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The Effect of Sunglass Price on Ocular Exposure to Ultraviolet Radiation

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Summary

Exposure to ultraviolet waves has been linked to skin cancer, sunburns, and ocular diseases, such as cataracts, macular degeneration, and pterygium. While sunglasses are readily encouraged, many do not wear sunglasses, or do not check the protection offered prior to purchase. One possible reason behind this is people consider price to be an indicator of the sunglass' quality. The purpose of this experiment was to test if the cost of sunglasses correlated with the amount of ocular protection from ultraviolet radiation provided. An ultraviolet omitting lamp (300 nm), natural sunlight, 20 sunglasses, and an illuminance probe were used to test this theory. No sunglasses and experimental groups of sunglasses (≤$10 or >$10) were tested in front of both light sources. Data was taken directly in front of a light source, at 45 degrees to the light source, and at 315 degrees to the light source, in order to test light passage from different angles. There was no significant difference between the protection offered from ≤$10 and >$10 sunglasses. The results of this research can be useful in occupational work. Although employers are not required to pay for an employee's sunglasses, a low-income employee who can purchase less expensive sunglasses for their occupation, while still safely protecting their eyes.

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Introduction

The ozone layer blocks most dangerous waves from reaching the Earth's surface; however, ultraviolet waves (100–400 nm) are an exception. While ultraviolet waves are invisible to the human eye, which can only see certain wavelengths of natural light (between 400–700 nm) emitted from the sun, they are more dangerous than visible light because of their higher energy levels. Ultraviolet waves, also found commonly in modern tanning beds, have been shown to damage one's skin and eyes [6]. These harmful waves cause the darkening of the skin's pigmentation, more commonly known as sunburn [2]. They also have been linked to melanoma skin cancers [1]. Protecting skin from cancer is more well-known, because of ultraviolet-blocking products, such as sunscreen. However, ultraviolet waves are precarious to ocular health as well. Overexposure to ultraviolet radiation has been linked to the development of cataracts and macular degeneration [3]. It has also been linked to the damaging ocular disease pterygium, a growth that starts in the conjunctive of the eye and then spreads to the sclera and cornea [4]. Those with a lighter colored iris are at more of a risk of these ocular diseases than those with a darker colored iris [5]. Through a survey conducted by the Agency for Healthcare Research and Quality (AHRQ), it was estimated the total direct medical costs for cancer in the United States in 2011 were $88.7 billion [11]. In 2015, there were 2,580 estimated new cases of ocular cancer. It was responsible for 270 estimated deaths in the same time period [12].

Ultraviolet waves can be split into spectral categories. Ultraviolet-C (UV-C) waves are 100–280 nm [15]. Ultraviolet-A (long-wave, UV-A) waves are 315–400 nm and classify the closest to visible light. Ultraviolet-B (shortwave, UV-B) waves are 280–315 nm and are the most threatening to human health of the three because of their high energy levels [13] (**Figure 1**).

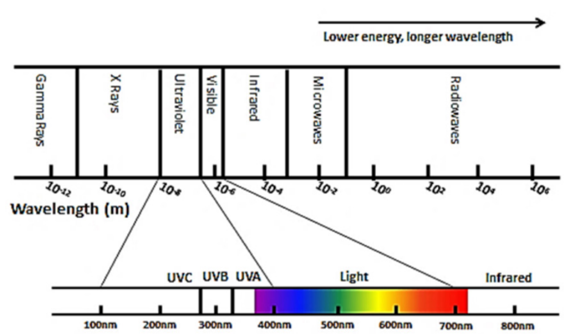

Figure 1: The electromagnetic spectrum of the sun's waves. Ultraviolet light can be split into three subcategories; Ultraviolet A (315-400), Ultraviolet B (280-315), and Ultraviolet C (100-280). These waves have a shorter wavelength and higher energy than visible light, making them more dangerous than visible light. The ultraviolet lamp used in the experiment used UV-B waves and the natural sunlight consisted of ultraviolet, visible, and infrared light (100-1,000,000).

