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Contrast Enhancing Filters in Ski Sports

ABSTRACT: The need to visually recognize irregularities in the terrain, such as hummocks or hollows, is necessary for the skier to react appropriately. The state of the art is to use blue attenuator filters or grey filters as sunglasses. But without knowledge of the spectra, e.g., the surface of the slope, it is impossible to choose or develop an optimal filter. We measured the spectra of snow under various conditions. These data served as a base to develop a new kind of filter suitable for skiing. Some physiological evidence is given why this new kind of filter is optimal for skiing. The filters are already used by the German Ski Federation World Cup team (women) in both training and competition.

KEYWORDS: contrast perception, color vision, skiing goggle, safety in winter sports, alpine skiing

Introduction

Varying light conditions or contrasts and lower contrast visibility (e.g., due to overcast skies, fog, or snowfall) place high demands on concentration and visual efficiency. It may be reasonable to assume that better contrast perception can improve performance in ski sports and possibly serve to reduce the injury rates amongst skiers who see well. The need to visually recognize irregularities in the terrain, such as hummocks or hollows, or problematic skiing conditions (icy sections) quickly, even at high skiing speeds, is necessary for the skier to react appropriately. This is reflected in the high demands made on the skier's visual acuity.

For many years, manufacturers of skiing, gliding, shooting, and cycling goggles have been among those recommending the use of color filters (goggle glasses/visors) specifically to improve contrast sensitivity in diffuse (hazy-misty) light conditions. For instance, yellow spectacle glasses in particular are ascribed a "contrast-enhancing" function, as they filter out the exceptionally diffusing blue portion of the light [1,3–8,10,11].

In field investigations in Valmorel (France) and Kaprun (Austria), an attempt was made to analyze more closely correlations between visual acuity and perceptive power on the slope from accident-prevention and injury-prevention aspects. For this purpose, a "perception test" was designed in which the participants have to recognize accident-relevant "danger points" (irregularities in the terrain or ground): Figure 1 shows the test field in which ground irregularities, such as hummocks or hollows, were prepared to the left and right, respectively, of a marking (distance signs no. 1–10) at various observation distances (5–50 m). From the point of view in Fig. 1, the subjects had to identify these "danger points" classified according to their "spatial depth" (before or after the sign, or at the level of the sign) [2,3]. For example, at the left

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side of sign no. 2, there is a hollow located 0.5 m farther away from the point of view than the sign no. 2 itself. At the right side of sign no. 2, there is a hump at the same distance as the sign. The subjects had to identify the kind of the "danger point" (hummock or hollow) and its position in relation to the sign (same distance, nearer, or farther). This experiment was done with several commercial filters. Best results were achieved with blue attenuating filters.

