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An overview of Polaroid sun eyewear: Function, application and market

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Abstract

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An Overview of Polaroid Sun Eyewear:

Function, Application and Market

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ABSTRACT

Patients are constantly looking for the newest technologies that will assist them in accomplishing the activities that they desire more comfortably and efficiently, in both their personal and professional lives. It is our responsibility as primary care practitioners to be current with the latest advancement in ophthalmic therapies, and effectively pass this knowledge on to our patients.

This paper will encompass the properties of specialty protective sun eyewear, emphasizing polarized sunglasses, and how they can be incorporated into a private practice as a viable profit center. The intent is to provide the practitioner with a general overview of the basic properties of light and the history of polarized sunglasses and the functional benefits that they may offer consumers. This review will help to enable a practitioner to feel confident and more comfortable in prescribing and recommending these specialty performance lenses to their patients.

INTRODUCTION

Sunglasses are one of the fastest growing segments in the eyewear market, and will continue to expand, as more consumers become aware of the importance of eye protection. As vision specialists, Optometrists must continually strive to find the best products to meet the needs of their patients.

Specialty eyewear may represent a large untapped potential market to the private practitioner who is looking for an alternative method to boost sales within the current market share. It is estimated that approximately 160 million Americans use some sort of eyewear on a regular or part time basis (1). Currently most consumers purchase their sunglasses from retail outlets such as Sunglass Hut, which results in Optometric professionals losing millions annually in potential sales.

Trends show that since 1995, eyewear sales have been steadily increasing and are projected to reach 19.5 billion dollars in 2002 (1), an increase of 40 percent over the last 7 years. A special issue called "Investment in Sight" has been published annually in financial magazines such as Research, and is used to inform investors and analysts on current market trends in this field. The research presented in the latter articles reveals that sales have steadily increased in all sectors of eyewear, but the largest market growth is in premium sunglasses over $150, which increased nearly 43% between 1998 and 1999 (2).

Sunglasses currently generate 3 billion dollars in annual sales, and account for approximately 10 percent of a 30 billion dollar eye care market; a number, which is, composed of doctor exams, surgeries, and other eyewear products (1). These figures illustrate that sunglass eyewear is in demand by consumers, and who better to offer them this service than an eye care professional they trust. To incorporate top quality sunglass materials into your practice the Optometrist or Optician must be thoroughly familiar with the product and must be able to convey this information on to the consumer. For reasons stated above, we are devoting this article to an informative evaluation of sun eyewear with a focus on polarized lenses. Polarized sun wear has doubled in sales between 1994 and 1998 and has shown no recent signs of slowing down (3).

DISCUSSION

History of Polarization

The concept of polarization dates back to 1669 when Erasmus Bartholin, a Danish physician and professor of mathematics made an experimental discovery using crystal calcite at the University of Copenhagen. The phenomenon that he described in a publication called, "Experimenta crystalli Islandici disdiaclastici quibus mira et insolita refractio delegitur" (4), was what we now know as polarization. Erasmus described his observations as an unusual case of refraction (4). The study of polarization continued to be researched and in 1808 a French military engineer named Etien Malus, proved that optical polarization could be used to reduce afternoon sunlight reflected from the windows of the Luxembourg Palace (5). This was a break through for theoretical physics because it could be described by the Electromagnetic Theory of Light that had been recently proposed (6).

Later that century, in 1888, Heinrich Hertz began studying the properties of radio waves using metal grids of parallel wires. The mechanism that Hertze discovered while studying radio waves was that when light was incident at a normal angle on these thin metal discs, the conduction electrons surrounding each atom within the vertical wires began to vibrate. He found that these electrons could only vibrate in the direction of the long axis of the wires and could not vibrate in the horizontal direction because no metal was present beside the thickness of the wire. In summary, Hertz had discovered that by using these thin metal wires it was possible to strongly absorb light that is oscillating parallel to the wire plane, resulting in polarization in that meridian. The other component of the incident light that is oscillating at a normal angle to the wires is transmitted (7).

