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Visual thresholds near a continuously visible or a briefly presented light-dark boundary†

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Detection thresholds were measured for a small spot of light appearing at various distances from a light–dark boundary. Thresholds were elevated for spots appearing adjacent to the boundary (sharpening) only when the boundary was viewed continuously and not when it was presented for a brief interval. It was concluded that sharpening develops with exposure duration, the full effect appearing only with prolonged viewing.

1. Introduction

Recently, a number of investigators [1–5] have noted an increase in threshold near a light–dark boundary presented continuously in the fovea. That is, if the intensity increment necessary for the detection of a test spot superimposed on an illuminated background is ΔI, then *removing* some of the background light adjacent to the test spot (and thereby producing a boundary) results in an increase in ΔI. In an unpublished study‡, one of us (G. S.) did not observe a comparable threshold increase near a light–dark boundary when the boundary was presented briefly (10 msec) in the fovea. A similar observation was made by S. N. when a boundary was presented for the same brief duration in the periphery. With continuous peripheral presentation of the boundary, however, threshold increases near the boundary were relatively easy to observe. The purpose of the present article is to report experiments which show the time dependence of this effect.

2. Apparatus

A general plan of the equipment is illustrated in figure 1. A Maxwellian view system was used with glow modulator tubes (Sylvania 1131C) operating at a current of 24 mA as light sources. The effective pupil at the eye was approximately 1·5 mm.

The geometric arrangement of the stimuli as they appeared to the observer is illustrated in figure 2. The observer always fixated a small square 7° 33′ to the left of the test spot with his right eye. In preliminary experiments, two small spots of light were individually adjusted to appear just inside the nasal and temporal boundary of the observer's blind spot. These spots were visible except when the eye was fixated upon the fixation point. The spots were never seen during the experimental session, thereby indicating that no *gross* eye movements occurred during the presentation of the boundary.

† The present experiments were conducted while one of the authors (S. N.) was a resident visitor at the Visual and Acoustics Research Laboratory of the Bell Telephone Laboratories, Incorporated. He is now at Vassar College, Poughkeepsie, New York.

‡ Sperling, G., Spatial and Temporal Visual Masking. Paper read at the Psychonomic Society, Columbia University, New York, September 1961.

The background subtended 19° 6′. It was illuminated to 64 trolands. A ' black ' area (bar) was produced by intercepting the light beam. It subtended 0° 53′. The bar was moved horizontally so that it appeared in various spatial locations relative to the test spot. The test spot subtended 13′. Because the location of the test spot remained fixed, any threshold change in the test spot can be attributed only to the relative location of the black bar.

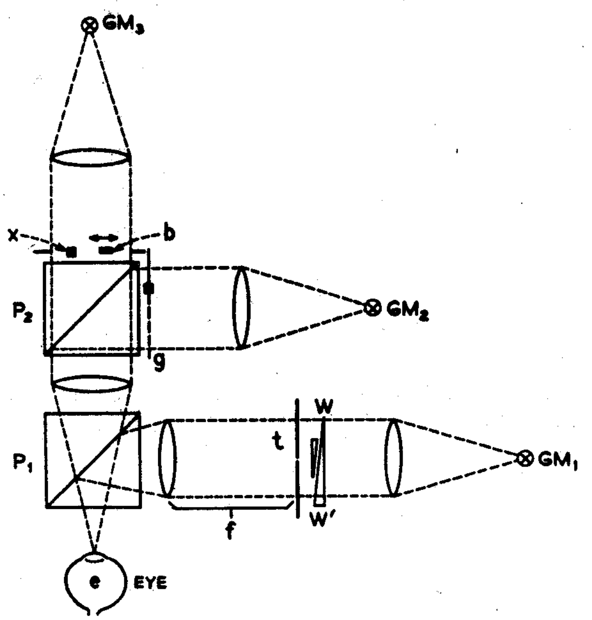

Figure 1. Schematic diagram of apparatus : e = observer's eye, GM = glow modulator light sources, f = F.L. of achromatic lenses (104 mm), p = partial reflecting 45° prism, x = fixation point, b = opaque bar (arrow indicates it is displaceable horizontally in plane of bar field), t = test spot, g = plane of background field, W–W′ = optical wedge and counterbalancing wedge.

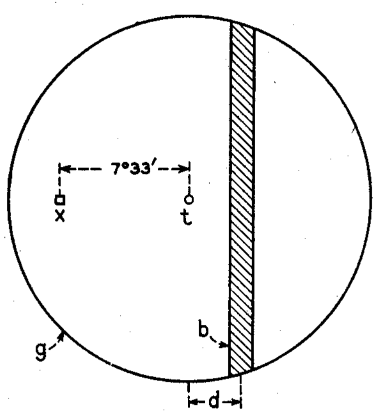

Figure 2. Composite view of stimuli : x = fixation point, t = test spot (13′), b = black bar (53′ in width), d = displacement of bar (variable, shown in + position), g = background (19° 6′, 64 trolands).

