Accredited Standards Committee for Ophthalmic Optics

SPECTRAL BANDS TASK FORCE TECHNICAL REPORT

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Developed by:
ASC Z80 Spectral Bands Task Force

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Executive Summary

This Technical Report documents the discussion and decisions of the ASC Z80 Spectral Bands Task Force that was formed in April 2021 to develop terminology/nomenclature for the 380 – 500 nm spectrum of radiation. The scope of this task force was to drive consensus on terms; to provide an alternative to color labels, which are neither quantifiable nor verifiable; and to explore the ability to create sub-bands for the region. The scope included specific guidance to exclude extensive discussions aimed at determining the acceptable amounts of ocular exposure to radiation in this range. The original Spectral Bands Task Force Scope Statement is included in Appendix A. Still, technical arguments hinging on ocular health and safety were heard and discussed in an effort to identify appropriate band limits and rationales for those limits. Descriptions of these discussions are captured in this report. In conclusion, this task force achieved its goal to determine nomenclature for this radiation range and has developed the following band scheme: 380 – 500 nm is defined as High Energy Visible (HEV) light with sub-bands of 380 – 400 nm (HEV 3), 400 – 455 nm (HEV 2), and 455 – 500 nm (HEV 1). This task force also recommends that any HEV claims be accompanied by a transmission spectrum for the full range of 380-500 nm and percentages of transmission for all three sub-bands. It is anticipated that the adoption of this scheme and claims guidance will aid orientation of future discussions about radiation in this range and will enable the industry to better understand the impact of HEV light through the usage of standardized vocabulary.

Background

Discussions and studies about the impact of electromagnetic radiation in the range of 380 – 500 nm on eye health have steadily increased over the last 20 years. Research is ongoing to elucidate its impact; product development in response to current understanding is in full swing; but this understanding of what is useful/necessary from a product standpoint is still evolving. One main stumbling block to true understanding and consensus is the lack of common language in the industry. When discussing the impact of radiation within the range of 380 – 500 nm, many different terms are used: blue light, violet light, blue-turquoise light, high energy visible light, near UV light, etc. In many cases, the terms are offered, but the exact range of radiation is not given and also assumed. This assumption is made in the literature and

in product marketing; statements of blocking or filtering light are made with no real delineation of the intended range.

Efforts to understand the impact of this radiation are shunted by the dearth of language and lack of standardization of terms. In the case of utilizing color terms, many discussions become sidetracked, departing from determining impact of radiation into a discussion of color that depends on human perception and may never reach agreement between humans on what is truly the delineation between 'blue-violet or blue-turquoise', for example. These tangents distract from scientific progress in the field. To move forward we must develop a foundation upon which to build our understanding, and the first step in that effort is the determination/standardization of language used to enable alignment of scientific concepts. This shared vision was the basis for the Spectral Bands Task Force – to develop nomenclature for radiation in this range of 380 – 500 nm to help clarify existing work and to enable future understanding of its impact moving forward.

Existing Standards, Guidelines, and Former Efforts

While the objective of the task force was to discuss the range of 380 - 500 nm, it is interesting to first consider the many standards that address electromagnetic radiation in general and the nomenclature associated with different ranges of radiation. **ISO 20473** – Optics and Photonics – Spectral Bands (1st ed., 2007) [1] supports "the delimitation, designation and description of the spectral wavelength regions of optical radiation for applications in the field of optics and photonics." It defines visible light to have the wavelength range of 380 – 780 nm, and unlike the ultraviolet and infrared radiation bands in the standard, it does not attempt to subdivide the visible range into narrower spectral bands. **ISO 21348** – Space Environment (natural and artificial) – Process for determining solar irradiances (1st ed., 2007) [2] does divide visible light into narrower bands and labels them by color. In comparison to ISO 20473, the visible range has a different upper limit and is defined as 'optical' with the wavelength range of $380\ nm \leq \lambda < 760\ nm$. It is also interesting that radiation of wavelengths smaller than 500 nm is defined according to the following sub-bands: $360 \leq \lambda < 450$ (purple) and $450\ nm \leq \lambda < 500\ nm$ (blue). While this standard does have terminology to address the region of interest, it has overlapping bands with those commonly used in ophthalmics which may lead to a lack of clarity. In addition, the color terms leave this range vulnerable to tangential discussions regarding human perception as described earlier.

From its inception through to current editions, **ISO 8980-3** – Optics and Photonics – Ophthalmic Optics – Uncut finished spectacle lenses – Part 3: Transmittance specifications and test methods [3], refers to the visible range to guide determination of luminous transmittance of spectacle lenses. Annex E of ISO 8980-3 further defines blue light transmittance by reference to the blue light hazard function, taken from the 1995-1996 guidance of **ACGIH** for threshold limit values and biological exposure indices [4], which comprises the wavelength range of 380 – 500 nm. **ANSI Z80.3** – Ophthalmics – Nonprescription Sunglass and Fashion Eyewear Requirements [5] also refers to the blue light hazard function comprising 380 – 500 nm.

