Best practices: measuring skin color and ITA with colorimeters/spectrophotometers, with a specific focus on the CM-700d (Konica Minolta).

Contents

Abstract

- Perform black and white calibrations before each measurement sessions.
- Ensure that SAV/MAV toggle matches with aperture before calibration, and don't change this afterwards.
- Hold device perpendicular to the skin to be measured, minimizing gaps but without pressure on the skin
- Repeat the measurement three times on the same spot and remove the device between each measurement.
- If the skin site to be probed allows for an 8mm aperture, this is preferred. Only use the 3mm for skin sites where the 8mm aperture would create large gaps. The aperture size (3mm or 8mm) appears to affect the measured ITA value only minimally, but the raw data (spectrum) is affected.
- Always keep keep records of the settings you used, and preferably also the reflectance spectra as they are incredibly useful to understand outliers when you analyze the data.

Introduction

This sections aims to make a few practical remarks on aspects of skin colorimetry that are not mentioned in the existing body of literature on the topic (Wang et al., 2015, 2018; Wei et al., 2007). Skin color measurement with colorimeters/spectrophotometers has been practiced for several decades with considerable success. **Disclaimer:** recommendations in the CM700d manual provided by Konica Minolta will always override any recommendations given herein. Many of the recommendations may or may not apply to colorimeters/spectrophotometers of other brands

Calibration

Procedure:

1) Check if the toggle matches the aperture (SAV/MAV),
2) Perform black and white calibrations,
3) Validate with a few known objects,
4) Don't switch the toggle or aperture anymore,
5) … ready for measurements ….

White calibrations are needed before each measurement session. Black calibration is not ***needed*** before each measurement session; you can do only a white calibration and proceed to measurement sessions. But it is good practice to do a black calibration nevertheless before every measurement session. Alternatively, you'd have to have a calendar where you'd remind yourself to do it monthly or so.

If ambient temperature fluctuates substantially (e.g. >10 degrees), repeat calibration procedure.

CM700d device, along with white and black calibration accessories.

Some measurement hygiene:

Keep the calibration accessories clean. (put the plastic covers back on after use). If they are dirty, this will indirectly affect the skin measurements.

The white calibration tile can be cleaned with a wet wipe.

BUT: DO NOT attempt to clean the black calibration accessory, as it will only get worse.

Follow the instructions about cleaning the aperture in the devices manual. If you do not want to look it up, just be aware that alcoholic wipes may affect plexiglass, or plastics so it might be better to use a simple wet wipe.

Important: The SW you use is probably one of two: 1) Skin Analysis (SA), or 2) SpectraMagix NX.

Both might give you warnings that a calibration was not possible (e.g. because the SAV/MAV toggle and aperture do not match). However, you might be able to 'cancel' this warning and proceed with measurements (as a black calibration is not required). So, it is possible to proceed with measurements with a white calibration only, and the SAV/MAV toggle and aperture mismatching. The measurements will be faulty and way off. As an example the L* of a black object might be measured as 40 while with the

correct settings (calibrated with toggle and aperture matching), you would have found an L* value of only 20.

If after proper calibration you switch the toggle, or change the aperture, you have to recalibrate.

With respect to apertures, the important thing is the aperture (SAV or MAV), not so much whether it has the flat plate on it or not.

In short: steps 1 and 4 in above check-list are important .

Validation after you calibrated. It might be good practice in a lab with various levels of experience to measure a few objects after you calibrated for which you know the expected Lab values. A couple of colored objects with stickers with known Lab values might serve the purpose (e.g. a red object, a blue, yellow object). And also the white calibration tile itself can be used for this purpose. Simply check if the Lab values are according to expectations. The color differences between subsequent measurements should be DE < 0.5. See (Wang et al., 2015) , for typical values of measurement variations. The actual value of these variations is the combination of material inhomegeneity and device imprecision.