2.1. *Experiment* 1

The bar was continually visible. The test spot was flashed for 10 msec with a 1 sec interval between flashes. A motor-driven neutral density wedge to control test spot intensity was operated by the observer. The observer's task was to adjust the intensity of the flashing test spot until it was 'just detectable'. Successive judgments were made at randomly chosen spatial locations. After preliminary training, observer JA made 26 judgments at each location and observer SN made 10.

The mean data for each of the observers are presented in figure 3. The abscissa (bar displacement) indicates the spatial location of the centre of the black bar relative to the test spot. Negative locations indicate bar to the left of test spot (i.e. between fixation and test spot). The ordinate indicates the average threshold intensity of the test spot. The data show that threshold is lowest when the test spot appears in the centre of the black area and is highest just outside of the black bar. When the bar appears immediately adjacent to the test spot, the threshold increase (relative to the uniform background) amounts to about 0·3 log trolands for observer JA and 0·6 log trolands for observer SN. These changes are of the same order of magnitude as those previously noted by other investigators.

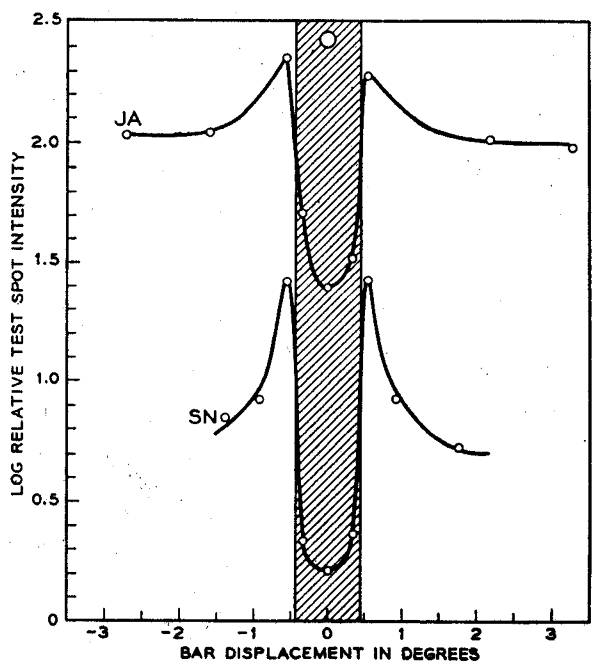

Figure 3. Threshold luminance of the test spot as a function of bar displacement (continuous bar, 10 msec test spot). Data for observer JA have been moved up 1·0 log unit. Relative sizes of test spot and bar are indicated at top with bar in zero displacement position.

2.2. *Experiment* 2

In the second experiment, the observers viewed a uniform background. The background was interrupted while the field containing the bar was presented for a duration of 10, 50, or 500 msec. The test spot was presented at the same time and for the same duration as the bar. The entire presentation was repeated after a 1 sec interval. The background was of the same intensity whether or not the bar was present.

The total stimulus presentation therefore consisted of a momentary darkening of the area subtended by the bar and simultaneous illumination of the test spot. The reason for using a darkening (instead of momentary illumination) to produce a boundary is that, by darkening a part of a field, an increase in threshold for the spot cannot be attributed to an increase in luminous flux. It must be attributed to changing the *pattern* of stimulation (i.e. producing a boundary) rather than increasing the amount of light. The reason for using a light test spot (instead of a dark test spot) is that the former is much easier to produce experimentally. However, experiments by one of the authors [6] indicate that, to a first approximation, thresholds for increment and decrement test flashes are closely correlated.

The mean data are presented in figure 4. The coordinates are the same as in figure 3 ; each point is based on six judgments. The data for 50 and 10 msec durations each have been displaced upward by an arbitrary amount. Data are available only for observer SN. Observer JA provided comparable data in some preliminary experiments but unfortunately he was unable to complete his observations.