The CIE (International Committee on Illumination) defines the blue light hazard in **CIE S 017** – ILV: International Lighting Vocabulary [6] as retinal injury related to exposure to wavelengths 400 – 500 nm with a note indicating that "the action spectrum extends into the UV-A for persons without a normal UV-A absorbing lens," [6]. As a sidenote, this concession for the wavelengths 380 – 400 nm is one of many examples of contention regarding these 20 nm of radiation which many believe should be considered UV and many others believe should be considered visible; this will be addressed later in this report. The CIE provides free access to all terms and definitions contained in CIE S 017 through the e-ILV [https://cie.co.at/e-ilv] [7]. At this site, the terms related to 'blue light hazard' are terms 17-26-055 thru 17-26-063 [7], and are not so much categorical definitions, as they are definitions of hazard from exposure to light in the near UV range. Different from the efforts described in this technical report, these CIE terms do not indicate a band scheme, nor do they provide sub-bands as is done for both UV and IR with terms for UV-A, -B, and -C (17-21-009, 17-21-010, and 17-21-011, respectively) [7], and IR-A, -B, and -C (terms 17-21-005, 17-21-006, and 17-21-007, respectively) [7].

The range of wavelengths of 380 – 500 nm referred to in these standards as the blue light hazard region was discussed in more detail in **ISO/TR 20772:2018** Ophthalmic optics – Spectacle lenses – Short wavelength visible solar radiation and the eye [8]. This technical report provides information about the science available on the subject up to the time of publication due to "ongoing concern about unverifiable spectacle lens and sunglass marketing claims for blocking wavelengths near to and greater than 380 nm…". While the report discusses much about the impact and considerations of radiation in this range, it does not suggest a band scheme for this region of radiation, nor does it provide a name for the region other than the 'blue light hazard'. It does cite the work of project groups for **ISO 13666** [9] and **ISO 4007** [10] to develop definitions in this space. These project groups were interested in developing definitions that standardized not only terms, but also inherent to those terms,

thresholds of radiation in this range. In the end, definitions were not developed: “it was ultimately not possible to reach agreement” [8].

In all these efforts and standards, definitions regarding the wavelength range of 380 – 500 nm, did not successfully strike to the heart of the issue of simple nomenclature as a first step. Instead, the efforts coupled terms with the ocular impact of the radiation. This tendency is completely reasonable and was fully experienced throughout the meetings of this task force. It took restraint to hear clinical considerations without delving too deeply into what was appropriate for safety. It also required constant realignment on the scope to redirect focus away from extensive clinical impact discussions when they would inevitably occur. Still, the Spectral Bands Task Force endured to decouple, as much as possible, the term from the impact, utilizing the latter minimally as rationale for band limits.

Band Scheme Discussions

Over the course of 8 meetings and 2 years, the Spectral Bands Task Force had many discussions regarding the problem statement, current standards and efforts, rationales for band limits, considerations of the impact radiation, issues in the ophthalmic industry as well as other industries, and possible unintended consequences. This report attempts to summarize those discussions and convey the extent of exploration on behalf of this team to consider this range of radiation from all perspectives, to be duly diligent in the development of meaningful definitions, and to gain consensus on standardized nomenclature. Figure 1 shows the culmination of those discussions as they relate to the band scheme that gained consensus in the context of other categories of electromagnetic radiation.

The first stage of alignment was the confirmation of the band of interest as 380 – 500 nm. Ample discussion was entertained regarding the appropriate lower limit of interest, be it at 380 or 400 nm. The discussion centered on the definition of ‘visible radiation’ or ‘light’ as “any optical radiation capable of causing visual sensation directly” [9]. Many felt that the wavelength bounding the lower end of this range is 380 nm, while others felt that it is 400 nm. In the end, the group agreed to choose 380 nm as the lower limit for this banding exercise. This decision hinged on the fact that many standards in the ophthalmic space cite 380 nm as the lower limit for visible light; it was the desire for any future bands to be continuous with other banding schemes.

The confirmation of the upper limit required less discussion. As this initiative was scoped to manage terminology encompassing 'blue light', it was natural to choose the wavelength bounding the blue light hazard function. **ISO 15004-2** – Ophthalmic instruments – Fundamental requirements and test methods – Part 2: Light hazard protection [11], contains a table in the annex with weighting functions for aphakic photochemical hazard in addition to the blue light hazard. This table provides support to the idea of 500 nm being the upper limit as it shows that damage becomes nominal for energies with wavelengths above 500 nm. Based on this data that radiation around 500 nm and below is sufficiently energetic to physically change a cell while that above quickly falls off in terms of impact, the team felt this was a reasonable rationale for the choice of 500 nm as the upper limit.

Another area of alignment was agreement on a term to encompass this range of radiation: 380 – 500 nm. The phrase High Energy Visible (HEV) light was initially offered, but many options were discussed including those with color in the title. Some felt the need to preserve color in the term to ease communication, to build an inherent connection and 'feel' for the term. After extensive discussion, the prevailing thought was that this rationale was the very basis for moving away from color, as it hinges on human perception and can lead to assumption and misalignment. In the end, 'High Energy Visible (HEV) light' was accepted as the overarching term for the band of radiation 380 – 500 nm. It is emphasized that the use of term, 'energy', in the HEV label describes the energy per photon, which is higher at shorter wavelengths. This energy is not to be confused with the total energy contained within a light source.

