Massachusetts hunter --- safety color test*

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THE PROBLEM BEFORE THE committee in charge of this test was to determine the color least likely to be confused with a white-tailed deer in terrain, lightning, and weather conditions met in hunting in this state. The lack of normal color vision found in 8 per cent of men was to be considered. When the deer runs, the tail is lifted and the underside of the tail and the back part of the deer are a near white. Any flash of white, such as a handkerchief or even eating an apple, is dangerous and has been shot at by a careless hunter. Even though, on an actuarial basis hunting is not a dangerous sport; nevertheless, the best protection should be made available and required legally.

The hunting law of the Commonwealth required wearing red or yellow clothing during the deer hunting season. A red cloth is not nearly as conspicuous as a red light and with poor lighting in the woods, red turns dark and is not seen. Yellow is bright and normally is an easily seen color. However, at dawn and dusk the yellow tends to be seen as gray or white and can be dangerous for this application. As the center of the

*The Committee consisted of Col. L. N. Altshuler, Lt. Col. H. M. Rutledge, Maj. N. King, Capt. E. Ritvo, Lt. R. B. Proffitt, and Lt. J. Panjian at the Fort; Mr. G. Pike and Mr. B. R. Chaplin of the Massachusetts Division of Law Enforcement, Mr. R. W. Woolber of the Fisheries and Game Division, and the author. For more detail see Richards, O. W., Woolber, R. W., and J. Panjian. 1960, “What the well-dressed deer hunter will wear,” National Safety News 82(5):43. The table and figures are reprinted from this article with the permission of the National Safety Council.

fovea is tripanopic, a small retinal image from a yellow cap at a distance appears white rather than yellow. These observations raised the question whether better colors could be found for protecting deer hunters. The longer lasting, much brighter daylight fluorescent colors offered promise.

Selection of Colors and Subjects

When detailed information is available as to the nature of illumination and the color reflection of materials, the changed appearance with different lighting can be estimated. As little information is available on the reflectivity of outdoor nature, this problem was investigated with a large field study.

Since blue is not very visible and green would not show against shrubbery, the available colors are yellows, oranges, and reds. For this particular study, a yellow and red cloth and fluorescent blaze orange, fire orange, neon red, and arc yellow were used. The materials were made into vests that could be worn over regular clothing. About 160 square inches of color showed in front and 200 square inches of color on the back and sides of the wearer. The specifications of the colors used are given in Table 1.

The field work was done at Fort Devens and personnel from the First and Second Battalions were used. Dr. Panjian screened one thousand soldiers with the AO-HHR Pseudoisochromatic Plates, illuminated with a standard Macbeth Easel Lamp and found 6 per cent to have deficient color vision. The men with medium and severe color deficiencies were tested using an experimental
anomaloscope. The relative brightness of the colors for these deficient observers was also measured using two degree subtence circles on a 21 per cent gray background, the Macbeth light and a Luckiesh-Moss Visibility Meter. The relative brightness of the colors for normal and deficient observers is shown on Figure 1. The irregular tops of some of the bars indicate that the light was too bright to bring those colors to threshold.

In programming the test, it was planned to use 8 per cent color vision deficient observers, but owing to maneuvers, sickness, and the shortening of some shooting tests by bad weather, only 6.7 per cent of the 526 observers were of known deficiency in color vision.

Three Series of Tests

The field tests consisted of two observational and a forced-choice shooting series simulating hunting. For the former, a 2.5 mile course was marked with the aid of a rope through clear areas, woods (evergreens and hardwoods), brush, up and down hill and across a small swamp in an isolated area of Fort Devens. At various places along the course, at 25, 50, 75, or 100 yards from the trail, army silhouettes of a man were set up and each covered with a colored vest. The dummies were marked with a numeral on the forehead for identification. Two-men teams walked the course at spaced intervals and the observer pointed out and named the color of all the targets he could see. The recorder was provided with field glasses for reading the numbers marked on the dummies. No observer or recorder had any information as to the color or location of the targets. Three test runs were made, during October with fall foliage colors, in November after the leaves had fallen, and in January with snow cover. In October and November, one hundred two-man teams covered the trail. In January, twenty-five two-man teams were used.

