

# Are Sunglasses Proper for Driving? Investigation and Prototype for Public Testing

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## Research

**Keywords:** sunglasses, driving safety, category and Q factor, traffic lights, ISO 12312-1.

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**Title: Are Sunglasses proper for driving? Investigation and prototype for public testing**

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## **Abstract**

**Background:** Sunglasses safety is important regarding driving conditions and is requirement of sunglasses standard ISO 12312-1, for testing traffic light and visible transmittances on lenses.

**Methods:** We have spectroscopically investigated 232 sunglasses regarding compliance with standard, in the 380 nm – 780 nm range, with 5nm steps. Category (0 – 4) were determined as well as Q factors, which evaluate color distortion for the vision on sunglasses. Furthermore, we developed a prototype for public to self-check sunglasses regarding safety for driving. Combination of white light illumination, 4-channels photo sensor detection and calculation, allows testing simultaneously the colors of traffic light, as well as the visible light transmittances (categories). Q factors are provided by the prototype.

**Results:** Spectroscopy shows that 75.43% complies with ISO 12312-1:2013. Prototype was validated by testing 232 sunglasses, with trained user and 60 from this set were double-checked with non-trained users, and compared to spectroscopic measurements. Bland-Altman analysis presented non-significant biases and narrow 95 % limits of agreement within pre-defined tolerances, for all measurements. Only 2 samples differed in category measurement.

**Conclusions:** Sunglasses on the market should adjust for driving conditions. Prototype it is a fine set up for guiding users on checking proper sunglasses for safe driving

**Significance:** Immediate attention on checking sunglasses for driving conditions is needed.

**Keywords:** sunglasses, driving safety, category and Q factor, traffic lights, ISO 12312-1.

## **Background**

Efforts of our team has been progressively done regarding sunglasses standard (Masili et al. 2019; Masili and Ventura 2016; Masili et al. 2014), including parameters for ocular safety for tropical countries, where irradiance from the sun is quite high, as it was done for the revision of former Brazilian standard ABNT NBR 15111 in 2013. This work is an extension of our researches that emphasizes sunglasses and ocular health.

Previous research of our team was the development of a kiosk for the public to self-check their own sunglasses regarding the ultraviolet (UV) protection, as required by the standards (Mello et al. 2014). In that system, the test provides a report of the category of the lenses (0 – 4) as well as UVA and UVB protection associated to the sunglasses' category. Brazilian national survey in order to improve nationalization of sunglasses standards; and studies conducted on revisiting requirements of worldwide sunglasses standards, in which this work is inserted. So, this work is one of the many systems that our lab is developing (Mello et al. 2014; Magri et al. 2017; Loureiro et al. 2016; Mello and Ventura 2013; Lincoln et al. 2010), to bridge this gap and it has the appeal to also keep public informed.

The public is usually interested on sunglasses style, eye comfort and UV protection when buying a pair of shades. Although these are relevant aspects, several others are noteworthy. One is its safety for driving (Nathan, 1964; Phillips, 1975, Palmer 1997; Dain, 2009). Lenses excessively dark could hinder object and traffic signal recognitions at safe distances, particularly in shadow. Moreover, lenses could excessively enhance or attenuate some colors, leading to distortion on

color perception. Thus, the choice of improper sunglasses may ultimately lead to dangerous situations (Dain 2003; Hovis 2011).

The international standard ISO 12312-1 establishes requirements for all afocal sunglasses and clip-ons, intended for protection against solar radiation for general use, including road use and driving.

The standard grades sunglasses in five categories (0 – 4) according to visible transmittance (380 nm – 780 nm range) of their lenses, i.e., depending on the level of sun glare reduction of their lenses. Sunglasses are recommended for specific situation according to their category. The categories are rated between 0 (clear lenses) and 4 (very dark lenses). Category 4 sunglasses are recommended for environments with high solar incidence, but are not proper for driving.

Although not recommended for normal conditions, category 4 filters may be recommended in extreme high luminance conditions, such as desert and snowfields under full sunlight.

If the transmission of the lens in the visible spectrum (380 nm - 780nm) is less than 75 %, sunglasses should not be used for road and driving in twilight or at night. Those with transmittance less than 8 % (category 4) are not appropriate for driving at any time. Additionally, regarding road use and safe driving conditions, the spectral transmittance of filters for the 475 nm - 650 nm range shall be not less than 0.2 times the visible transmittance. These specifications are for regular tinted sunglasses, photochromic sunglasses lens for road use and driving requires additional steps described in standards (ISO 2013a).

Table 1 reproduces the limits of visible light transmittance for establishing the categories of sunglasses according to ISO 12312-1:2013.

Table 1: Sunglasses category limits, adapted from ISO 12312-1:2013.

Filter category	Visible spectral range
	Range of luminous transmittance $\tau_V$ 380 nm to 780 nm
0	$\tau_V > 80\%$
1	$43\% < \tau_V \leq 80\%$
2	$18\% < \tau_V \leq 43\%$
3	$8\% < \tau_V \leq 18\%$
4	$3\% < \tau_V \leq 8\%$

The visible transmittance,  $\tau_V$ , is defined as

$$\tau_V = \frac{\int_{380}^{780} \tau_F(\lambda) V(\lambda) S_{D65}(\lambda) d\lambda}{\int_{380}^{780} V(\lambda) S_{D65}(\lambda) d\lambda} = \frac{\int_{380}^{780} \tau_F(\lambda) W_V(\lambda) d\lambda}{\int_{380}^{780} W_V(\lambda) d\lambda} \quad (1)$$

in which  $\tau_F(\lambda)$  is the spectral transmittance of the filter,  $V(\lambda)$  is the spectral luminous efficiency function for photopic vision,  $S_{D65}(\lambda)$  is the visible part of the solar spectrum at sea level for air mass 2 (terrestrial solar spectrum occurring when the sun's position vector is 60.11 degrees from the zenith),  $W_V(\lambda)$  is the luminous weighting function (ISO 2013a).

Each category has a recommended use. Darker lenses (less luminous transmittance) are recommended for environments with higher solar incidence, while lenses with luminous transmittance inferior to 3 % are not considered appropriate to be used.

Traffic light transmittances,  $\tau_{signal}$ , are defined for red, yellow, green and blue (some countries has a blueish type of traffic light) as:

$$\begin{aligned}\tau_{signal} &= \frac{\int_{380}^{780} \tau_F(\lambda)V(\lambda)E_{signal}(\lambda)d\lambda}{\int_{380}^{780} V(\lambda)E_{signal}(\lambda)d\lambda} \\ &= \frac{\int_{380}^{780} \tau_F(\lambda)W_{signal}(\lambda)d\lambda}{\int_{380}^{780} W_{signal}(\lambda)d\lambda}\end{aligned}\tag{2}$$

where,  $E_{signal}(\lambda)$  is the spectral energy distribution of the red, yellow, green, or blue traffic signals, which is different for traffic lights lit by incandescent and LED lamps and is available in the standards (ISO 2013a).

