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INDUCED DESENSITIZATION

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Abstract—Viewing of annuli modulated in color in a sawtooth fashion in time results in differential threshold elevations for the detection of color changes of inscribed disks. The elevations are of nearly the same magnitude as those resulting from viewing modulated disks. However, the differential effects on thresholds for complimentary colors are reversed. The differential effects, thus, are correlated with the variation in appearance of the test area.

Induction Desensitization Habituation Color Transretinal interaction Appearance Simultaneous contrast

INTRODUCTION

This paper is concerned with the question of whether detection thresholds may be influenced through neural interaction by stimuli which fall on other regions of the retina. Another more provocative question is whether thresholds are determined by the appearance of the region on which tests fall. There are several examples of transretinal effects that do not seem explicable in terms of physical factors such as stray light (Craik, 1938; Guth, 1973; Heinemann, 1961; Westheimer, 1967). On the other hand, there do not seem to be any cases in which changes in appearance of a test region *per se* result in changes in thresholds. Negative evidence is often not published but Cornsweet and Teller 1965) and Sternheim (1970) found that increment thresholds were essentially unchanged when the luminance or hue of the annulus surrounding the test area was varied even though this manipulation resulted in large changes in the brightness or hue of the area on which the tests fell. Here we report clear evidence that detection thresholds can be altered markedly by stimuli previously presented to other retinal regions than that upon which the test stimulus falls. Furthermore, these changes are correlated with the changes in appearance of the test region induced by the remote stimuli, making simple physical explanations improbable.

Krauskopf *et al.*, (1982) found that thresholds for detecting changes in saturation are raised following viewing of a field sinusoidally modulated in color over time. This effect was highly selective with regard to color. Thresholds for seeing reddish and greenish stimuli were elevated maximally following viewing of fields modulated sinusoidally between red and green, while thresholds for seeing yellowish and bluish changes were not altered. On the other hand, thresholds for seeing yellowish and bluish changes were maximally elevated following yellowish-bluish modulation which had no effects on thresholds for reddish and greenish changes. In addition, differential elevation of the thresholds for reddish vs greenish or yellowish vs bluish tests (Krauskopf *et al.*, 1982) and for increments and decrements in brightness (Krauskopf, 1980) were found when the conditioning field was modulated in a saw-toothed fashion in time.

When one views a neutral disk on a colored annular surround the disk is tinged in the color complementary to that of the surround. If the annulus is modulated in color in time, for example, from red to green, the disc appears to be modulated in counterphase. The question we asked was two-fold: would thresholds be elevated for disc tests when a stimulus modulated in a sawtooth fashion in time fell on an annular region surrounding it, and if so would the elevation be that predicted by the phase of the actual modulation of the surround or the apparent modulation of the test region. The results were that threshold elevations were those predicted by the appearance of the test area.

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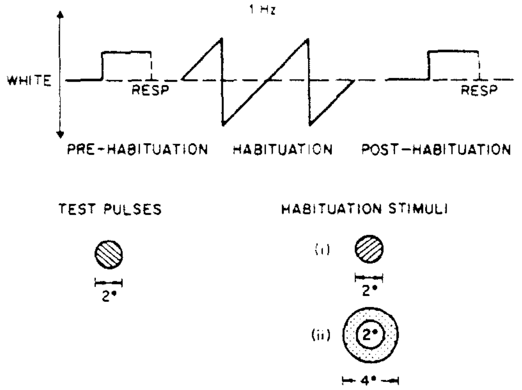

Fig. 1. Experimental design.

METHOD

The observers fixated the center of a T.V. monitor. Initially the whole 9 by 10 deg display was an equal energy white of 100 cd/m^2. This was the time averaged chromaticity and luminance of the display throughout the course of the experiments. The display was driven by an Adage frame buffer controller which allowed 10 bit specification of the intensity of each T.V. primary for 2^{30} possible colors, of which any subset of 256 colors could be painted in 480 by 512 pixels.

The experimental conditions are illustrated in Fig. 1. Thresholds for the detection of stepwise changes in the color or brightness of a 2 degree disk in the center of the rectangle were measured by a yes-no staircase procedure. The changes in the disk were in one of the cardinal directions identified by Krauskopf *et al.* (1982). One chromatic cardinal axis is the Constant B axis along which only R and G cone inputs vary isoluminantly and the other is a Constant R&G axis along which only B cone input varies. The third cardinal axis is the luminance axis. The stimuli appeared to be steps in a reddish, yellowish, greenish or bluish direction, or increments or decrements in luminance. The stimulus offset remained until the observer responded. This was a vital feature because we wanted the observer to base his or her judgement on the first step change alone. The results were, in fact, predictably different with pulses and steps.