One way to protect eyes from damage from daily exposure is to wear sunglasses that protect against ultraviolet radiation [13]. While this protection is available, many choose not to wear sunglasses or wear sunglasses that do not offer full UV protection. Even though sunglasses are designed to protect the eyes from any ultraviolet waves, some sunglasses substitute ultraviolet filters for dark-tinted lenses. This causes dilation to the eye, letting ultraviolet radiation enter the retina and lens [8]. The American National Standards Institute issued a guide that classifies sunglasses based on their ultraviolet absorption profile and the lenses' degree of shading [9]. However, manufacturers of sunglasses are not required to follow this guide, therefore resulting in sunglasses that offer shade, but not ultraviolet protection. Through research by the American Academy of Ophthalmology, a poll of more than 2,000 adults showed that only 47% of American adults who admit to wearing sunglasses said they check the ultraviolet protection label before purchase [7]. This could be possible because customers correlate sunglass price with the protection offered by the sunglasses.

The purpose of this experiment was to determine whether or not the cost of sunglasses related the amount of ocular protection from ultraviolet radiation. Sunglasses with higher levels of protection, due to the lens material, appear to better shield the eye from damage, due to the chemical composition of the filter material. The unpolarized light waves strike the filter and then are absorbed by it [14]. However, less expensive sunglasses with this lens material may provide protection similar to more expensive sunglasses, resulting in an inexpensive alternative. The price difference may lie purely in the design and purpose of the sunglasses (e.g., snowboarding sunglasses cost more than sunglasses from a drugstore). Because of this, it would seem likely that, no matter what the price, all ultraviolet-protectant sunglasses would offer similar protection.

The results of this research can be useful in occupational work. People who work outside, such as landscape architects, archaeologists, environmental scientists, wild land firefighters, farmers, construction workers, and geologists, could benefit, as their occupation requires extended periods of time exposed to ultraviolet waves. The Occupational Safety and Health Administration requires employers to keep outdoor workers safe by supplying them with personal protective equipment, such as hardhats or goggles. However, employers are not required to pay for their employee's sunglasses, leaving employees to purchase their own [10]. Low-income workers may find what are considered the most sufficient sunglasses to be too expensive. If suitable and more cost-effective sunglasses can be found, more workers may consider using proper eye protection from ultraviolet waves.

Results

The data was split into two sections: data taken in the laboratory (exposed to the ultraviolet lamp in a dark room) and in the field (exposed to natural sunlight). The data set taken in the laboratory consisted of multiple trials (all ten pairs of sunglasses in both experimental groups) at each angle (0°, 45°, and 315°). The laboratory control group, with no sunglasses, resulted in an average illuminance of 117±0 lux at 0°, 117±0 lux at 45°, and 117±0 lux at 315°. Standard deviation in the control group was 0, because of the precision of the illuminance probe. There was no light source shining on the probe during control trials, therefore the standard deviation was not altered or affected by an external light source. The ≤$10 sunglasses trials resulted in an average illuminance of 23±2 lux at 0°, 23±2 lux at 45°, and 23±2 lux at 315°. The >$10 sunglasses trials resulted in an average illuminance of 24±1 lux at 0°, 25±1 lux at 45°, and 25±2 lux at 315° (**Table 1**).

The data set taken in the field contained numerous trials (all ten pairs of sunglasses in both experimental groups) at each angle (0°, 45°, and 315°). The control group (no sunglasses) resulted in an average illuminance of 8419±0 lux at 0°, 8419±0 lux at 45°, and 8419±0 lux at 315°. Similar to the control group in the laboratory trials, standard deviation in the control group was 0 because of the precision of the illuminance probe. The LBC prevented contamination from additional light sources. The ≤$10 sunglasses trials resulted in an average illuminance of 6093±1724 lux at 0°, 6593±1871 lux at 45°, and 7632±983 lux at 315°. The >$10 sunglasses trials resulted in an average illuminance of 7632±1195 lux at 0°, 6054±1683 lux at 45°, and 7989±747 lux at 315°. As the price of the sunglasses changed, the amount of protection offered remained equal (**Table 2**).