In the second series, the observers and recorders were stationed along the course and soldiers wearing the vests walked the trail. The objective was to determine the distance at which the colored vests could be seen and whether the colors would appear to change as they approached the observer. The soldiers were not good enough at estimating distances in the woods and brush to provide the desired information.

On the completion of both series, the observers were asked which color they thought was easiest and hardest to see, which was most artificial or least natural, and which color they would prefer to wear for protection if they were hunting. The opinions were obtained with numbered colors to avoid the problem of uncertain color names.

The third series used a small hill on which a number of silhouettes of deer were so arranged that by pulling ropes the "deer" could be turned at right angles to the line of view for four seconds, then turned in line.

![Figure 1. Relative brightness of the colors as seen by normal and color deficient observers. W = white, BO = blaze orange, FO = fire orange, NR = neon red, R = red, AT = arc yellow and Y = yellow.](image-url)
with the direction of view, in which latter position they were not visible. These “deer” were placed from fifty to two hundred and forty-five yards from the firing position and subtended 19 minutes (colored part 10 minutes) of arc at the observer’s eye from the farthest position. Eight targets were painted white and 2 each blaze orange, fire orange, arc yellow, yellow and red (Table 1). Two silhouettes of a man were painted yellow and fire orange and placed at the edge of the woods.

A soldier at the firing position was told to shoot all the white “deer”, but none of the colored “deer”. The “deer” were exposed for four seconds at a time and in a random order. The tests were usually underway by late afternoon with an average luminance of the target area of 400 ft-L and continued until it was too dark to see the targets at about 0.02 ft-L. Shooters in October numbered 42, in November 32, and in January 23.

Results of the Tests
For the first series, 13,528 sightings of 222 men are summarized in Figure 2. For each color, the first column indicates the October, the second the November, and the third column the January sightings. To make the results comparable, they are expressed as percentages seen. For each color in October and November, a 100 per cent score would be 1200 correct sightings, and for January 800 correct sightings. In no case were all twelve vests of each color seen.

White was included as a reference even though it must be avoided by deer hunters. Note the poor visibility of white in January against snow. The extra light reflected by the snow increased the brightness of the fluorescent colors. Red was more conspicuous than yellow in October. Slightly more red vests (1087) were seen than yellow vests (1035); a difference too small to show on Figure 2. The observations of the men with deficient color vision are plotted separately in Figure 3A for the protans and Figure 3B for the deutans. In these plots, errors are indicated as well as the correctly named sighting. An error is a vest sighted but miscalled as to color, e.g. a red vest seen but called green. A color named within its color range, like calling neon red pink was not tabulated as an error. The number of errors indicates uncertainty. Of the 35 color-vision-deficient men, 7 were mild, 13 were protans, and 15 deutans. Eight protans and 4 deutans were so severely deficient that matches were possible throughout the scale of the anomaloscope. The marked darkening of the red
separated the protanopes from the deuteranopes. The opinions of the observers as to the relative difficulty of seeing the colors are given in Figure 4.

In the shooting test of 592 deer targets shot at, 13 were yellow, 4 each fire orange, dark yellow, and red, and 1 blaze orange. One severe protanope shot at each, probably shooting at the movement of the target. He was next to the last man to shoot at near darkness in the January series. Deducting his score leaves 10 yellow, 2 fire orange, 3 are yellow, and 1 red shot at. Both the yellow and fire orange hunter silhouette targets were shot at. The colored “deer” targets, with two exceptions, were shot at after the average luminance was less than 4 ft-L. One yellow “deer” was fired on at 4:30 P.M. with a target area average luminance of 20 ft-L. Red, are yellow, and yellow were fired on at 3.5 ft-L. Most of the other colored “deer” were fired on at 1 ft-L or less luminance. In the four shooting tests, the deficits appeared not to shoot when unsure of a color and thus avoided making errors. Several men commented that the yellow and arc yellow targets were difficult to see in poor light. The red targets just disappear at dusk.

Discussion of Color Visibilities

The fluorescent colors are appreciably brighter as will be seen in Table 1. The reason for this is that they absorb some of the ultraviolet, blue, and possibly green light which is converted to their color and radiated along with the reflected light. The blaze orange has a reflectance of 219 per cent. Such a color appears artificial and out of place against the woods, where few objects, excepting light rocks and white birch trees, reflect more than 50 per cent.