After initial thresholds were measured, thresholds were remeasured in an habituated state. That is, there was an initial exposure to a field varying in luminance or color, followed by interspersed test trials and top-up exposures of the temporally varying field. The habituation stimulus varied in a sawtooth fashion in time. For example, in one cycle, the field might vary slowly from red to green and then snap back to red. The initial habituation was 30 cycles and each top-up habituation was 5 cycles.

In this experiment we used a 2 deg disk as the test while the habituation stimulus was either a 2 deg disk, replicating the earlier experiments of Krauskopf *et al.* (1982), or an annulus with an inner diameter of 2 deg and an outer diameter of 4 deg. In the latter case the observers reported induced changes in the appearance of the central disk. For example, if the annulus was slowly modulated in a yellowish to bluish direction and rapidly back in the yellowish direction, the central disk appeared to be modulated slowly in the bluish to yellowish direction and rapidly back in the bluish direction.

RESULTS

Threshold changes following viewing of *disks* modulated in the Constant B, Constant R&G,

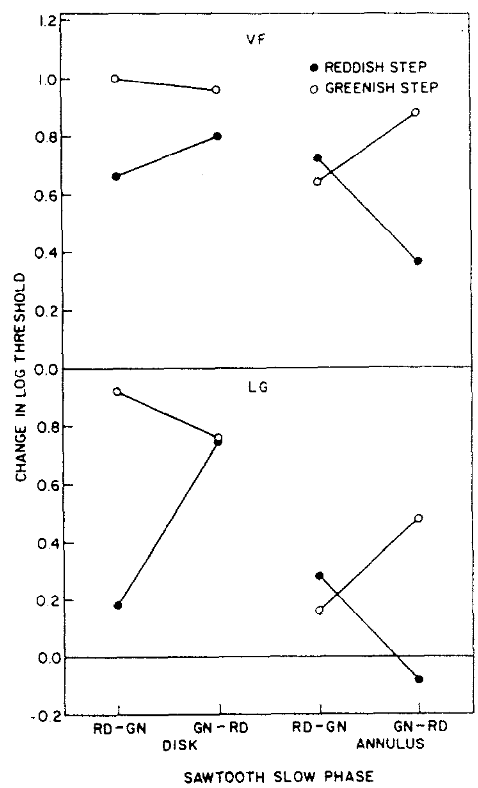

Fig. 2. Changes in log threshold following viewing of modulated fields. Results on the left are for the case that the habituation stimulus is a disk, those on the right for the case that the habituation stimulus is an annulus. Habituation and test stimuli are in the Constant B direction in color space. RD–GN implies that the disk (or annulus) varied slowly in the reddish to greenish direction along the Constant B axis. The results for two observers are plotted. Each point is the mean of two determinations. The mean range of the pairs of observations determining the points is 0.11 log units.

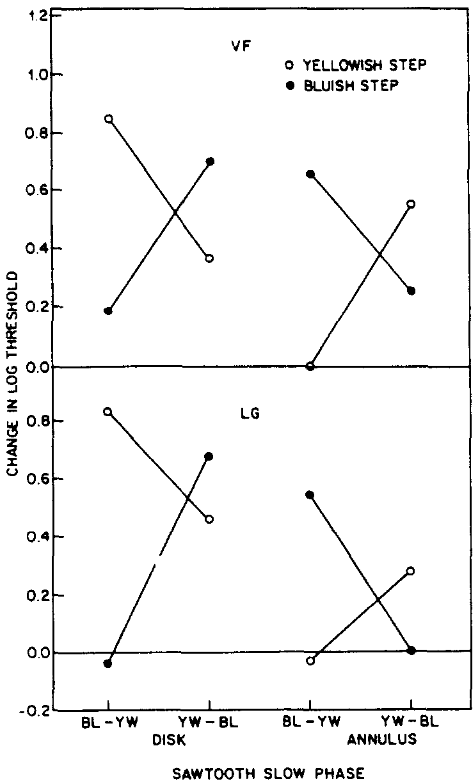

Fig. 3. Changes in log threshold following viewing of modulated fields. Similar to Fig. 2 except stimuli are in the Constant R&G direction of color space, BL–YW implies that the disk (or annulus) varied slowly in the bluish to yellowish direction along the Constant R&G axis. The mean range of the pairs of observations determining the points is 0.09 log units.