The committee of experts was tasked to assess and make recommendations regarding the subdivision of the HEV spectral range into 2 or 3 sub-ranges. The group considered rationales rooted in different branches of science and technology: from the clinical aspect by considering the biological responses and cascades stemming from radiation in this range; from the physical aspect by considering limits according to energy amounts and electron volts; and finally, from a technological aspect considering what is easily measured and/or what is most useful for products in the marketplace. Most rationale discussions tended toward the clinical to underpin the ranges of interest. A few examples of such clinical considerations are noted below. Each example is a state of impact due to exposure to radiation in this range and each is followed by how a band scheme could communicate this impact.

1. Retinopathy – a scheme to delineate ranges of radiation that lead to retinopathy

    a. Acute exposure
    b. Cumulative exposure
    c. Combined acute and cumulative exposure
    d. Periodicity of exposure - fatigue
    e. The many different conditions that constitute exposure
        i. Viewing solar eclipse
        ii. Viewing welding arc
        iii. Looking near the sun with binoculars
        iv. Normal sunlight much less energy than those hazardous environments
        v. Lower still, energy from electronic devices in this spectral region
2. Temporary versus permanent damage - a scheme to delineate regions of irreversible damage
    a. Wavelength and energy combinations resulting in temporary damage
    b. Wavelength and energy combinations resulting in permanent damage
3. Impact on ophthalmic structures and function – a scheme to delineate impact on different ocular tissues
    a. Biological impact – impact to different tissues
        i. Many bands, each based on the effect on different tissues
        ii. Range centered on wavelength of greatest impact and then range determined by choosing a given threshold percentage.
    b. Performance impact
    c. Impact as a function of time
    d. Impact as a function of age
4. Impact on circadian rhythms – a scheme to delineate regions that hinder and promote natural circadian rhythm
5. Impact for eyes with and without a natural lens – a scheme to highlight the hazard for eyes with and without a natural lens
6. Band schemes tied to the type of device in question – schemes to delineate specific needs for different types of products according to device considerations, e.g., ranges of interest that may differ for aphakic and pseudophakic patients vs. contact lens wearers.

Each of these areas generated productive discussion and identified areas for further work to understand the impact of HEV light. Each indicated a different action spectrum which when overlayed produced a veritable continuum of bands. For example, multiple anterior and posterior ocular structures absorb photons within this range, and quantified filtering within these three sub-bands may not have unique impacts on any one structure. There was no simple scheme that could fit all clinical considerations and the more that these ideas were considered,

the more granular the group felt a scheme would need to be to be inclusive. This line of discussion started to depart from the objective of developing a simple scheme to communicate orientation to a detailed course of study to better understand impact of radiation. This characterization of the group's discussion, which was the case at many points, is to emphasize that the development of meaningful nomenclature for this region was not taken lightly and was thoroughly considered from many angles. As this task force was not scoped to fully explore the impact of radiation, the above discussion points are captured in this summary for consideration of future work in this area.

Unintended Consequences and Claims

While opining on the benefits and usefulness of a banding scheme, the group also spent time discussing unintended consequences. As the nomenclature was intended to be meaningful, there was concern that an unintended meaning could arise from any scheme chosen. It was remarked that banding could communicate levels of safety, even if that was not the intent of the exercise. There was concern that the development of bands would obscure the hazard from smaller ranges within; that such banding would result in misleading claims. The hypothetical apprehension was that the banding would lead patients into thinking they were protected from a hazard by claims of blocking/filtering in a band when in fact the product would not offer sufficient protection from a specifically harmful set of wavelengths within that band. The overall unease with the exercise was the fear that banding would oversimplify the impact of radiation in this region enabling consumers of this scheme to wrongly characterize one band as wholly 'bad' while another band as wholly 'good' and claims of blocking/filtering in these bands could be used indicate a safety profile that would be incomplete.

In order to address this concern, the task force decided that in addition to banding, guidance on the usage of such a band scheme for claims should also be provided. The task force felt that when making claims regarding the blocking or filtering of radiation in the range of 380 – 500 nm, a transmission spectrum for the *full range of 380 – 500 nm* needs to accompany those claims. The full range spectrum is recommended whether the claim is regarding the full range or simply a subset of wavelengths within that range. As the impact of radiation in the range of 380 – 500 nm is so various, depending on the spectrum of the radiation, as well as the entity experiencing this radiation, any measure would be incomplete if only communicating blocking/filtering in terms of percentages or if only providing transmission spectra for a subset of

this range. Therefore, it is recommended that HEV claims be accompanied by the transmission spectrum for the full range of 380 – 500 nm radiation.