History of Manufacturing

The first person to apply the concept of polarization to light, using man made products to control glare for optical purposes, was Dr. Edwin Herbert Land. His long years of study and research became a reality in 1928 when he invented J-sheet Polaroid. J-sheet Polaroid was replaced by his later invention H-sheet Polaroid, because of hazy imaging due to increased light scatter. It wasn't until 1938 with the invention of H-Sheet Polaroid that the commercial potential of the product became apparent, as the image produced was much clearer.

The basic manufacturing process consists of heating a sheet of clear polyvinyl alcohol, and stretching it in one direction. During the stretching process, the sheet's long hydrocarbon molecules become aligned. Following this, the sheet is dipped in an ink solution that is rich in iodine. The iodine becomes incorporated into the plastic and by attaching to the straight long chain molecules effectively forming a chain of its own. This permits the conduction electrons within the iodine to move along the long chains as if they were long thin metal wires (7). This in turn produces an absorption axis, which is aligned with the chains, and a transmission axis, which is perpendicular. For example:

Horizontal iodine chains = Vertical light transmission

Vertical iodine chains = Horizontal light transmission

Edwin's invention was used in various products such as World War II army goggles, 3D-Glasses and Sunglasses (5).

Originally, polarized sunglasses were constructed by laminating the sheets of polyvinyl film between two pieces of flat glass. This design was not successful due to continual de-lamination and the poor image quality produced. As various plastics were introduced into the optical market, eventually this lamination process was preformed on plastic lenses. Originally, these lenses were sold in over the counter stores such as drug stores, prior to being introduced to the Optometric market with the advent of prescription polarized sunglasses. New technology today uses injection molding techniques instead of the traditional lamination process. The injection molding process involves the film being suspended in the middle of the mold and a plastic monomer is poured around the film.

Following this, the plastic material solidifies around the film producing a solid integrated lens (9). The benefit of this process is that de-lamination is now a thing of the past, and that the image quality is far superior.

Basic Properties of Light

In order to understand how polarized sunglasses function, you must first be familiar with the basic properties of light. For years, scientists have debated over the composition of light, but agree with the notion that it is a form of electromagnetic radiation and as such falls within the electromagnetic spectrum. The conflict however lies in whether light should be viewed in terms of a wave or as a stream of particles. The current belief in physics is that it is a combination of the two, and as such demonstrates the physical properties of both. It was Albert Einstein who first said, "Whether light behaves like a wave or like a particle depends on how the light is observed (it depends on the experimental setup)!" (10).

If light is defined as a wave, it is best described as a transverse wave, which means that the wave front travels perpendicular to the direction of travel, similar to waves in the ocean. All electromagnetic waves however, are composed of two fields: magnetic and electric, each of which oscillates at right angles to one another. The electrical field coincides with the orientation of the wave and when the electrical field is vertical then the light is considered to be vertically aligned (10).

Typically, light is described by its wavelength, which is defined by the separation between two similar points, using either the wave peaks or the troughs. It may also be described in terms of its frequency, which is defined as the number of waves, which pass by a specific point in a specified period of time (7). If light is a wave, its properties permit it to be added or subtracted from one another. This can either be a complete or partial phenomenon depending if the wavelengths are equal in magnitude and if the two waves are propagating in or out of phase, (do the peaks and/or troughs coincide or are they opposite). These wave characteristics enable two light sources to be combined, when they are in phase and of equal wavelength, to produce a brighter light. As well, two light sources that are out of phase and of equal wavelength can be combined to produce darkness. These principles were first shown using double slit interference experiments and were referred to as constructive and destructive interference (7).