Data collected in the laboratory (ultraviolet lamp in a dark room) using ≤$10 sunglasses and >$10 sunglasses were also compared using a two-tailed t-test. At a 0° angle in the field, no difference was found at the 95% confidence level ($t=\pm1.84$, $0.1>p>0.05$, $df=16$). The average illuminance of ≤$10 sunglasses and >$10 sunglasses at a 45° angle in the field were found to be similar at the 99% confidence level ($t=\pm2.49$, $0.05>p>0.01$, $df=16$). Similarly, the average illuminance of ≤$10 sunglasses and >$10 sunglasses at a 315° angle in the field were found to be no different at the 99% confidence level ($t=\pm2.55$, $0.05>p>0.01$, $df=15$). After statistical analysis, it was revealed that the protection offered by ≤$10 and >$10 sunglasses was statistically not different, meaning both groups of sunglasses

Condition	0°		45°		315°	
	Avg. Light Level	SD	Avg. Light Level	SD	Avg. Light Level	SD
No Sunglasses	117.00	0	117.00	0	117.00	0
Less Expensive Sunglasses	23.20	2.10	23.00	2.10	23.20	2.20
Expensive Sunglasses	24.70	1.50	25.00	1.50	25.80	2.60

Table 1: The averaged data from the control group (no sunglasses), the experimental groups, and each angle in the laboratory (ultraviolet lamp in a dark room) setting. 10 trials were conducted (and 200 samples collected per trial) for each condition and degree pairing.

Condition	0°		45°		315°	
	Avg. Light Level	SD	Avg. Light Level	SD	Avg. Light Level	SD
No Sunglasses	8419.00	0	8419.00	0	8419.00	0
Less Expensive Sunglasses	6093.45	1724.47	6593.40	1870.72	7632.30	983.28
Expensive Sunglasses	7632.30	1194.90	6054.80	1682.67	7989.30	747.18

Table 2: The averaged data from the control group, the experimental groups, and each angle in the field (natural sunlight) setting. 10 trials were conducted (and 200 samples collected per trial) for each condition and degree pairing.

efficiently blocked the passage of UV light through the lens. Analysis of the control and experimental groups also found that the sunglasses protected equally (**Figure 2A**).

Data collected in the field (natural sunlight) from ≤\$10 sunglasses and >\$10 sunglasses groups were also compared using a two-tailed t-test. Once again, we found there to be no difference between the average illuminance values measured for ≤\$10 sunglasses and >\$10 sunglasses at the 99.9% confidence level (t=±4.26, 0.001>p, df=9) for 0°, at the 99% confidence level (t=±3.08, 0.05>p>0.01, df=9) for 45°, and at the 90% confidence level (t=±1.95, 0.1>p>0.5, df=9) for 315°. After this statistical analysis, it was revealed that, when exposed to sunlight, the protection offered by ≤\$10 and >\$10 sunglasses were statistically not different, meaning both groups of sunglasses efficiently blocked the passage of sunlight through the lens. Analysis of the control and experimental groups also found that the sunglasses protected equally (**Figure 2B**).