Figure 1 shows the spectral weighting functions for traffic lights,  $W_{signal}(\lambda)$ , that is the spectral distribution of emissions from incandescent traffic light lamps,  $E_{signal}(\lambda)$ , weighted by human eye sensitivity,  $V(\lambda)$  (ISO 2013a).

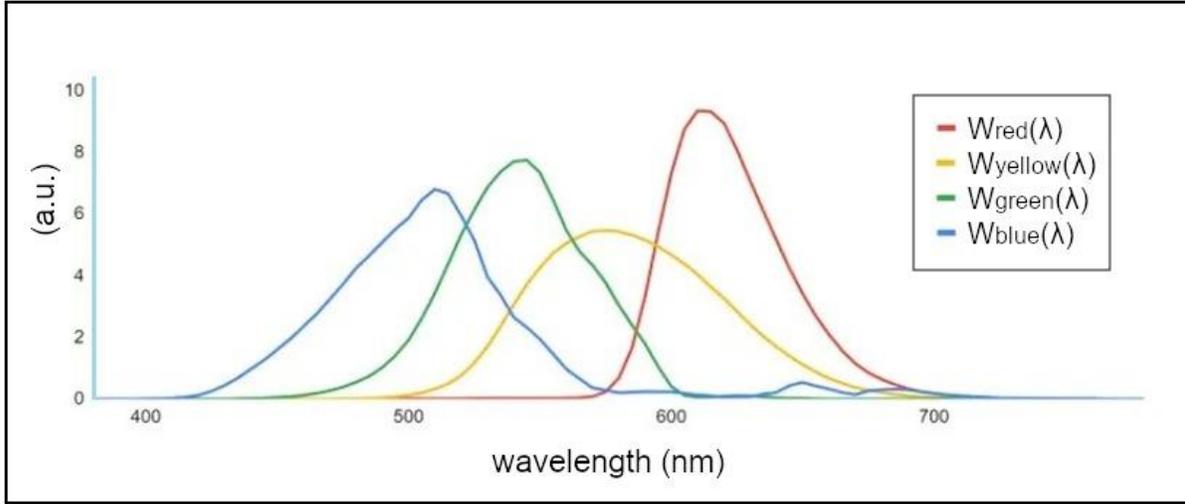


Figure 1: Spectral distribution of emissions from incandescent traffic light lamps,  $W_{signal}(\lambda)$ .

There is also a relative visual attenuation quotient for the three colors of traffic light detection, denoted by  $Q_{signal}$ , is and defined as

$$Q_{signal} = \frac{\tau_{signal}}{\tau_V}. \quad (3)$$

As stated, traffic light transmittances and consequently, relative visual attenuation quotients are defined for incandescent and LED lights; however, standard requirements take into account only the relative visual attenuation quotients (Q factors), which are related to incandescent lights.

According to the standards, for sunglasses of categories 0, 1, 2 and 3, luminous transmittance should be equal or greater than 8%, and Q factors shall not be less than 0.80 for the red signal light, and not less than 0.60 for the yellow, green and blue signal lights.

Figure 2 illustrates the required transmittances for red, yellow and green from traffic lights.

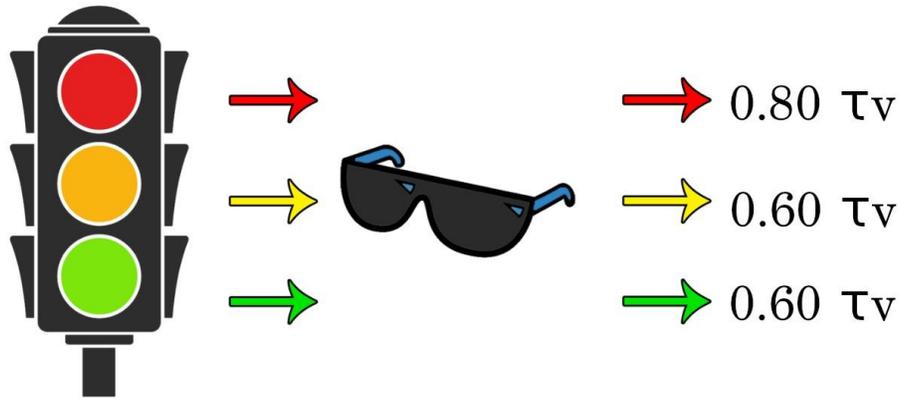


Figure 2: Schematics of Q factor for traffic lights,  $\tau_v$  is the transmittance in the visible range (380 – 780 nm).

It is important that community should have a way to test their sunglasses to assess their optical properties, besides UV protection, such as the categories and if they are suitable for driving land vehicles. Furthermore, after long exposures to the sun, transmittance characteristics of sunglasses lenses may change considerably (Masili et al. 2019; Loureiro et al. 2016). Therefore, transmittance information that comes along sunglasses may become outdated after long periods of use and new measurements should be made to determine their optical characteristics. Since transmittance tests are complex and require the use of scientific equipment, the public does not have any access for testing their own sunglasses.

Hence, we have developed a prototype for the public for self-testing their sunglasses, to check their category and if they are suitable for driving.

The prototype has been developed by the ISO 12312-1:2013 requirements as well as a friendly interface for the public, reporting the luminous transmittance, i.e., the category of sunglasses, and whether sunglasses are proper for driving, i.e., the traffic light transmittances for red, yellow and green signals.

## **Results**

A set of 232 sunglasses was tested, and 222 were unbranded sunglasses.

The relation of unbranded (222) and tagged sunglasses (10) is well representative of the sunglasses market in Brazil and in many countries worldwide. Most samples belong to category 3 (42.2%), 32.8% to category 2, 19% to category 4 and 3% to category 1, which are the lightest pigmentation lenses. In the set there was no category 0 lens (clear lens), and for 3%, (7 samples), the transmittance in the visible range was less than 3%, so they were not categorized (not proper for driving whatsoever). The vast majority of lenses are made of polycarbonate, the rest, PMMA (acrylic), CR-39 and polyamide.

Figure 6a shows the typical transmittance spectrum of a pair of sunglasses which complies with ISO 12312-1:2013, and Figure 6b, shows the transmittance spectrum of a pair of sunglasses that does not comply with ISO 12312-1:2013, for red region, Q factor = 0.66.

The samples were then tested in the prototype by trained user, to assure reliable results for the prototype, performed the measurements.

Measurements in the prototype resulted in out of 232 samples, 175 were proper for driving and 57 were not proper for driving, matching the results from spectroscopy.

However, 02 samples have differed on category measurements. Both of them belonged to the category's definition limits.

