Why iPhone 12 series displays have a green tint?

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Apple recently released iPhone 12 series products, with all the products using OLED displays. Posts on social media reported that green tint appears on these products, especially when the displays are showing neutral gray colors. Though the significant green tint shown in some photographs could be due to the cameras, camera settings or intentional adjusting, Apple has acknowledged the existence of the issue and is seeking solutions through an iOS update.

When we checked products in an Apple Store, though we did not see the tint as serious as shown in online posts, noticeable green tints can be perceived, especially when an old LCD iPhone was placed next to these new products and when they were viewed under daylight.

Spectral measurement and colorimetric characterization

As the green tint appears more obvious when gray images are shown on the display, we generated a series of images, which were actually solid colors at different gray levels (i.e., 0, 5, 10, 20, 40, 70, 100, 130, 160, 190, 220, 255) occupying the entire display, and showed each image on the display. A PhotoResearch 655 spectroradiometer was used to measure the spectra from the image center, with the meter aiming perpendicularly to the display. Functions (i.e., true tone, auto brightness, reduced white point, and night shift) were all switched off, and the display brightness was set to the highest.

Table 1 Colorimetric characteristics of the two iPhones derived using the measured spectra and the CIE 1931 color matching functions

Digital Counts	iPhone 11 (LCD)					iPhone 12 (OLED)				
	Y	*u'*	*v'*	CCT	Δ*u'v'* to D65	*Y*	*u'*	*v'*	CCT	Δ*u'v'* to D65
255	643.9	0.1949	0.4640	6983	0.004	641.4	0.1997	0.4697	6307	0.003
220	461.1	0.1952	0.4639	6970	0.004	462.9	0.1996	0.4696	6318	0.003
190	334.3	0.1956	0.4633	6984	0.004	335.2	0.1996	0.4699	6304	0.003
160	225.8	0.1953	0.4638	6969	0.004	228.9	0.1996	0.4698	6305	0.003
130	144.2	0.1951	0.4640	6969	0.004	145.6	0.1994	0.4697	6320	0.003
100	81.1	0.1954	0.4634	6995	0.004	81.4	0.1994	0.4703	6291	0.004
70	36.6	0.1952	0.4637	6985	0.004	37.4	0.1987	0.4704	6325	0.004
40	10.9	0.1954	0.4645	6914	0.003	11.0	0.1982	0.4715	6294	0.005
20	2.3	0.1956	0.4617	7103	0.006	2.5	0.1990	0.4719	6229	0.005

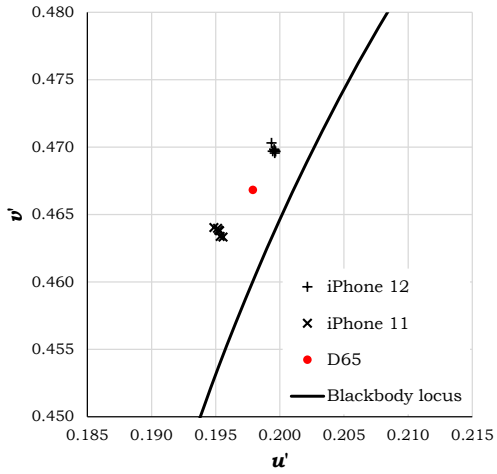

Figure 1 Chromaticities of the gray colors on the two displays using the CIE 1931 CMFs.

The chromaticities of the gray images of both iPhone 11 (LCD display) and iPhone 12 (OLED display) were very close to D65, which were generally smaller than 1 JND using the CIE 1931 color matching functions (CMFs). For each display, the chromaticities of the various gray images were very stable, suggesting the great efforts made by Apple on display calibration. However, the chromaticities cannot explain the green tint issue.

Effect of Color Matching Functions (CMFs)

Recently, we carried out an experiment in which one LCD and several OLED displays were used to match the color appearance of a broadband D70 stimulus produced by a spectrally tuneable LED source. It was found that the OLED displays needed to shift the chromaticities towards the +*u*'-*v*' direction in the CIE 1931 chromaticity diagram for producing a color match, suggesting the OLED displays appeared greenish when having same chromaticities as the LCD display. This seems to explain the green tint issue of iPhone 12 series products.

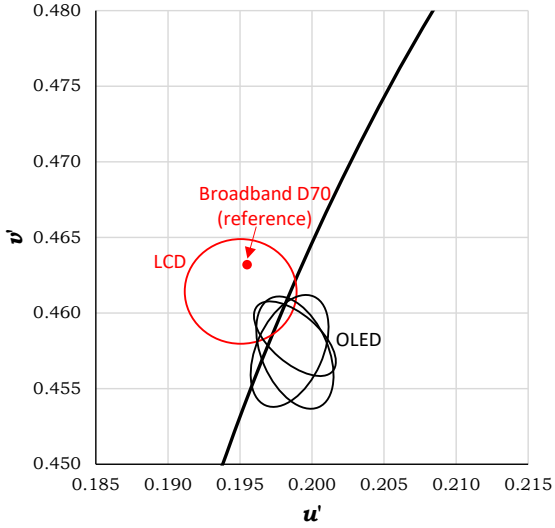

Figure 2 Fitted ellipses of the adjusted chromaticities to match the color appearance of a broadband D70 reference stimulus produced by a multichannel spectrally tunable source using LCD and OLED displays (for illustration).

The weaknesses of the CIE 1931 CMFs are well known. Particularly, it underestimates the sensitivities to the radiation in the short wavelengths, especially when the field of view is larger than 4°. The other two CMFs (i.e., CIE 1964 and CIE 2006 10°), which were found to better correlate to human color perception in many past studies, were then used to calculate the chromaticities of the gray images on the two phones. The distributions of the chromaticities using the both CMFs are similar, with the iPhone 12 chromaticities shifting towards the -*u*'+*v*' direction, which suggests a green-yellow tint.

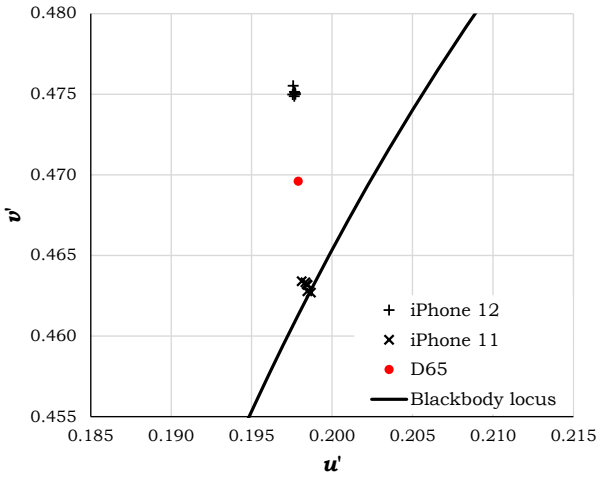

Figure 3 Chromaticities of the gray colors on two displays using the CIE 1964 CMFs. Similar distribution can be observed when using the CIE 2006 10° CMFs.

Though hardware or software artifacts may exist in some units, it is likely that the weaknesses of the CIE 1931 CMFs also have some effects on the green tint issue. With the large variations of the CMFs among people, this issue may be more serious to some users.

If the green tint issue is really caused by the CIE 1931 CMFs, it is possible to mitigate the issue through an iOS update. And it is also time for the community to use new CMFs for system calibration and characterization.

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