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EFFECT OF SURROUND AND STIMULUS LUMINANCE ON THE DISCRIMINATION OF HUE

by

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SUMMARY PAGE

THE PROBLEM

To determine whether one's ability to discriminate colors is affected by changes in the intensity of the stimulus (hue) itself, or of the intensity of the surrounding area.

FINDINGS

Changes in the illumination of the surround had no effect on hue discrimination until the background was considerably brighter than the stimulus. Within the range investigated, hue discrimination improved with increasing stimulus intensity.

APPLICATIONS

As the displays on submarines and other Naval vessels become more complex, knowledge of coding processes becomes increasingly important. This study is directly applicable to color coding, since it investigates the effects of the attendant variables on the discrimination of color

ADMINISTRATIVE INFORMATION

This investigation was conducted as a part of Bureau of Medicine and Surgery Research Project MR005.14-1001-1, Psychophysiological Studies of Visual Factors in Submarine Operation. The present report was approved for publication on 14 November 1963, and subsequently published in the J. of Opt. Soc. of Amer., Vol. 54, No. 5, 693-695, May 1964, and designated Report No. 36 on the Subtask indicated.

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Effect of Surround and Stimulus Luminance on the Discrimination of Hue

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The effects of changes in the luminance of the stimulus and the surround on hue discrimination were experimentally investigated, using the method of constant stimuli. All observations were made at 550 mμ; the standard deviation was used as the measure of sensitivity. Surround luminance was found to have no effect on hue discrimination until the surround had three or more times the luminance of the stimulus. As the surround to stimulus ratios increased, the threshold rose sharply. Increase of the stimulus intensity over a range of 1.5 log units from the photopic threshold increased the discrimination threshold by an average of only about 2 mμ.

MOST of the researches dealing with hue discrimination have been referred to by Siegel in presenting his own carefully measured results. His works,[1,2] together with those of previous authors,[3–5] have accurately defined both the relative shapes of the hue discrimination curves and the absolute changes in wavelength necessary for the discrimination of hue under certain stated conditions. Color coding, the area to which these data are most immediately applicable, is widely used in a variety of visual environments. It is therefore equally important to define the effects of the attendant variables. Two of these variables are the subject of this paper.

The first, the level of surround luminance, has been investigated relative to its effect on luminance discrimination,[6,7] acuity,[8–10] and CFF.[11,12] In general, foveal thresholds have been found to be minimal when the surround and the stimulus are equally bright.

The second variable to be explored is the luminance of the stimulus. Acuity is known to improve with increased luminance.[10,13] Stimulus luminance is also known to influence hue[14] as well as saturation.[15] However, there seem to have been no systematic studies of the effect of these observed changes in hue and saturation on hue discrimination.

Bishop and Crook,[16] when reporting errors in the absolute identification of colors, conclude that the performance deteriorates markedly when the ratio of target to surround luminance drops below 1:1. They found further that more errors were committed at low levels of stimulus luminance. Although these conclusions are suggested by their data, it is difficult to separate the effects of their several experimental variables. The present study is an attempt to measure, separately and systematically, the results of changes in surround luminance and stimulus luminance on the discrimination of hue.

APPARATUS

The instrument used was a Farrand 1000-mm monochromator equipped with a double-exit slit. This attachment provides two beams of light, each of which is independently adjustable. A complete description of the apparatus can be found in a paper by Kinney.[17] The beams were focused on separate halves of a horizontally divided circular field which subtended 2 deg at the observer's eye. This stimulus appeared through a hole in the center of the surround screen. The stimulus light source was a 750-W projection bulb. For this experiment the upper half of the divided field was set at 550 mμ and all judgments were made in relation to this standard. A bandwidth of 6 mμ was used throughout the study. This setting was necessary to obtain the highest luminance to be used. Lower stimulus levels were obtained by inserting neutral Wratten filters. The source for the surround, a Macbeth daylight lamp, was mounted behind the observer and varied by filters. This light was reflected off a white screen which filled the observer's entire field of vision. By positioning the screen slightly in front of the stimulus, the illumination of the surround was prevented from mixing with the stimulus.

