamic metadata of Dolby Vision and for formats such as HDR Vivid, HDR10+ etc. are not the same.

Smartphones nowadays can have different supports for these HDR encoding formats. For example, Apple and certain smartphones by Xiaomi and LG support Dolby Vision, HDR10+ is supported by a variety of smartphone brands, and HDR Vivid is supported by Huawei and a variety of Smart-television brands.

Another aspect of these HDR encoding formats is licensing. HLG and HDR10 are open-source formats. Any smartphone brand can use the encodings free of charge, while Dolby Vision and HDR10+ are licensed encoding formats. HDR10+ is free to use for content creators and has a maximum $10,000 annual license for some manufacturers. Dolby Vision is a proprietary format for which a license needs to be purchased from Dolby.

The transfer function used in HDR encodings can be designed using an absolute or a relative scale.

External illumination condition is an important factor that influences human perception. Smartphones have an auto-brightness setting that changes the brightness of the phone depending on the ambient illumination detected by the ambient light sensor of the phone. The CIE has proposed the usage of external illuminance to calculate color appearance correlates in Color Appearance Models (CAMs) such as CIECAM02 and CIECAM16 using the parameter L_A, also known as the luminance of the adapting field. Another parameter that can be chosen in CAMs is the surround ratio, S_R. In CIECAM02 or CIECAM16, it can be set as dark, dim or average depending on the S_R.

$$S_R = L_{SW}/L_{DW} \tag{1}$$

where L_{SW} and L_{DW} are the luminance of the surround and device white point respectively. S_R less than 0.2 correlates to dim while equal or more than 0.2 represents an average surround. S_R of 0 signifies a dark surround (CIE, 2004, 2022).

HDR videos preference and objective performance can be influenced by the choice of various parameters that are used to produce the videos. They can be compressed using different approaches (Myszkowski et al., 2022; Reinhard et al., 2010), be backward compatible with SDR displays (dual layer instead of single layer, explained later), encoded using different formats, or evaluated under different viewing conditions.

HDR encoding formats can have different preferences from a general population as well as can perform differently using objective metrics. HDR video compression formats have been compared in a study by Mukherjee et al., where different objective metrics and subjective preferences were used to quantify and qualify the efficiency and preference of compression algorithms as compared to the uncompressed version of the videos (Mukherjee et al., 2016). Another study by Pan et al. established a database that consisted of subjectively ranked HDR videos (that were created with either the PQ or HLG EOTF transfer function) with the AVS2 compression algorithm (Pan et al., 2018). Such a database for HDR videos with several different encoding formats was not found in literature. A study was conducted by Mir et al. objectively quantified the performance of single layer (HDR-MPEG, HDR10 (PQ) and HLG HDR-TV) and dual layer (AdaptRes and SHVC) HDR encoding formats (Mir et al., 2019). Dual-layer HDR formats have a base layer containing the tone mapped LDR version of the HDR video for backward compatibility to SDR displays. While single layer HDR formats do not have this information. The study concluded that HDR10 outperforms other single layer or dual-layer HDR encodings using several objective metrics. Another study by Khan et al. dealt with the objective analysis of single and dual-layer HDR encoding formats, for normal viewing as well as for machine vision. It was concluded that despite having acceptable display quality, HDR10 was not found to be at par with state of the art dual layer encoding formats, especially for machine vision tasks, such as automatic vehicle control, medical diagnostics, automatic scene analysis etc. (Khan et al., n.d.).

Shang et al. studied the aspect of evaluating HDR10 videos under different viewing conditions. The videos were acquired using a RED camera but different levels of noises were added to encode it to the HDR10 format. These videos were then subjectively evaluated under viewing conditions comprising of dark lab-room or bright living-room environments. It was concluded that subjects preferred the same videos more under dark environments as compared to their preference under bright environments. Thus, it was shown that viewing conditions can influence HDR video preference (Shang et al., 2022).

