



## CHARACTERIZING PROTECTION ABILITY OF BLUE BLOCKING LENSES USING K-MEANS CLUSTERING

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### Abstract

*Blue light protection ophthalmic lenses have been regularly marketed as the ultimate protection against short-wavelength visible radiation mainly in the range of 400 nm and 450 nm. However, the actual protective effects of such lenses are currently unknown; most claims are provided by the manufacturers with limited scientific validation. This will not only make selling such lenses challenging but may provide the lens wearers little or no protection against the blue light hazard. It is recently discovered that the protection needs to take into accounts the light source that the wearers wish to protect from – heavy electronic gadget users for instance, are exposed to different spectrum of radiation compared to non-users. This problem is aggravated when the hazard needs to further be classified into the visual and non-visual effects. Non-visual impact includes the disruption in the circadian cycle which is governed by the physiological cycles of our body within 24 hours such as the melatonin hormone secretion. Such knowledge will help to educate optometrist to explain to their prospective customers and will also assist the spectacle wearers to*

**Keywords:** Blue-blocking lens; retinal index; circadian index; k-means clustering

### I. Introduction

Our previous works have shown the importance of incorporating mathematical models to provide objective quantification in clinical setting [XVIII-

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XII]. This includes aiding the optometrists to make clinical decision based on validated scientific data, not by mere hunches or instincts. We have demonstrated that with the right tool, the application of physical knowledge can be leveraged to benefit non-physical areas including in healthcare.

Recent research conducted by various research institutes and universities attempted to formulate standardised indices that can be used to measure the protective effects of blue-blocking ophthalmic lenses from the blue light [IX-VXVII]. The parameters not only quantify the physical harm [XVII] of the blue light to the eye but also the magnitude that it may affect the circadian rhythm [X]. These indices can provide useful reference to mitigate the excessive blue light exposure which can induce damage to the retina. While there are variations in the parameters proposed, the constants used in the formulas are based on widely accepted international standards for blue light quantification [I].

The blue light exposure is not all bad, a substantial amount of radiation is required to assist normal visual function for example for colour discrimination [VIII] and vision during the night [IV]. Conversely, insufficient dosage of blue light during the day is known to be associated with sleep disorder [XX]. An optimal dosage of blue light is needed to strike a balance between benefits and risks of the exposure. This can be achieved by having a set of standardised parameters that can characterise the blue light and, inadvertently help us to gauge its exposure limits. With this standardisation, the optometrists will be able to advise their customers based on their needs and daily activities [IX]. For instance, while there is a need to protect the retina from physical injury, the impact to the circadian rhythm can now be regulated by allowing or blocking the exposure within that particular spectrum.

While lens manufacturers often claim the superiority of their blue-blocking treatments, there are no standardised parameters used to quantify the performance of the coating. The claims include their lenses are able to provide blue light protection to prevent eye strain and fatigue, reduce glare for more comfortable and relaxed vision and enhances colour perception [V].

Daily activities vary between spectacle wearers – some may engage more with electronic gadgets compared to others. Blue light hence, needs to be further categorized based on the standard illuminant [XIX] and light emitted by LCD screen [IX]. Instead of using the physical characteristics of the lens to describe its blue-blocking ability, many papers suggest the use of transmittance data for this purpose [IX-XVII], which is defined as the ratio between the amount of light transmitted through and incident on the lens across the visible spectrum.

This paper provides the summary of indices characterizing blue-blocking lenses from various manufacturers. We have also introduced a new parameter aggregating the indices to provide quick comparison of the lenses protection ability.

## **II. Methodology**

### **A. Transmittance Measurement**

Transmittance data of 12 blue-blocking lenses were obtained using T80 UV-VIS Spectrophotometer (PG Instrument Ltd., UK) with 5 nm scanning interval. The

instrument has the accuracy of  $\pm 0.3$  nm and reproducibility of  $\leq 0.2$  nm. The spectrometer uses dual beam optics of tungsten and deuterium sources to ensure stability of the acquisition. The data were exported to MS Excel format from the device's UVWin software.