Red is not a very visible color and disappears at dusk. Red was miscalled green, orange, pink, brown, black, dark or doubtful, and white, depending on the surrounding and the lighting. Six times as many men voted for red as yellow in the personal choice results, Figure 4, probably a result of associating red with danger, although both red and yellow were the least visible of the colors used.

The plain yellow cloth was less visible than red and appeared gray or white under poor light. This yellow was miscalled chartreuse, green, orange, pink, and white. Fewer yellow vests were seen by the deutans although the protans did well with it in November. Four times more yellow “deer” were shot at than any other color. The yellow hunter silhouette was fired on during the October and January tests. This yellow is not a safe protective color for deer hunters.

The arc yellow is actually an orange. The sightings were poor against fall foliage and good with snow background. Arc yellow was miscalled green, crimson, red, and gray. Arc yellow “deer” were shot at in the third series. Being the brightest color used, it was the preferred choice for both the protans and deutans for wear, even though their sightings of the targets fail to support their opinions. As the arc yellow turns whitish in poor light, it is too yellow for protection of deer hunters.

The fire orange was not seen very well against fall foliage and was only third best with snow. Both protans and deutans reported difficulty in seeing it. Fire orange was miscalled white, yellow, green, and black. This is too red a hue for hunter protection.

The neon red was second only to blaze
orange for all observers. It becomes more conspicuous against snow for men with normal color vision, but not for men with defective color vision. It was the poorest color against colored fall foliage for the deutan. Both protan and deutan reported it difficult to see and only one chose it for wear while hunting, presumably because he thought it was the least visible of the colors. Neon red was misclassified white, yellow, and gray-black. It was considered the most artificial color due to its purple fluorescence. The blue component of the fluorescence may be what the protans see.

**Most Conspicuous Color: Blaze Orange**

The most conspicuous color is the blaze orange for normals and protans, and is second only to arc yellow for the deutan. It was called chartreuse, gold, pink, red, and white only once by a severely color-vision-deficient individual. With exception of November series, when neon red was sighted more often, blaze orange was the best seen of the colors used. Blaze orange was the second choice in the opinion poll as to which color would be used for hunting protection by the normal, but not by the deutan with deficient color vision.

The fluorescent colors are more visible than the non-fluorescent yellow and red cloth. The arc yellow was too yellow to show well at dawn or dusk and the fire orange was too red to be seen well by men with deficient color vision, or with poor light and normal vision. The best protective color of those tested is blaze orange, although a study of the data shows that no single color can be best for all people, with all kinds of terrain, against colored foliage, no leaves, or snow, and with inadequate lighting. Taking into consideration the sensitivity of the human eye and the information from the test, the color to be chosen for protective clothing for hunters of white-tailed deer must not be much yellower than the blaze orange used and no more red than necessary to give a reasonable manufacturing tolerance.

The recommended color shall have a dominant wavelength between 595 and 605 nm, a luminance factor of not less than 50 per cent, and an excitation purity of not less than 90 per cent. This specifies the daylight fluorescent orange recommended to the Legislature of Massachusetts for inclusion in the hunting law.

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**Vitamin A and its Effect on Dark Adaptation**

Professor George Wald, world renowned biochemist from Harvard University, presented a lecture series on the “Molecular Basis of Vision” at The Ohio State University, recently, under the joint sponsorship of the Institute for Research in Vision and the School of Optometry. Professor Wald discussed the photochemical, anatomical and electrophysiological aspects of rod and cone vision.

Of extreme interest were his discussions on the electronmicroscopy studies of the rods in animals deprived of Vitamin A. The studies revealed that there was not only a resultant loss in dark adaptation but there was also induced pathological changes in the retina, similar to changes observed in retinitis pigmentosa. These data indicate that prolonged studies on dark adaptation in man in which there is insufficient Vitamin A in the diet may result in actual pathological changes in the retina.

Wald showed how various opsins can be added to retinene which is a Vitamin A aldehyde to produce various luminosity curves. He postulated that color vision may be served by three receptor processes which have the same retinene factor but are attached to three separate opsins.

