The Effect of Sunglass Price on Ocular Exposure to Ultraviolet Radiation

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Key Words

Ultraviolet, radiation, sunglasses, ocular

ABSTRACT

Ultraviolet rays have been linked to skin cancer, sunburns, and ocular diseases, such as cataracts, macular degeneration, and pterygium. While sunglasses are readily encouraged, many do not to wear them, or do not check the protection offered prior to purchase. One theory behind this is the price. The hypothesis of the experiment was to demonstrate that the cost of sunglasses did not alter the amount of ocular protection from ultraviolet radiation provided. An ultraviolet lamp (300 nm), natural sunlight, 20 sunglasses, and an illuminance probe were used to test this. No sunglasses (no sunglasses) and experimental groups (≤$10/>$10) were tested in front of both light sources. Data was taken directly in front of a light source, 45° from the light source, and 315° from the light source, in order to test light passage from different angles. The hypothesis was accepted; there was no significant difference between the protection offered from ≤$10 and >$10 sunglasses. The results of this research can be useful in the work field. Since employers are not required to pay for their employee's sunglasses, an employee who receives a low income can purchase less expensive sunglasses for their occupation, while still safely protecting their eyes.

Author's Summary: The investigation was conducted to confirm whether or not the price of sunglasses that protect eyes from ultraviolet rays affected the amount of protection offered by said sunglasses. The data revealed that ≤$10 and >$10 sunglasses blocked both isolated ultraviolet light and natural sunlight (whole light spectrum) similarly. The results of the experiment could offer a less expensive alternative for outside workers who wish to protect their eyes from ocular diseases or possible cancer.

Introduction

The human eye can only see certain rays of natural light omitted from the sun. The naked eye alone can only detect waves between 400-700 nm. The ozone layer blocks any dangerous rays from reaching the Earth's surface. However, ultraviolet rays (100-400 nm) are a unique example. The human eye cannot detect ultraviolet rays; their frequency is beyond what the eye can identify. However, ultraviolet rays are more dangerous than visible light, because of their higher energy levels. The harmful rays have been linked to the cause of melanoma skin cancers [1]. Ultraviolet rays also cause the darkening of skin's pigmentation, more commonly known as a sunburn [2]. Ultraviolet rays can be split into spectral categories; Ultraviolet A (long-wave, UV-A) rays are 315-400 nm, and classify the closest to visible light. Ultraviolet B (shortwave, UV-B) rays are 280-315 nm, and are the most threatening to human health of the three ultraviolet classifications, because they are not blocked by the ozone layer. Ultraviolet C (UV-C) rays are 100-280 nm, and are entirely blocked by the ozone layer (Figure 1).

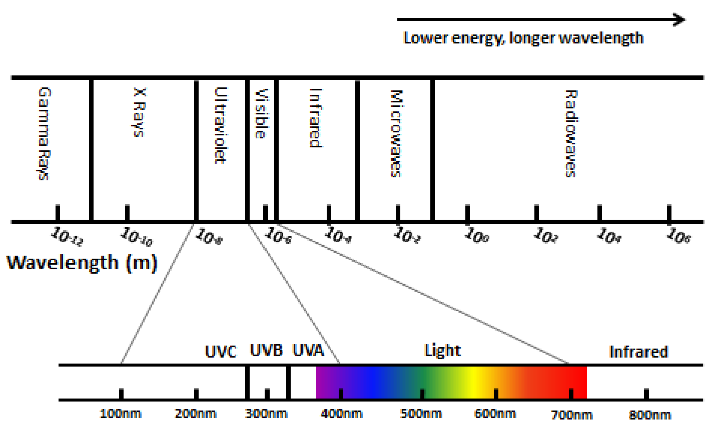

Figure 1: The electromagnetic spectrum of the sun's rays. Ultraviolet light has a wavelength of 400-700 nm and can be split into three subcategories; UV-A (315-400), UV-B (280-315), and UV-C (100-280). As shown, ultraviolet rays have a shorter wavelength and higher energy than visible light, being more dangerous than visible light. Excessive exposure to the rays can be linked to melanoma and other skin cancers.