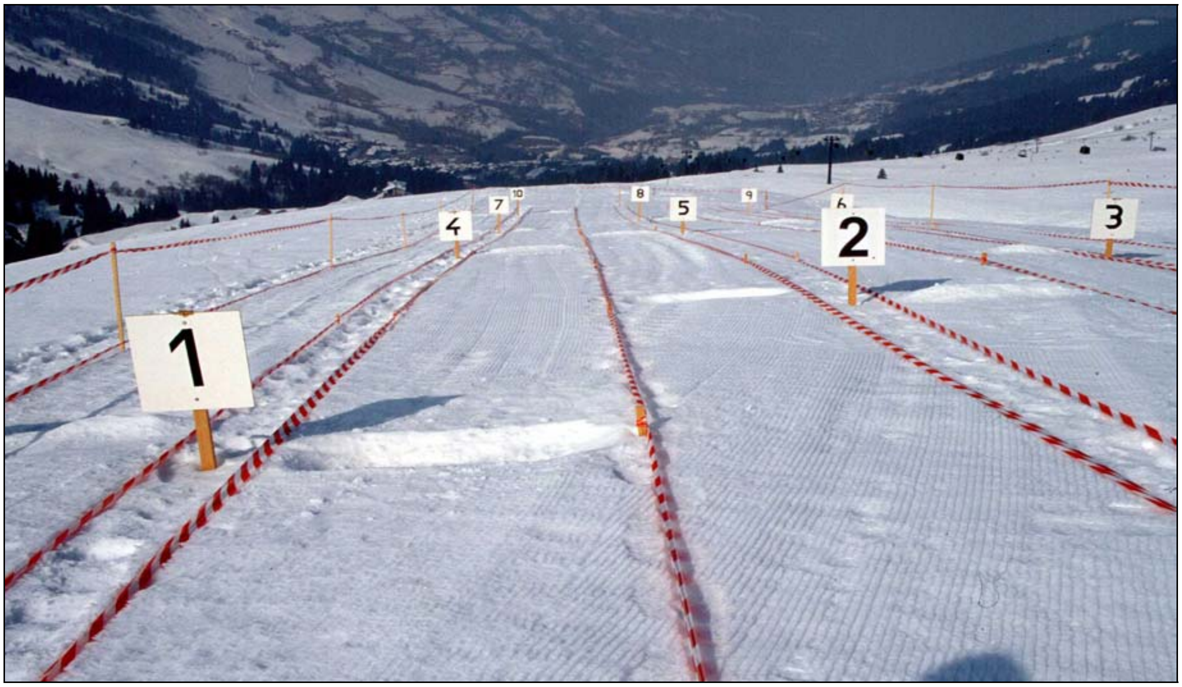


FIG. 1—*Test field in which ground irregularities such as hummocks or hollows were prepared to the left and right, respectively, of a marking (distance signs no. 1–10) at various observation distances (5–50 m). The subjects had to recognize these "danger points" classified according to their "spatial depth" at the level of the sign [2,3].*

Method

In a new approach, a spectral photometer (Minolta CS-S1w) was used to record wavelength spectra of the hollows and humps of the test field in Fig. 1. At sign no. 2 it is obvious that the hollow to the left of the sign is brighter than the hump to the right, due to the special weather conditions. Not only is their brightness different, but the spectral distribution of the hollow is different to that of a hump, even if both are of nearly the same brightness. Only in fog conditions does the difference of the spectra vanish.

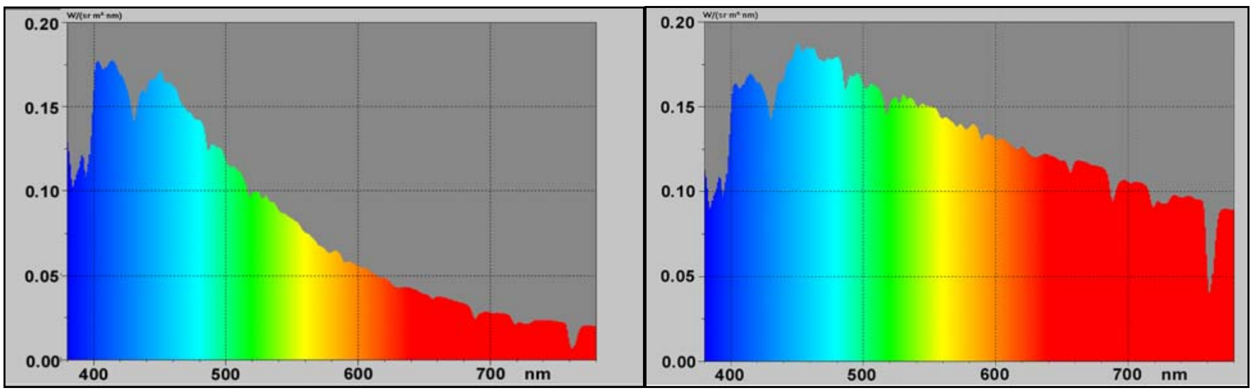
Measurements of the spectra were used to develop a mathematical model to configure and later manufacture new filters optimized to these ski-specific contrast conditions. The effectiveness of these newly developed filters was tested in field studies (in Valmorel, France 2002). The subjects had to rate several filters concerning contrast, distortion of color, and ease of seeing during skiing. Also, a visual performance test like that described in Fig. 1 was done with several commercial filters and the new filter.