All these differences in HDR encodings coupled with the final decoding strategies used by different smartphone manufactures finally influence the final perception and preference trends towards them. Due to the gaps in state of the art related to the subjective analysis of the decoding strategies of smartphone manufacturers towards HDR encoding formats with dynamic metadata, especially under various ambient lighting situations, a study is thus proposed in this paper. A psychophysical study was performed with 31 observers who provided valuable data in terms of their preference to the decoding of dynamic metadata encoded HDR formats, such as Dolby Vision (HLG), HDR Vivid and HDR10+ on three different smartphones by different manufacturers. The evaluation was done under four environments: dark, ITU, indoor and outdoor. This paper provides a framework for conducting a subjective analysis of user preferences to decoding strategies to HDR video encodings and the same framework can be used to replicate the study to compare decoding strategies of other HDR encoding algorithms in the future.

2. Experimental Apparatus

Three smartphones were considered in this study (named Smartphone A, B and C) which were respectively used to render videos encoded using the Dolby Vision, HDR Vivid and HDR10+ encoding formats respectively. Ten video sequences (see Figure 1) were considered in this study. A set of ten sequences were derived in 3 formats, Dolby Vision profile 8.4, HDR Vivid profile and HDR 10+ profile B. The content of the sequences covered a variety of scenarios, studio fixed frame, skin tones, different light conditions from night to sunny outdoor, high dynamic range scene, colorful scenes, night scene etc.

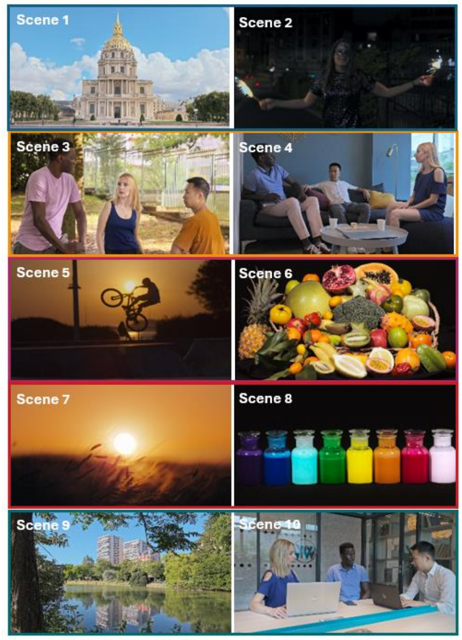

Figure 1: The different video sequences that were used in this study. Scenes 1, 3, 5, 7 and 9 correspond to outdoor scenarios. Scenes 6 and 8 are studio scenes. Scene 2 is a night-time scenario. Scenes 4 and 10 are indoor scenarios with skin-tones.

The video sequences were shot using Canon and RED cameras in RAW format. The HDR grading from RAW was performed using DaVinci Resolve 18.6 using a Sony BVM-HX310 monitor as the master. The mastering color space was DCI- P3 with a white point of D65, Ultra-HD resolution, with the SMPTE ST 2084 PQ as the EOTF. All scenes were encoded to mp4 HEVC Full HD format using the same HDR master using Resolve Delivery capabilities. Dolby Vision 8.4 (Dolby Vision tools integrated to DaVinci Resolve with a Dolby license used for transcoding HLG to 8.4 profile (Dolby, 2022)), HDR10+ and HDR Vivid.

Four ambient lighting conditions were used for this experiment. The four conditions corresponded to dark, lowlight, indoor and outdoor lighting conditions. The details about the illuminance falling on the devices surface and the luminance from the devices' holder surface for the four illumination conditions can be found in Table 1. The CCT of the ITU, indoor and outdoor conditions was 6500K (diffuse) provided by using LED light sources by Kino Flo (Kino Flo, 2023).

	Dark	ITU	Indoor	Outdoor
Illuminance (lux)	< 1	82	300	1150
Surface Luminance (nits)	< 1 nits	5	18	56

Table 1: Illuminance, luminance and CCT details of the lighting scenarios used in the study.

Devices were plugged into power during the entire experiment. They were factory reset at the beginning of the survey. No manual adjustments of devices were done. Auto-brightness was kept ON so that the devices could adjust their brightness to ambient lighting. Any white point adaptation setting was turned off and the devices were used in natural color and dark mode. As a result of the auto-brightness mode, the devices had the ability to adapt their luminance. **Table 2** gives an overview of the luminance of an HDR 10% APL pattern under the various ambient illumination conditions used in the experiment.

HDR white 10% APL	Dark room	ITU standard	Indoor lighting	Outdoor lighting
Smartphone A	16	692	759	997
Smartphone B	32	307	321	481
Smartphone C	19	345	447	887

Table 2: Luminance of an HDR 10% APL pattern under the various ambient illumination conditions used in the experiment.

