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Device for Measuring Driving Suitability and Blue Light Protection in Sunglasses

Dispositivo para Medição em Óculos de Sol de Adequação para Condução e de Proteção contra a Luz Azul

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Resumo

A maioria das pessoas, quando escolhe óculos de sol, não leva em consideração importantes características relacionadas à segurança. Entre outros requisitos, óculos de sol não devem prejudicar a visão dos usuários durante a condução de veículos. Dessa forma, testes de transmitância (da luz visível e das luzes semafóricas) são requisitos da norma ISO12312-1. Foi desenvolvido um protótipo para que o próprio usuário possa testar seus óculos de sol quanto à adequação para direção e quanto a proteção contra a luz azul danosa. O protótipo consiste de uma fonte luminosa (LED de alto brilho) e um fotossensor de quatro canais, produzindo quatro medidas de transmitância com funções de ponderação diferentes. Combinando os quatro valores medidos, foram obtidos valores de transmitância com ponderações que se aproximam das definidas na norma para transmitância luminosa, das luzes semafóricas e da luz azul danosa. Os fatores Q exigidos nas normas avaliam a distorção de cor para a visão em óculos de sol e são medidas fornecidas pelo protótipo. A transmitância luminosa e os fatores Q para 60 lentes de óculos de sol foram medidos em um padrão dourado e foram usados para avaliar nosso protótipo. A análise de Bland-Altman apresentou viés não-significativo e limites de concordância de 95% estreitos, dentro das tolerâncias pré-definidas, para todas as medições. Os resultados mostram que o protótipo é uma alternativa válida para proporcionar ao público acesso às informações de adequação para condução e de proteção azul de seus próprios óculos de sol, bem como para a indústria e o mercado comercial para verificação rápida de seus produtos. Além disso, nosso protótipo tem um papel importante na educação da população sobre as características que devem ser consideradas antes da compra de óculos de sol.

Palavras-chave: dispositivos de proteção dos olhos; luz; luz azul; condução de veículo; ISO12312-1.

Abstract

Sunglasses safety plays an important role for the wearer and most when choosing their sunglasses do not consider some important features. Among other relevant tests, sunglasses should have properties that do not negatively interfere with the user's vision when driving land vehicles. Testing sunglasses for transmittance of total visible light and traffic lights are requirements of the sunglasses standard ISO12312-1. We have developed a prototype for users to self-check their sunglasses for traffic lights regarding the safety for driving. The prototype consists of an illumination source and a detection photosensor that yield four transmittance values weighted with different functions. Combining the values of the four outputs of the sensor, it is possible to provide luminous bands quite similar to the required from the standards regarding the visible spectrum and traffic light transmittances. The Q factors required on the standards evaluate the color distortion for the vision on sunglasses and are measurements provided by the prototype. The luminous transmittance and Q factors for 60 sunglasses lenses were measured in a gold standard and were used for evaluating our prototype. Bland-Altman analysis presented non-significant biases and narrow 95 % limits of agreement within pre-defined tolerances, for all measurements. The results show that the prototype is a worthwhile alternative for providing the public with access to their own sunglasses' information on driving suitability, as well as for industry and retailers for quick verification of their products. This work is potentially significant in educating the public about some features to consider before purchasing sunglasses and in providing the public with a means to self-test their sunglasses regarding their quality and driving safety. It is also a wake-up call for the sunglasses industry and retailers to be aware of the quality of sunglasses on the market with respect to the driving safety of users.

Keywords: *eye protective devices; light; blue light; automobile driving; ISO12312-1.*

1. Introduction

Efforts of our team have been progressively done in order to have an eye safe standard for sunglasses (1–3), including ocular safety for tropical countries, as we did in 2013 (4), when we were part of committee for revising the Brazilian standard (NBR15111:2013). This work is an extension of our researches that focuses on ocular health. Three outlines are the basis for this research: authors' previous work, which has provided the public to self-check their own sunglasses regarding the ultraviolet protection compatible to their 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 plays its role. So, this work is one of the many systems that our lab is developing (5–9), to bridge this gap and it also keeps public conscious.