Even more so than skin, ultraviolet rays are also precarious to ocular health. Overexposure to ultraviolet radiation has been linked to the development of cataracts and macular degeneration [3]. They have also been linked to the damaging ocular disease, pterygium, a growth which 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 than those with a darker colored iris [5]. These rays are also found in tanning beds and have been shown to damage one's skin and eyes [6].

For everyday exposure to the sun's rays, a way to protect eyes from damage is to wear sunglasses that are listed to protect from ultraviolet radiation. While this protection is available, many choose not to wear sunglasses. Through research by the American Academy of Ophthalmology, a poll of more than 2,000 adults, it was found only 47% of American adults who admit to wearing sunglasses said they check the ultraviolet protection label before purchase [7]. One idea behind this is the price. Even though sunglasses are designed to protect the eyes from any ultraviolet rays, some sunglasses substitute ultraviolet filters for dark-tinted lenses. This causes dilation to the eye, letting ultraviolet radiation enter the retina and lens [8]. For example, the American National Standards Institute issued a guide that classifies sunglasses biased on their ultraviolet absorption profile and the lenses' degree of shading. However, manufacturers of sunglasses are not required to follow this guide, therefore resulting in sunglasses that offer shade, but not ultraviolet protection [9].

The hypothesis of the experiment was to demonstrate that the cost of sunglasses did not alter the amount of ocular protection from ultraviolet radiation provided. 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. However, less expensive sunglasses with this lens material may provide protection similar to more expensive sunglasses, therefore resulting in an inexpensive alternative.

The results of this research can be useful in the work field. Outside workers such as landscape architects, archaeologists, environmental scientists, wild land firefighters, farmers, construction workers, and geologists, could benefit, being as their occupation requires them to spend extended periods of time exposed to ultraviolet rays. The Occupational Safety and Health Administration requires employers keep outdoor workers safe by supplying them with personal protective equipment, such as hardhats or goggles. However, there are some exemptions. Employers are not required to pay for their employee’s sunglasses, therefore leaving employees to purchase their own [10]. Workers who may receive a low income may find buying what is considered the most sufficient sunglasses expensive. If suitable sunglass choice can be determined, a more cost effective step towards proper eye protection from, while minimizing the risk of, ultraviolet rays can be recognized.

Materials and Methods

A system for testing the illuminance (lux) received by an illuminance probe was created. An ultraviolet lamp was used to omit proper short wave (3000 Ångströms, or, 300 nanometers) 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, exposed to natural sunlight, so the illuminance probe could perceive the whole light spectrum. Data collected in natural sunlight was taken from 1:30-2:30 p.m. (time), PST, at 47.33° longitude and 188.68° latitude on March 18th, 2015. Sunglasses with prices ranging from approximately \$3 to \$300 were classified into two groups; ≤\$10 and >\$10. Ten pairs of sunglasses were in each individual group. All sunglasses used in the experiment were labeled, “100% Ultraviolet Protection” in order to ensure consistency in the lenses' material. An illuminance probe, which measured the illuminance of its environment in terms of lux, and a Vernier LabQuest, was used to test the light absorbance from the light sources after passing through the sunglasses.

In order to detect the light passage to the LBC, an illuminance probe and Vernier LabQuest were used. A 12x12 centimeter (cm) light-blocking container (LBC) was designed and constructed to solidify 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 illuminance probe (Figure 2).