3. The experiment

The GUI was designed using the Python Qt library (Qt, 2023) and the connection to the devices was managed via the application Jellyfin (Jellyfin, 2023) on a laptop placed in front of the observer (see **Figure 2**). The three smartphones were placed next to each other resulting in a simultaneous match psychophysical experiment with a side-by-side comparison. The subjects entered the dark room and answered some questions regarding their age and background in psychophysical experimentation exercises. After adapting to the dark environment, the first session under the same environment was started. The observer task was to answer the questions presented on the laptop for the three smartphones A, B and C. The ten video sequences were shown in random order to the subject who chose the most preferred video out of the three options as 1, 2 or 3 (all viewed together side-by-side), in the order of most preferred to least preferred. The subject had the option of replaying a video sequence if they wanted to evaluate it again before choosing an option. After the dark room condition, the ambient illumination condition was changed to lowlight, indoor and outdoor lighting conditions respectively, with the subjects performing the same exercise of ranking the three video sequences randomly presented to them.

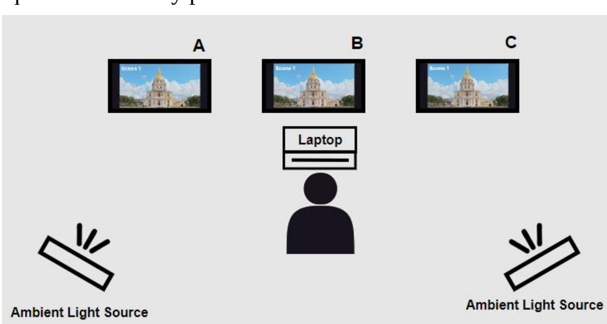

Figure 2: Experimental setup showing the three smartphones A, B and C with the three different decoding strategies to Dolby Vision, HDR Vivid and HDR10+ encoded videos respectively. The ambient light sources were placed behind the observer. The observer provided the response to the questions using a laptop.

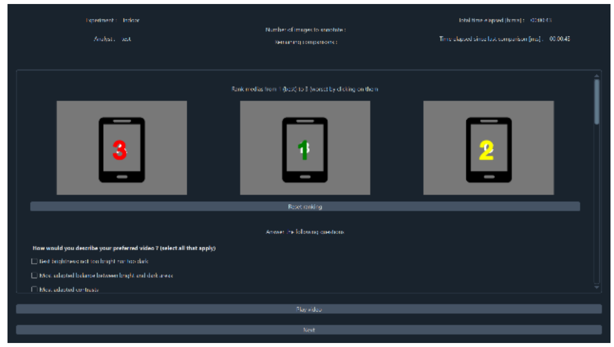

Figure 3: The GUI used to conduct the experiment, designed using the Python Qt library.

Additionally, for each video, the subjects also had to answer the following questions (question 1, followed by question 2 which was repeated for the three videos A, B and C):

1. How would you describe your preferred video? (select all that apply)

- Best brightness levels: not too bright nor too dark
- Most adapted balance between bright and dark areas
- Most adapted contrast
- Most adapted highlights
- Most pleasant colors
- Best brightness and details for faces
- Most accurate and pleasing colors for faces
- Most realistic
- I don't know

2. What (if any) could be improved in video A/B/C? (select all that apply)

- Brightness levels are too low / too high
- Contrast is too low / too strong
- The highlights are too strong / are too low
- The highlights lack details
- Details in the dark areas are too visible / lost
- Midtones lack depth / look too sharp
- Colors are inaccurate / unpleasant / lack nuances
- Colors are too dull / too vivid
- Faces color are inaccurate / lack nuances / unpleasant
- Faces color are too dull / too vivid
- Faces lack depth / look harsh
- Visible artifact, specify:
- I don't know

The answers to these questions were instrumental to dive deeper into actual user trends in the preference order of the videos, and what a particular HDR format decoding strategy excelled in or lacked.

Thirty-one color normal observers participated in the experiment conducted in a dedicated psychophysical experimentation room at the facilities of DXOMARK near Paris, France. Out of the 31 observers, 10 were experts and 21 were naïve. The expert observers were employees of DXOMARK who had a strong background in display and image quality evaluation. The naïve observers did not have much prior experience with video preference evaluation and considered themselves as normal everyday users of smartphones, who used it for viewing videos on social media or entertainment apps.