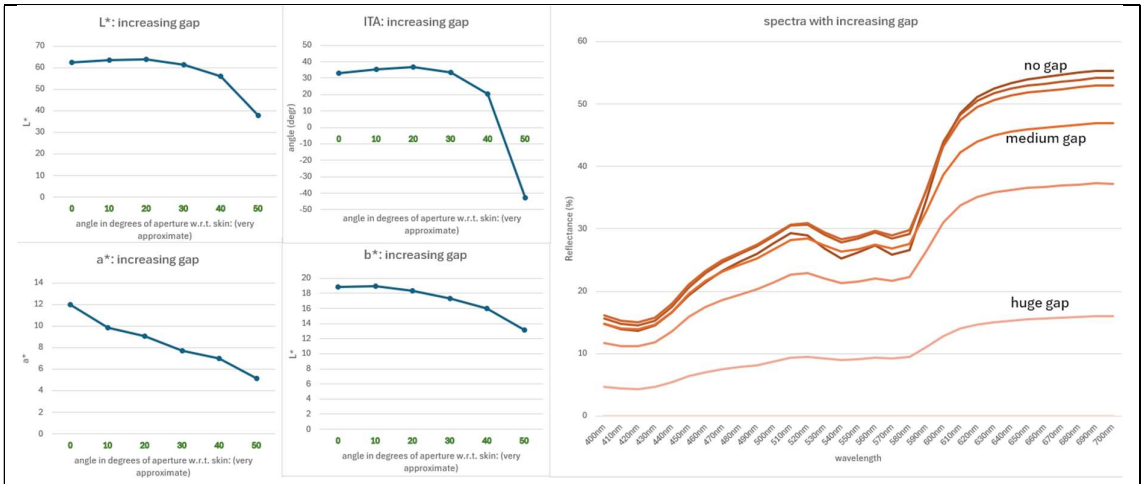
These 'quick checks' habit will help avoid miscalibrations such as with SAV/MAV.

Measuring on skin

Repeats It is recommended to measure three repeats on the same spot (motto: ' one measurement is no measurement'). In between measurements the device is taken off the skin and placed back on the same spot, for the next measurement.

Device placement on the skin. The aperture should be positioned perpendicularly to the skin such that there are minimal gaps. A quick investigation in how a gap in between the skin and the aperture impacts the measurement values (shown below), shows that the gap is not very critical. It is therefore not good practice to apply pressure on the skin to remove gaps. Pressure would redistribute blood in the skin and impact the skin color. Therefore, it is better to place the aperture on the skin gently, and risking some small gap, than to apply pressure with the intent to guarantee a seal all around the aperture periphery.

While the pressure has an impact on the colour measurements, Wang et al (Wang et al., 2018) noted that the pressure in fact also has relatively small impact on the color. They state that '… aperture size had more influence on the colour shifts than the measurement pressure …'. . Please refer to the section aperture size for more information.

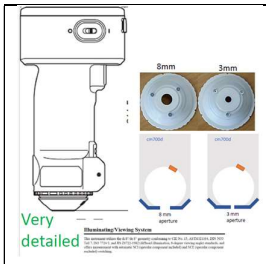
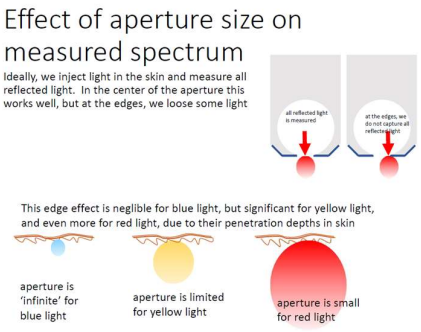
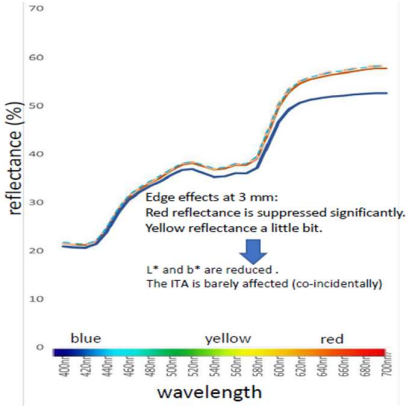


The gap between aperture and skin was deliberately created by increasing the angle of the device wrt to the skin. The ITA is minimally affected when moderate angles (e.g. < 30 degr.) are created. This would correspond roughly to a gap of about 1 mm . This example is for white skin (palm of hand). For dark skin, the results might be somewhat different; this has not been investigated.