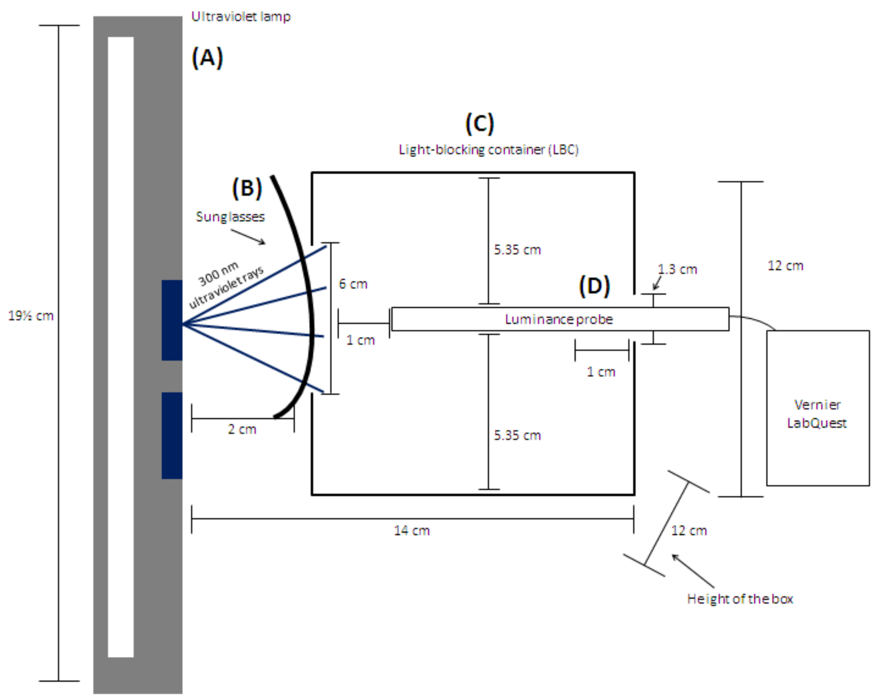

Figure 2: (A) An ultraviolet lamp and natural sunlight were used to omit light into the illuminance probe. (B) Sunglasses were set 2 cm in front of the large opening. (C) A light-blocking container was used to solidify unsolicited rays from reaching the illuminance probe. (D) An illuminance probe and 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.

To secure the sunglasses in front of the LBC, a clamp and a pole were used. The clamp gently held the sunglasses in place as they were set 2 cm in front of LBC. The entire setup was set in front of the appropriate light source (Figure 3).

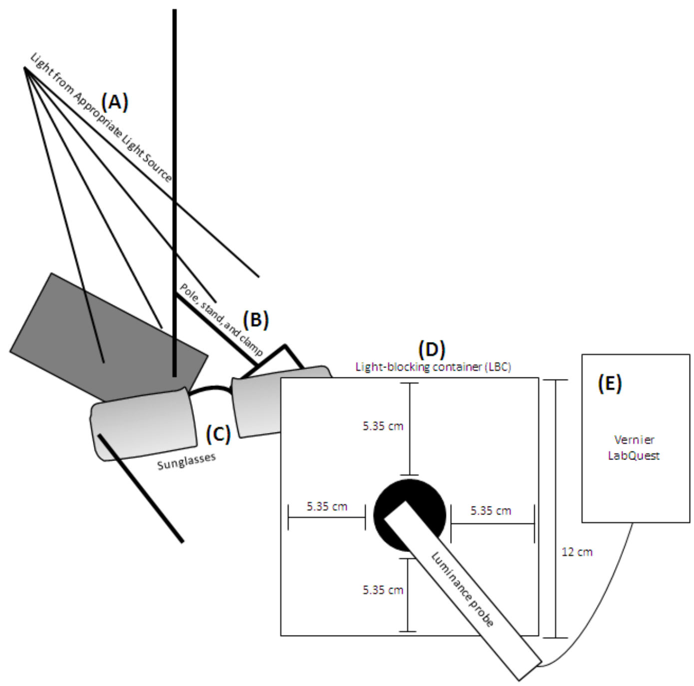

Figure 3: (A) Light was cast directly to an opening in the light-blocking container (LBC). (B) A pole and clamp were used to steadily position the sunglasses in front of the appropriate opening. (C) Sunglasses were placed in a smaller opening of LBC. (D) The LBC secured and solidified the illuminance probe from external light. (E) A Vernier LabQuest and an illuminance probe were used to collect 200 samples of the illuminance over the span of ten seconds.

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. The LBC was shifted 45°; the methods listed previously were repeated and data was recorded. The LBC was then shifted 315°, or, 45° in the other direction, to record data from a third angle. The procedures above were conducted. This process was repeated a total of ten times using the ultraviolet lamp in a dark room. The complete procedure was then conducted in an outside setting, this time 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.

Sunglasses were categorized into two experimental groups: ≤$10 sunglasses and >$10 sunglasses. The methods used to conduct the control trials (no sunglasses) were completed with sunglasses in both experimental groups. 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.

Results

The data was split into two sections; data taken in the laboratory (exposed to UV 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 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 there were no sunglasses blocking the illuminance probe and LBC from the lamp's ultraviolet rays, therefore each trial was exposed to the same amount of radiation. 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).