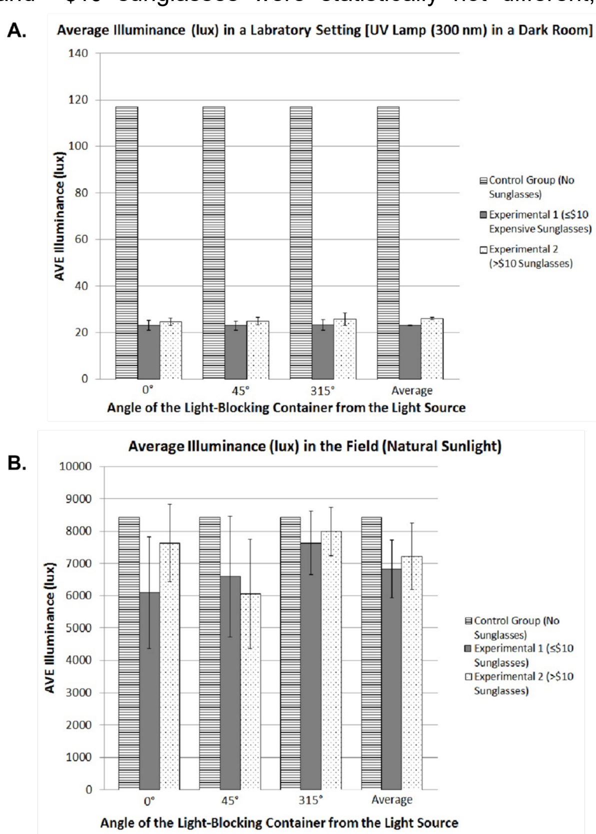

Figure 2: Average illuminance at varying angles. The LBC was shifted at different angles (0°, 45°, and 315°) of the light source during data collection. (**A**) Ultraviolet lamp in a dark room and (**B**) Outside measurements at 300nm. All outside data was taken on the same day. Data is shown as mean ± standard deviation.

Discussion

The data from this research showed that the illuminance passage remained equal, even as the price of the sunglasses changed. The overlapping standard deviation error bars in the data also showed no statistical difference between the price of the sunglasses and the ocular protection from exposure to ultraviolet radiation. Statistical analysis showed that both classifications of sunglasses offered equal protection from natural sunlight.

For further expansion on this experiment, the ultraviolet lamp could be replaced with a higher-quality ultraviolet emitter, being as the one used in the experiment only emitted 300 nm ultraviolet waves. Also, data taken in natural sunlight were much greater than those taken in the dark room with the ultraviolet lamp. This is because the sun emits more than just ultraviolet waves. Therefore, these waves could be factored in and subtracted from the total luminosity, thus revealing just the lux of the ultraviolet waves. Another way to improve the experiment would be to test different lenses (e.g., sunglasses that are not labeled "100% Ultraviolet Protectant").

In conclusion, the price of the sunglasses made little difference in the protection offered (**Figure 3**). Since employers are not required to supply employees with sunglasses, this research may be useful to low-income, outdoor workers who want to protect their eyes at a lower cost. In addition, an owner of a construction site or an orchard can now consider supplying their employees with sunglasses. The experiment demonstrated how a \$3 pair of sunglasses can protect eyes just as efficiently as a \$300 pair. Buying mass amounts of \$3 pairs of sunglasses for employees will be much less expensive than the cost of cancer medical care. The only loss would be the style and features of the sunglasses, such as wrap-around or non-plastic frames. With the option of purchasing functional but less expensive sunglasses, eyes can be protected from ultraviolet waves and the diseases and cancers they produce, all while saving money on medical care and sunglasses.

Materials and Methods

A system for testing the illuminance (lux) received by an illuminance probe was created. An ultraviolet lamp

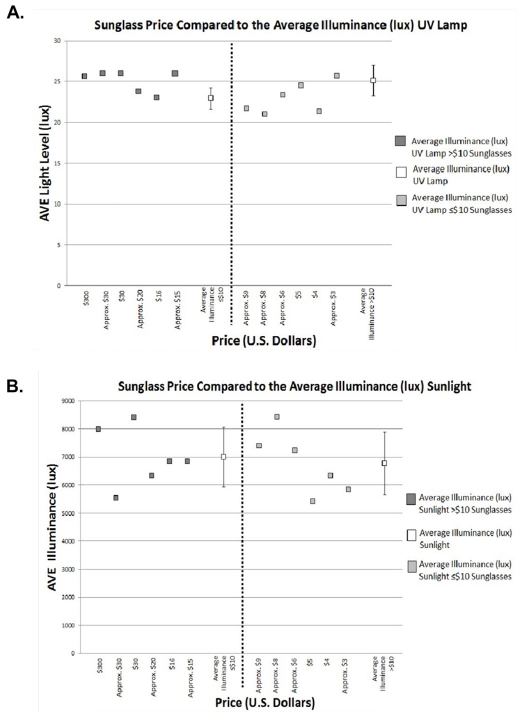

Figure 3: Average illuminance with ultraviolet lamp vs natural sunlight. Measurements taken in a (**A**) dark room with ultraviolet light source and (**B**) natural sunlight. Data to the left of the dashed lined represents sunglasses >$10 and to the right represents ≤$10. There was no statistical difference between groups in **A** or **B** demonstrating that the price of the sunglasses does not affect the protection the eye receives. Data is shown as mean ± standard deviation.

