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DEPTH PERCEPTION WITH YELLOW GOGGLES

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SUMMARY PAGE

PROBLEM

To determine, under field conditions, whether depth perception in the snow is improved by the use of yellow goggles.

FINDINGS

There were significant improvements in the ability of individuals to judge the depth of depressions in the snow under overcast conditions with yellow goggles.

APPLICATIONS

The use of yellow will be made part of the specifications for eye-protective goggles for use in the snow.

ADMINISTRATIVE INFORMATION

This investigation was undertaken under Naval Medical Research and Development Command Work Unit M0095-PN.001-1040 - "Protective devices for the eye in cold weather." This report was submitted for review on 3 Aug 1981 and approved for publication on 11 Aug 1981. It was designated as NavSubMedRschLab Report No. 960.

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ABSTRACT

A field study of the ability of subjects to judge depressions in the snow was conducted at a cross-country ski area. Many pairs of depressions were made in the snow and each subject was asked to judge which depression in each pair was deeper. The percentage of correct judgments was significantly greater on an overcast day with yellow goggles than with luminance-matched neutral goggles.

Previous research has suggested that the use of yellow goggles may improve vision under certain conditions in snow-covered terrain.[1,2] Laboratory studies were conducted first; in these, both depth perception and contrast sensitivity were compared using yellow goggles and neutral goggles matched for luminance transmittance. Yellow goggles improved both the perception of depth of low contrast contours and the time required to respond to low contrast patterns.[1] In a subsequent field experiment, marines made judgments about depressions in the snow while wearing either yellow or transmittance-matched neutral goggles. In general they could see the depressions at greater distances and judged their depth more accurately with yellow goggles under low or flat lighting conditions, although not all the differences were statistically significant.[2]

These positive results on the use of colored goggles are rather unusual in the literature since most previous investigations have shown no improvement in vision from wearing yellow lenses as long as the total quantity of light transmitted by the goggles was constant. In a review of the literature, Clark[3] surveyed some 98 studies of tinted goggles and reported that the vast majority of these showed no improvement with yellow. However, acuity was the measure of vision employed in almost all of these investigations. Our search for other visual functions that might be improved by yellow goggles stems from our analysis of modern theory of color vision and its consequences for visual perception.[1]

The present investigation was a second field study of depth perception with yellow goggles, conducted to further delineate the conditions under which yellow might be effective.

EXPERIMENTAL PROCEDURE

The field experiments were conducted on two consecutive days during February at a cross-country ski center in Vermont. Several courses were laid out along the cross-country ski track so that subjects could be recruited as they skied by. In each area, there were six pairs of depressions made in the snow on either side of the track. Each pair was 15 feet from the next pair. Every pair had one deep and one shallower depression, each of which was about two feet in diameter. The courses were laid out in a north/south direction and the subject stood at the south end, facing north, to make his judgments.

The subject's task in each case was to state which depression, of each pair, was the deeper. Each subject made judgments with two different pairs of goggles, one yellow and the other a transmittance-matched neutral. The different goggles were used on different courses, to preclude the subjects' being influenced by their previous answers. Each subject thus made 12 judgments with one pair of goggles in one area and 12 judgments with the other pair in a different area. The order in which both the goggles and the areas were employed was counterbalanced across subjects.

The first day of the experiment was clear and sunny with illumination of about 10,000 footcandles. The depressions were easy to see and had noticeable shadows. Dark goggles

were chosen for these conditions; both the yellow or "glacier" (a dark yellow designed for extremely high light levels) and the neutral had transmittances of .09. Data were collected on 24 subjects on this day.

The second day was completely overcast, with even gray lighting of 2000 footcandles. There were no shadows anywhere and it was difficult to even see the depressions. Light goggles, both yellow and neutral, of .78 transmittance were chosen for testing on this day. Forty subjects participated.

The spectral transmissions of the various goggles are shown in Fig. 1 and their CIE chromaticity values* in Fig. 2. Hue differences between the two pairs of yellow goggles are minimal; the major difference is, of course, the overall percentage of light transmitted. Dark goggles worn on a sunny day and light ones on a dark day result in similar overall light levels at the eye.

RESULTS

The average percentages of correct judgments of depth, with yellow and neutral goggles, for the two days are given in Table I. Overall performance on the sunny day was much better than on the overcast day. Yellow was superior on both days, but the difference was larger on the overcast day. An analysis of variance performed on the data, for each day separately, showed significantly higher percentages of correct judgments with yellow ($p<.05$) on the overcast day. The differences on the sunny day were not significant.

Table I. Average percentage of correct judgments of depth under all conditions.