Table 1: The averaged data from the control group (no sunglasses), the experimental groups, and each angle in the laboratory (UV lamp in a dark room) setting are displayed in the Table.

*200 samples were taken per trial.

Laboratory (UV light in a dark room)											
0°				45°				315°			
	AVE Illuminance (lux)	±SD (lux)	N (trials)		AVE Illuminance (lux)	±SD (lux)	N (trials)		AVE Illuminance (lux)	±SD (lux)	N (trials)
Control (No Sunglasses)	117	0	10*	Control (No Sunglasses)	117	0	10*	Control (No Sunglasses)	117	0	10*
Experimental 1 (≤$10 Sunglasses)	23	2	10*	Experimental 1 (≤$10 Sunglasses)	23	2	10*	Experimental 1 (≤$10 Sunglasses)	23	2	10*
Experimental 2(>$10 Sunglasses)	24	1	10*	Experimental 2 (>$10 Sunglasses)	25	1	10*	Experimental 2 (>$10 Sunglasses)	25	2	10*

The data set taken in the field contained of 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 previously stated in the laboratory trials, standard deviation in these trials was also 0, because there were no sunglasses blocking the probe and LBC from sunlight, leaving each trial exposed to the same amount of radiation. 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°, 605±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).

Table 2: The averaged data from the control group, the experimental groups, and each angle in the field (natural sunlight) setting are displayed in the Table.

*200 samples were taken per trial.

Field (Natural Sunlight)											
0°				45°				315°			
	AVE Illuminance (lux)	±SD (lux)	N (trials)		AVE Illuminance (lux)	±SD (lux)	N (trials)		AVE Illuminance (lux)	±SD (lux)	N (trials)
Control (No Sunglasses)	8419	0	10*	Control (No Sunglasses)	8419	0	10*	Control (No Sunglasses)	8419	0	10*
Experimental 1 (≤$10 Sunglasses)	6093	1724	10*	Experimental 1 (≤$10 Sunglasses)	6593	1870	10*	Experimental 1 (≤$10 Sunglasses)	7632	983	10*
Experimental 2 (>$10 Sunglasses)	7632	1194	10*	Experimental 2 (>$10 Sunglasses)	6054	1682	10*	Experimental 2 (>$10 Sunglasses)	7989	747	10*

Discussion

Using a two-tailed t-test, the average illuminance from all sunglasses in ≤$10 sunglasses and >$10 sunglasses groups in the laboratory (ultraviolet lamp in a dark room) were compared. The average illuminance between the control group (no sunglasses) and both the >$10 sunglasses and ≤$10 sunglasses groups were statistically different at all angles at the 95 % confidence level. The statistical analysis showed that the ≤$10 and >$10 sunglasses were similar, meaning the both groups of sunglasses proficiently blocked the passage of ultraviolet light (Figure 4).