The public is usually concerned with the protection against UV rays in sunglasses and with style. Mainly because the public is not aware that there are other important factors to be observed when buying sunglasses. One of these important factors is whether they are appropriate for driving. Sunglasses lenses excessively dark could obstruct an object, signal recognitions, and slow down user reaction time, especially in shadow spots. Moreover, lenses could excessively enhance or attenuate some colors leading to distortion on color perception. These phenomena may lead to risky situations (10,11).

Lenses of fixed tint are graded according to the optical density of the tint and must be labeled and show the filter category number. Sunglasses standards describe five different categories for sunglasses for general use depending on the level of sun glare reduction of their lenses. The categories are rated between 0 (clear lenses) and 4 (very dark lenses). The standards for sunglasses, more specifically, ISO12312-1:2013 and mirrors, have requirements that refers to compliance for driving. Lenses that have transmission in the visible spectrum (380 nm - 780nm) less than 75 % shall not be used for road use and driving in twilight or at night. Those with less than 8 % (category 4) are not appropriate to drive at any time. For wavelengths between 475 nm and 650 nm, the spectral transmittance of filters suitable for road use and driving shall be not less than 0.2 times visible transmittance. Testing photochromic sunglasses lens suitability for road use and driving requires additional steps described in standards (12).

Luminous transmittance, i.e., visible transmittance, τ_V, is defined according to Equation (1).

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

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 (12).

Sunglasses categories are defined in Table 1, according to the standard ISO12312-1:2013.

For each category, the standards indicate recommended use. Darker lenses (less luminous transmittance) are recommended for environments with higher solar incidence. As lenses with luminous transmittance inferior to 3 % are not considered appropriate for general use, then they are not covered by ISO12312-1.

Table 1 - Sunglasses categories for general use, adapted from ISO12312-1:2013

Filter category	**Range of luminous transmittance** τ_V 380 nm to 780 nm
0	τ_V > 80%
1	43% < τ_V ≤ 80%
2	18% < τ_V ≤ 43%
3	8% < τ_V ≤ 18%
4	3% < τ_V ≤ 8%

Source: The Author (2022).

Traffic light transmittances, τ_{signal}, are defined for red, yellow, green and blue lights as shown in Equation (2).

$$\tau_{signal} = \frac{\int_{380}^{780} \tau_F(\lambda) V(\lambda) E_{signal}(\lambda) d\lambda}{\int_{380}^{780} V(\lambda) E_{signal}(\lambda) d\lambda}$$
$$\tau_{signal} = \frac{\int_{380}^{780} \tau_F(\lambda) W_{signal}(\lambda) d\lambda}{\int_{380}^{780} W_{signal}(\lambda) d\lambda} \quad (2)$$

in which $E_{signal}(\lambda)$ 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 (12).

The relative visual attenuation quotient for traffic light detection, Q_{signal}, is defined by Equation (3).

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

As stated, traffic light transmittances and, by consequence, relative visual attenuation quotients are defined for incandescent and LED lights; however, standard requirements for suitability for road use and driving take into account only relative visual attenuation quotients (Q factors) related to incandescent lights. To be proper for road use and driving, sunglass filter luminous transmittance shall be not less than 8 % (categories 0, 1, 2 and 3) and Q factors shall not be less than 0.80 for red signal light and not less than 0.60 for yellow, green and blue signal lights.

It is of interest that one has a way of assessing optical characteristics of sunglasses to determine their categories (recommended use) and whether or not they are suitable for road use and driving. Furthermore, after long exposure to the sun, transmittance characteristics of sunglasses lenses could change considerably (1,6). Therefore, transmittance information that comes along sunglasses may become outdated after long period of use and new measurements should be made to determine their optical characteristics. Since transmittance tests are complex and require the use of a piece of scientific equipment, the lay public has no means of testing their own sunglasses.