Essential Results

The Color of Snow

Physically, the color of snow is blue and not white. It is the visual system which shifts the perceived color to white. Snow is illuminated by the blue sky. In the spectrum of the blue sky, of course most energy is concentrated in the blue range, which corresponds to a wavelength from 380 nm to about 500 nm (Fig. 2*a*). Therefore it is no wonder why also in the spectrum of snow the maximal energy is concentrated in the blue range. Figure 2*b* shows the typical spectrum of snow. The blue scattered light reduces information. All colors in every natural scenery are shifted toward blue. The colors are desaturated.

A blue attenuator filter can compensate for this effect. If blue is taken out, the colors become saturated again. Today blue attenuators are standard as so-called contrast enhancing filters.



(a) (b)

FIG. 2—*Spectral power of the sky (*a*) and of snow (*b*).*

Different Kinds of Filters

As a simplification, we divide filters into three categories, which are neutral filters (grey filters), blue attenuators, and blue blockers.

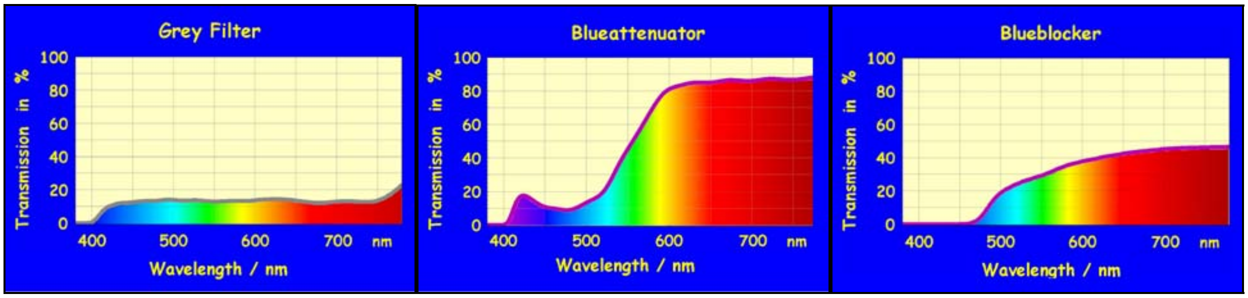
In a neutral filter the transmission is nearly constant for all wavelengths (Fig. 3*a*). The advantage of a neutral filter is that no color distortion occurs.

"Blue attenuators" (Fig. 3*b*) reduce the amount of blue light. These filters have low transmission in the short-wave range and a steeper increase in transmission in the long-wave range. Warm (long-wave) colors are accentuated.

It should be noted that nowadays all plastic filters are treated with a UV-absorber. Otherwise the plastic will turn yellow after some years of use. The standard UV-absorber cuts off all radiation up to 400 nm. Therefore the spectral transmission of this kind of filter is equal to 0 up to 400 nm.

In the extreme case, all blue is taken out ("blue blocker," Fig. 3*c*). At first glance a "blue blocker" is good for skiing due to the tremendous contrast enhancement. On the other hand, there is maximum color distortion. The subjects denied using blue blocker for skiing because they are unsuitable for skiing. The visual system seems to need blue information for peripheral vision.

With some blue attenuators or blue blocker a subjective brightening might be perceived. This effect can be accounted for by the slight displacement of the perceived color into the yellow range – in other words, toward higher wavelengths. A person's ability to distinguish between colors is greater in this range, i.e., more colors can be perceived. As a result, the filter tends to "brighten" what is seen, and contrast sensitivity is improved both subjectively and objectively.