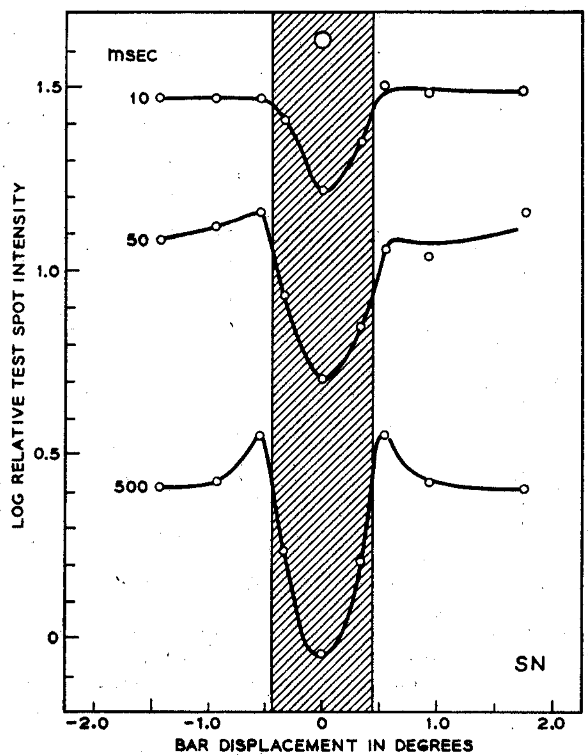

Figure 4. Threshold luminance of the test spot as a function of bar displacement. Parameter is the exposure duration of the test spot and bar. Data for 50 and 10 msec durations have been moved up an arbitrary amount.

As before, the data indicate that thresholds are lowest when the test spot appears within the bar. When the bar and test spot duration was 10 msec, the threshold of the test spot adjacent to the bar is about the same as for more remote positions. When the bar duration is 500 msec, the threshold for a test spot adjacent to the bar is clearly higher than at more remote positions. Although the data obtained at the 50 msec exposure duration are particularly variable, they do suggest a slight threshold elevation for test spots adjacent to the bar.

3. Discussion

Threshold changes occurring near a boundary are usually attributed to an interaction between nerve cells which results in a 'sharpening' of the stimulus pattern. Keeping in mind the restriction to the particular observation conditions, the results of the second experiment suggest that sharpening develops with exposure duration, the full effect occurring only with prolonged exposure.

4. Summary

A small test spot was flashed briefly upon a steady, illuminated background. Viewing was peripheral. The intensity threshold of the test spot was measured as a function of its distance from a boundary produced by a 'black' bar. That is, the bar appeared in various locations relative to the test spot. In the first experiment the bar was presented continuously. Thresholds were elevated most when the spot test appeared immediately adjacent to the boundary. In the second experiment, the test spot and black bar were presented simultaneously for durations of 10, 50, or 500 msec against the continuously illuminated background. With an exposure duration of 500 msec, a threshold elevation was clearly observed for spots adjacent to the bar. With the 50 msec viewing time, thresholds of spots near the boundary were slightly elevated. No such threshold elevation was discernible with a 10 msec exposure.

On a mesuré les seuils de discrimination pour une petite tache de lumière apparaissant à diverses distances d'une frontière séparant une zone éclairée d'une zone obscure. Les seuils étaient élevés pour des taches apparaissant juste à la frontière, uniquement lorsque celle-ci était vue de façon continue et non lorsqu'elle était présentée pendant une courte durée. Il en a été déduit que le pouvoir de discrimination augmente avec la durée d'exposition, l'effet n'apparaissant entièrement que pour des observations prolongées.

Für einen kleinen Lichtfleck, der in wechselndem Abstand von einer Hell-dunkel-Grenze dargeboten wird, wurde die Erkennbarkeitsschwelle gemessen. Die Schwellenwerte waren für Flecke, die unmittelbar an der Grenze lagen, nur dann erhöht, wenn die Grenze kontinuierlich beobachtet wurde, nicht aber wenn sie nur für ein kurzes Zeitintervall dargeboten wurde. Man kann daraus folgern, daß die Schärfe mit der Expositionsdauer wächst und die volle Wirkung erst bei längerem Beobachten auftritt.

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Increment Thresholds

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IN his recent letter, Matthews[1] reports an experiment in which he uses basically the same procedure, finds basically the same results, and comes to basically the same conclusion as Novak and Sperling[2] did in an article which Matthews overlooked. There are some minor differences, e.g., Novak and Sperling used 7°33′ peripheral viewing; Matthews used central fixation. Both studies agree that the threshold for a spot adjacent to a light–dark boundary is higher than the threshold for the spot away from the boundary only when the boundary is exposed for more than about 50 msec. Matthews' final conclusion, that "brightness and increment threshold do not depend on the same mechanism" (which we interpret to mean that brightness and increment threshold may vary independently) also has been anticipated by Sperling,[3] Cornsweet and Teller,[4] and others.[5]

[1] M. L. Matthews, J. Opt. Soc. Am. **56**, 1401 (1966).
[2] S. Novak and G. Sperling, Opt. Acta **10**, 187 (1963).
[3] G. Sperling, J. Opt. Soc. Am. **55**, 541 (1965).
[4] T. N. Cornsweet and D. Y. Teller, J. Opt. Soc. Am. **55**, 1303 (1965).
[5] See J. Nachmias and R. M. Steinman, Vision Res. **5**, 545 (1965); D. A. Burkhardt, J. Opt. Soc. Am. **66**, 980 (1966).