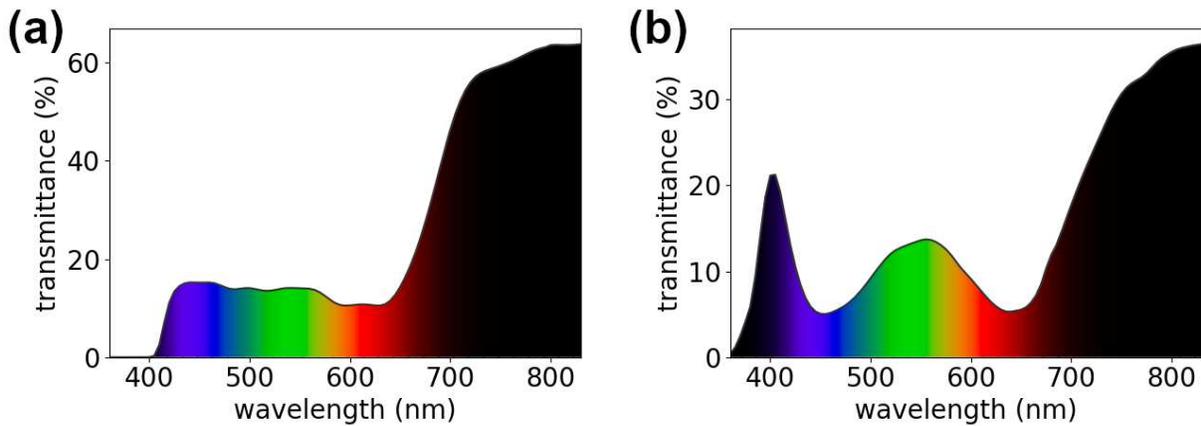


Figure 6: (a) Transmittance spectrum of sample code LE 0 381, which complies with ISO 12312-1:2013, (b) transmittance spectrum of sample code LE 23 4, that does not comply with ISO 12312-1:2013, for red region, Q factor = 0.66.

Analysis of agreement between our system and gold standard spectrophotometer was assessed by using the Bland-Altman method.

For luminous transmittance, the bias adopted as significant should be greater than 0.5%. The 95% interval of agreement was considered wide if the upper limit is greater than 5% or the lower limit is lesser than -5%. For the Q factors, the bias was adopted as significant if it is greater than

0.1. The 95% interval of agreement was considered wide if the upper limit is greater than 0.3% or the lower limit is lesser than -0.3%.

Additionally, sunglasses lenses have been tested on the prototype, by non-trained users, which were people on the street of São Carlos (SP) in Brazil, as well as in the campus of University of São Paulo in the same town, out of which 60 lenses were randomly selected and submitted to transmittance spectroscopy in VARIAN CARY 5000 spectrophotometer. This evaluation reflects the reliability of the prototype results by non-trained public.

Out of 60 tested samples, one sample belonging to category 1 ( $\tau_V = 43.3\%$ ) was reported as category 2 (41.0 %). All the other 59 lenses were in agreement with respect to the category results as well as proper/non-proper for driving results. Furthermore, out of the 60 selected lenses, four samples presented luminous transmittance less than 8 %, and were excluded from further traffic lights measurements. Therefore, the luminous transmittances were determined for all 60 lenses and the traffic light visual attenuation quotients were determined for the remaining 56 lenses. Bland-Altman plots are shown in Figure 7.

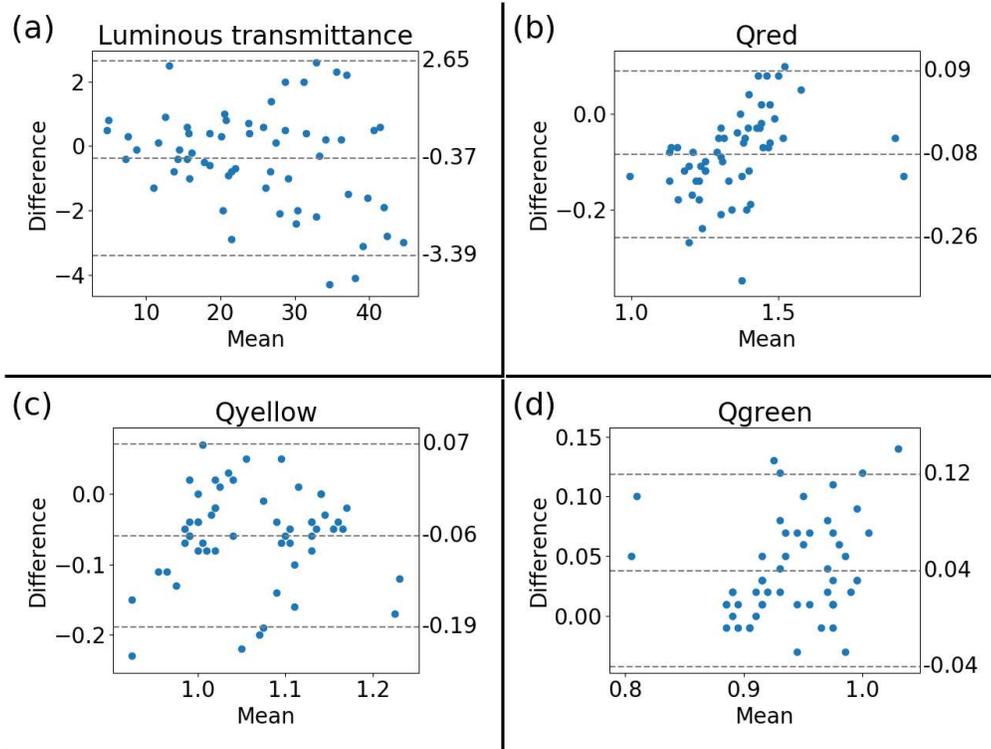


Figure 7: Bland-Altman plots for: (a) luminous transmittance; and traffic light Q factors – (b) red; (c) yellow; (d) green.

The bias and the 95 %-limit-of-agreement interval are shown in Table 2.

These values are within pre-defined tolerances.

Bland-Altman plots (Figure 7) indicated consistent variability across the graphs, without trends, for all plots. On average, prototype measures were lower than gold standard ones except for  $Q_{green}$ .

Table 2: The bias and the 95 %-limit-of-agreement interval for each measure.

	<b>bias</b>	<b>95 %-limit-of- agreement interval</b>
$\tau_V$	-0.37	[-3.39, 2.65]
$Q_{\text{red}}$	-0.08	[-0.26, 0.09]
$Q_{\text{yellow}}$	-0.06	[-0.19, 0.07]
$Q_{\text{green}}$	0.04	[-0.04, 0.12]

## Discussion

Bland-Altman plots presented non-significant biases and narrow 95 % limits of agreement within pre-defined tolerances, for all plots.

The plots also indicated consistent variability across the graphs, without trends, for all plots.

Therefore, prototype measurements presented good accuracy compared to spectrophotometer gold standard measurements within pre-defined tolerances.

Although one of the lenses diverged in category measurement, for that particular lens, transmission was in the range of category overlap, bearing the limit of the range (2.3 %).