PROCEDURE

The method of constant stimuli, reported to be the most reliable measure of hue discrimination[18] was used. Three levels of stimulus luminance, 0.06, 0.2, and 2.0

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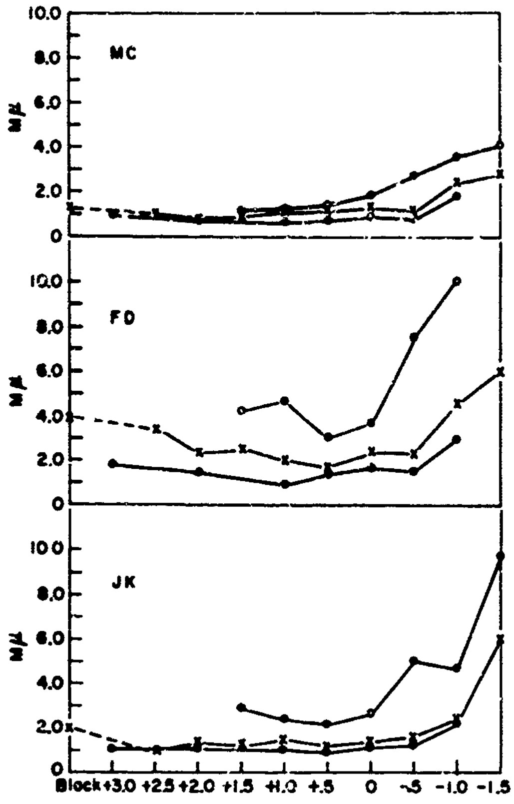

FIG. 1. Standard deviations in mμ as a function of stimulus to surround ratio for three levels of stimulus luminance. ○——○ 0.06 ft-L, ×——× 0.2 ft-L, •——• 2.0 ft-L.

ft-L were investigated. The surround luminance ranged from no surround light ("black") to a level 30 times the luminance of the stimulus. Each experimental session, lasting approximately 40 min, consisted of two series of judgments, all taken at one level of stimulus luminance and for one level of surround luminance. In the first series, involving 50 judgments, the observer's task was to judge if the comparison field (bottom) was "yellower" or "not yellower" than the standard. In the second comparable series, the judgment was "greener" or "not greener" than the standard. The order of these series was reversed for half the sessions. Two experimental sessions were run for every stimulus and surround combination, involving 200 judgments per observer at each experimental condition. Twenty-four stimulus-surround combinations were investigated. The levels of surround luminances were randomized among both experimental sessions and observers.

OBSERVERS

The three observers of this study had normal color vision and had previously served in hue discrimination experiments involving similar judgments.[1,2] Two were myopic and one hyperopic; all wore corrective lenses. For all sessions, the left eye was occluded and judgments were made with the right eye

TREATMENT OF THE DATA

From the data of each experimental session two Gaussian curves were drawn from which standard deviations in mμ for "yellower" and for "greener" were computed. The mean of these standard deviations was then averaged with the comparable value of the replicated session, yielding the measure of discrimination for a given experimental condition. This measure is referred to as the standard deviation and is used as the measure of hue discrimination.[1]

RESULTS

The data of the individual observers are shown in Fig. 1. The value indicated in the abscissa is the logarithm of the ratio of the stimulus luminance to the surround luminance. The ordinate shows the value of the standard deviations in mμ. Although there are differences in the absolute levels of discrimination among observers, the general shapes of the curves at each stimulus luminance and the relationships between the curves for different luminances remain the same for all observers. Therefore, the results were combined; the standard deviations, averaged for observers, are shown in Fig. 2.