Breadth of Industry

While most of the members of the task force were working in the field of ophthalmics, members of the display technology industry were also represented. The concern for HEV light was in all cases one of impact of the radiation, but for many, it was from the perspective of radiation transmitting *through* a device as opposed to radiation emitted *from* a device. The display technology industry, being concerned about the impact of radiation emitted from devices, brought forward points regarding the requirements of chromatic contrast and a maximization of vision enhancing radiation while simultaneously minimizing harmful radiation. The team largely benefitted from discussion about the work in this industry, specifically by exposure to the Radiance Protection Factor (RPF®). Developed by Eyesafe, RPF helps convey the blue light (i.e., HEV) protection provided by a display [12]. It is based on the blue light hazard weighting function [5] and has been adopted by TÜV Rheinland and leading electronics companies. This simple metric provides a rating system "to help end-users identify and compare blue light emissions from a device at a specific brightness level (200 nits)" [12]. RPF is based on research and supported by leaders in the eye care community. While discussion of this RPF system opened up new directions on the topic, in the end it was decided that this system was one step beyond the development of simple nomenclature and was not pursued further.

HEV Band Scheme

After almost 2 years of discussion, the Spectral Bands Task Force gained consensus to name the 380 – 500 nm range of radiation High Energy Visible (HEV) light and to divide the range into 2 – 3 bands. The consensus also included the guidance that claims made regarding HEV should require disclosure of the transmission spectrum for the full HEV range. The remaining work was regarding the determination of sub-bands, at what wavelength(s) to form the band(s), the rationales to support the banding, and what to call them.

As the blue light hazard function was a common point of discussion, it was invoked at one point to provide a basis for bands, specifically, utilizing thresholds on this curve to create bands. In one case, a band could be formed by considering all radiation with an impact of

greater than some percentage, and the other two bands would be those on either side of this central band. For example, if one considers the blue light hazard function [3] and draws a threshold at 80% and considers all radiation with impact of greater than 80% to comprise its own band, this band would be from $415 \leq \lambda \leq 460$. This is shown in Figure 2. By consideration of the overall range of 380 – 500 nm, this then creates three bands: 380 – 415 nm, 415 nm – 460 nm, and 460 – 500 nm. If one were to consider the threshold to be 90%, the three bands would be: 380 – 420 nm, 420 – 455 nm, and 455 – 500 nm. Alternatively, as shown in Figure 3, one could utilize the same approach to create two bands by taking the upper wavelength for this threshold percentage and dividing the range into two. This banding would then define the two bands as one with wavelengths inclusive of radiation above this threshold and the other with wavelengths of energy all below that threshold. For example, the two band schemes considering the thresholds just mentioned would have bands of 380 – 460 nm and 460 – 500 nm in the case of 80% and 380 – 455 nm and 455 – 500 nm in the case of 90%.

In all these schemes utilizing the blue light hazard as the sole rationale for sub-bands, the band of highest energy bounded on the low wavelength end by 380 nm was felt to be too broad. It was felt that there needed to be narrower ranges for bands near the demarcation between UV and Visible. To this end and after much discussion, the group decided to depart from the use of the blue light hazard to underpin the highest energy band and aligned on choosing an upper demarcation based more historical need. As aforementioned, the radiation in the range of 380 – 400 nm has long been contested as visible light. Choosing this range as a band unto itself enables discussions such as these to account for it, to further define it, and to describe it. Essentially, having this range of 20 nm as a stand-alone band alleviates some of the extra effort that has gone into notes and caveats throughout standards and technical papers to explain why it is or is not included in the study of interest. Moving forward, alignment can be made on the limit of UV at 380 nm followed by a sub-band of HEV from 380 – 400 nm.

This choice of 380 – 400 nm as a band of HEV left the range of 400 – 500 nm to consider. It was decided to break up this band into two and the rationale for the wavelength at which to divide the range was tied back to information provided in the ISO/TR 20772 [8]. The report cites work done by Arnault and Diaz [13] as the photobiological state of the art at the time which identified the range of 400 – 455 nm as a “harmful blue bandwidth” for age-related macular degeneration [13]. While many meetings and discussions had pointed out the seeming oversight of a band scheme to the multitude of biological responses by focusing only on the impact of one – in this case the range of radiation most contributory to age-related macular

degeneration – the need “to start somewhere” at this stage of the process overshadowed this concern. This demarcation line at 455 nm resonated with the work done by other companies represented in the task force, as well as discussions held by a prior roundtable on the subject [14], and it was felt to have a stronger rationale and historical alignment in comparison to the other possible wavelengths of demarcation, 450 nm and 460 nm.

Having determined the band scheme, the final task was to determine the naming of the bands. The naming of the bands was decided to be consistent with UV and IR to keep the larger level name of the radiation in each band and distinguish by a letter or number. As UV and IR are delineated by different letters, it was decided to delineate bands of HEV with numbers to distinguish visible radiation from non-visible radiation. The order of the numbers was then chosen to correlate with the energy of the wavelengths in the bands such that the higher the energy of the wavelength, the higher the number of the sub-band. This resulted in the following scheme: HEV (380 – 500 nm) with sub-bands of HEV3 (380 – 400 nm), HEV2 (400 – 455 nm) and HEV1 (455 – 500 nm) shown in Figure 4. Figure 5 illustrates the final HEV band scheme overlayed with the blue light hazard function.