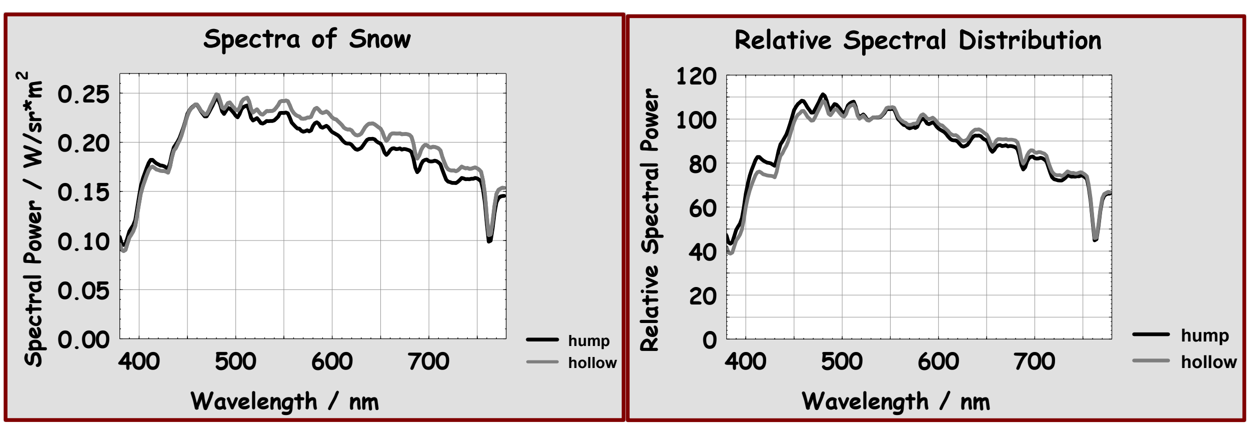
(a) (b) (c)

FIG. 3—*Typical spectral transmission-curves of different kinds of filters: grey filter (*a*), blue attenuator (*b*), and blue blocker (*c*).*

A New Kind of Filter

We measured the spectra of the snow at different locations of the test field of Fig. 1. Typical results are shown in Fig. 4, i.e., the spectrum of a hump and a hollow. Besides a slight vertical shift, the spectra seem to be identical. The small difference in the spectra leads to a small difference in brightness. In Fig. 4*b* the curves are normalized. The transmission at 560 nm is set to 100, which is the normal procedure to calculate the position in the colorspace. Only now the difference is obvious. The spectra behave like a swing. In the left part the dark curve is above the grey one, and beyond 560 nm it is vice versa. Besides the small brightness difference there is also a color difference between hump and hollow which might be amplified with an optimized filter.

A blue attenuator will amplify the difference of the spectra in the long wavelength range. But nobody cared about the blue end. Obviously the difference in the spectra carries some information, especially at the far end of the spectrum.



(a) (b)

FIG. 4—*Two spectra of snow (*a*) and relative spectra of snow (*b*).*

We designed a filter which partially removes the blue range like a blue attenuator (Fig. 5). But there is still some transmission in the range below 400 nm. This will exaggerate the difference of the spectra of Fig. 4 at the far blue end of the spectrum. The result is a contrast enhancement between the appearance of snow in a hollow and on a bump.