It can be seen from Fig. 2 that, with the exception of a slight increase in threshold at the "black" condition, no change in hue discrimination resulted from reducing the surround luminance from the level of the stimulus. This conclusion is valid over three log units or when the luminance of the stimulus is up to 1000 times that of the surround. For the two higher stimulus luminances investigated, increase of the surround brightness had no effect on hue discrimination until the luminance of the surround was more than three times the luminance of the stimulus; the effect became more pronounced when the luminance of the surround was further increased. At the lowest level of stimulus luminance, a

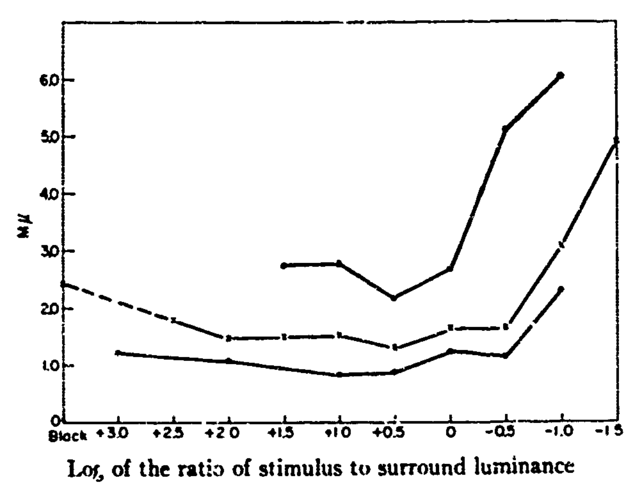

FIG. 2. Standard deviations in mμ, averaged for observers, as a function of stimulus to surround ratio for three levels of stimulus luminance. ○——○ 0.06 ft-L, ×——× 0.2 ft-L, •——• 2.0 ft-L.

marked reduction in ability to discriminate hue was apparent when the stimulus-surround ratio was 1/3. Discrimination was further reduced when the ratio was reduced to 1/10. With a ratio of 1/30 sensitivity fell considerably and for one observer, no meaningful measurements could be made.

Increasing the stimulus luminance resulted in lowering the threshold for discrimination. Although in some cases the change in luminance produced small differences, the effect was consistent for each observer and for every ratio investigated.

DISCUSSION

Although in general a three and a half log units change of surround luminance produced no change in ability to discriminate color, the observers reported consistent variations in the appearance of the stimulus with the various surround luminances. One such discrepancy between the reported appearance and the discrimination threshold was with the 1/3 stimulus-surround ratio. Here the stimulus appeared "washed out" against the brighter surround. Again, when the stimulus was considerably brighter than the surround (by one and a half log units or more), the observers stated that the stimulus was "desaturated." In some instances, the stimulus was reported as having no noticeable color. This phenomenon would be anticipated from the observed effect of luminance on saturation.[15] Yet, there was no reduction in hue discrimination.

It is difficult to provide a fixation point that will not seriously influence foveal judgments and at the same time maintain a dark surround. In an effort to circumvent this problem a tiny dot of luminous paint was mounted on a wire which was placed in front of the horizontal dividing line of the stimulus field. This aided the observer somewhat in locating the area where the stimulus was to appear but it was not sufficiently bright to enable him to fixate easily. The slight increase in threshold at the "black" condition is believed to reflect the difficulty in fixating rather than any effect of the stimulus-surround ratio.

The 0.06-ft-L stimulus represents the lowest luminance at which readings could easily be taken. Any further reduction would lower the stimulus from the photopic range. Although by broadening the bandwidth the luminance of the stimulus could be increased above the 2.0 ft-L maximum of this study, it is doubtful that any further increase in stimulus luminance would result in any marked decrease in discrimination threshold. The averaged data of Fig. 2 show that an increase of the stimulus one half log unit from 0.06 to 0.2 ft-L results in a greater reduction in threshold than a one log unit increase from 0.2 to 2.0 ft-L. For all observers, the curve for the 2.0-ft-L stimulus is highly sensitive and probably represents an absolute minimum or near minimum discrimination threshold. This means that, excluding the effect of a brighter-than-stimulus surround, the total change in hue discrimination resulting from any change in stimulus luminance averages less than 2 mμ.