### **B. Retinal Index**

Characterization of the lenses adopts the formulas used in the previous work [IX]. The first parameter is the Retinal Index (RI) which defines the damage of the short-wavelength to retina based on the blue light hazard specification published by The International Commission on Non-Ionizing Radiation Protection (ICNIRP):

$$RI = \frac{\sum_{300\text{ nm}}^{780\text{ nm}} T(\lambda) \times I(\lambda) \times B(\lambda) \times \Delta\lambda}{\sum_{300\text{ nm}}^{780\text{ nm}} I(\lambda) \times B(\lambda) \times \Delta\lambda} \quad (1)$$

where  $T(\lambda)$  is the transmittance of the lens in the visible spectrum, quantifying the ratio of light intensity transmitted through the lens to the light intensity incident over the specified wavelengths (380 nm – 780 nm),  $I(\lambda)$  is the source illuminant, and  $B(\lambda)$  is the blue light hazard function. Theoretically,  $RI = 1$  indicates the lens does not provide protection to the retina from the blue light, while  $RI = 0$  denotes the lens totally protects the retina from the exposure.

### **C. Circadian Index**

Circadian Index (CI) gauges the protection provided by the lens against the disruptive effects of blue light on the circadian cycle:

$$CI = \frac{\sum_{300\text{ nm}}^{780\text{ nm}} T(\lambda) \times I(\lambda) \times M(\lambda) \times \Delta\lambda}{\sum_{300\text{ nm}}^{780\text{ nm}} I(\lambda) \times M(\lambda) \times \Delta\lambda} \quad (2)$$

where  $M(\lambda)$  denotes circadian efficiency function [I] which provides spectral weightage of the exposure in terms of its disturbance on the circadian cycle.  $CI = 1$  indicates the lens does not give protection to the non-visual photoreceptor from the blue light, while  $CI = 0$  denotes the lens provides whole protection to the non-visual photoreceptor from the exposure.

### **D. K-Means Clustering**

The RI and CI indices are further categorized into the types of  $I(\lambda)$  used; standard illuminant D65 and spectral emission of LCD screen. In this paper, we propose to aggregate the four indices namely CI(D65), CI(LCD), RI(D65) and RI(LCD). The aggregation is important to summarize the level of protection of individual lens and would provide quick reference on the level of protection the blue lens can offer.

The protection class can be assigned based on the following k-means clustering algorithm [XVI]:

1. Random centroid cluster initialization:  
*Class 1, Class 2, Class 3.*
2. Repeat until convergence:

$$\begin{aligned}
 &\{ \\
 &\text{For every } i, \text{ set} && c^{(i)} := \arg \min_j \|x^{(i)} - \mu_j\|^2. \\
 &\text{For each } j, \text{ set} && \mu_j := \frac{\sum_{i=1}^m 1\{c^{(i)} = j\}x^{(i)}}{\sum_{i=1}^m 1\{c^{(i)} = j\}}. \\
 &\}
 \end{aligned}$$

$x^{(i)}$  represent the lenses and  $\mu_j$  denote the current Class centroids. Two main steps are involved in this process for each iteration: (1) Each lens is assigned to the closest class and (2) Each class is moved to the mean of the lenses assigned to it. The algorithm was executed in MATLAB 2019b (MathWorks Inc., Natick, Massachusetts).

### III. Results and Discussion

To increase the number of samples and in turn provides better convergence to the classes, we augmented the samples in the k-means clustering step with the publicly available data [IX]. Note that yellow-tinted glasses were removed in the assignment of the class due to their extreme values. Table I summarizes the results with Class 1 signifies lenses with highest protection against the short-wavelength source.

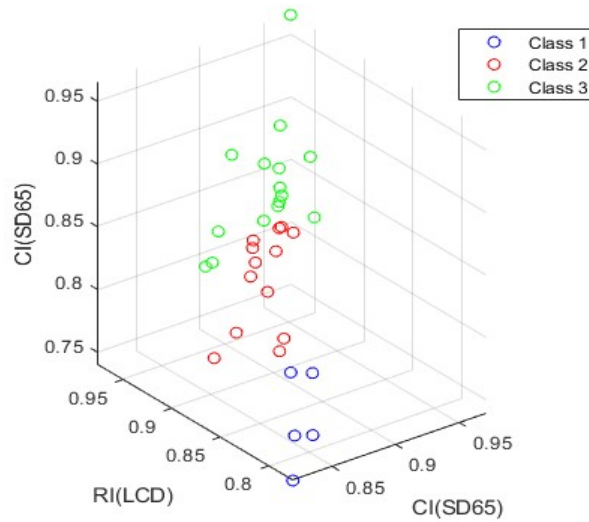
**Table 1: CHARACTERIZATION OF BLUE-BLOCKING LENSES.**