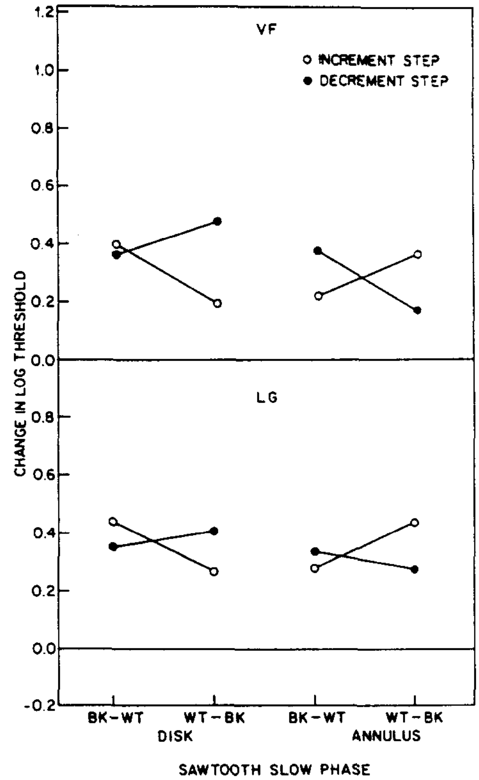

Fig. 4. Changes in log threshold following viewing of modulated fields. Similar to Fig. 2 except stimuli are in the luminance direction of color space. BK–WT implies that the disk (or annulus) varied slowly in the black to white direction along the luminance axis. The mean range of the pairs of observations determining the points is 0.08 log units.

and in luminance are shown in the left panels of Figs 2, 3 and 4, respectively. Thresholds are raised more for steps when they are in the *same* direction as the slow phase of the habituation stimulus than when they are in the *opposite* direction to the slow phase of the habituation stimulus.

The novel results are plotted in the right panels of Figs 2, 3 and 4. These are for the case of annular habituating stimuli. Once again the thresholds are generally elevated after viewing the modulation stimulus but the relation between the sign of the sawtooth and the magnitude of threshold elevation is reversed. Thresholds are raised more for steps when they are in the *opposite* direction to the slow phase of the habituation stimulus than when they are in the *same* direction as the slow phase of the habituation stimulus.

The reliability of the results can be assessed by noting that there are twelve lines in each the left and the right panels of Figs 2, 3 and 4. In all cases the slope of the lines in the right panel has the opposite sign to that for the same test stimulus in the left panel. This will occur by chance by one time in 4096. The main range of the pairs of observations determining the points is 0.09 log units.

DISCUSSION

There are several interesting features of these results. One is that rather large elevations of thresholds, almost 1.0 log units in magnitude, occurred when the habituation stimulus was acting on a region other than that on which the test fell. The size of these indirect effects is only slightly, if at all, smaller than the direct effects of disk habituation stimuli on disk test stimuli. The threshold elevating effect of the annulus cannot be due to stray light effects, else the sign of the interaction would be the same as that in the case that the disk was modulated.

There are not many examples of transretinal interaction for which physical explanations are clearly ruled out. The "Westheimer Effect" is one such but the interactions in that case occur over much shorter visual distances (Westheimer, 1967). Craik (1938) and Heinemann (1961) have shown that brightness discrimination, as reflected by flicker detection thresholds and increment thresholds, is the best when the distant surround brightness is approximately equal to that of the focal area. The variation in the surround results in a change in the appearance of the focal area but the changes in discrimination are not simply correlated with changes in appearance. Indeed, Cornsweet and Teller (1965) and Sternheim (1970) conclude that increment thresholds are dependent only on the retinal illuminance of the region upon which the test is added when proper account is made of the effects of stray light. Guth (1973) argues that the presence of a surround would effect the appearance of both the test field and any increments added to it making predictions of the effects of surrounds on increment thresholds problematic.

In the present case, interactions are unequivocally consistent with the *appearance* of the disk during the modulation phase of the experiment rather than that of the annulus. Of course, this correlation with appearance does not constitute an explanation of the effects. One speculation is the annulus induces effects in some structures, or elements, that are ordinarily directly effected by the modulation of the disk, and that these effects are responsible for the threshold elevations in both cases. Alternatively, the desensitization results from quite distinct processes in the direct and induced cases. If the later is true, the induced effect may prove valuable in the investigation of higher order mechanisms in color vision (Krauskopf *et al.*, 1986).

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