Sky condition	Yellow	Neutral density
Sunny	77.4 ±14.7	74.7 ±19.5
Overcast	58.1 ±18.7	50.6 ±23.7

In another analysis of the same data, the mean percent correct at each distance was determined and is plotted in Fig. 3. On the overcast day, higher percentages of correct judgments with yellow goggles occurred at all distances. On the sunny day, yellow was superior only for the intermediate distances. The differences between yellow and neutral goggles are quite sizeable when a specific percent correct is considered as a criterion. For example, in order to achieve 50% correct judgments, the average subject on a sunny day had to be at 71 ft with neutral goggles but could perform as well at 80 ft with yellow goggles. Similarly, on a cloudy day, a distance of 58.5 ft with yellow goggles gave equivalent responses to a distance of 50 ft with neutral goggles.

DISCUSSION

These data, together with those from the two previous experiments, show that yellow goggles do yield significant improvement to the

* The CIE (Commission Internationale de l'Eclairage) is the standard international system for measuring color.

perception of depth under certain conditions. The greatest advantage occurs for large, low contrast objects on overcast days, when there are no shadows, and the visibility is in general very poor. Thus, the perception of large, low contrast contours has been significantly improved in laboratory studies involving reaction times to such targets,[1] and in the depth judgments collected in the snow in the previous field study[2] and now, in this study, in the perception of depth contours on the overcast day. At the same time, acuity or the discrimination of small, high contrast objects is unaffected by the use of yellow goggles, both in our data[1] and that of others.[3,4] Thus the previous puzzle as to why skiers preferred yellow goggles when visual research did not support their choice is explained.

The physiological mechanism underlying the improvement of low contrast sensitivity with yellow goggles was discussed extensively in the previous paper.[1] Briefly, the theory suggests that visual perception mediated by the opponent or chromatic system of vision (as contrasted with the additive or achromatic system) can be enhanced by elimination of subtractive, opponent activity. Yellow goggles, of course, eliminate all the short wavelength contributions to both the blue-yellow and red-green opponent systems. Further developments in this theoretical approach, a highly active area of research, should add greatly to our understanding of the range of visual functions which can be improved by yellow goggles.

On a practical level, the major advantage to the use of yellow goggles is found in uniform lighting on snow; such conditions are found on overcast days, in flat lighting when the sun is behind mountains, in snow or fog and in the classic, Arctic "white-out." Nonetheless, the use of yellow goggles,in the dark version, on sunny days is not precluded since some form of dark goggle is essential in high brightness and a small advantage may accrue under some conditions.

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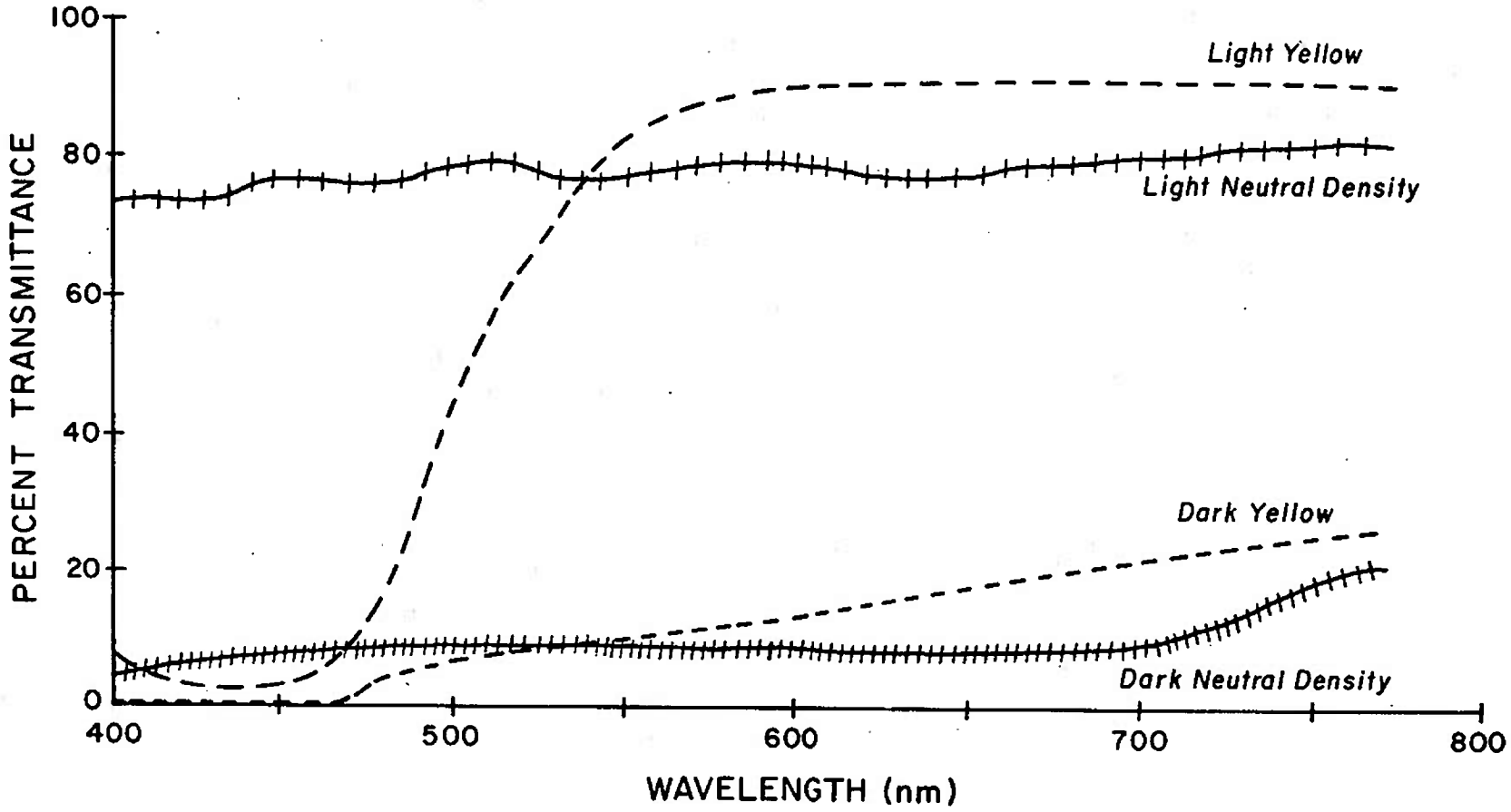