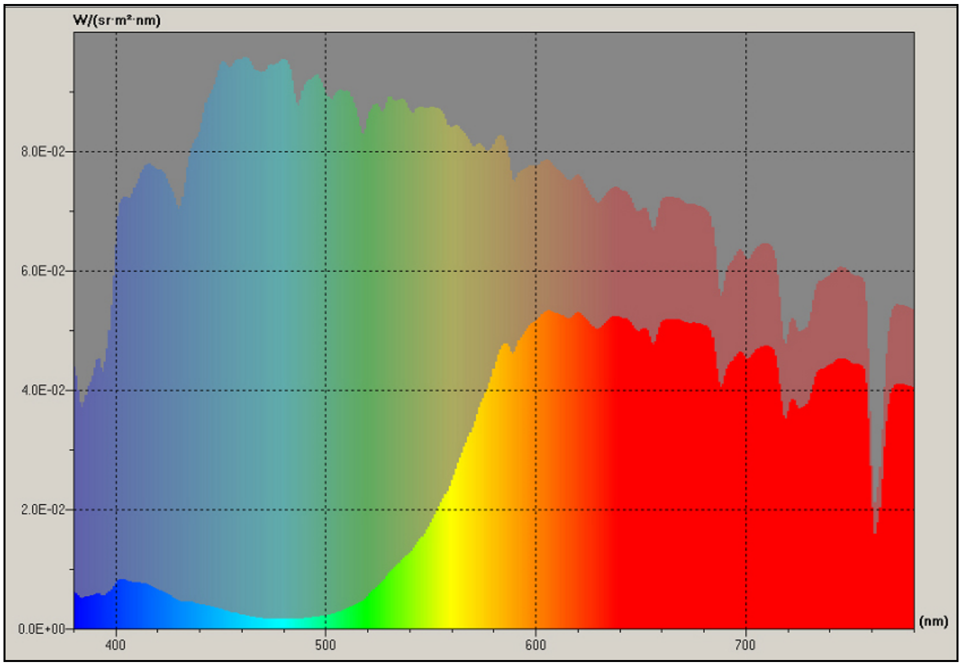


FIG. 5—*New type of filter. The less saturated curve shows the spectrum of snow of Fig. 2b. The curve in front shows what is left through the new filter. In principle it is a blue attenuator, but for the very short wavelengths the filter has a higher transmission.*

Physiological Aspects

The optical system of the eye shows a tremendous chromatic aberration (Fig 6). Each color has its own focus. The focus of blue light is located in front of the retina, while red light is focused behind the retina. The difference of refraction between red and blue might be up to 3 diopters. Usually a normal eye accommodates yellow light. When looking at a white object, a blue haze is added to the picture on the retina. Due to this haze, the color of any object is shifted toward blue. The "blue curtain" covers all objects, which additionally reduces the contrast in the image.

For photopic vision, the fovea is covered by three types of receptors (cones). According to the range of their sensitivity, they are called S-, M-, and L-cones (i.e., short, middle, and long wavelengths). The terms Red-, Green-, and Blue-receptors (R, G, B) are still in use, but they are not quite correct. The maximum of the sensitivity curve of the L-cone is located about 565 nm, which would be perceived as yellow and not as red. Thus, it is not a Red-receptor. The perceived color red is the result of the difference between the inputs of M- and L-cones.

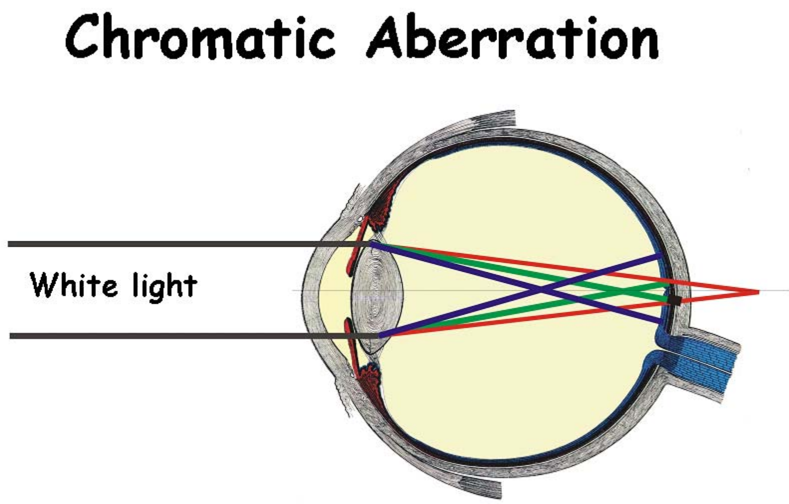


FIG. 6—*Chromatic aberration of the eye. Blue light is focused in front of the retina. The result is a "blue curtain" superimposing the image on the retina.*