Conclusion

In conclusion, while many ideas were discussed, the group kept coming back to a similar conception of a scheme that would be relatively simple: one overarching band to encompass the wavelength range of 380 – 500 nm, and two to three sub-bands that did not overlap by more than 1 nm and that were continuous to other standards in the ophthalmic space. Consensus was reached for the following band scheme: HEV (380 – 500 nm) with sub-bands of HEV3 (380 – 400 nm), HEV2 (400 – 455 nm) and HEV1 (455 – 500 nm). It is the recommendation of this task force that standardization of this nomenclature come with additional guidance for claims regarding HEV. This guidance is to require the provision of a transmission spectrum over the full HEV range and the reporting of transmission percentages in all three sub-bands of the scheme. In this way, the full impact of the spectrum may be understood, as well as give orientation as to the general nature of the radiation in question. This task force was formed to define terms to be used by individuals and organizations as they conduct studies and report outcomes, standardizing the language used and allowing us to start to build knowledge bringing definition to this range of radiation. It is the intent of this task force to begin to help clarify what

is being described in articles and claims and to help move the industry forward in its understanding of the impact of HEV.

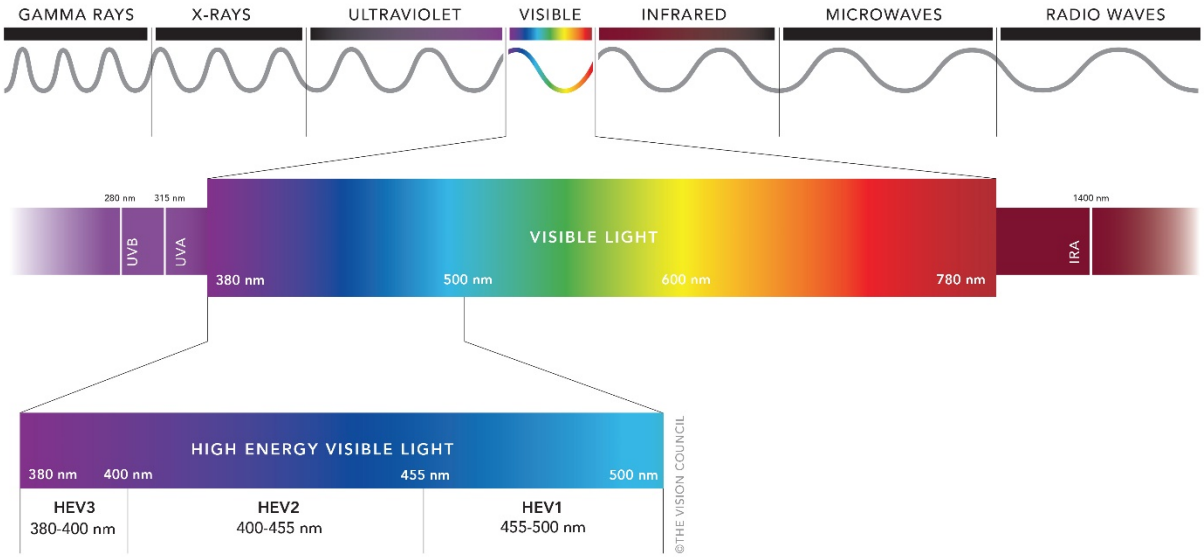

Figure 1: High energy visible (HEV) light in the larger context of categorized electromagnetic radiation.