The aim of this study was to develop a prototype for sunglasses self-testing, in order to provide information for users about their sunglasses, based on the requirements of ISO12312-1. Our prototype measures transmittances in sunglasses and it calculates and reports to the user their luminous transmittance and traffic light transmittances for red, yellow and green signals, as well as it reports whether measured sunglasses are suitable for road use and driving. Additionally, it also tests the blue light transmittance, so that users may test their blue light filters.

2. Methods

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 - CAAE: 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.

Photosensors provide integrated responses with specific spectral weights, so for measuring the transmittance of light in sunglasses, the baseline should be obtained previously to the measurements. Baseline consists in illuminating the photosensor directly by the light source, with no object in the optical path. Furthermore, sunglasses lenses are positioned in the optical path, so the response of the photosensor is measured. For linear response photosensors, 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 photosensor. If a photosensor has no linear response, a simple mathematical correction should be made.

In our developed system, a white LED of high brightness (OSRAM Golden Dragon Ultra White LED) and a four-channel photosensor (AMS TAOS TCS3472) was used, to obtain four measurements simultaneously: the luminous transmittance in the visible range (category of lenses) and the colors the three traffic lights for sunglasses (red, yellow and green). Since the chosen photosensor produces four different responses, it is possible to measure the transmittance of the sample with four different known weighting functions (Fig. 1). Then the four known functions may be linearly combined to estimate the desired weighting functions list.

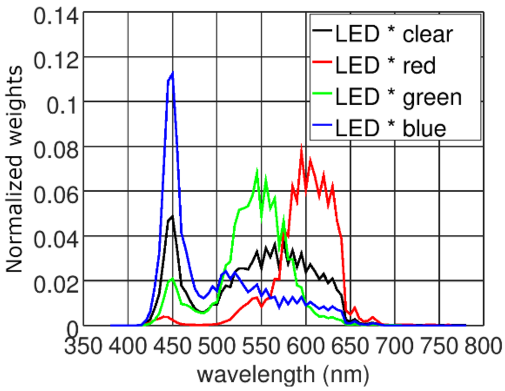

Figure 1 - Four spectral weighting functions generated by TCS3472 illuminated by Golden Dragon LED.

In addition to measuring visible light transmittance and traffic light values in accordance with ISO 12312-1, our device also indicates if requirements of the standard agree and reports to whether sunglasses are safe for driving.

We have compared the prototype results and the agreement between our system and gold standard VARIAN CARY 5000 spectrophotometer by using the Bland-Altman analysis. For luminous transmittance 0.5 % and +/-5 % were adopted as values above which bias absolute value and upper/lower 95 % significant limits of agreement, respectively. For traffic light visual attenuation quotient values, we have adopted 0.1 and +/-0.3, respectively.

The emphasis of the measurements is to evaluate if tested sunglasses are proper for driving land vehicles. Additionally, due to the requirements of the standard, for sunglasses that luminous transmittance is less than 8 % should already be labeled as not proper for driving, regardless of their traffic light attenuation quotients, so in these cases the quotients are not presented to the user and are excluded in our evaluations.

The approximate weighting functions of the standard obtained by linear combinations are shown in Fig. 2.

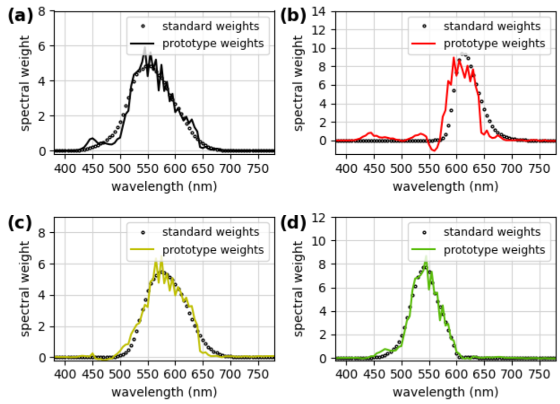

Figure 2 - Traffic light testing: Prototype's weighting function (continuous line) and the weighting function defined in the standard (empty circles) for the following transmittances (a) luminous; (b) red color; (c) yellow color; (d) green

As for the blue light filter testing, the prototype's weighting function is presented in Fig. 3.