Aperture size (SAV/MAV)

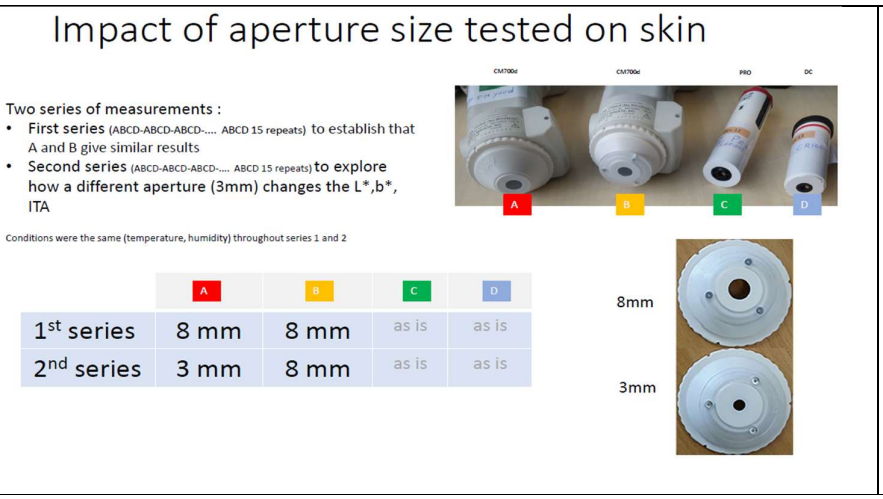
The aperture is ideally considered a semi-infinite surface from which reflectance is collected. Semi-infinite means that the the fraction of light reflected collected is independent of the aperture size. The 'semi-infinite-ness' assumption is more valid for the large aperture size, simply because it is bigger. So, in principle it is recommended to use the larger aperture, when possible. Indeed, (Wang et al., 2018) find that the 'large aperture size gave the most repeatable results'. This may be due to the fact that inhomogeneities in skin colour are averaged out better with the large aperture.

On very small surface it can occur that the smaller aperture is needed because the large aperture would create large gaps. One should always ensure that the calibration was properly done for the SAV (both toggle and aperture, calibrated). Despite a new calibration, it can be understood from tissue optics that the colour results from skin cannot be expected to be the same as for the MAV. This is simply because the limited validity of 'semi-inifinitess' depends on wavelength, which, in turn, depends on the fact that skin is a turbid medium. Turbid means that a significant fraction of the light penetrates into the skin to some substantial depths, before being remitted.

		
Two apertures are available for the CM700d	*At the edges of the aperture, some light is lost that should have been collected. This error is considerably bigger for red light than for blue light.*	*Reflectance spectra for the 8mm device illustrating the spectrally dependent relative errors. The blue spectra are for the 3mm aperture and show a signficant reduction in the red light, and less so at shorter wavelengths.*

Some of this light will be remitted in the aperture and collected by the device. But some light will also end up outside the aperture, and NOT be collected. This represents an error, because ideally one would also collect this light, contributing to the reflectance. Since red light penetrates much deeper and travels longer paths into skin, this error is larger for red light than for shorter wavelengths (green, blue).

Although very limited in scope (only white skin, one subject), a somewhat systematic investigation into impact of aperture size on measured ITA is shown below. The result is that the ITA is barely affected by aperture size, even though the L*, and b* are signficantly affected. The investigation also involved the measurement with two much less expensive (< 250 USD) devices. We find that for this skin the ITA measured with these devices was about 7 degrees higher than with the CM 700d devices.