Figure 2. HEV Band Scheme Discussion - Proposal A

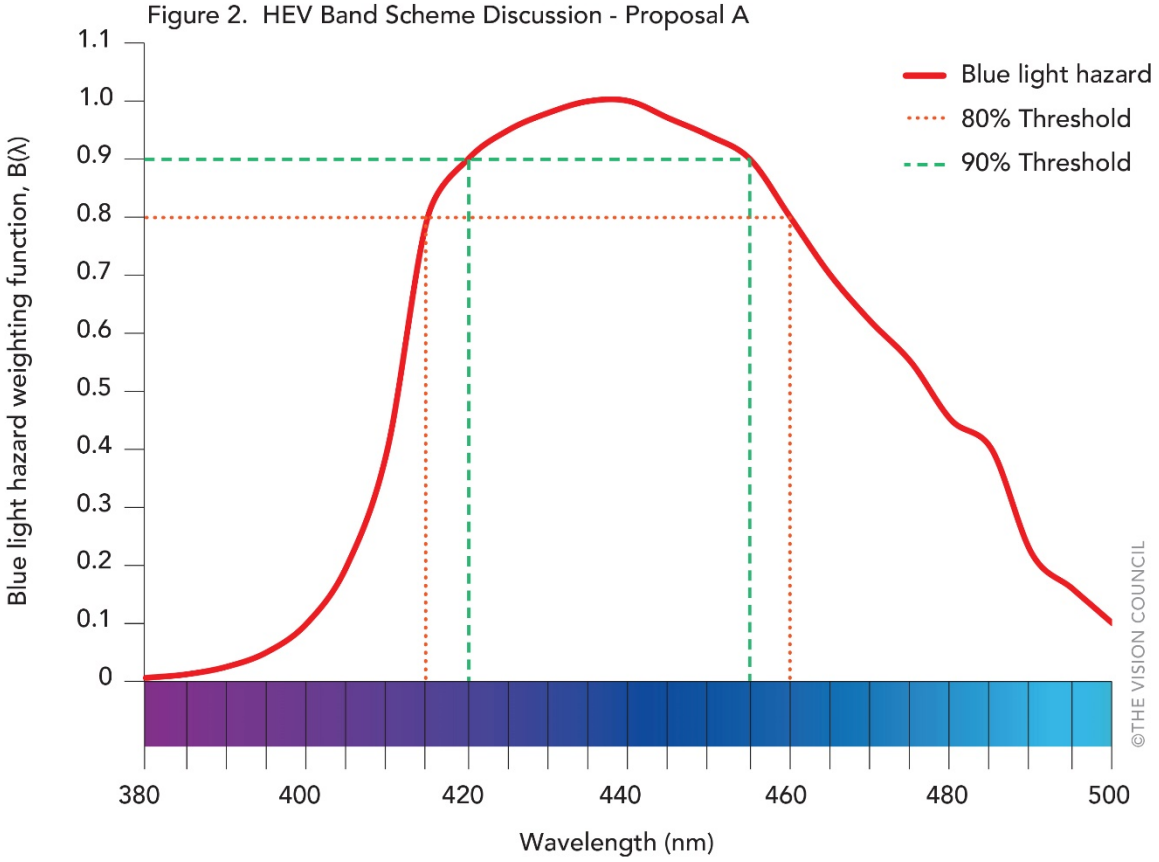

Figure 2: Three wavelength regions defined by percentage thresholds of the blue light hazard weighting function, B(λ) [3]. The short-dashed lines show a region defined by considering a blue light hazard weighting function of 80% or greater. This occurs at wavelengths between 415 nm and 460 nm. This threshold consideration results in 3 bands: 380 – 415 nm, 415 – 460 nm, and 460 – 500 nm. Similarly, the long-dashed lines show the band scheme that falls from a consideration of a 90% threshold.

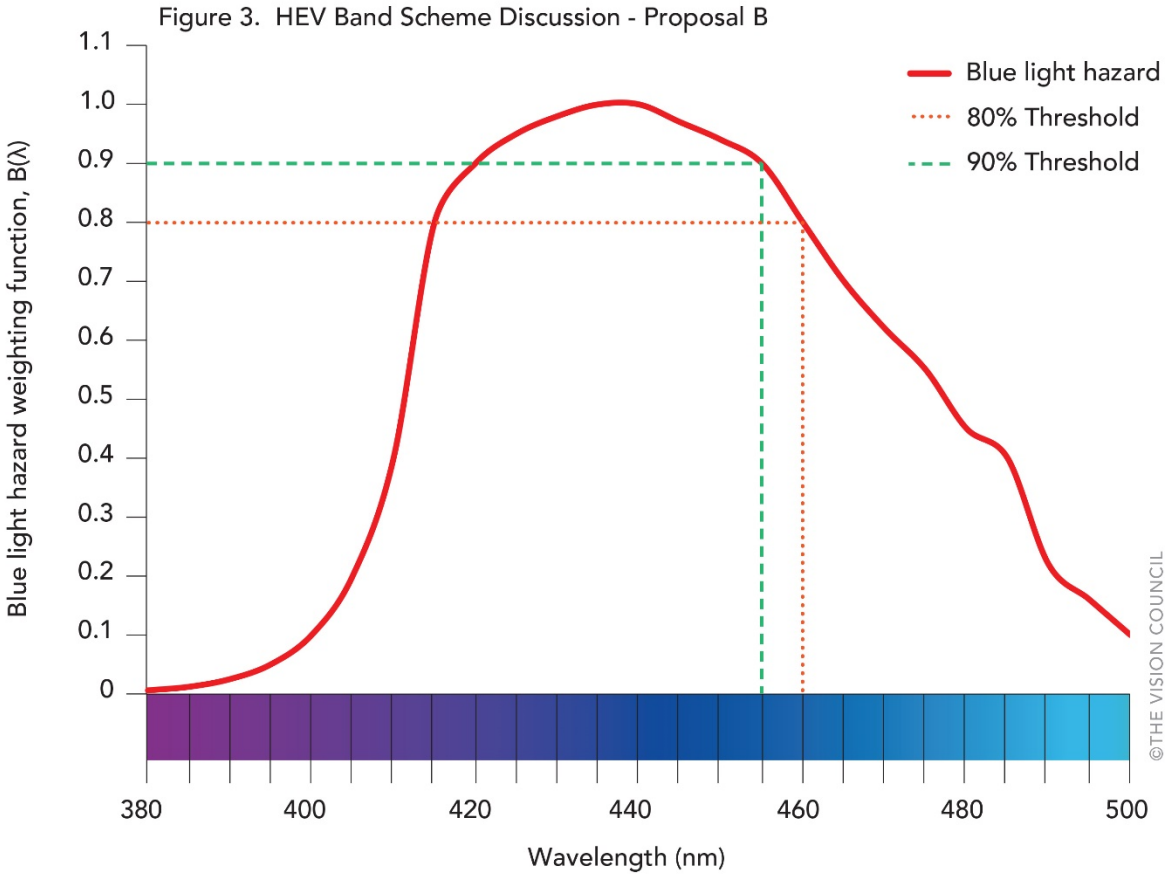

Figure 3: Two wavelength regions defined by percentage thresholds of the blue light hazard weighting function, B(λ) [3]. The short-dashed line shows the bisection of the HEV region at the upper wavelength of an 80% threshold consideration on the blue light hazard weighting function. This threshold consideration results in a 2-band scheme: 380 – 460 nm and 460 – 500 nm. Similarly, the long-dashed line shows a 2-band scheme that falls from a consideration of a 90% threshold.