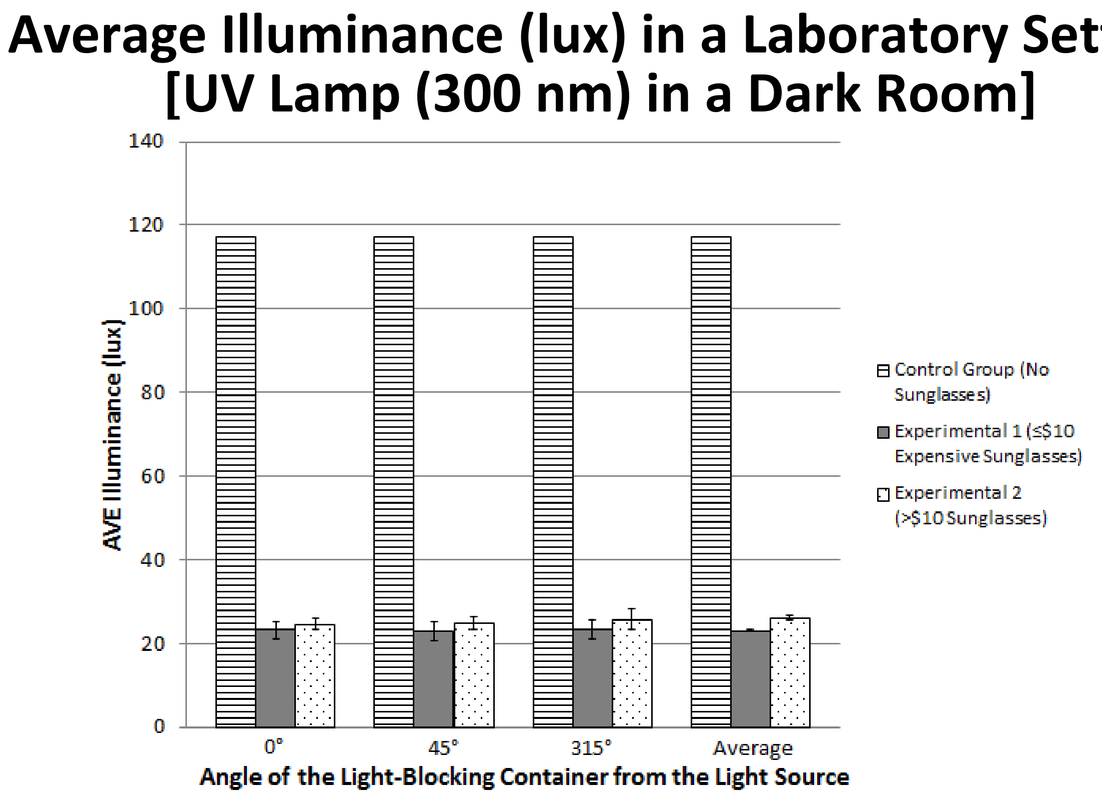

Figure 4: The average illuminance with standard deviation taken in a dark room with a UV lamp, at varying degrees from 300 nm. The LBC was shifted different angles (0°, 45°, and 315°) of the UV lamp during data collection, in order to ensure that protection was offered at viewpoints.

Tests conducted in the field (natural sunlight) from ≤$10 sunglasses and >$10 sunglasses groups were also compared using a two-tailed t-test. At a 0° angle in the field was found to be a difference at the 95% confidence level ($t=\pm2.3$, $0.05 > p > 0.01$, $df=16$). The average illuminance of ≤$10 sunglasses and >$10 sunglasses at a 45° angle in the field was found to be a difference at the 90% confidence level ($t=\pm3.1$, $0.1>p>0.5$, $df=17$). The average illuminance of ≤$10 sunglasses and >$10 sunglasses at a 315° angle in the field were found to be different at the 90% confidence level ($t=\pm1.9$, $0.1>p>0.5$, $df=16$). After statistical analysis, it was revealed that 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 displayed that the sunglasses protected equally (Figure 5).

