The influence of central search task luminance upon peripheral visual detection time

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Twenty Ss were exposed to a wide range of luminances (8.5, 55, 792, 6,800 fL) of a centrally located diffuse white search panel. Each S attempted to detect the onset of seven randomly presented test lights (90, 60, 30 deg of arc left and right of 0 deg of arc along the horizontal meridian) concurrently with a continuous search task. The findings suggest that the visual field constricts with an increased central panel luminance. This is shown by an increased peripheral detection time (DT) and by more undetected peripheral test lights, even though the difficulty of the central search task was held constant. These results on the effect of an environmental stressor (high luminance) upon peripheral DT are related to findings from previous investigations as well as various applied situations.

It is reasonably well established that peripheral stimuli are more difficult to detect when attention is focused on simultaneously presented foveal stimuli (Kobrick, 1965; Leibowitz & Appelle, 1969), when the stimuli are imaged at increasing angular distances from the fovea (Bartz, 1962; Rains, 1963; Haines, 1968), and when the informational load is excessive (Sanders, 1963; Mackworth, 1965). Certain environmental stressors have also been shown to contribute to an increase in detection time (DT) to peripheral stimuli. Bursill (1958), using heat, and Kobrick & Dusek (1970), using hypoxia, have also demonstrated an increased peripheral DT.

The basis for an increase in peripheral DT has been interpreted as resulting from a "constriction" of attention. Sanders (1963), in summarizing the results of a series of experiments on information processing, refers to the "functional" or "effective" visual field which shrinks or expands depending upon the perceptual load of the task. Similarly, Mackworth (1965) has shown that visual noise causes (functional) tunnel vision where the "useful" field contracts to prevent an overloading. Teichner (1968) has referred to a cortical (attentional) tuning process as a mechanism which has an increased responsiveness to certain stimuli and reduced responsiveness to others. He further states that environmental (physical) stressors and/or symbolic stressors increase the neurophysiological activation level, and, as this level increases, so does the degree of regulatory activity; this leads to further selectiveness (i.e., constriction) of attention.

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In view of the studies cited above, it was expected that DT to peripheral stimuli would increase with an increase in luminance of a centrally located continuous visual search task when the luminance of the search task panel is high enough to be considered an environmental stressor. Attention is defined as the degree to which a S can respond successfully to peripherally presented stimuli while also engaged in a central search task; constriction of attention is measured by an increased DT and/or an increased number of errors (i.e., DTs over 2 sec) committed to peripheral test lights.

One must be able to detect and respond to peripheral visual stimuli in a variety of real-life situations (e.g., piloting aircraft, driving surface vehicles, and monitoring many kinds of indicator/control panels). And it is at these times, when a physical stressor is present, that one can least afford to have his peripheral visual detection capability impaired. The purpose of the present investigation is to determine the relationship that exists between a high-luminance stressor, which is also part of the S's central search task panel, and his peripheral visual detection capability.

SUBJECTS

Twenty paid college students (17 male, 3 female), ranging in age from 18 to 28 years, participated. All had 20:20 uncorrected acuity (Snellen) or better and full and normal visual fields.

APPARATUS

Peripheral detection was measured by the use of a 24-in. radius laboratory perimeter, upon which was located seven incandescent red 0.63-in.-diam (1 deg 30 min of arc) test lights, each separated by 30 deg of arc along the S's horizontal meridian. Test light luminances were: 90 deg L and R = 115 fL; 60 deg L and R = 105 fL; 30 deg L and R = 83 fL; 0 deg = 95.8 fL; where L = left and R = right of the 0-deg test light. The interstimulus interval was varied randomly in seven intervals ranging from 6 to 10 sec (mean = 8 sec).

A diffuse white 17 x 14 in. panel was located on the left and right sides (intersecting at a 45-deg angle) of a 14 x 14 in. (30 deg 15 min of arc wide) central white (90% reflectance) panel. The two 30-deg-arc test lights and the 0-deg test light were seen through 1-in.-diam holes made in these three panels. The stimuli used in the central search task consisted of a 5 x 5 matrix of photographically reproduced English alphabet letters. Each of the black letters (letter-to-background contrast = —.9) were on 2.5-in. centers (height = 0.08 in; width = 0.06 in.), and at the 24-in. viewing distance, the stroke and line separation was equivalent to an acuity of 20:200 (10 min of arc). The interletter visual angle, horizontal and vertical, was 6 deg of arc; from one corner letter to the opposite diagonal letter was 30 deg 30 min of arc and from any diagonal letter to any adjacent letter was 8 deg 27 min of arc.

PROCEDURE

Each S viewed the perimeter and central panel from a 24-in. distance within a testing facility described elsewhere (Haines & Burgard, 1967). A solar simulator (5,800° K) illuminated the central panel. Neutral filters were inserted in the beam to obtain the following luminances: 55, 792, 6,800 fL. Standard fluorescent (3,200° K) ceiling lamps were used to produce a control panel luminance of 8.5 fL.