The particle theory of light is based on the principle that everything has mass, no matter how small the particle. This theory states that light is composed of minute packets of energy called photons; a photon being a particle of electromagnetic radiation. The difference between the particle theory and the wave theory is that photons travel in a straight line (10). The two theories are similar with respect to intensity, as an increased number of photons are equivalent to an increase in the frequency or a decrease in the wavelength. Sunglasses work by manipulating the properties of light, either by decreasing the number of photons transmitted (intensity of light) or by selectively transmitting and absorbing various wavelengths.

Science of Polarization

When we talk about light being polarized or unpolarized we are referring to the direction of travel of light waves and the orientation of their oscillations. The universe is made up of billions of light waves all propagating in different planes, and is known as unpolarized light. In order for light to become polarized, all of its wave fronts oscillating in the same orientation, the light must pass through a selective filter, undergo small particle scatter, or reflect from a smooth surface. It is light's electrical properties that permit it to become plane or linearly polarized and this phenomenon affects all wavelengths in the electromagnetic spectrum equally.

Ocular Health

i) Wavelength Effects

The visible light portion of the electromagnetic spectrum ranges between 380nm and 760nm depending on the source. The color of light that is perceived by the eye is determined by its particular wavelength. The long wavelengths within the visible spectrum begin with red and then progressively shorten through orange, yellow, green, blue, and violet. Shorter wavelengths, such as blue, begin the transition out of the visible light spectrum and into the ultraviolet range, but have been shown to cause adverse affects similar to ultraviolet. Figure 1, illustrates the types of interaction mechanisms and the potential adverse effects associated with each spectral band.

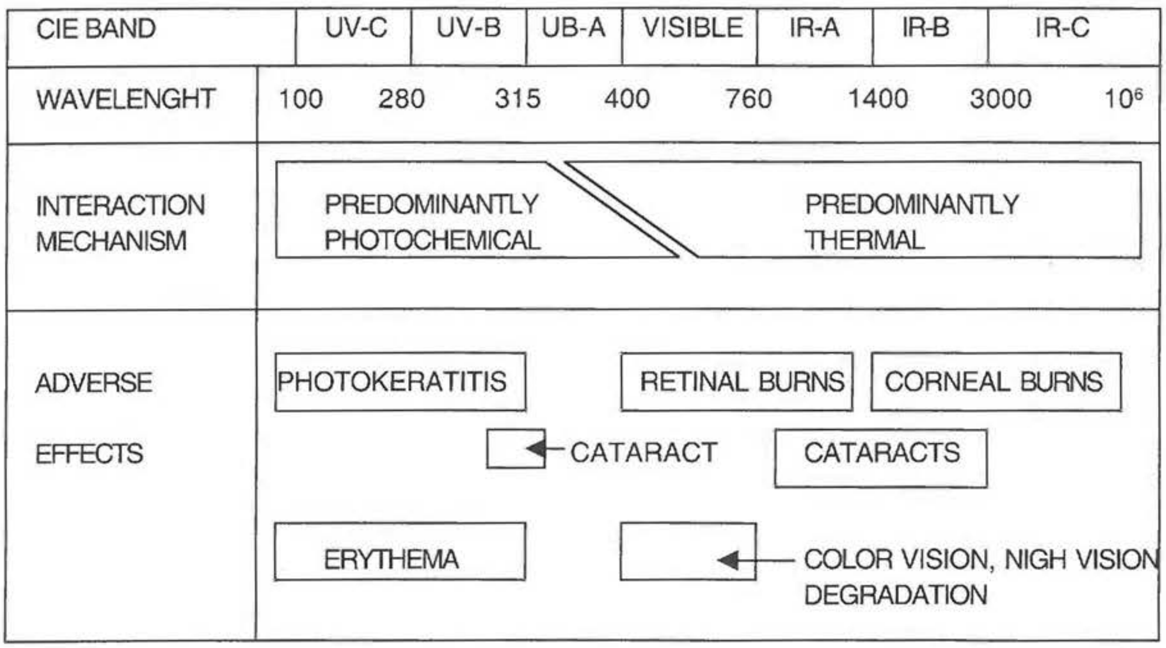

FIGURE 1: SPECTRAL BAND AND ASSOCIATED BIOLOGICAL EFFECTS WITH EACH SPECTRAL BAND (Adapted from Pitts & Kleinstein, 1993)