Figure 4. Final Scheme

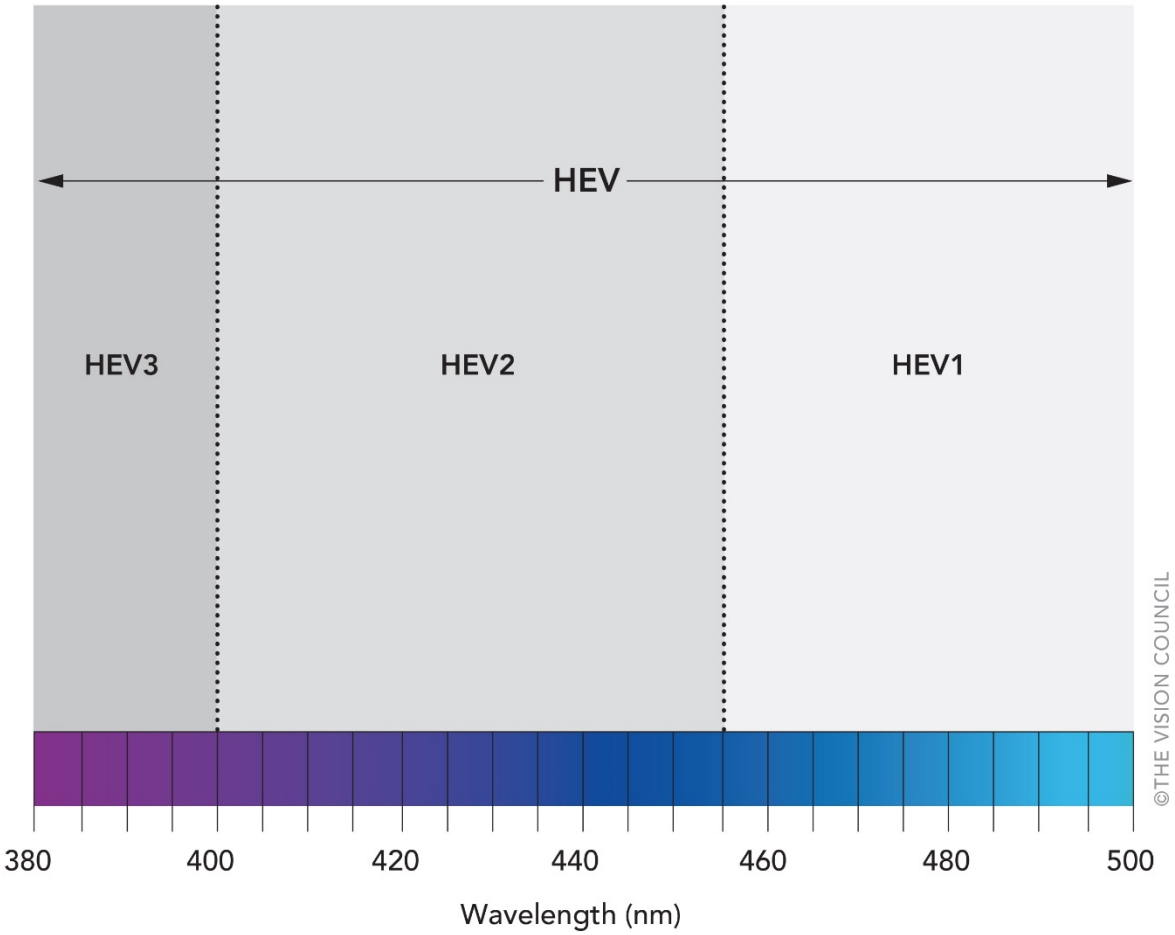

Figure 4: HEV band scheme developed by the ANSI Z80 Spectral Bands Task Force. This figure shows high energy visible (HEV) light to comprise the wavelengths of 380 – 500 nm with sub-bands of HEV3 (380 – 400 nm), HEV2 (400 – 455 nm) and HEV1 (455 – 500 nm).