## Conclusions

The purpose of this work was to evaluate a set of sunglasses, which represents the Brazilian market, and ultimately the sunglasses market worldwide, to check if the products that are used by consumers are proper for driving safely land vehicles.

Most of them, 75.43% complies with ISO 12312-1:2013. Only 3% of them are not safe at all for driving, since lenses are extremely dark.

Although developed prototype may not be used for checking sunglasses' compliance with ISO 12312-1:2013, regarding the proper use for driving land vehicles, it is a fine set up for guiding users on proper sunglasses for safe driving, before purchasing their sunglasses.

The results show that the prototype is a worthwhile system for providing to lay public access to information, as well as educating the public, since it is a quite important safety item to be considered when purchasing a pair of sunglasses.

The easiness on testing individual's own sunglasses and its self-explanation screens might have a potential market for retailers, as well as adding value to their product, since it provides knowledge to salespeople who also do not commonly have access to this type of information. It may also be used in the stores for checking their own sunglasses as well, for the consumer, working as an additional advertising of their product.

Immediate attention of population should be called about checking their sunglasses for driving conditions before purchasing them. Likewise, the good job that the market has done over the

years about the UV protection on sunglasses filters, advertisement should be done on driving conditions.

## **Methods**

### *A. Spectroscopy Measurements*

Electromagnetic spectroscopy – transmittance – was performed on sunglasses with the CARY 5000 (VARIAN) spectrophotometer, which is a double-beam system, in the visible range, from 380 nm - 780 nm, with 5 nm steps.

The standard also establishes that spectroscopic measurements should be performed so that the optical path from the light source to the sensor passes through the geometric center of the lens, in a region of 5 mm in diameter.

The transmittance spectrum of the sunglasses' lenses in the visible range, as well as the traffic lights colors range, led to determining the categories of the lenses as well as the Q factors, for red, yellow and green. Therefore, check if the sunglasses comply with ISO 12312-1:2013, item 5.3.2 *Requirements for road use and driving*.

### *B. Prototype Development*

This study has been submitted to Ethical Committee - CONEP (Conselho Nacional de Ética em Pesquisa – National Consul of Ethics in Research) and it has been approved under the registration number: 160.248 - CCAE: 02140312.5.0000.5504 at the Ethical Committee of CEP

UFSCar. The study is being conducted in accordance with the provisions of the Declaration of Helsinki for experimentation involving human ethics.

The developed system provides a baseline for the luminous transmittance (380 – 780 nm) as well as for each of the transmittances for the red, yellow and green wavelengths. The baseline is obtained previously the measurements and is denoted as CALIBRATION of the system.

The system consists of a high brightness white LED (OSRAM Golden Dragon Ultra White LED) and a four-channel photo sensor (AMS TAOS TCS3472). Four measurements are performed simultaneously in order to obtain the luminous transmittance in the visible range, for determining the category of lenses (0 – 4) and the colors the three traffic lights for sunglasses (red, yellow and green).

The photo sensors provide integrated responses with specific spectral weights and in this particular model, different spectral weights for each of the four channels were used. The baseline consists in illuminating the photo sensor directly by the light source, with a free optical path, and registering this value as the 100% transmittance. Subsequently, sunglasses lenses are positioned in the optical path, and the response of the photo sensor is measured.

For linear response photo sensors, the ratio of the measured value of the sample and baseline value is equal to the light transmittance, weighted with a spectral function given by the term-to-term product of the spectral emission of the light source and the spectral response of the photo sensor. If a photo sensor has no linear response, a simple mathematical correction should be made.

The TCS3472 photo sensor provides four different responses; therefore, it is possible to measure the transmittance of the sample with four different known weighting functions (Figure 3). Furthermore, the four known weighting functions are linearly combined to estimate the desired weighting functions for each type of measurement.

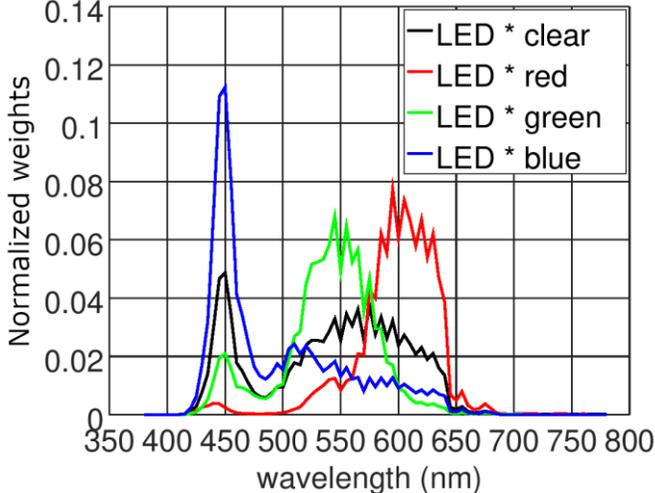


Figure 3: Four spectral weighting functions generated by TCS3472 and illuminated by Golden Dragon LED.

The weighting functions, regarding the established values of the standard, obtained by linear combinations, for each photo sensor channel, visible range, red, yellow and green, are shown in Figure 4.

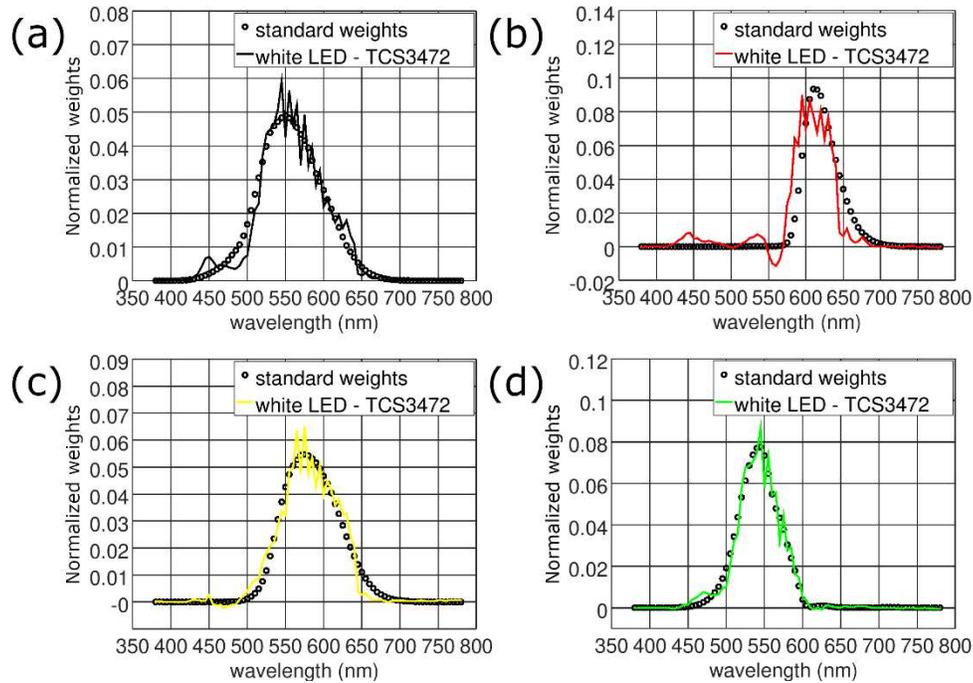


Figure 4: Prototype’s weighting function (continuous line) and the weighting function established by the standard (empty circles) for the following transmittances (a) luminous; (b) red color; (c) yellow color; (d) green color.