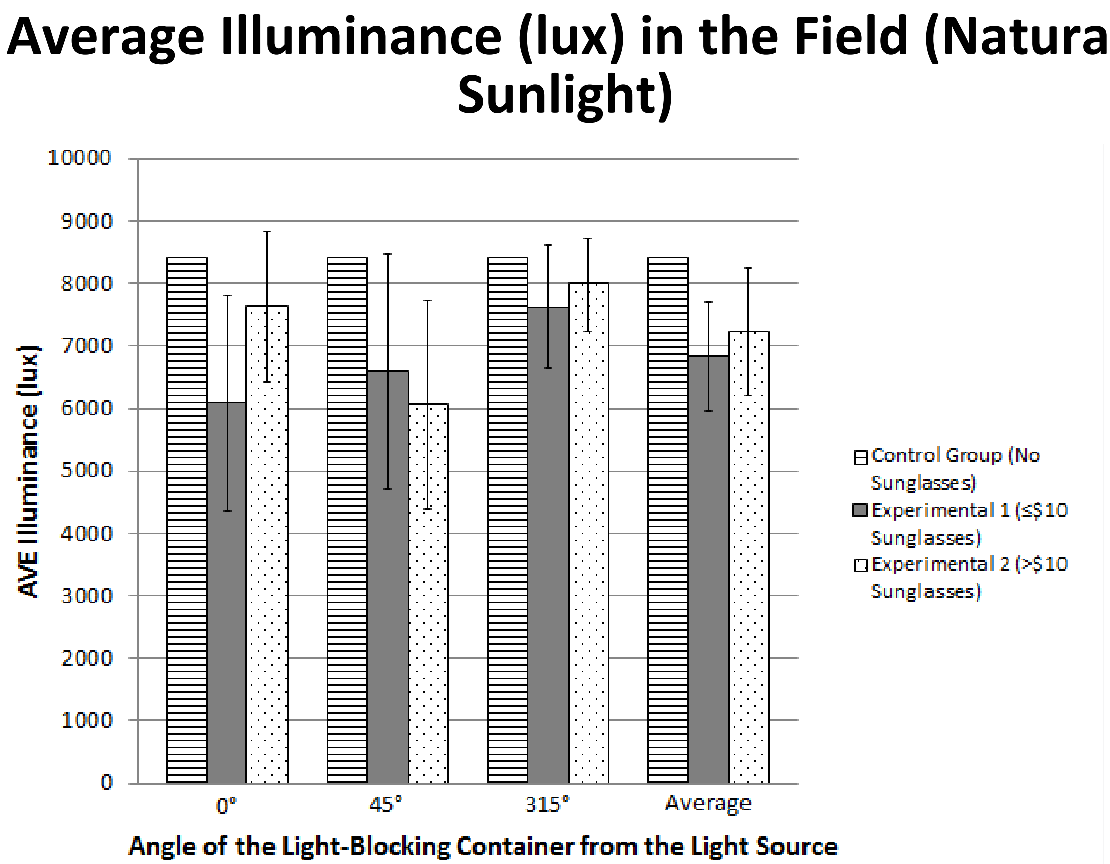

Figure 5: The average illuminance with standard deviation taken outside. The LBC was shifted different angles (0°, 45°, and 315°) of the UV lamp during data collection, in order to ensure that protection was offered at viewpoints. All outside data was taken on the same day.

The average illuminance of ≤$10 sunglasses and >$10 sunglasses in the laboratory was compared with a two-tailed t-test was at the 90% confidence level ($t=\pm6.1$, $0.1>p>0.05$, $df=2$). The average illuminance of ≤$10 sunglasses and the control group (no sunglasses) in the laboratory was at the 95% confidence level ($t=\pm3.6$, $0.05>p>0.01$, $df=2$). The average illuminance of >$10 sunglasses and no sunglasses in the laboratory was at the 90% confidence level ($t=\pm2.1$, $0.1>p>0.05$, $df=2$). The statistical analysis showed that the ≤$10 and >$10 sunglasses tested in isolated ultraviolet light were similar, even as the price of the sunglasses was altered. This statistical analysis showed that even as the price of the sunglasses changed, the protection offered did not alter. Also, the standard deviation bars overlapped, further demonstrating a statistical equivalence of illuminance.

When compared using a two-tailed t-test, the average illuminance of ≤$10 sunglasses and >$10 sunglasses in the field was at the 90% confidence level ($t=\pm0.6$, $0.1>p>0.05$, $df=3$) (Figure 6).

