

DCI Memorandum on HDR Double-Blind Image Testing

Approved 1 July 2021

Digital Cinema Initiatives, LLC, Member Representatives Committee

Background

For the past several years, Digital Cinema Initiatives, LLC (DCI) has been working to determine appropriate criteria for next-generation projection and display specifications, particularly to enable High Dynamic Range (HDR) in the theatrical environment. DCI's efforts were undertaken in response to technological advancements in HDR, filmmaker desires for additional storytelling capabilities, manufacturer requests for guidance, and a desire to further enhance the movie-going experience.

As part of the specification development process, DCI performed a number of double-blind image testing studies to determine the perceptibility of certain technical parameters, particularly black levels and peak brightness.

The first set of double-blind image testing sessions was performed in December 2017 and focused primarily on determining appropriate black levels. The testing included content in SDR and HDR with various black levels and a peak brightness of 48 cd/m² and 100 cd/m².

While the results yielded very good data points on the perception of black levels, the results for the 100 cd/m² to 48 cd/m² comparisons were inconclusive. This demonstrated that additional testing would be useful to determine the qualitative perception of higher peak brightness. This led to the second set of double-blind image testing conducted in January and February 2020, which concentrated primarily on the perceptibility of various peak brightness levels.

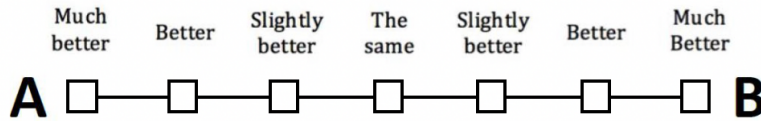
In order to narrow the focus and best determine the values for peak brightness and black level, color gamut perceptibility was not part of the testing. All test content was displayed within the DCI P3 color volume.

The purpose of this memorandum is to provide a summary of the process and findings from these testing efforts, how they guided the specification development process, and define peak brightness and black level values for next-generation projectors and displays based on the results.

Testing Methodology

All the testing sessions coordinated by DCI were designed as double-blind tests, which meant that the person evaluating the content and the person running the test had no knowledge about the parameters of the images that were being presented. Each sequence of clips was randomly

generated. Each clip was approximately ten seconds in duration and each sequence consisted of two versions of the same clip, presented twice, in the following order: Version A / Version B / Version A / Version B / Scoring. At the end of each sequence, the participants had to rate their preference between version A and version B on a 7-point scale.



Double-Blind Image Testing 2017 – Black Levels

During the month of December 2017, twenty-four double-blind image testing sessions were hosted at Walt Disney Studios, leveraging state-of-the-art RGB laser projection capable of displaying extended dynamic range content. This study included both expert and non-expert viewers from member studios, along with participants from industry organizations such as AMPAS, ASC, and NATO. In total, **128 individuals participated** in this study.

Content Preparation

Six different test clips were selected, and multiple versions of each clip were prepared ahead of time. In total, seven versions for each clip were created with the following black level and peak brightness limitations.

Peak Luminance	Minimum Black Level	Maximum Contrast Ratio
48 cd/m ²	0.024 cd/m ²	2,000 : 1
100 cd/m ²	0.020 cd/m ²	5,000 : 1
100 cd/m ²	0.010 cd/m ²	10,000 : 1
100 cd/m ²	0.005 cd/m ²	20,000 : 1
100 cd/m ²	0.002 cd/m ²	50,000 : 1
100 cd/m ²	0.001 cd/m ²	100,000 : 1
100 cd/m ²	0.0005 cd/m ²	200,000 :1

Table 1: Image attributes during 2017 DCI Double-Blind Image Testing

Black Level Test Results

The comparisons in Figure 1 below illustrate the ratings of the SDR version against the various new versions and black levels.