Figure 5. Final Scheme with blue light hazard

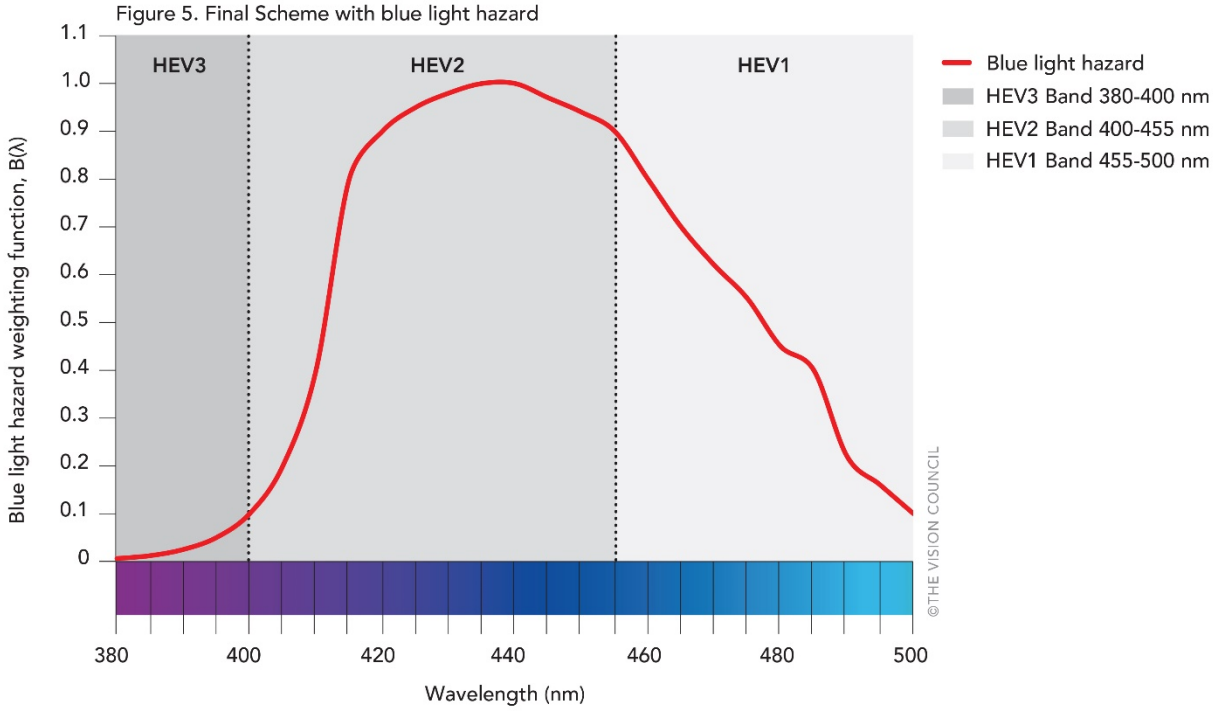

Figure 5: HEV band scheme developed by the ANSI Z80 Spectral Bands Task Force overlayed with the blue light hazard function.

Appendix A

ASC Z80 Spectral Bands Task Force

Scope Statement

The scope of this task force will be for the ASC Z80 Standards group to gain consensus and determine a range of wavelengths within the visible radiation range, suggested 380 – 500 nm, that can be labeled as High Energy Visible (HEV) Light.

A standardized definition of an HEV range will aid discussions of the impact of such radiation by providing a category of reference for study and comparison. Such taxonomy will also help discussions by eliminating confusion stemming from the meaning of human perceptive color labels such as ‘blue’, ‘purple’, or ‘violet’.

The task force will consider current standards that refer to high energy radiation, such as the blue light hazard, to ensure that determination of an HEV range is harmonized with these definitions and calculations.

While a determined range/category will help facilitate and align future discussion, the scope of this task force will NOT be to determine the clinical health or safety of exposure to any amount of light in this range. The many discussions in the literature that aim to elucidate the effects of light in this range may be called upon by this task force for reference, but only in so much as they may provide suggestions for a range of interest. These references will not be used to inform as to whether any particular amount of radiation in this range is ‘good’ or ‘bad’, nor will it be the goal of this task force to determine or discuss what amount of radiation in this range is appropriate for any specific condition.

The goal will simply be to propose a range of wavelengths and any subdivision therein that is useful as a standard category, proposed label at the outset as High Energy Visible (HEV), and that does not interfere with the classifications and calculations of light for any other activities in any other related standards.

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[1] ISO 20473 – Optics and Photonics – Spectral Bands (1st ed., 2007)

[2] ISO 21348 – Space Environment (natural and artificial) – Process for determining solar irradiances (1st ed., 2007)

[3] ISO 8980-3 – Optics and Photonics – Ophthalmic Optics – Uncut finished spectacle lenses – Part 3: Transmittance specifications and test methods

[4] American Conference of Governmental Industrial Hygienists (ACGIH), *TLVs and BEIs Based upon the Documentation of the Threshold Limit Values for Chemical Substances and Physical Agents and Biological Exposure Indices for 2023,* American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 2023.

[5] ANSI Z80.3 – Ophthalmics – Nonprescription Sunglass and Fashion Eyewear Requirements

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[7] e-ILV at https://cie.co.at/e-ilv

[8] ISO/TR 20772:2018 Ophthalmic optics – Spectacle lenses – Short wavelength visible solar radiation and the eye

[9] ISO 13666 – Ophthalmic optics – Spectacle lenses – Vocabulary

[10] ISO 4007 – Personal protective equipment – Eye and face protection – Vocabulary

[11] ISO 15004-2 – Ophthalmic instruments – Fundamental requirements and test methods – Part 2: Light hazard protection

[12] Defining Blue Light Requirements for Digital Displays, Eyesafe, White Paper, 2022, https://eyesafe.com/standards; *How to Save Your Eyes in the Digital Age,* Friess et al. 2022 https://eyesafe.com/handbook, pp. 147 – 148.

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