 	A	B	C	D
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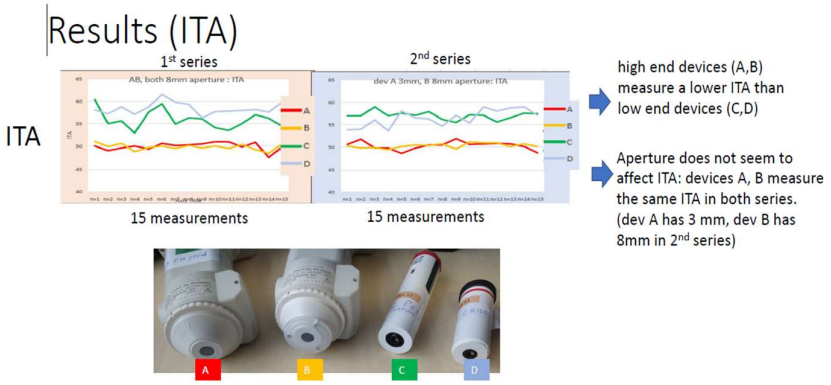
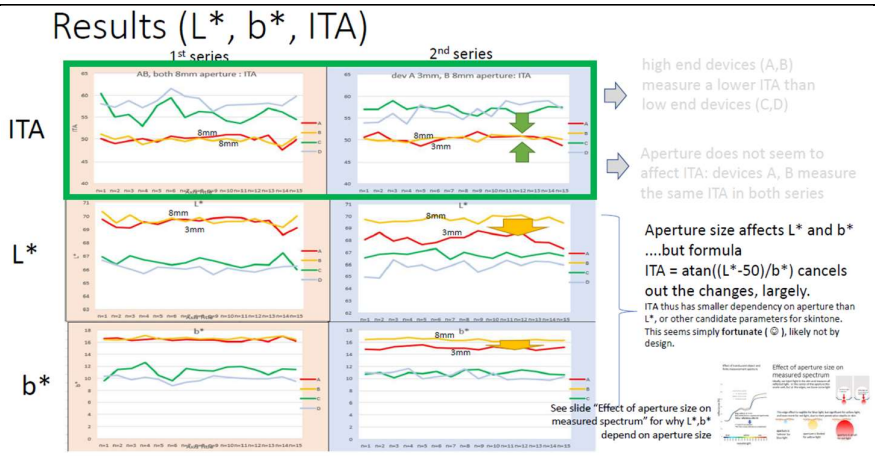
1st series	8 mm	8 mm	as is	as is
2nd series	3 mm	8 mm	as is	as is		Protocol: two measurement series of 15 repeat measurements on the same skin. Four devices were used (ABCD).

<table>
<tr>
<td> 
</td>
<td>ITA is not significantly affected by the aperture change in devices A and B. In each of the 4 sets of 15 measurements (two devices, two series) the ITA is 50+- 2 (rough estimate), regardless the aperture.</td>
</tr>
<tr>
<td> 
</td>
<td>Importantly, while the ITA is largely unaffected, the underlying L* and b* are significantly affected by the aperture size. Coincidentally, the ITA formula largely cancels out these changes and as a result the ITA is not changed very much.</td>
</tr>
<tr>
<td colspan="2">A small investigation into the impact of aperture size illustrates that the ITA is not much affected in this example. The investigation also shows that less expensive devices deviate in their measurement of ITA. This difference is largely due to the translucency (turbidity) of skin because on non-turbid samples, (e.g. Pantone SkinTone guide swatches, or other painted objects), the difference between KM and cheaper devices was found to be much smaller.</td>
</tr>
</table>