The lens and cornea of the eye play a vital role in absorbing high energy ultraviolet radiation that is incident on the eye and as a result helps to protect the retina from both photochemical and photo thermal damage. The negative impact of corneal and lenticular absorption of ultraviolet radiation is the potential formation of both cataracts and photokeratitis. Currently, premium sunglasses and other high quality ophthalmic lenses block virtually all wavelengths up to 400nms. This differs from clear ophthalmic lenses, which do not block all wavelengths up to 400nms (other than polycarbonate, which has UV blocking properties), and therefore it is vital for an Optometrist to prescribe an additional ultraviolet coating for these lenses.

ii) Filter Properties

All ophthalmic materials and tints have different absorption strengths within the visible spectrum. Some ophthalmic materials absorb longer wavelengths while other materials absorb shorter wavelengths and are known as selective absorbers. The color transmitted through the ophthalmic lens is the color perceived by the cortical centers responsible for our sensory perceptions. This implies that many sunglasses in the market place acts as a type of color filter that selectively absorbs some of the incident light while transmitting the remaining wavelengths. The result is that the spectral distribution of the light emerging from the filter isn't the same as the incident light on the filter, resulting in the transmitted light giving the filter its colored appearance (11). A neutral density filter has a flat transmission curve, which means that all wavelengths have the same transmission characteristics within the visible spectrum. This results in minimal color distortion as equal amounts of light are absorbed and transmitted.

Selective filter properties allow the Optometrist to customize the color of the lens for a patient's specific needs. The color of lenses that you prescribe your patient depends on the patient application. The polarized selective filters and the materials that are most available in today's polarized lens market are as follows: gray, brown and yellow, all of which are available in CR-39, glass, polycarbonate, and 1.56 high index (9).

iii) Environmental Glare and Applications

Without the proper eyewear, glare can be an unavoidable nuisance, resulting in visual discomfort and decreased contrast sensitivity. Typically, glare is divided into 3 types: disability, discomfort and reflection. Disability glare can result in decreased contrast sensitivity and inability to distinguish objects of regard. Disability glare is commonly the result of an intense point source of light directed towards the target of regard, washing out the desired visual information. For example, overhead lights can often bleach out text being observed on a classroom board or computer screen. The problem of disability glare arises due to the eye's inability to form a perfect image on the retina, because the eye is not an ideal optical system. This results in light being focused, in front of, on and behind the retina, as well as being diffracted into its principal colors due to the chromatic aberration of the eye. Discomfort glare is the result of the eye trying to cope with the sudden changes in brightness from the eye's adapted state to a much brighter situation or vice-versa. This phenomenon is common for people to experience on a daily basis, for example when you first turn the bathroom lights on in the morning. Other examples include looking at a television in a dark room, or observing a bright computer screen in a poorly lit environment. An individual, who attempts to look back and forth between the two different illumination levels, may experience visual discomfort, pain, and an inability to see until their eyes become adapted to the new light level. Reflection glare is the typical glare that most individuals are familiar with, and would describe if asked to define glare. It is the result of light being reflected from shiny surfaces such as roads, car windshields, water and snow. When light hits a refractive surface it will either be partially or completely polarized (12). In order for light to be completely polarized, the incident light must be exactly perpendicular to the reflected light (90degrees) which is known as Brewster's angle. Brewster's angle varies depending on the medium in which the light is traveling and the medium from which it is reflected (13).