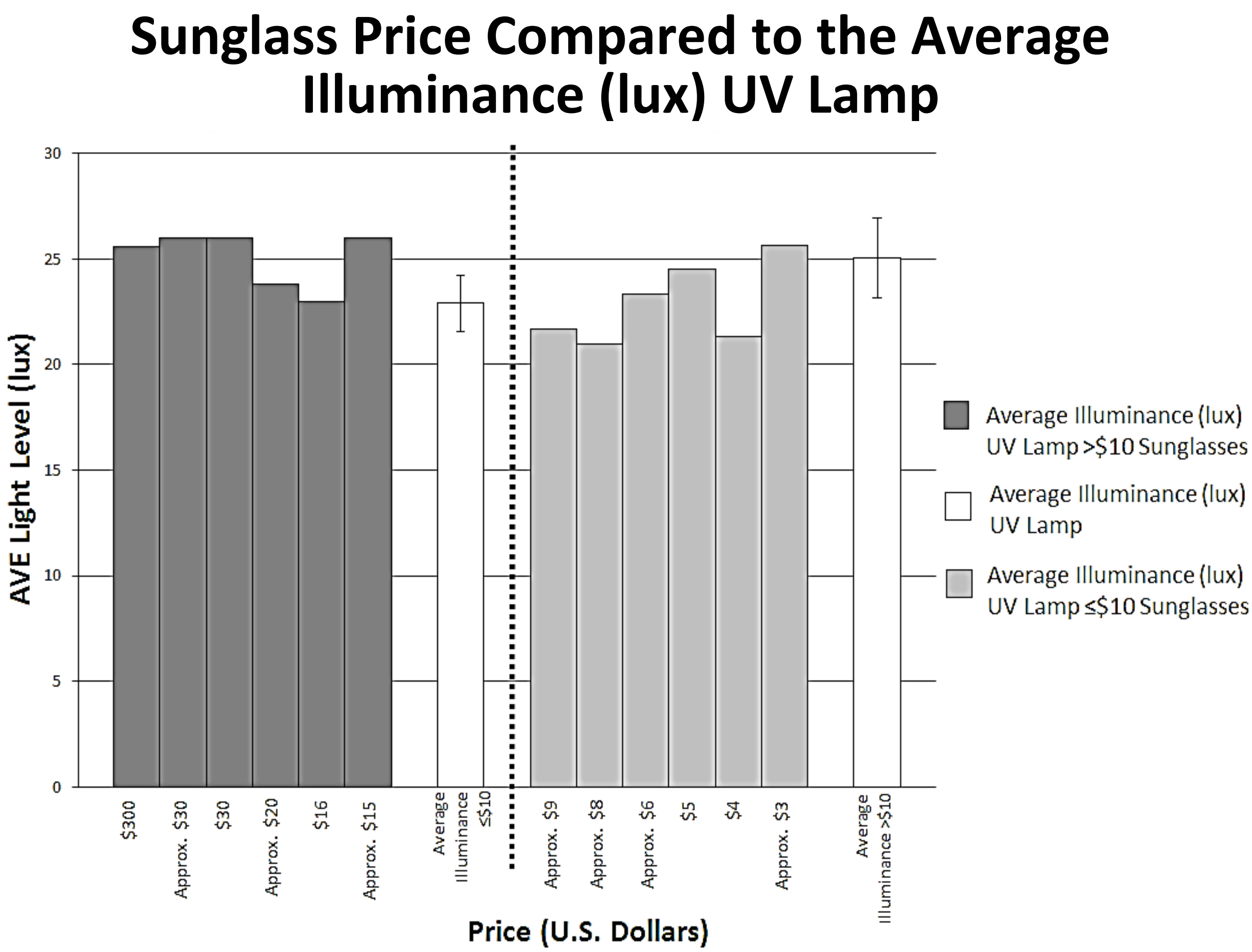

Figure 6: To further examine the relationship between the price and illumination, the average illuminance taken in a dark room with a UV lamp light source was displayed. Data to the left of the dashed line are in the >$10 sunglasses group and data to the right of the dashed line are in the ≤$10 sunglasses group. There was no statistical difference between the groups, demonstrating that the price of the sunglasses does not affect the protection the eye receives.

The average illuminance of ≤$10 sunglasses and no sunglasses in the field was at the 90% confidence level ($t=\pm3.6$, $0.1>p>0.05$, $df=2$). The average illuminance of >$10 sunglasses and no sunglasses in the field was at the 90% confidence level ($t=\pm2.1$, $0.1>p>0.05$, $df=2$) (Figure 7).