Name	CI <sup>a</sup> (LCD)	CI <sup>a</sup> (SD65)	RI <sup>a</sup> (LCD)	RI <sup>a</sup> (SD65)	Class <sup>a</sup>
Lens1	0.84	0.84	0.78	0.77	1
Lens2	0.93	0.92	0.92	0.86	3
Lens3	0.92	0.92	0.88	0.86	3
Lens4	0.93	0.93	0.90	0.90	3
Lens6	0.85	0.85	0.85	0.84	2
Lens7	0.87	0.86	0.81	0.79	1
Lens8	0.89	0.87	0.85	0.79	2
Lens9	0.83	0.82	0.77	0.74	1
Lens10	0.88	0.86	0.83	0.78	1
Lens11	0.93	0.91	0.92	0.85	3
Lens12	0.93	0.89	0.91	0.83	2
Lens13	0.92	0.89	0.91	0.82	2
Lens14	0.93	0.90	0.90	0.84	2
Lens15	0.93	0.87	0.92	0.75	2
Lens16	0.96	0.90	0.96	0.80	3
Lens17	0.97	0.91	0.97	0.82	3
Lens18	0.98	0.97	0.98	0.97	3
Lens19	0.90	0.90	0.89	0.88	3
Lens20	0.89	0.89	0.88	0.87	2

Lens21	0.92	0.92	0.92	0.92	3
ILT Energeye 1.61	0.92	0.91	0.89	0.85	2
ILT 12 Balance 1.56	0.93	0.92	0.91	0.88	3
ILT Energeye 1.56	0.94	0.92	0.92	0.88	3
Essilor FSV 1.56 AIRMARK	0.89	0.87	0.85	0.80	2
Essilor FSV AS Ormix AIRMARK	0.85	0.84	0.80	0.76	1
Essilor FSV 1.56 TRVII	0.91	0.88	0.90	0.84	2
Stellify SL 155AS	0.92	0.91	0.90	0.87	3
Stellify 16	0.91	0.89	0.88	0.87	2
Stellify 155S2G	0.97	0.92	0.97	0.87	3
HOYA HL 153BG-H	0.92	0.88	0.90	0.85	2
HOYA HL 160 HVLL- BC	0.94	0.92	0.93	0.89	3
HOYA TRANS 1.6	0.89	0.85	0.87	0.80	2
Kodak Total Blue	0.95	0.88	0.95	0.81	3

<sup>a</sup>. CI=circadian index, RI=retinal index, LCD=spectral emission from LCD, SD65=standard illuminant. Lower values indicate higher protective effect in all cases.

Figure 1 illustrates the spatial location of the lenses according to their classes. For the purpose of visualization in 3-dimensional plot, CI(LCD) has to be dropped from the axes. Clear separation of the three classes can be observed from the plot.



**Fig. 1:** Protection levels of the blue blocking lens based on all indices. Class 1 lens has the highest protection.

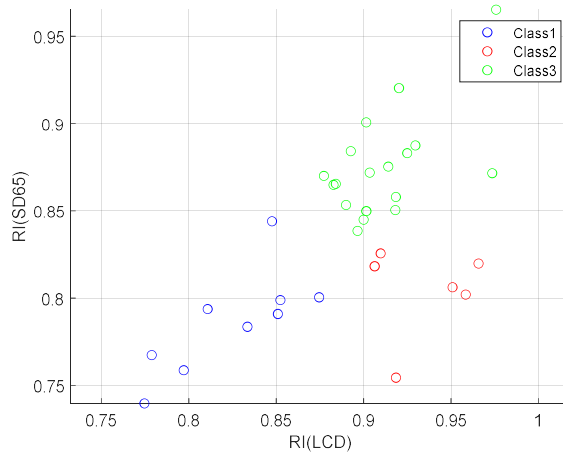
According to [IX], Lens18 to Lens21 are not treated with blue-blocking chemicals. All of those lenses are correctly assigned to Class 3 except Lens20. It is possible that Lens20 is made of material that has inherent blue-blocking properties (e.g., polycarbonate vs CR39).