Using the weighting values shown in Figure 4, for obtaining the baselines as well as the transmittances for category and traffic lights measurements, we have additionally developed a program using C++ language for providing the user reports regarding if the tested sunglasses are proper for driving according to ISO 12312-1:2013.

Touchscreen display, DWIN 4.3" DMT48270T043\_18WT, was used as user interface.

Figure 5 shows the prototype and three of its screens, as well as a QR code of the video of the set up.

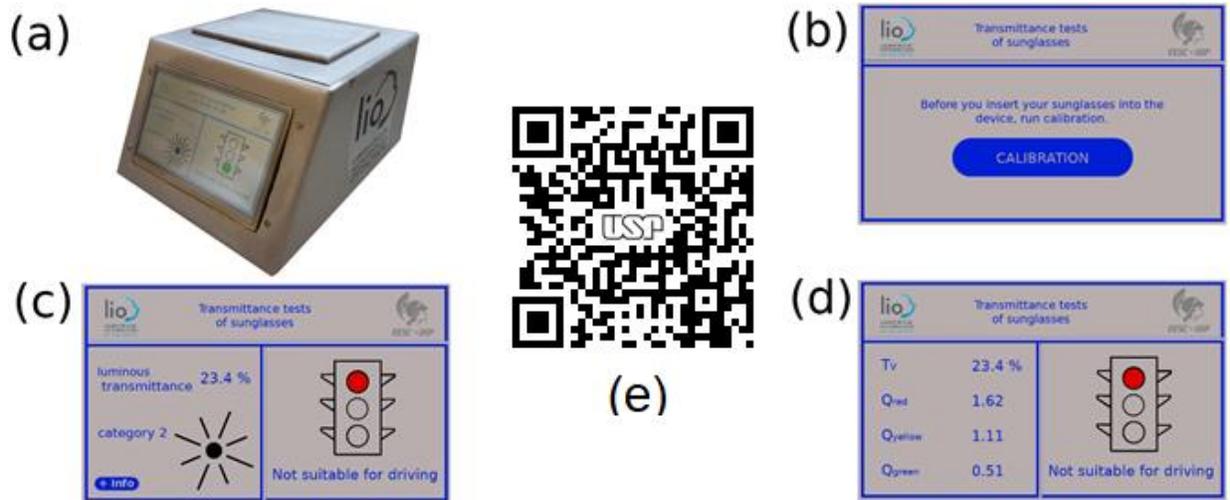


Figure 5: (a) Prototype with touch screen display; (b) default initial screen; (c) primary result screen of tested sunglasses; (d) secondary result screen with details; (e) QR code of prototype's video.

Prototype's (Figure 5a) primary screen (Figure 5b) invites people to self-test their sunglasses and to select the CALIBRATION button (baseline). As the calibration button is selected, the device inputs the baseline and guides user for next step of sunglasses positioning. After positioning the sunglasses, user selects the TEST button and the device yields the result screen (Figure 5c), notifying whether tested sunglasses are proper for driving, its luminous transmittance, its category and its recommended use.

To access user's sunglasses traffic light visual attenuation quotients (Figure 5d), user should select MORE INFORMATION button.

## **List of abbreviations**

$\tau_v$ : Luminous transmittance;

LED: Light-emitting diode;

Qred: Red Q factor;

Qyellow: Yellow Q factor;

Qgreen: Green Q factor;

Qblue: Blue Q factor;

UV: Ultraviolet.

## **Declarations**

### **Ethics approval and consent to participate**

This work has been submitted to Ethical Committee - CONEP (Conselho Nacional de Ética em Pesquisa – National Consul of Ethics in Research) and it has been approved under the registration number: 160.248 - CCAE: 02140312.5.0000.5504 at the Ethical Committee of CEP UFSCar. The study is being conducted in accordance with the provisions of the Declaration of Helsinki for experimentation involving human ethics.

### **Consent for publication**

Not applicable.

### **Availability of data and material**

Not applicable.

### **Competing interests**

The authors declare that they do not have competing interests.

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### **Authors' contributions**

All the authors actively participated in the design of this study, calculations interpretation of results and in the preparation of the manuscript. All authors read and approved the final manuscript.

### **Acknowledgements**

Not applicable.

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# Figures

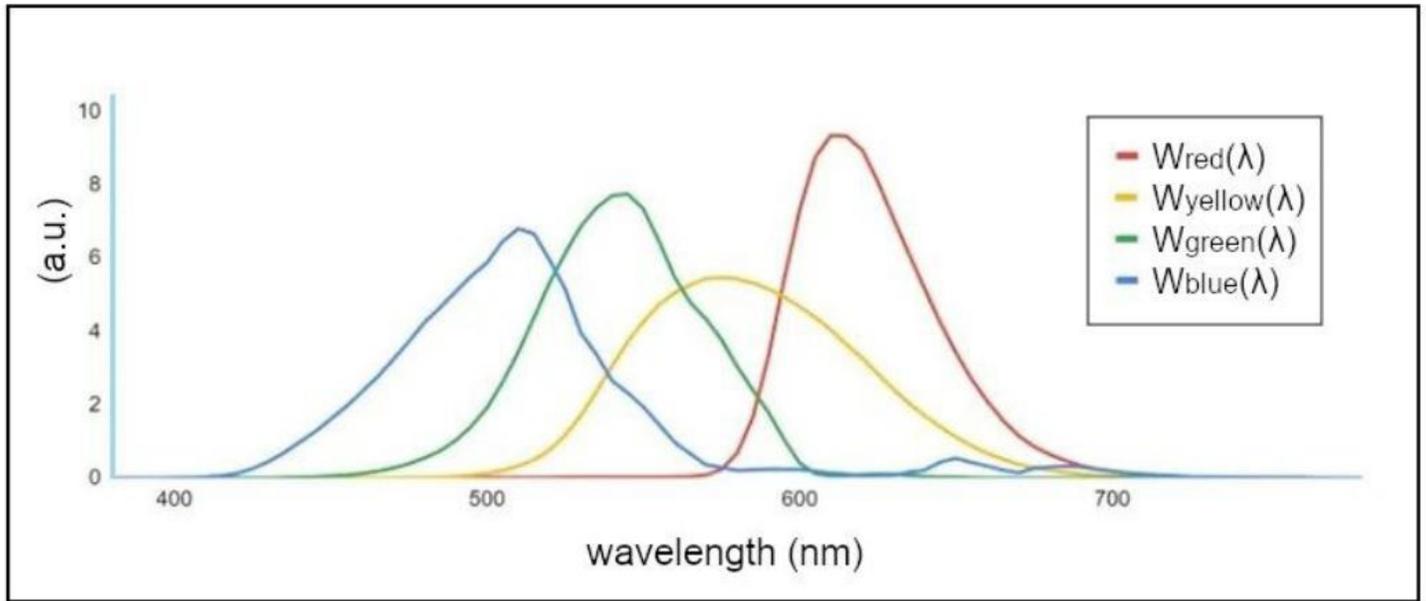


Figure 1

Spectral distribution of emissions from incandescent traffic light lamps,  $W_{signal}(\lambda)$