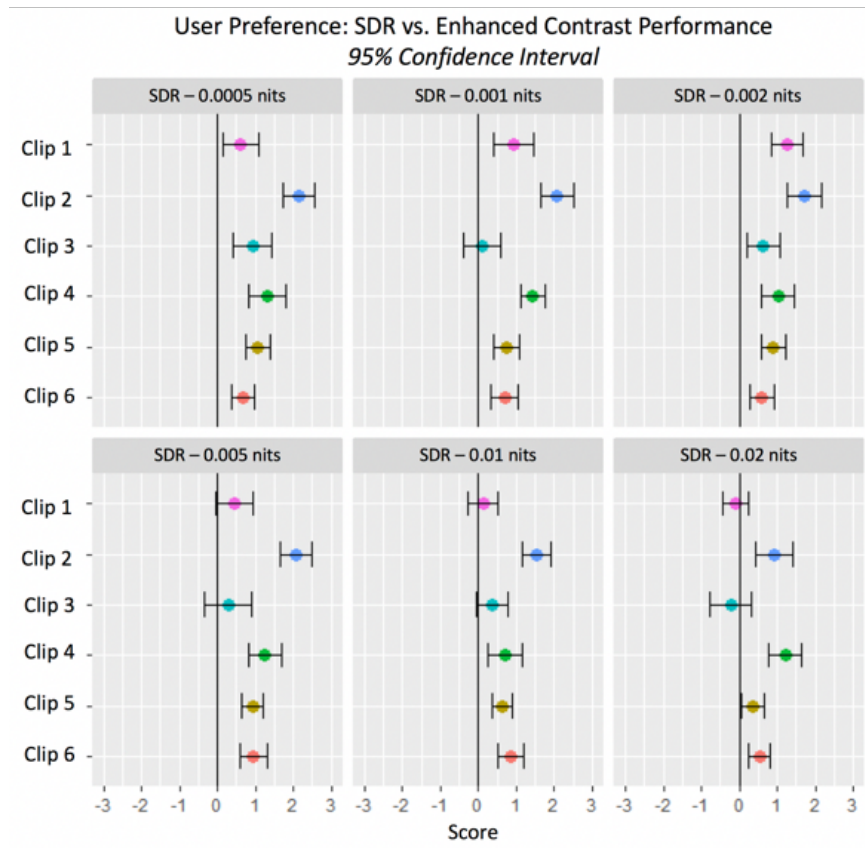


Figure 1: Test results comparing SDR against various Black Level versions

Generally speaking, Figure 1 shows a correlation that lower black levels receive better ratings. To further illustrate this, Figure 2 captures the average values across all clips and versions.