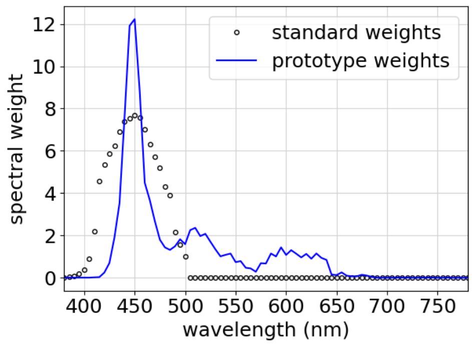

Figure 3 - Prototype's weighting function (continuous line) and the weighting function one defined in the standard (empty circles) for solar blue transmittance

3. Results and discussion

The final version of the prototype and three of its screens are shown in Fig. 4. Touchscreen display, DWIN 4.3" DMT48270T043_18WT, was used as user interface.

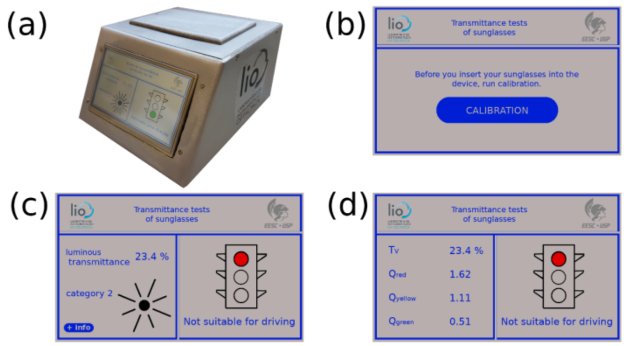

Figure 4 - Final version of the prototype for traffic light testing: (a) prototype itself with touch screen display; (b) default initial screen; (c) primary result screen of tested sunglasses (d) secondary result screen with details.

Prototype's (Fig. 4a) primary screen (Fig. 4b) invites people to self-test their sunglasses. As the calibration button is selected, the device inputs the baseline and guides user for sunglass positioning. After sunglasses are inserted, user selects the TEST button and the device yields the result screen (Fig. 4c), 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 (Fig. 3d), user should select MORE INFORMATION button.

Sunglass lenses have been tested on the prototype, by ourselves (trained user) and by 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 a VARIAN CARY 5000 spectrophotometer.

Out of 60 samples, one sample belonging to category 1 (τ_V = 43.3 %) were categorized as category 2 (41.0 %). All lenses were correctly categorized as proper for driving. Furthermore, from the 60 selected lenses, 4 samples presented luminous transmittance less than 8 %. Therefore, the luminous transmittance was determined for all 60 lenses and the traffic light visual attenuation quotients for 56 lenses. Bland-Altman plots are shown in Fig. 5.

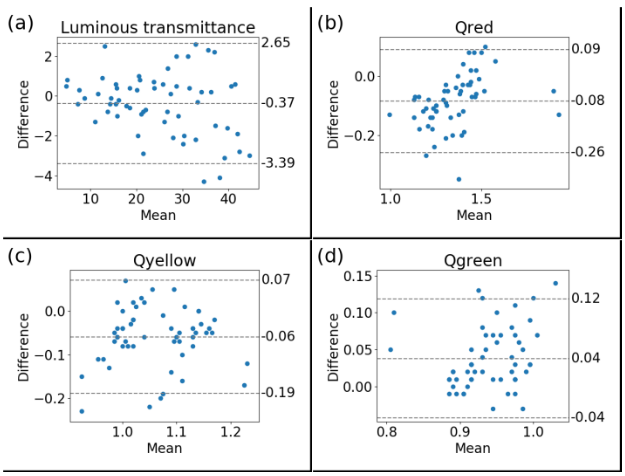

Figure 5 - Traffic lights testing. Bland-Altman plots for: (a) luminous transmittance; and traffic light Q factors – (b) red; (c) yellow; (d) green.