Fig. 1. The spectral transmissions of the various goggles used in the experiment.

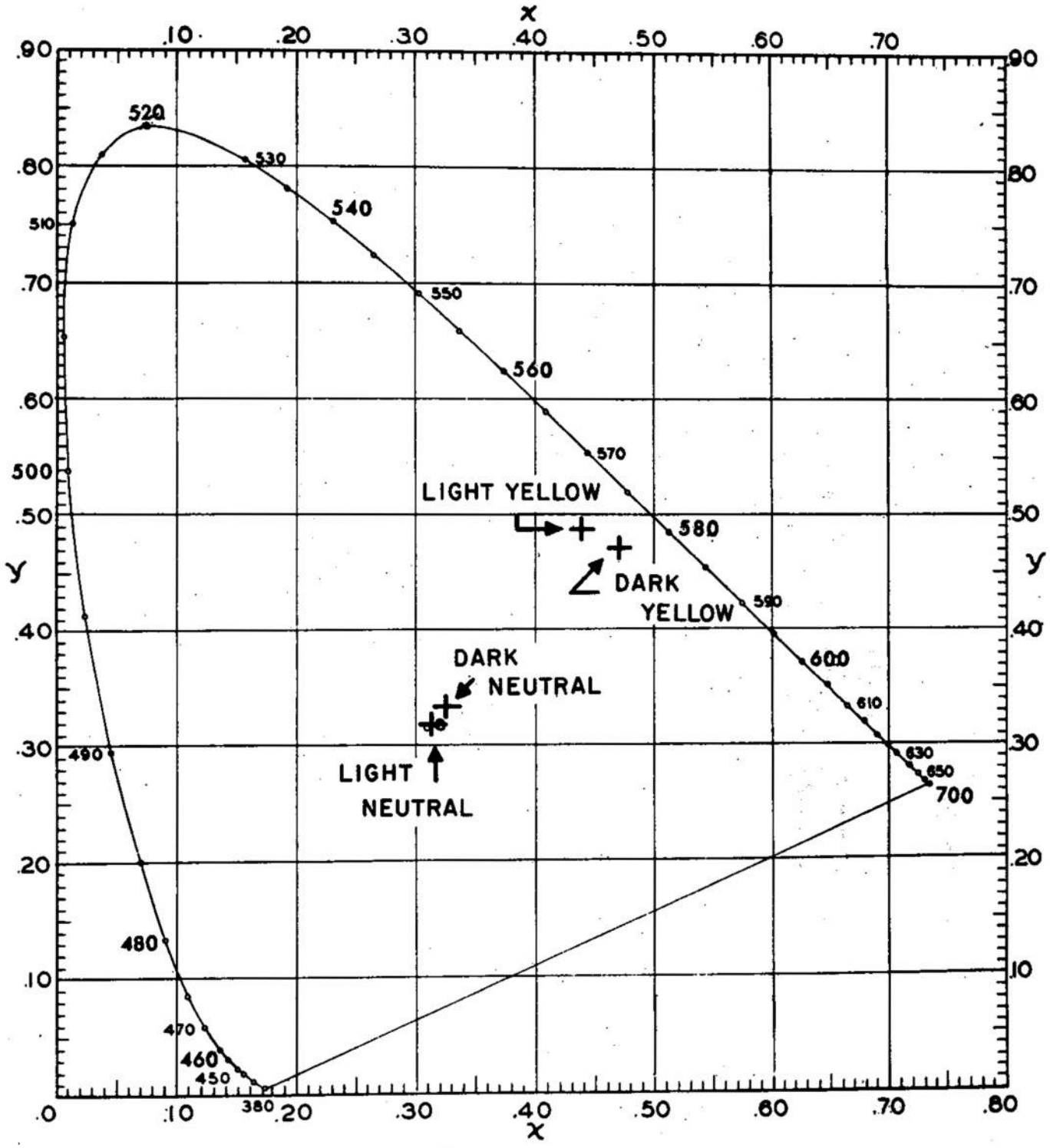

Fig. 2. Diagram showing the CIE chromaticity values of the various goggles used with daylight (Illuminant C).