The different types of cones are not equally distributed on the retina. There are no Blue-cones in the fovea. The fovea is blue blind. But as it can be seen in Fig. 7, M- and L-cones are sensitive to blue, e.g., both receptors can catch light of about 450 nm. In the presence of blue light, therefore, the difference between L- and M-cone inputs is relatively reduced, and as a consequence, the contrast is reduced as well. A classical blue attenuator or blue blocker will reduce this effect, but the blue information might be lost. Subjectively, the world might look more colorful, but only in the middle and long wavelength range, which is from green to red. Blue and blue-green might change to green. This effect does not occur in the new filter according to Fig. 5. In the range from about 420–480 nm most of the blue light is cut out. But the transmission is higher in the range from 380–420 nm. The M- and L-cones are not sensitive to this "blue curtain." Therefore these short wavelengths do not reduce the contrast. On the other hand, the S-receptor is sensitive to the short end of the spectrum. The blue information, which is needed mainly in peripheral vision, is still present. Color distortion is minimized, while contrast enhancement is optimized.

Seven different filters were designed for different weather conditions, which include sunny, cloudy, overcast, foggy, and snowfall. In each weather condition, the subjects improved their vision ability with one or two of the new filters compared to other filters. These filters got the best rating in comparison to other filters. The theoretical described features were confirmed by the tests.

Conclusion

The studies showed that the high amount of blue scattered light should be reduced for skiers generally – particularly with unfavorable conditions such as overcast skies, twilight, diffuse light, fog, and snowfall, because then the blue scattered light additionally reduces the contrast.

"Blue attenuators" or other filters that work in a similar way reduce the amount of blue light. These filters have low transmission in the short-wave range and a steeper increase in transmission in the long-wave range; red colors are accentuated.

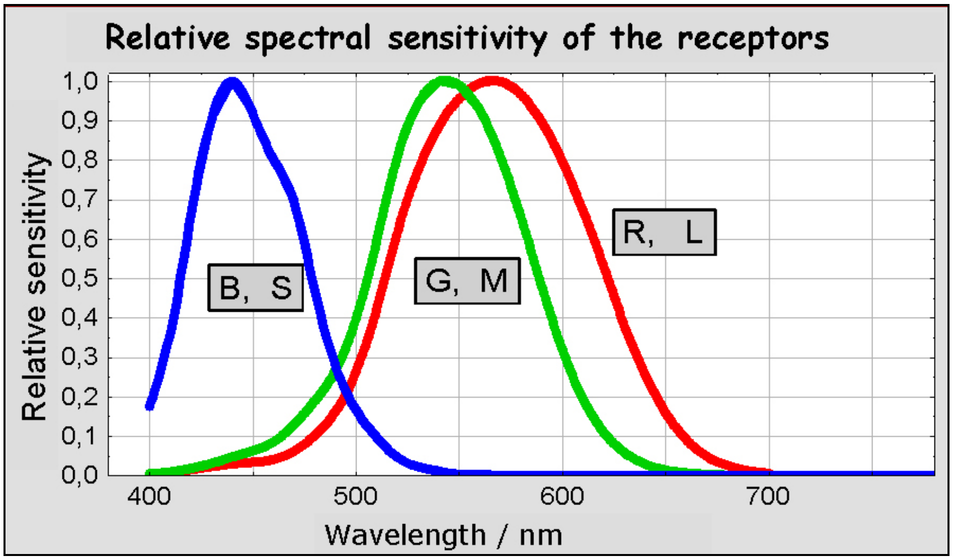


FIG. 7—*Relative sensitivity of Short- (Blue), Middle- (Green) - and Long- (Red) wavelength cones. Below 420 nm the sensitivity of the M- and L-cones is close to zero.*

"Blue blockers," which filter out blue light completely, are rather unsuitable to skiing since they restrict the necessary perception of blue in peripheral sight.

The new kind of filter, which is presented here, has the advantage of a blue attenuator but without complete loss of blue information. A higher transmission in the short end of the spectrum does not reduce the information processing of the M- and L-cones. On the other hand, the S-cones can catch sufficient blue light to minimize color distortion.

The result is a colorful and high contrast vision of the (ski) world as it was not seen before. This is why the filters are used by the German Ski Federation World Cup team (women) in both training and competition, especially during the 2002 winter Olympic games in Salt Lake City, UT.

Acknowledgments

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