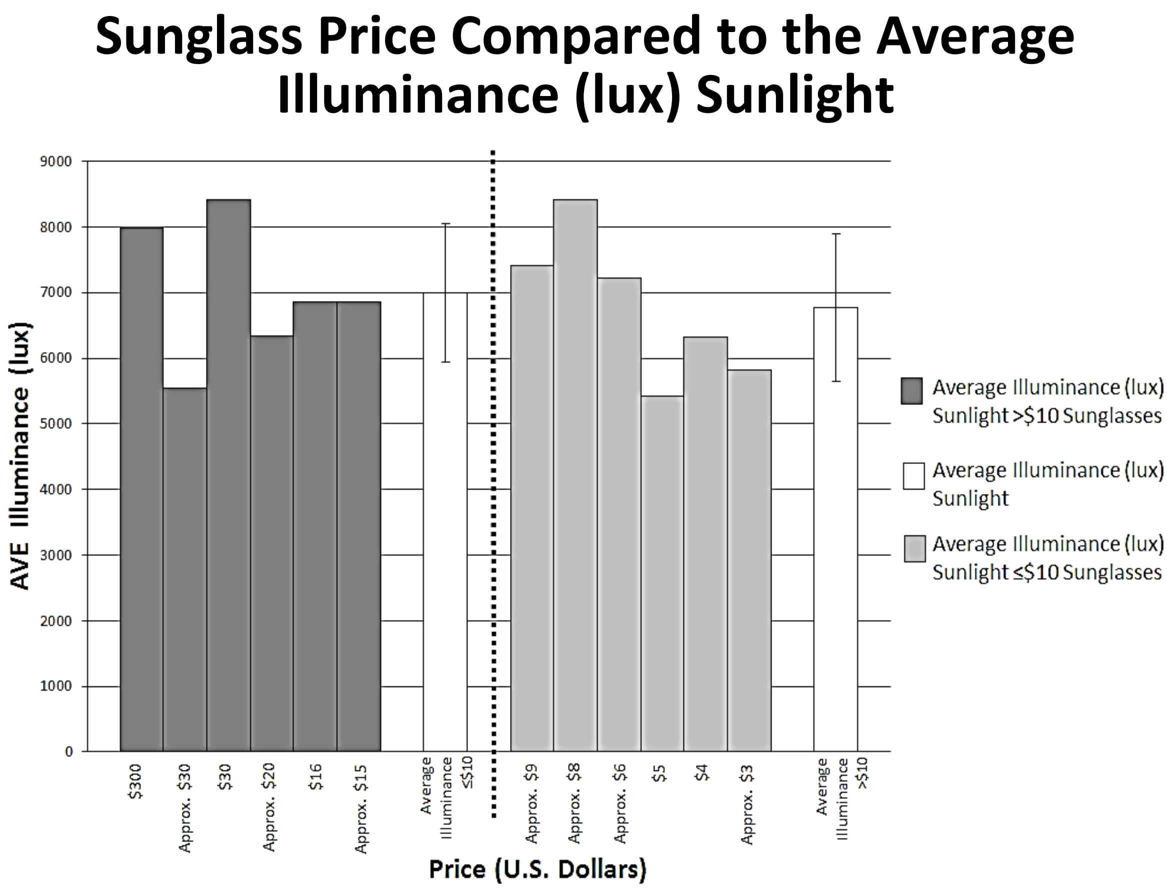

Figure 7: The average illuminance when exposed to natural sunlight was examined to display the relationship between price and illuminance. As displayed in the Figure, the average illuminance when exposed to both light sources remained similar, even as the price of the sunglasses changed. Data to the left of the dashed line are in the >$10 sunglasses group and data to the right of the dashed line are in the ≤$10 sunglasses group. There was no statistical difference between the groups, demonstrating that the price of the sunglasses does not affect the protection the eye receives.

This statistical analysis showed that both classifications of sunglasses offered equal protection from natural sunlight. The overlapping standard deviation bars also showed a statistical equivalence in illuminance. The price of the sunglasses was also compared to the price to further observe that the price did not alter the protection offered.

In conclusion, the research was a success; the hypothesis was accepted because the price of the sunglasses made little difference in the protection offered. Since employers are not required to supply employees with sunglasses, this research is useful to outside, migrant workers who receive a low income. For example, an employer 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. 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 have been 2,580 estimated new cases of ocular cancer. It has also been responsible for 270 estimated deaths in the same time period [12]. With the option of purchasing proficient less expensive sunglasses, the eye can be protected from ultraviolet rays and the impacting diseases and cancers they produce, all while saving money in medical care and sunglasses. 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.

Acknowledgements

This research was conducted my sophomore year at Odessa High School in the Advanced STEM Research Laboratory under the guidance of mentor, Jeffery Wehr. I wish to thank Mr. Wehr, the ASR laboratory, and Odessa High School for access to equipment, laboratory space, and guidance throughout the experiment. I would also like to thank Tim and Jill Larson, Chance Messer, and Ellen Holman for donating their 100% UV-protectant sunglasses for the experiment.

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