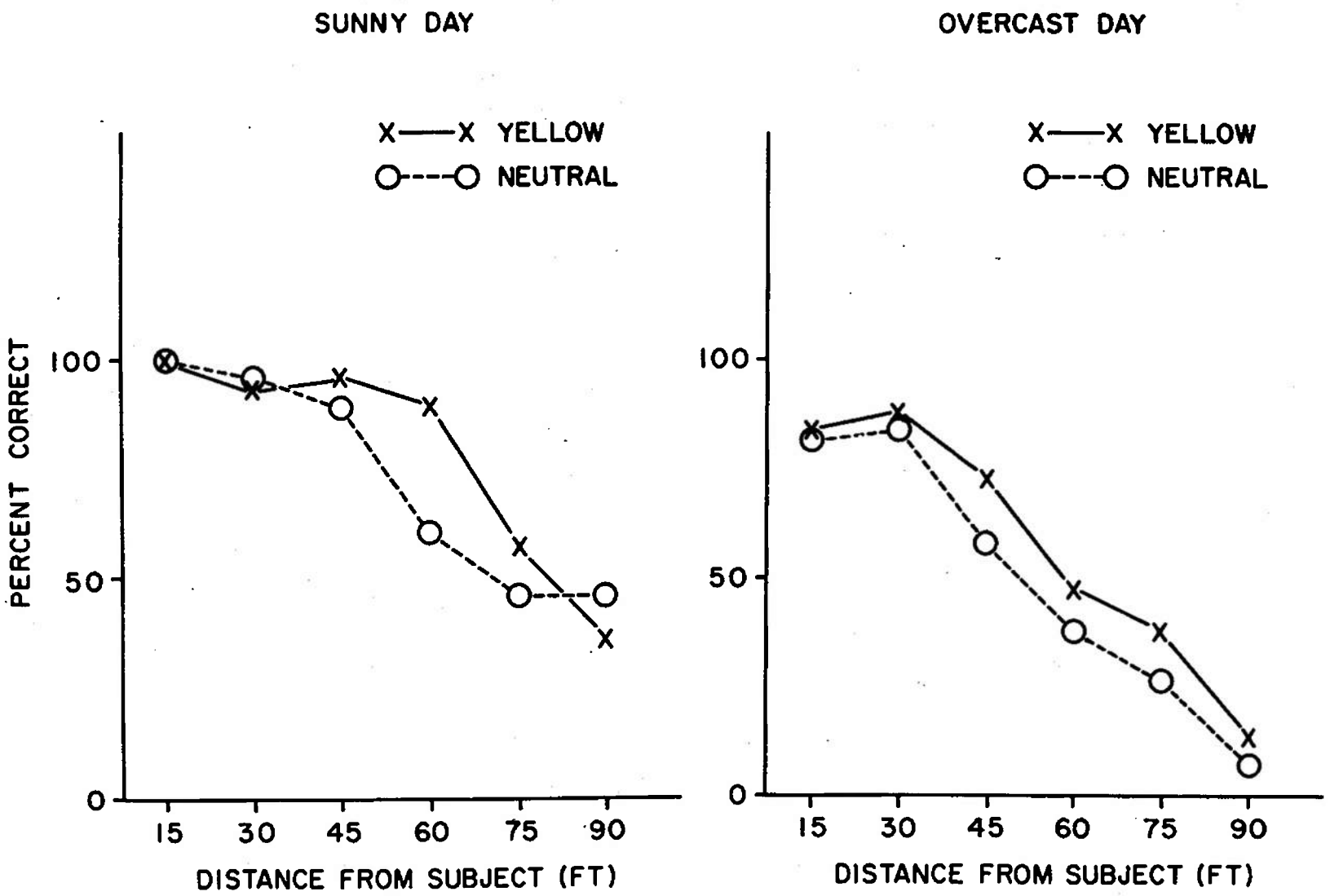

Fig. 3. The mean percentage of correct judgments of depth, for all subjects, under two conditions of illumination.

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