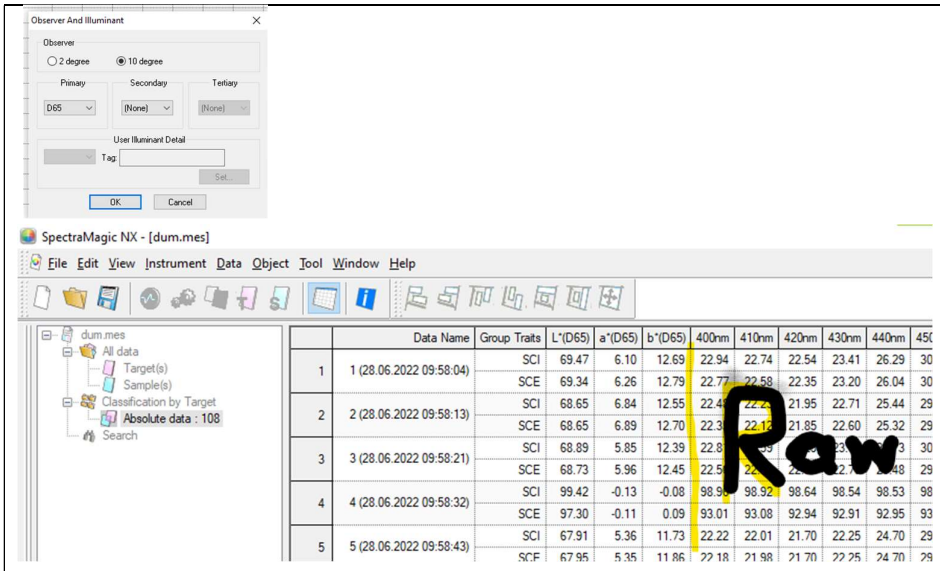
CM700d settings, record keeping

The raw measurement is the reflectance spectrum. This is the basis from which CIELab values can be computed, and then an ITA (from the L* and b*). For this computation, one has to select an illuminant and a standard observer. Defaults are typically D65 and 10 degree observer, respectively. As long as you have the raw measurement, you can always recompute the CIELab (and thus also ITA) for different combinations of illuminants and observer choices.

It is much easier though, to let the KM software do the computation so you store the CIELab values along with the raw measurement (and minimal processing is needed for analysis, just the ITA from L* and b*). In this case, just ensure that you have the right choices (e.g. D65 and 10 degree observer, but look this up in an ISO standard or FDA guideline).

So, keep a record of :

- SW package,
- standard observer and
- illuminant used for computation of CIELab values.
- if applicable, whether SCI or SCE, or both was used.



Screenshots of the user interface of the SpectraMagic NX software. Top: a window to select which illuminant and standard observer is used to compute Lab values for the raw data. The three columns with CIELab values on the left of the yellow line are NOT raw data, but are for a specific set of illuminant and standard observer (the illuminant is indicated in the column header).

With the SpectraMagic NX software it is possible to configure the devie to measure both SCI and SCE. The device will then make two flashes (about 1.5 seconds apart) and also store two rows of data for each measurement, as can be see in the screenshot. SCI and SCE refer to specular reflectance Included and Excluded, respectively.

IMPORTANT: in this setting you need to get used to a different cadence of measurement as there will be two flashes for each measurement. Keep the device still on the skin during this time and wait for the second flash before you remove the device. If you take away the device before the 2nd flash, you will later on see that the SCE line in the spreadsheet will show erroneous (likely much smaller reflectance values) data.

For our purposes (getting an estimate of the ITA) the difference between SCI and SCE is not very interesting. It is safe to say that a single measurement (preferably SCE) is performed. It will be a faster procedure.

Wang, M., Xiao, K., Luo, M. R., Pointer, M., Cheung, V., & Wuerger, S. (2018). An investigation into the variability of skin colour measurements. *Color Res Appl*, *43*(4), 458–470. https://doi.org/10.1002/col.22230

Wang, M., Xiao, K., Wuerger, S., Cheung, V., Luo, M. R., Xiao, K., Wuerger, S., Cheung, V., & Luo, M. R. (2015). Measuring Human Skin Colour. *Color and Imaging Conference*, *23*, 230–234. https://doi.org/10.2352/CIC.2015.23.1.art00041

Wei, L., Xuemin, W., Wei, L., Li, L., Ping, Z., Yanyu, W., Ying, L., Yan, L., Yan, T., Yan, W., & Li, C. (2007). Skin color measurement in Chinese female population: Analysis of 407 cases from 4 major cities of China. *International Journal of Dermatology*, *46*(8), 835–839. https://doi.org/10.1111/j.1365-4632.2007.03192.x