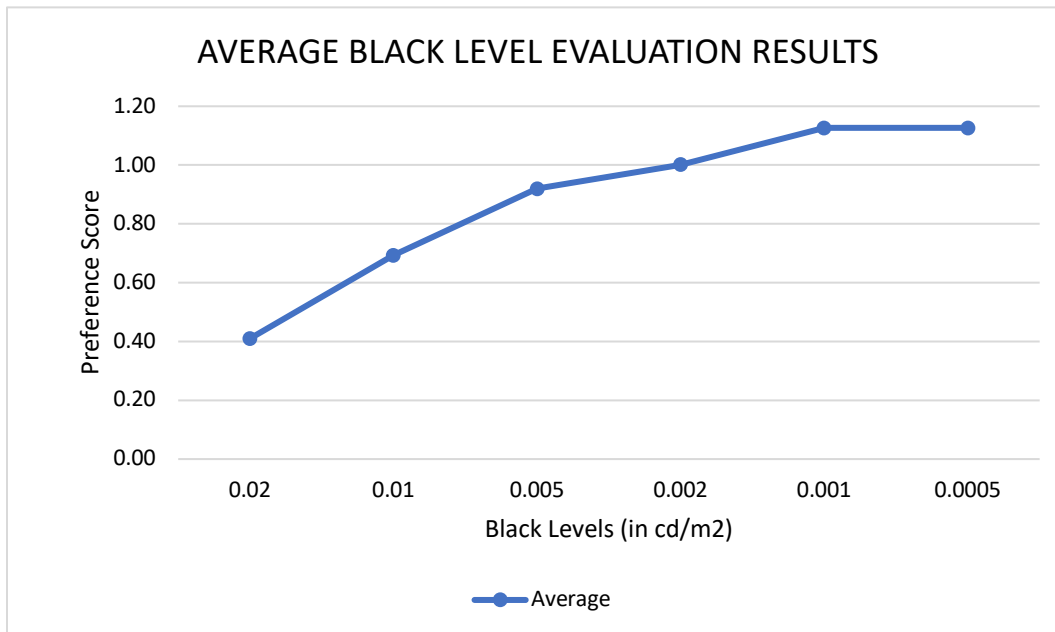


Figure 2: Average test scores comparing SDR against various Black Levels

As the user preference score for the average of all test clips increases with decreasing black levels, the curve starts to flatten around 0.005 cd/m². This means, that the perceived differences with black levels lower than 0.005 cd/m² are not as noticeable. At the same time, the results suggest that black levels above 0.005 cd/m² are much less preferred (average rating of 0.69 for 0.01 cd/m² compared to 0.92 for 0.005 cd/m²).

Black Level Conclusions

These test results indicate that a black level of 0.005 cd/m² provides a sufficiently differentiated viewing experience. It is DCI’s conclusion that black levels above that level are insufficient in achieving a compelling HDR experience, and black levels below 0.005 cd/m² perform similarly and do not provide significant additional value. With that in mind, **DCI intends to specify 0.005 cd/m² as the black level requirement for next generation HDR projection and display Cinema systems.**

Double-Blind Image Testing January/February 2020 – Peak Brightness

During the months of January and February 2020, ten double-blind image testing sessions were hosted at Sony Pictures Studios, leveraging the installation of the Sony CLED display for playback and review. As with the black level tests, this study included both expert and non-expert viewers, with participants also from industry organizations such as AMPAS, ASC, and NATO, as well as cinema equipment manufacturers. In total, **157 individuals participated** in this study.

Content Preparation

Eight different test clips (Clip A – H) were selected and multiple versions of each clip were prepared ahead of time, each of them specifically graded for the Sony CLED display by colorists familiar with the content to the levels in the below table:

Clip A	Wedding Ringers	SDR & HDR (100, 300, 500, 800 cd/m ²)
Clip B	Into America’s Wild	SDR & HDR (100, 300, 500, 800 cd/m ²)
Clip C	Inside Out (Intro)	SDR & HDR (100, 300, 500, 800 cd/m ²)
Clip D	Finding Nemo	SDR & HDR 100 cd/m ² with varying black levels
Clip E	Incredibles 2	SDR & HDR 100 cd/m ²
Clip F	Inside Out (Subconscious)	SDR & HDR 800 cd/m ²
Clip G	Dr. Strange (Clip 2)	SDR & HDR (100, 300, 500, 800 cd/m ²)
Clip H	Dr. Strange (Clip 3)	SDR & HDR (100, 300, 500, 800 cd/m ²)

Table 2: Test content prepared for 2020 DCI HDR Double-Blind Image Testing

For the purposes of analyzing the preferences related to **peak brightness** capabilities, only Clip A, B, C, G, H were deemed relevant. Clip D, E, F were designed for very targeted tests outside the scope of this document, and while they were present in the testing sequences, they are not included in the analysis.

Testing Limitations

Given the large amount of content and testing parameters, some limitations were imposed by necessity during the study. As a result, not all HDR versions for each clip were compared against the SDR version. Table 3 below shows which brightness levels were compared in the study.

		100 cd/m ²	300 cd/m ²	500 cd/m ²	800 cd/m ²
Clip A	SDR	X	X	X	X
Clip B	SDR	X	O	X	X
Clip C	SDR	X	X	X	X
Clip G	SDR	X	X	X	O
Clip H	SDR	X	X	O	X

Table 3: Test content brightness level comparisons

An additional limitation was the large number of comparisons within a short amount of time for testing to avoid viewer fatigue. Each randomly generated sequence was held to four minutes or less, with one minute between sequences to score, comment and readjust for the next sequence. The total duration of the test for each participant was held to 30 minutes. This resulted in each participant not being able to view every combination, thus widening the error bars of the testing results as shown in Figures 3 and 4.