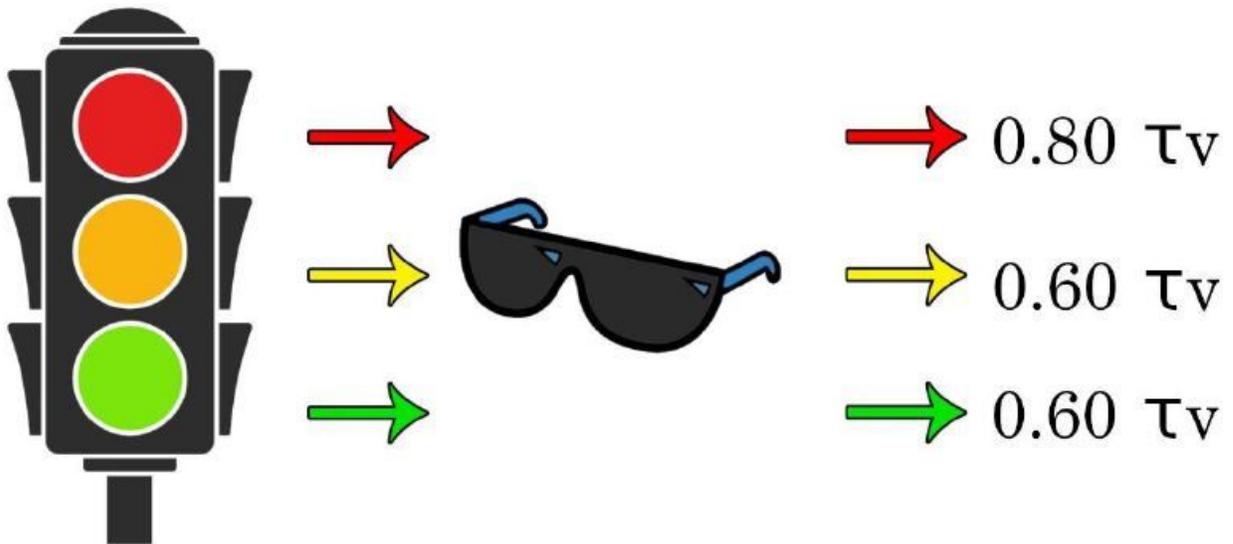


Figure 2

Schematics of Q factor for traffic lights,  $\tau_v$  is the transmittance in the visible range (380 – 780 nm).