4. Results

The prime question that the observer had to respond was:

"Rank the displayed videos from most pleasing to the least pleasing. The following criteria should be considered when ranking the videos:

- Brightness levels
- Balance between light and dark areas
- Colors
- Face rendering (brightness, color, and details)"

The response to this question was a number 1, 2 or 3 (*ranks*), ranking the video sequences in the order of most preferred to least preferred respectively (see **Figure 3**). The overall rank for a decoding strategy on a particular smartphone for a viewing condition was calculated using equation 2:

$$(1\times R_1 + 2\times R_2 + 3\times R_3)/I_T = R_O \qquad (2)$$

where R_1, R_2 *and* R_3 correspond to the instances that the encoding format on a smartphone was given a *rank* of 1, 2 and 3 respectively and I_T is the total number of instances.

As an example, if for one viewing condition and one video sequence, Smartphone A was given a rank of 1 by 20 observers (R_1), 2 by 5 observers (R_2) and 3 by 6 observers (R_3), for the total 31 instances of ranking (I_T) for 31 observers, the overall rank for this smartphone for this viewing condition was calculated using equation 2 as 1.29. The more an *overall rank* was closer to 1, was considered better. The *overall rank* for all the scenes altogether was calculated by repeating the process for the ten scenes together for each viewing condition. The results can be seen in **Figure 4**.

Statistical significance of the rankings was also performed using the Friedman test. For each ranking, the Friedman test was used to determine whether there is significant difference in the mean ranks of the devices. The Conover post-hoc test was employed to address the statistical significance per pair of devices and to build the statistical significance matrix and p-values were reported. This provided information about the randomness of data i.e., did any of the devices rank consistently higher or lower than the others?

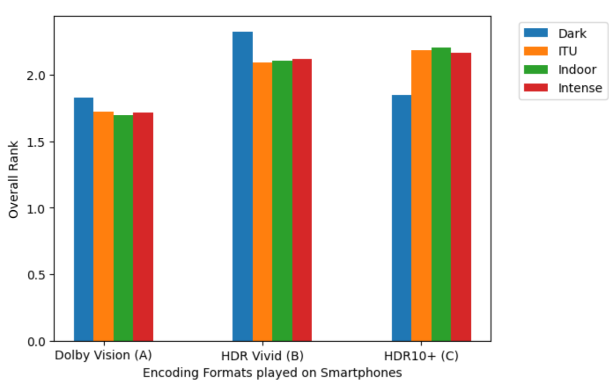

Figure 4: Overall results for the four viewing environments for the three encoding formats.

The decoding strategy of Dolby Vision videos on Smartphone A ranked consistently statistically significantly better ($p<0.001$) than decoding strategies on the other two smartphones, under conditions with ambient illumination (ITU, indoor and outdoor), while for the dark environment, none of the decoding strategies were found to be decoded statistically significantly better than the others but strategy for HDR Vivid performed significantly worse than the others ($p<0.001$) for the night scenario.

It should be noted that none of the decoding strategies of the HDR formats consistently performed statistically significantly worse than the other formats for the ITU, lowlight or outdoor ambient lighting situations.

4.1. Trends across video sequences

The data was also evaluated for trends across the different video sequences' content, as can be seen in **Table 3**. The values in bold imply statistically significant results.

		Preference Encoding				
#	**Tag**	**Night**	**ITU**	**Indoor**	**Outdoor**	**Overall**
1	Outdoor	+ (C)	+ (C)	+ (C)	**+ (C)**	**HDR10+**
		1.6	1.7	1.7	**1.5**	
2	Night	+ (C)	DV (A)	DV (A)	DV (A)	**Dolby Vision**
		1.7	1.5	1.6	1.8	
3	Outdoor	DV (A)	DV (A)	DV (A)	DV (A)	**Dolby Vision**
		1.6	1.8	1.7	1.7	
4	Indoor	+ (C)	DV (A)	DV (A)	DV (A)	**Dolby Vision**
		1.6	1.7	1.7	1.8	
5	Outdoor	DV (A)	DV (A)	DV (A)	**DV (A)**	**Dolby Vision**
		1.8	1.7	1.5	**1.5**	
6	Studio	DV (A)	**DV (A)**	**DV (A)**	**DV (A)**	**Dolby Vision**
		1.8	**1.4**	**1.4**	**1.4**	
7	Outdoor	+ (C)	DV (A)	DV (A)	**DV (A)**	**Dolby Vision**
		1.7	1.7	1.6	**1.5**	
8	Studio	+ (C)	+ (C)	DV (A)	V (B)	HDR10+
		1.5	1.8	1.9	1.9	
9	Outdoor	DV (A)	DV (A)	DV (A)	DV (A)	Dolby Vision
		1.6	1.7	1.7	1.8	
10	Indoor	DV (A)	DV (A)	DV (A)	DV (A)	**Dolby Vision**
		1.6	1.6	1.5	1.6	