In addition to the blue-blocking lenses, tinted lenses from sunglasses were also included in the experiment. As a comparison the indices measured from the tinted lenses resulted in indices ranging from 0.05 to 0.07. This indicates this type of lens can give overall protection against the short-wavelength source. However, tinted lenses are known to cause alteration in the colour perception.

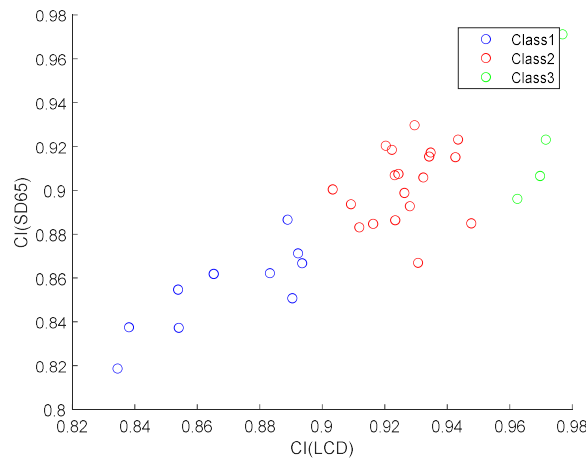
To observe the individual impact of CI and RI respectively, Table II is also added to give the k-means classification results when they are separately analyzed. This information is particularly useful when one wants to differentiate between visual- and non-visual protection provided by the blue-blocking lenses. It can be observed that the difference is quite significant across lenses. Kodak Total Blue for instance, is classified as Class3 for when the class was calculated based on all indices but then identified as Class2 when analyzed separately as tabulated in Table II.

**Table 2: CHARACTERIZATION OF BLUE-BLOCKING LENSES BASED ON SEPARATE K-MEANS ANALYSIS OF THE INDICES.**

Name	Class (RI)	Class (CI)
Lens1	1	1
Lens2	3	2
Lens3	3	2
Lens4	3	2
Lens6	1	1
Lens7	1	1
Lens8	1	1
Lens9	1	1
Lens10	1	1
Lens11	3	2
Lens12	2	2
Lens13	2	2
Lens14	3	2
Lens15	2	2
Lens16	2	3
Lens17	2	3
Lens18	3	3
Lens19	3	2
Lens20	3	1
Lens21	3	2
ILT Energeye 1.61	3	2
ILT 12 Balance 1.56	3	2
ILT Energeye 1.56	3	2
Essilor FSV 1.56 AIRMARK	1	1
Essilor FSV AS Ormix AIRMARK	1	1
Essilor FSV 1.56 TRVII	3	2
Stellify SL 155AS	3	2
Stellify 16	3	2
Stellify 155S2G	3	3
HOYA HL 153BG-H	3	2
HOYA HL 160 HVLL-BC	3	2
HOYA TRANS 1.6	1	1
Kodak Total Blue	2	2



**Fig. 2:** Protection levels of the blue blocking lens based on retinal indices. Class 1 lens has the highest protection.



**Fig. 3:** Protection levels of the blue blocking lens based on circadian indices. Class 1 lens has the highest protection.

Fig. 2 and Fig. 3 compare between classes calculated using retinal and circadian indices respectively. Separation of the classes in Fig. 3 shows a positive linear relationship for both axes which implies a positive correlation between the classes and the circadian indices regardless of the source of exposure (i.e., LCD or standard illuminant). On the contrary, retinal indices does not exhibit such trend where overlapping of classes can be observed for LCD source in the region of  $0.9 < RI(LCD) < 1$ .

**IV. Conclusion**

We have presented a strategy to aggregate the indices of the protective effects of blue-blocking lenses and summarizes them into a single value. While this method can be used to give general protection level of a lens, the existing indices are still



needed to capture the types of source (i.e. LCD or standard illuminant) and the site of exposure (i.e., visual or non-visual).

One advantage of using k-means clustering algorithm in assigning the class is the discovery of the class can be done without training phase and additional parameters except the maximum number of class.

This simplistic classification can provide a quick reference to the optometrists, opticians and the wearers. It must, however, be highlighted here higher CI is also sometimes favourable to the wearers in certain conditions [IX].

## **V. Acknowledgment**

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