Peak Brightness Test Results

Test Results: SDR vs HDR Levels

The comparisons in Figure 3 below illustrate the ratings of the SDR version against the various HDR versions and brightness levels.

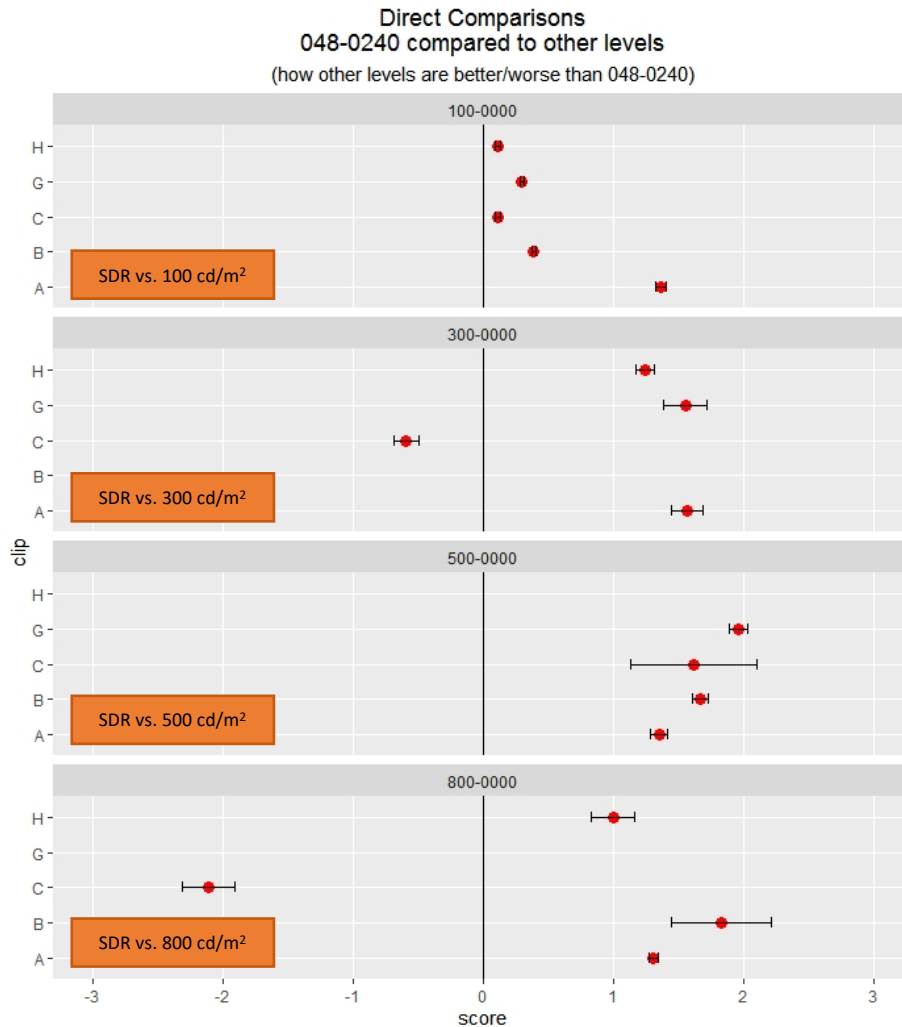


Figure 3: Test results comparing SDR against the various HDR brightness versions

Observations: SDR vs 100 cd/m²

As Figure 3 shows, with the exception of Clip A, the 100 cd/m² versions are only marginally better than the SDR version. This result is consistent with the observations from the prior DCI Testing at the end of 2017.

Observations: Clip C anomaly

Looking at the results for Clip C in Figure 3 shows that the scores are very inconsistent. The score comparing the SDR and 100 cd/m² version are rated about the same; and comparing SDR against the higher brightness versions shows a preference for SDR when comparing against the 300 cd/m² and 800 cd/m² version, and a preference for 500 cd/m² compared to SDR.

One explanation could be that this particular clip – the introductory scene from “Inside Out”, with the birth of the character – opens with a longer period of complete darkness followed by full brightness across the entire frame. The intended creative purpose for this is to make viewers

very uncomfortable, matching the experience of birth. While this desired purpose was successful in making the testing participants uncomfortable, it resulted in very inconsistent ratings and therefore has been excluded from these test results.