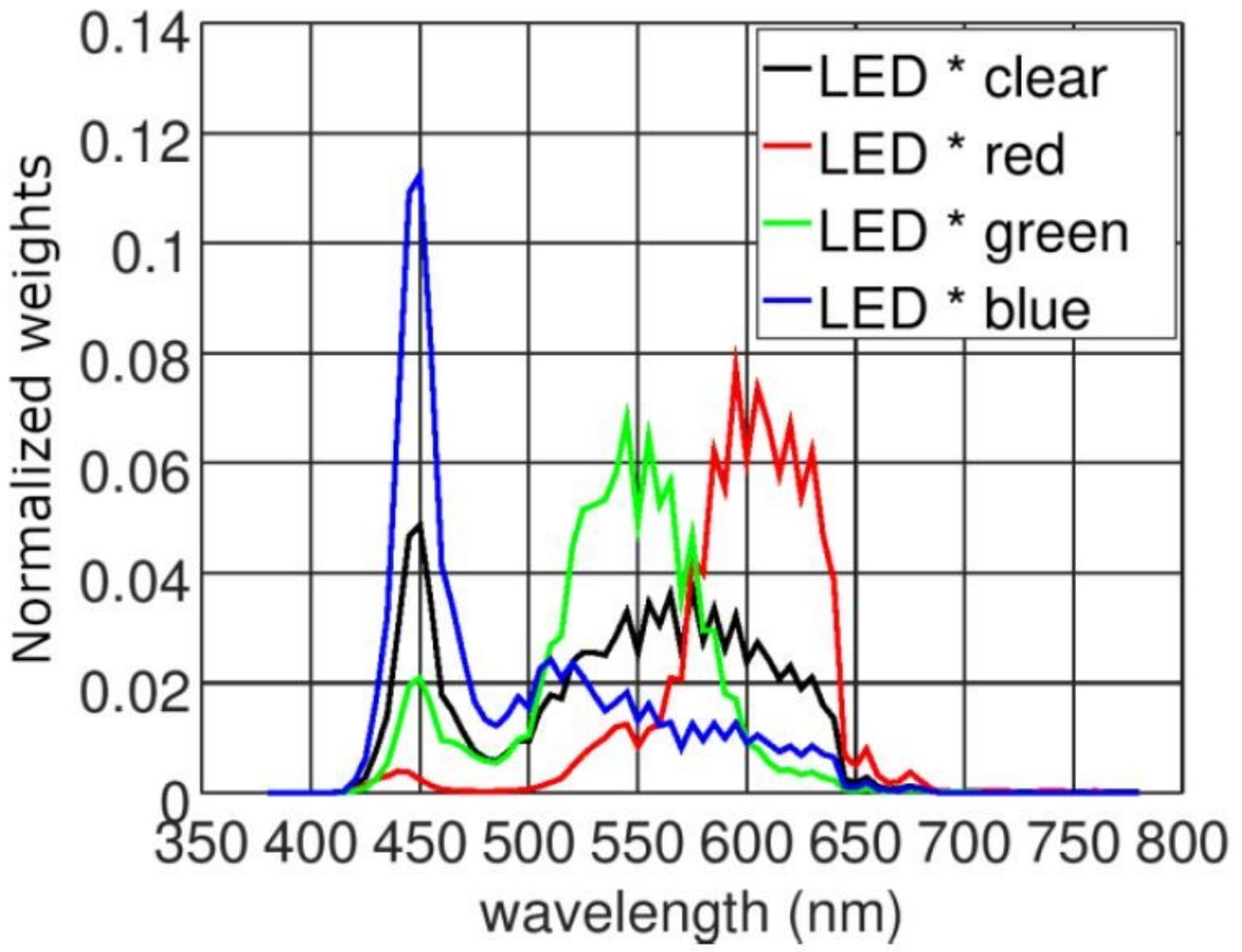
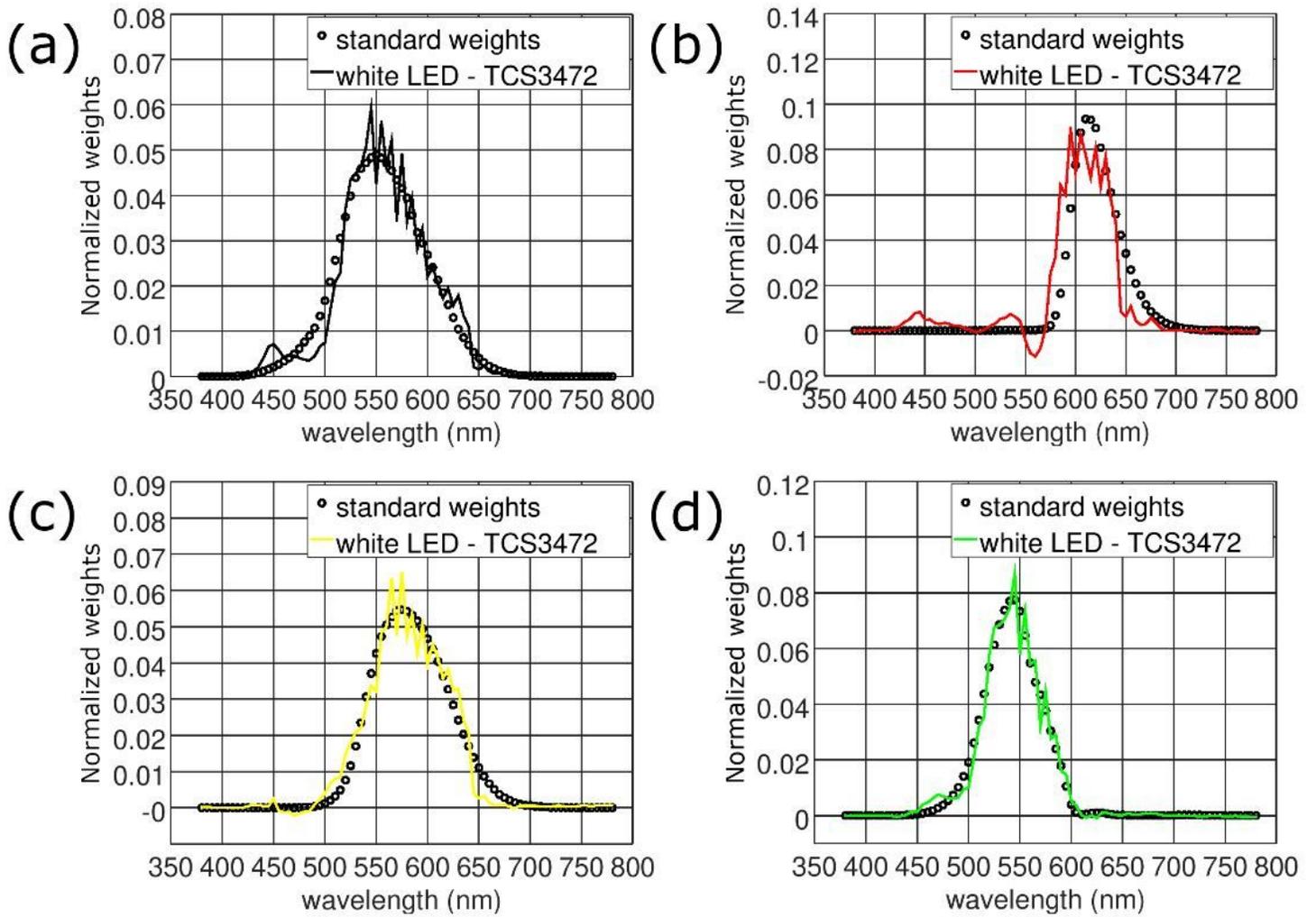


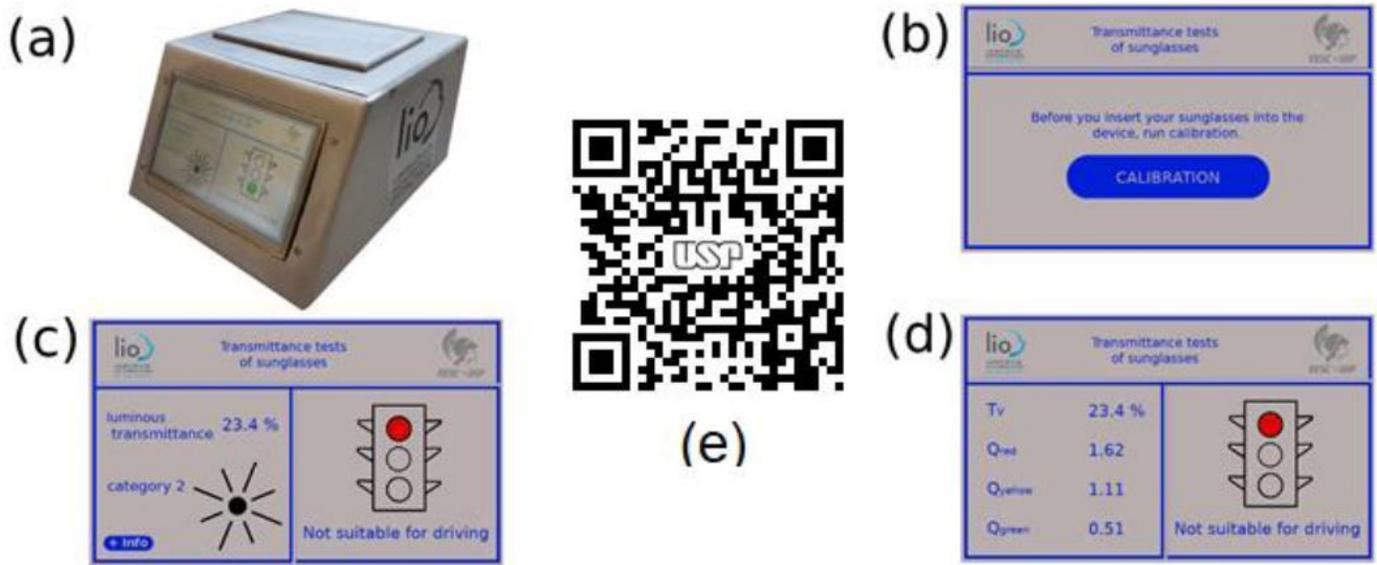
Figure 3

Four spectral weighting functions generated by TCS3472 and illuminated by Golden Dragon LED.