was used to omit proper short wave (3000 Ångströms, or 300 nm) radiation. The ultraviolet lamp was tested in a dark room to ensure that external light did not interfere with the data readings. Data was also taken outside in natural sunlight, so the illuminance probe could measure the whole light spectrum. Data collected in natural sunlight was taken from 13:30–14:30 PST, at 47.33° longitude and 188.68° latitude on March 18th, 2015. The temperature was approximately 15.5°C at the time of data collection, and there were no visible clouds that could have blocked the sun. Sunglasses with prices ranging from approximately $3 to $300 were classified into two groups: ≤$10 and >$10. Ten pairs of sunglasses were in each group. All sunglasses used in the experiment were labeled "100% Ultraviolet Protection" to ensure consistency in the lens material.

In order to detect the light passage, a Vernier illuminance probe, which measures the illuminance of the environment in terms of lux, and a Vernier LabQuest, were used to test light absorbance from the light sources after passing through the sunglasses. A 12x12 cm light-blocking container (LBC) was designed and constructed to cover the illuminance probe so that it was directly exposed to the appropriate light source. The LBC had 2 circular openings on both sides: one to place the illuminance probe and the other to allow light passage to the probe. To secure the sunglasses in front of the LBC, a clamp and a pole were used. The clamp gently held the sunglasses in place 2 cm in front of LBC. The entire setup was set in front of the appropriate light source (**Figure 4**).

In the control trials (no sunglasses), the illuminance probe was exposed to ultraviolet radiation in a dark room. Data was collected on the Vernier LabQuest and recorded with the LBC at 0°, 45°, and 315° (or -45°). This process was repeated a total of ten times. The complete procedure was then conducted in an outside setting, with natural sunlight as the light source. The Vernier LabQuest recorded data over the span of ten seconds and took 20 samples per second, resulting in a total of 200 samples per angle.

The methods used to conduct the control trials (no sunglasses) were used with sunglasses in both experimental groups: ≤$10 sunglasses and >$10 sunglasses. The average illuminance of all sunglasses in the no sunglasses, ≤$10 sunglasses, and >$10 sunglasses groups were statistically analyzed using a two-tailed t-test.

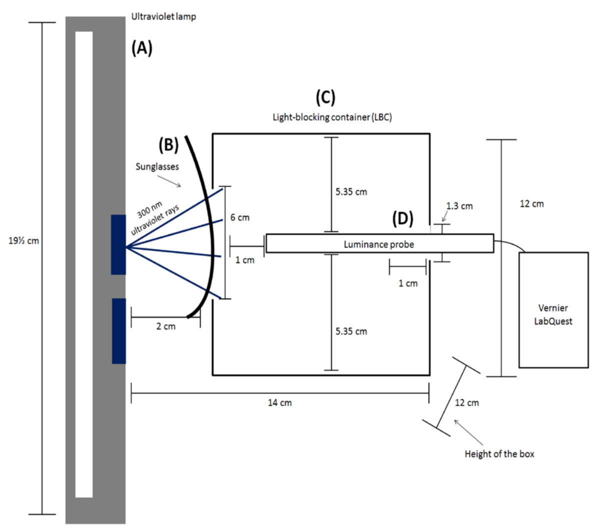

Figure 4: Experimental setup. (**A**) An ultraviolet lamp and natural sunlight were used to omit light into the illuminance probe. (**B**) Sunglasses were set 2 cm in front of the large opening. (**C**) A light-blocking container was used to solidify unsolicited waves from reaching the illuminance probe. (**D**) An illuminance probe and Vernier LabQuest were used to test the illuminance. The Light-blocking container (LBC) included a top panel, which was not represented in the Figure, in order to accurately depict the interior of the box during experimentation. The LBC also did not have a bottom panel.

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