Test Results: SDR vs HDR Levels (excluding Clip C)

Given the very inconsistent results for Clip C, Figure 4 below shows further analysis excluding this Clip. For each of the comparisons between different versions, we also calculated the mean scores between the different clips.

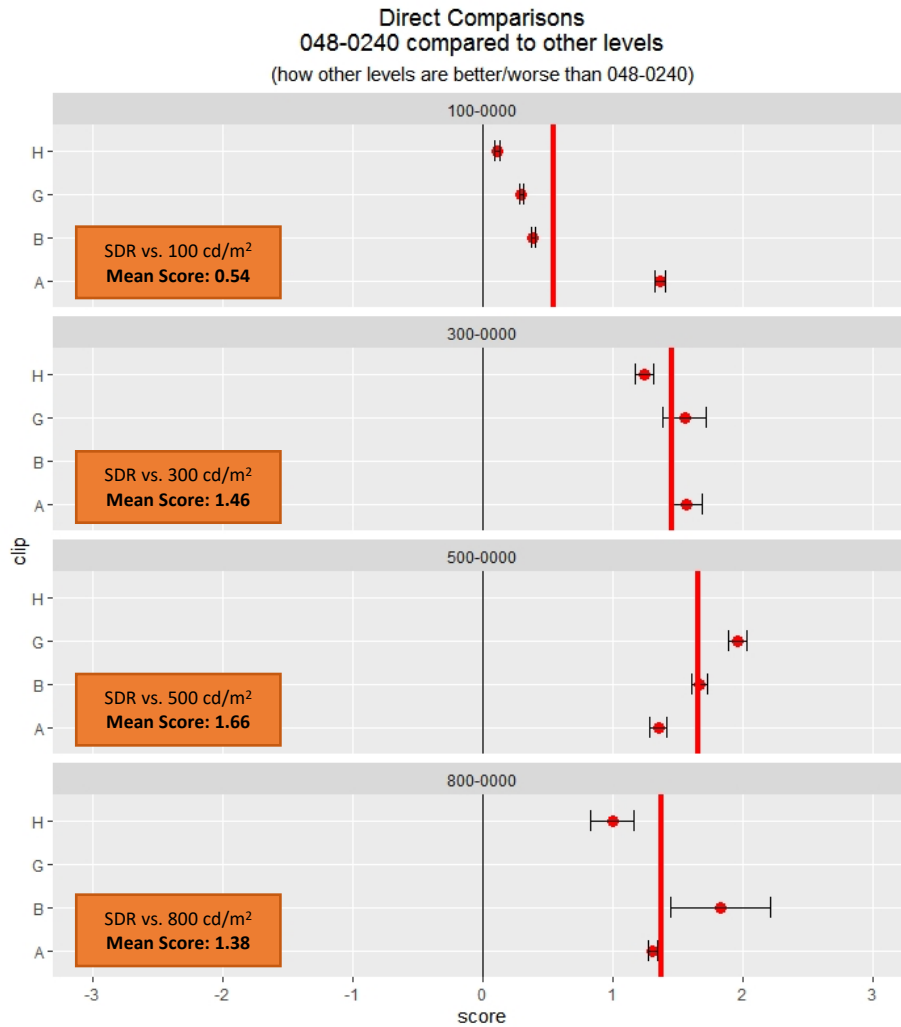


Figure 4: Test results comparing SDR against the various HDR brightness versions (excluding Clip C) and with mean scores

As Figure 4 shows, while the preference for 100 cd/m² HDR content is only marginal compared to SDR (mean score of 0.54), there is a significant increase in preference for HDR content at 300 cd/m² or higher brightness levels with mean scores of 1.46 (300 cd/m²), 1.66 (500 cd/m²), and 1.38 (800 cd/m²), respectively.