The spectral sensitivity of the eye and light and dark adaptation could be easily explained on a photochemical basis, Wald concluded.

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The Hunter

The image shows a hunter standing behind a large deer. The text is partially visible and reads:

"...The Hunter - orange. This is a buck that is a little bigger than..."

Unfortunately, the text is cut off and not fully legible.
THE Massachusetts hunter-safety color study was a practical field test of garments that could be worn by hunters to prevent being mistaken for a white-tailed deer and to produce maximum visibility in the woods. In the first part of each series of tests, a 2½-mile trail was marked with string through a variety of deer hunting country. Here, Army personnel and men of the divisions of Law Enforcement and Fisheries and Game discuss a target location.

Targets observers hunted for along the trail were cloth vests, placed on Army silhouette targets, and numbered to ensure accurate interpretation of test data. Fluorescent colors tested were blaze orange, neon red, fire orange, and arc yellow. Standard colors tested were "Old Glory" red, and a bright yellow closely matched to the shade selected in past tests. 84 targets were placed, 12 of each color, at distances of 25, 50, 75 and 100 yards. Order of colors was selected at random.
All personnel used as observers in the test were screened to determine their color vision. Six and one-half percent of observers used had deficient color vision, to correspond with the national average. Here, Dr. Oscar W. Richards, chief biologist of the American Optical Company, tests one of the men.

Briefing of personnel was as complete as needed to insure correct procedure and accuracy of results — and as incomplete as necessary to prevent any possible chance of biasing results. Men were told what they were to do — but not what they would see. Observers were told to look for targets along the trail and tell their accompanying recorder the color they saw. The recorder was told to write down, on forms provided, exactly what the observer told him, and to record the actual number of the target.

SEE "BE SEEN" — The 16mm sound and color film about the Massachusetts Hunter-Safety Color Test. It's available to groups now — write the Information and Education Section, Fisheries and Game Field Headquarters, Westboro, Mass.
Observers and recorders were paired off, and a data sheet prepared on each observer. Information as to weather, time of day, light conditions, and the observer's name, Army serial number and hunting experience were recorded. The recorders used this same sheet to record observer's reaction to targets sighted in the field.

Observer points out target to his recorder. After three tests, October (with fall foliage), November (without foliage), January (with snow), observers had sighted fluorescent blaze orange a total of 2,243 times. Neon red was second, with 2,223 sightings. Fire orange was sighted 2,038 times. Arc yellow was at the bottom of the fluorescent colors with 1,957 sightings. Ordinary red was found 1,887 times, and ordinary yellow made the poorest showing; soldiers found it only 1,635 times.
The second part of each series of tests had targets—now placed on men—moving along the marked trail. Stationary observers and recorders made the same observations as in the previous part. Results were the same—blaze orange was rated the best color.

After completing their portion of the test, each observer was asked which color he thought was easiest to see, which was hardest to see, which color looked least like anything in nature, and which color he would choose to wear for protection while hunting. Blaze orange was rated easiest to see and the choice for hunting, by a majority of men, followed by neon red. Ordinary yellow was picked by only nine of the 425 soldiers who answered the question. Results of the interviews tallied with results of field observations.

Third part of each series of tests, run through a variety of weather and seasonal conditions, was set up to simulate the tension and excitement of hunting—and to find out if any of the test colors could be mistaken for white and draw fire from "flag shooters". Eighteen disappearing targets like this were used, nine of them painted white, the rest painted in test colors. Soldiers were instructed to shoot only at the white "tails." Ranges were from 50 to 225 yards.
Two surprise targets—human figures—were included. One had a yellow vest and cap, the other wore a fluorescent fire-orange outfit. The yellow vest on this human cutout drew two shots in mistake for white.

Soldiers fired 369 rounds at white targets during the three test series—as instructed. They also fired 13 times at yellow targets in the mistaken belief they were white. Blaze orange drew only one shot—and the soldier who fired this had a rare type of color vision which resulted in his firing at all targets that moved. Results of all three parts of the series of tests show that fluorescent blaze orange was consistently the most visible, the most unnatural looking, and the least likely to be mistaken for white. Legislation requiring wearing this color during the firearm deer season is recommended by the test committee.

Wear Blaze Orange, Be Seen, Be Safe!