Brewster's Angle:

$$\text{TAN (incident angle in degrees)} = \frac{\text{N2 (surface to be reflected off of)}}{\text{N1 (medium that light is in)}}$$

Of these different types of glare, regular sunglasses will reduce the discomfort experienced from all three of these sources, but are best suited for the first two. Non-polarized sunglass eyewear simply decreases the total light transmission to the eye. Polarized sunglasses reduce all three types of glare equally well. Polarized sunglasses work by decreasing the light transmission to the eye and through the elimination of polarized light found in reflection glare. As a result, instead of merely reducing the magnitude of the glare the glare is essentially eliminated, yielding tremendous benefits to a patient.

Advantages and Disadvantages

Are these lenses for everyone or only a select number of our patient's? Generally speaking, this type of eyewear can be worn by many who are currently enjoying the benefits of traditional sunglasses. More importantly, individuals who are in high glare environments may experience greater benefits. Examples of these environmental situations include: fishing, boating, water sports and driving.

As mentioned earlier, there are many positive aspects to wearing polarized sun-wear. Not only will they help to decrease eye irritation, fatigue, headaches and squinting they are a great option for contact lens wearers, sports enthusiasts and post cataract surgery patients (14). These patients may experience larger amounts of glare in their daily activities and can result in decreased contrast sensitivity more so than other patients. Polarized sunglasses can help to partially restore this loss in contrast sensitivity by minimizing scattered light entering the eye. Although polarized lenses appear to have numerous benefits, there are drawbacks to this modality.

Sunglasses that are designed to cut down glare through polarization do so by eliminating all but the desirable light waves. Many of today's electronic devices use similar filters (polarization) in order to create a clear glare free image for the viewer. If a person is wearing polarized sunglasses and encounters a device that transmits polarized light in a different meridian, this may result in the cancellation or severe reduction of light entering the eye and as a consequence will decrease the visual information seen by the observer (7). For example, this can manifest with the use of liquid crystal diodes (LCD) found on automobile instrument panels, palm pilots, and other electronic devices.

Another phenomenon that typically occurs in an automobile is the formation of stress patterns noticed in the side and rear windows, known as cross-hatching. Cross-hatching is a result of the automobile's windows being heat tempered for safety. This pattern is not noticed on the front windshield because it is laminated and not heat tempered (7). A similar optical pattern is seen on the windows of large commercial airplanes in which partially polarized light, from small particle scatter in the air, is incident on the cockpit window and interacts with the polarized filters he/she is wearing. The pilot may notice stress patterns in the side windows, which is the result of uneven cooling of the plastic, or unequal pressure exerted by the window frame (much like a plastic lens that is deformed into an ophthalmic frame). As a result, polarized lenses are typically not recommended for pilots, as these images may be disturbing. The mechanism behind these disadvantages is that light incident from the sun interacts with particles in the sky causing the light to scatter and become partially polarized, resulting in the previously noted perceptual phenomenons. Generally, polarizing lenses are best suited for situations where the reflecting surfaces are flat such as ice, snow, water, and road surfaces. Other activities like golf and alpine skiing, where the reflecting surface is irregular, can cause variability in the light transmission that can result in perceived changes in ambient light levels.

Conclusion

Polarized sunglasses tend to possess a higher price tag than regular sunglasses and some consumers may not initially be willing to pay the extra expense. By making use of well-informed opticians, this potential draw back can be reduced through appropriate patient education. Educating the patient of the many potential advantages of using polarized eyewear should begin in your exam chair and continue into the dispensary with the use of visual aids and demonstrations. When educating your office staff it is very important that they understand all of the benefits, such as decreased eyestrain, improved visual acuity, increased contrast sensitivity, and finally decreased optical glare. Furthermore, it is essential that office staff notify the potential customer that polarized eyewear is considered "performance eyewear." It has been found that when consumers understand that polarized sunglasses are categorized as performance eyewear, they will tend to have more price acceptance because the perceived value of the product is greater in the eyes of the consumer.

In summary, recommending and selling polarized eyewear to your patients will depend both on their daily activities and their primary need and your recommendations as a doctor. Prescribing sunglasses should be viewed no differently than prescribing medications for your patient care.

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