Table 3: Overall ranks for each scene and viewing environment. DV stands for Dolby Vision, V stands for HDR Vivid and + stands for HDR10+. The cells in bold signify statistical significance in results.

Overall, for scenes 2-7 and 10, Dolby Vision decoding strategy on smartphone A was found to be statistically significantly better than other formats, whereas HDR10+ decoding strategy on smartphone C was preferred for scene 1. Individually, considering all scene-ambient lighting condition, Dolby Vision decoding strategy on smartphone A was preferred for 30 out of 40 scenarios as shown in **Table 3**. Therefore, for most of the ambient lighting situations under which the scenes were evaluated, Dolby Vision decoding strategy in smartphone A was preferred. Nevertheless, for the night scene (scene 2), the HDR10+ decoding strategy on smartphone C was preferred over other decoding strategies. Based on the responses to Question 1 discussed in section 3, it was found that the preferred decoding strategies were chosen mostly due to best adapted brightness levels and conttrast.

4.2. Gender

The data was also evaluated for difference of trends followed between the only-male and only-female population with respect to that followed by the entire population respectively. Overall, male as well as female observers statistically significantly preferred the Dolby Vision decoding strategy on smartphone A over other formats' decoding strategies ($p<0.01$). For the night scenario, it was observed that males or females did not have a statistically significantly different preference as compared to the entire population. For the ITU environment, males did not have a clear preference, while females preferred the Dolby Vision decoding strategy ($p<0.01$). For the indoor and outdoor scenario, males and females both statistically significantly preferred Dolby Vision decoding strategy on smartphone A (at $p<0.01$ and $p<0.05$ level respectively).

4.3. Experience of subjects

The overall background of the subjects who performed the experiment was used to divide the population into 10 experts and 21 naïve observers. Overall, naïve as well as expert observers statistically significantly preferred the Dolby Vision decoding strategy on smartphone A over other formats' decoding strategies ($p<0.001$). Individually for the night situation, HDR10+'s decoding strategy on smartphone C was chosen by the naïve observers, while the expert observers preferred Dolby Vision, although, this preference was not found to be statistically significantly different as compared to the entire population. HDR Vivid was voted as the worst HDR decoding strategy on smartphone B for the night scenario at a significance level of $p<0.05$. For the ITU and indoor lighting condition, both expert and naïve observers statistically significantly preferred the Dolby Vision decoding strategy on smartphone A over other decoding strategies ($p<0.05$). For the outdoor lighting situation, the naïve observers very clearly preferred the Dolby Vision decoding strategy on smartphone A ($p<0.001$) while no significant trend was found for the expert observers. No statistically significant trend was found for the worst decoding strategy for the three situations with ambient illumination condition (ITU, indoor and outdoor).

4.4. Age

The ages of the observers were used to divide the overall population into three age groups of 18-29 years, 30-39 years and equal to or more than 40 years of age. It was observed that overall, for the four ambient lighting situations together, the decoding strategy of smartphone A for Dolby Vision was statistically significantly preferred over other decoding strategies of other smartphones for other formats ($p<0.001$). The individual situation result can be found in **Table 4**, where statistically significant results are marked in bold. It was observed that individually for the lighting situations-age group combination, the Dolby Vision decoding strategy on smartphone A was given a higher preference for the age group of 18-29 years. Observers in the age group equal to 30 years gave a higher score to HDR10+ decoding strategy of smartphone C for the night and Dolby Vision for the ITU, indoor and outdoor lighting situations.