Test Results: Brighter HDR Levels

Taking a closer look at the preferences between higher brightness levels such as 300 cd/m², 500 cd/m², and 800 cd/m²; Figure 5 below shows the comparison of the 300 cd/m² version for each clip against the 500 cd/m² version; and Figure 6 shows the comparison of the 500 cd/m² version for each clip against the 800 cd/m² versions.

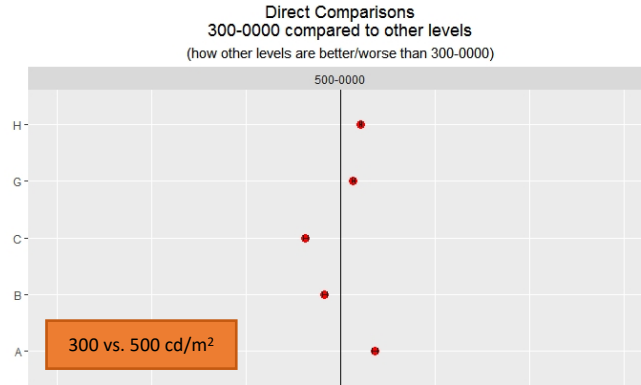


Figure 5: Test results comparing HDR 300 against HDR 500cd/m² versions

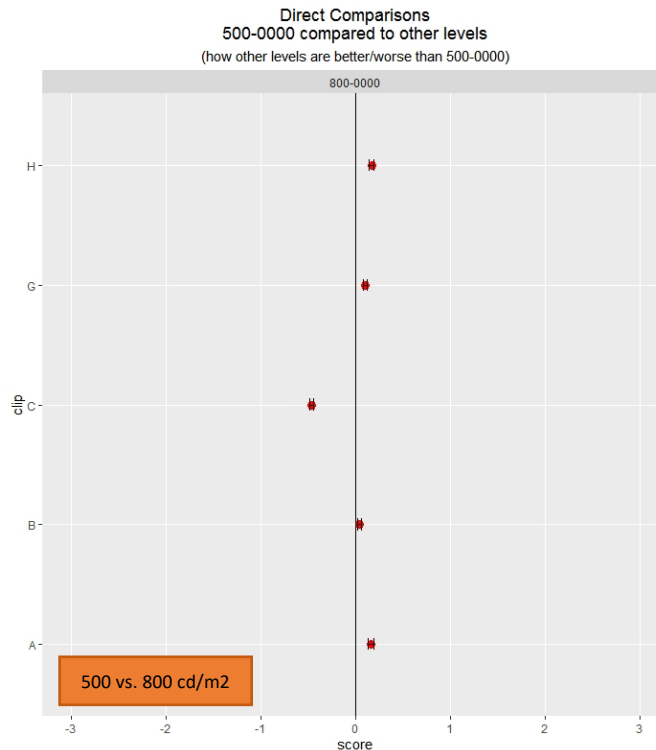


Figure 6: Test results comparing HDR 500 against HDR 800 cd/m² versions

The result shows that all of these versions are mostly rated the same, with not much added preference. This indicates that there is not much viewer preference for brightness capabilities above 300 cd/m².

Peak Brightness Conclusions

These test results indicate that a peak brightness of 300 cd/m² for HDR content provides a sufficiently differentiated viewing experience. It is DCI's conclusion that brightness levels below that level are insufficient in achieving a compelling HDR experience. Brightness levels above 300 cd/m² perform similarly and do not provide significant additional value. With that in mind, **DCI intends to specify 300 cd/m² as the peak brightness requirement for next generation HDR projection and display Cinema systems.**

Summary

Ongoing technological innovation assures that the next generation of D-Cinema will be capable of higher contrast and peak brightness with lower black levels. DCI has dedicated a number of years to testing, statistical analysis and industry collaboration to determine the levels necessary to achieve a sufficiently differentiated HDR experience.

Through these tests and other studies, DCI finds that the following parameters for next-generation HDR cinema projection and display systems will provide a significantly enhanced movie-going experience:

Peak Brightness:	300 cd/m² ("300 nits")
Black Level:	0.005 cd/m² ("5 millinits")

DCI thanks all of the industry specialists and manufacturers for giving their time and sharing their valuable knowledge in this process and looks forward to continued collaboration.