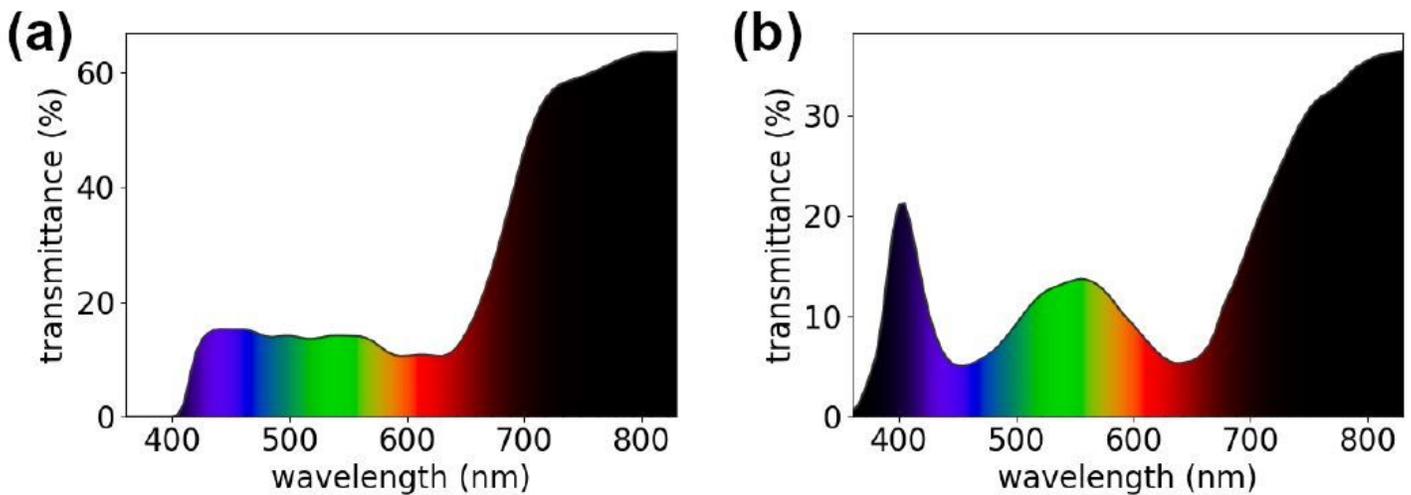
**Figure 4**

Prototype's weighting function (continuous line) and the weighting function established by the standard (empty circles) for the following transmittances (a) luminous; (b) red color; (c) yellow color; (d) green color.



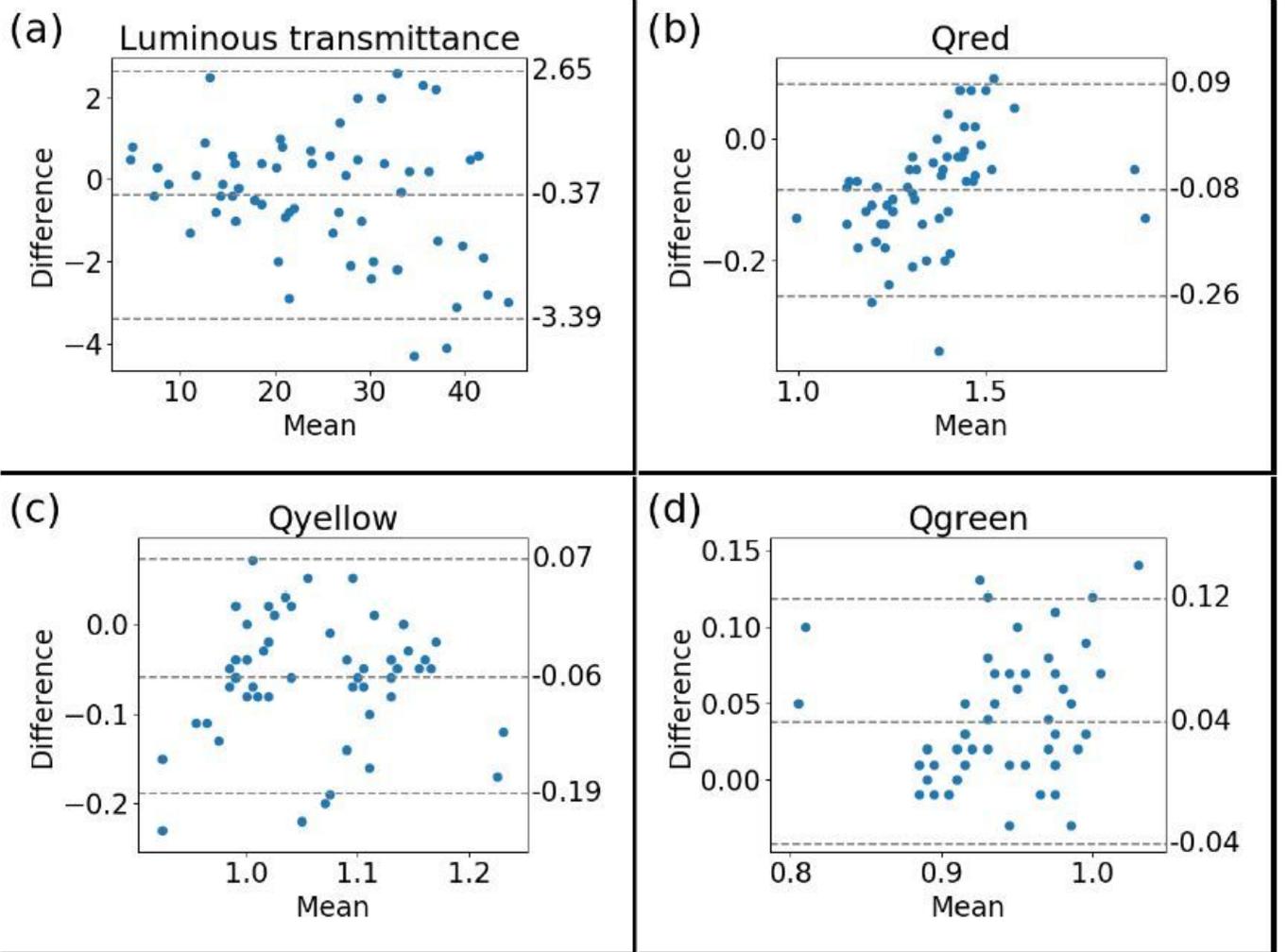
**Figure 5**

(a) Prototype with touch screen display; (b) default initial screen; (c) primary result screen of tested sunglasses; (d) secondary result screen with details; (e) QR code of prototype's video.



**Figure 6**

(a) Transmittance spectrum of sample code LE 0 381, which complies with ISO 12312-1:2013, (b) transmittance spectrum of sample code LE 23 4, that does not comply with ISO 12312-1:2013, for red region, Q factor = 0.66.



**Figure 7**

Bland-Altman plots for: (a) luminous transmittance; and traffic light Q factors – (b) red; (c) yellow; (d) green.