Preferred Encoding					
Age (years)	**Night**	**ITU**	**Indoor**	**Outdoor**	**Overall**
18-29	Dolby Vision	Dolby Vision	**Dolby Vision**	**Dolby Vision**	**Dolby Vision**
30-39	HDR10+	Dolby Vision	Dolby Vision	Dolby Vision	**Dolby Vision**
>40	HDR10+	**Dolby Vision**	**Dolby Vision**	**Dolby Vision**	**Dolby Vision**

Table 4: Age group and viewing environment wise preference results.

5. Discussion and Conclusion

Smartphone manufacturers can use different strategies to decode videos that are encoded with different HDR formats. Decoding strategies of three such smartphones A, B and C, towards videos encoded in Dolby Vision, HDR Vivid and HDR10+ formats respectively were subjectively evaluated in this paper. The psychophysical experiment was conducted for four ambient illumination scenarios (dark, ITU, indoor and outdoor). It was found that for most scenarios, the decoding strategy of smartphone A for Dolby Vision encoded HDR videos was preferred the most by all the observers collectively or by observer groups (expert, naïve, males, females etc.). For some situations the decoding strategy of smartphone C for videos encoded with the HDR10+ format was preferred (especially for night scenes or under night ambient lighting situation), but the trends were not found to be statistically significant.

6. References

CIE. (2004). *A colour appearance model for colour management systems : CIECAM02*.

CIE. (2022). *The CIE 2016 colour appearance model for colour management systems : CIECAM16*. 32.

Dolby. (2014). *Dolby Vision - Official Site - Dolby*. https://www.dolby.com/technologies/dolby-vision/

Dolby. (2022). *Best Practices: Create Dolby Vision Profile 8.4 using DaVinci Resolve with an external HDR display*. https://professionalsupport.dolby.com/s/article/Best-Practises-Create-Dolby-Vision-Profile-8-4-using-DaVinci-Resolve-with-an-external-HDR-display?language=en_US

HDR10+. (2017). *HDR10+*. https://hdr10plus.org/

HiSilicon. (2021). *HDR Vivid UHD Audio and Video | HiSilicon*. https://www.hisilicon.com/en/techtalk/hdr-vivid

Jellyfin. (2023). *The Free Software Media System | Jellyfin*. https://jellyfin.org/

Khan, I. R., Siddiq, A., Khan, R., & Ahmed, J. (n.d.). *Evaluation of the Encoding Accuracy of the PQ based HDR Content Delivery Formats*. https://www.researchgate.net/publication/348355800

Kino Flo. (2023). *Celeb 250 LED DMX - Kino Flo*. https://kinoflo.com/celeb-250-led-dmx/

Mir, J., Talagala, D. S., Fernando, A., & Arachchi, H. K. (2019). A Comprehensive Study and Performance Evaluation of HDR Video Coding. *Arabian Journal for Science and Engineering*, *44*(3), 2427–2444. https://doi.org/10.1007/s13369-018-3583-6

Mukherjee, R., Debattista, K., Bashford-Rogers, T., Vangorp, P., Mantiuk, R., Bessa, M., Waterfield, B., & Chalmers, A. (2016). Objective and subjective evaluation of High Dynamic Range video compression. *Signal Processing: Image Communication*, *47*, 426–437. https://doi.org/10.1016/j.image.2016.08.001

Myszkowski, K., Mantiuk, R., & Krawczyk, G. (2022). *High dynamic range video*. Springer Nature.

Pan, X., Zhang, J., Wang, S., Wang, S., Zhou, Y., Ding, W., & Yang, Y. (2018). HDR video quality assessment: Perceptual evaluation of compressed HDR video. *Journal of Visual Communication and Image Representation*, *57*, 76–83. https://doi.org/10.1016/j.jvcir.2018.10.016

Qt. (2023). *Python UI | Design GUI with Python | Python Bindings for Qt*. https://www.qt.io/qt-for-python

Reinhard, E., Heidrich, W., Debevec, P., Pattanaik, S., Ward, G., & Myszkowski, K. (2010). *High dynamic range imaging: acquisition, display, and image-based lighting*. Morgan Kaufmann.

Shang, Z., Ebenezer, J. P., Bovik, A. C., Wu, Y., Wei, H., & Sethuraman, S. (2022). *Subjective Assessment of High Dynamic Range Videos Under Different Ambient Conditions*. http://arxiv.org/abs/2209.10005