The bias and the 95 %-limit-of-agreement interval are respectively -0.37 and [-3.39, 2.65] (for τ_V); -0.08 and [-0.26, 0.09] (for Q_{red}); -0.06 and [-0.19, 0.07] (for Q_{yellow}); 0.04 and [-0.04, 0.12] (for Q_{green}). These values are within pre-defined tolerances. Bland-Altman plots (Fig. 5) 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}.

The device described here was developed to provide to general public a mean for accessing suitability-for-driving information about their own sunglasses. However, it could also be used in trade to add value in sales of sunglasses and in industry for quick conference of sunglasses produced.

For the blue light prototype, Fig. 6 presents its screen for the user.

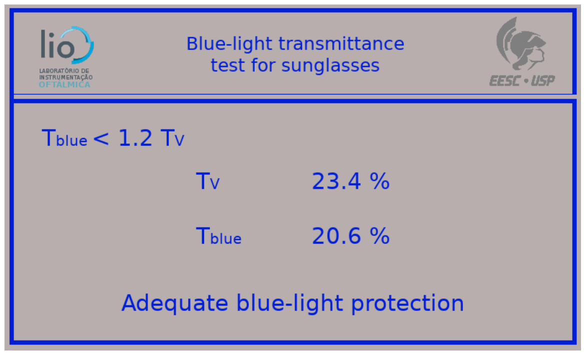

Figure 6 - Final version of the prototype for blue light testing: (a) prototype itself with touch screen display; (b) default initial screen; (c) primary result screen of tested sunglasses (d) secondary result screen with details.

The results are presented as ADEQUATE protection, based on former British standard (13) BS2724:1987, where there is pre-established limit of that the transmittance of blue light, τ_B, should not exceed 1.2 times the luminous transmittance, as described by Equation (4).

$$\tau_B < 1.2\tau_v \qquad (4)$$

where τ_V is the average transmittance in the visible range. The luminous light transmittance, τ_V, is calculated as an average transmittance of each wavelength, in the 380 nm to 780 nm range, weighted by the spectral distribution of radiation from the CIE D6515 standard illuminant and by the spectral luminous efficiency function for photopic vision. The spectroscopy measurements are performed at 5 nm steps for ISO 12312-1:2018, and 10 nm steps for BS2724:1987.

Figure 7 presents the blue light testing using Bland-Altman analysis.

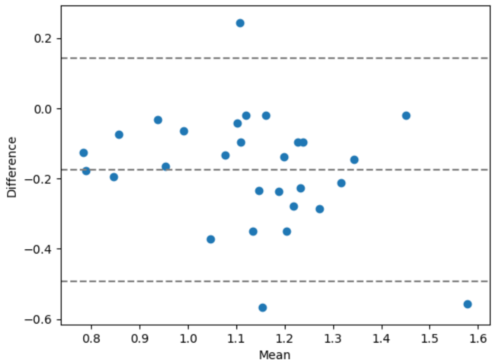

Figure 7 - Blue filter testing. Bland-Altman plots for blue light transmittance.

5. Conclusions

Bland-Altman plots presented non-significant biases and narrow 95 % limits of agreement within pre-defined tolerances, for all plots. They also indicated consistent variability across the graphs, without trends, for all plots. Therefore, prototype measurements are appropriate with good accuracy compared to spectrophotometer gold standard measurements within pre-defined tolerances. However, one of the lens diverged in category measurement, since for that particular lens, transmission was in the range of category overlap, bearing the limit of the range (2.8 %).

The results show that the prototype is a worthwhile alternative in providing to lay public access to the information of suitability-for-driving about their own sunglasses, as well as for industry and trade market for quick checking of their products. Regarding the blue light filter, although there is no mandatory limit on the standards for the blue light transmittance, there is a safe recommendation and this prototype is able to provide this information to the public.

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