All Ss responded to the onset of a test light by pressing a normally open spring-loaded switch held in their preferred hand. A Model S-1 Standard Electronic Clock started when the test light came on and stopped with the S's response. DT measurements are accurate to approximately 10 msec. The randomized letter presentation order for the search task was pretaped on a Cassette recorder. One letter of the alphabet was called out approximately every 5 sec over the intercom. The S searched for this letter, fixated it for about 1 sec, and then refixated the center 0-deg test light until the next letter was called out. The S's head was positioned by a chinrest, and vision was always binocular. The S was light-adapted for at least 2 min to each panel luminance.

Each daily session (160 responses per S) lasted about 20 min. The total number of DT responses collected on all Ss was 11,200. The presentation order of all conditions was

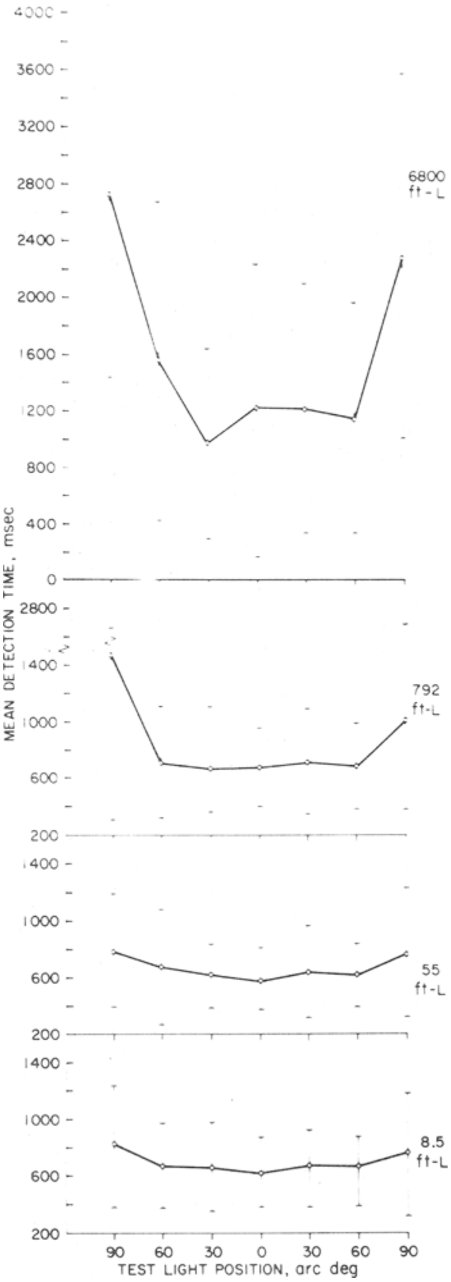

Fig. 1. Mean detection time to peripheral lights under 8.5-, 55-, 792-, and 6,800-fL luminances.

appropriately counterbalanced to help control for order and learning effects. All Ss were given two complete training sessions just prior to the 4-day experimental data collection.

The S was told that the lights would appear at any position and at any time during the testing session. It was emphasized that he was to respond as fast as possible to both test light onset and to each letter called out and not to stop performing one task in order to do the other; i.e., the test instructions did not bias S toward either task.

RESULTS

The results are presented in Fig. 1. Plus and minus one standard deviation is shown about each DT (in milliseconds). Each DT is based on 400 responses.

The first analysis of variance (Bennett & Franklin, 1954) performed used a luminance (L) by light position (P) by Ss (S) design and included all test lights. Significant main effects were obtained for luminance, $F(3/57) = 25.01$, $p < .001$; for light position, $F(6/114) = 43.97$, $p < .001$; and for Ss, $F(19/10604) = 52.41$, $p < .001$. The Position by Luminance interaction, $F(18/342) = 20.75$, $p < .001$, and the Position by Luminance by Ss interaction, $F(342/10604) = 5.15$, $p < .001$, were also significant. A subsequent Newman-Keuls test indicated that the significant ($p < .01$) 90-deg light position contributed the majority of the total variance. Therefore, a second analysis of variance was performed which excluded the 90-deg test lights. This analysis showed that the main effects were significant, as was the Position by Luminance by Ss interaction, $F(228/7600) = 1.57$, $p < .001$.

It can be seen in Fig. 1 that DT within 60 deg of arc increases slightly on both sides of the 0-deg test light position. However, t tests showed that mean DTs associated with both 90-deg test light positions differ significantly ($p < .001$) from the 0-, 30-, and 60-deg arc left and right test light positions. For each of the luminance levels (55, 792, 6,800 fL), t-test differences were significant (all $p < .001$). The 8.5-fL condition did not differ significantly from the 55-fL condition, but did differ significantly from the 792- and 6,800-fL conditions (each $p < .001$).

If S did not respond to the onset of a test light within 2 sec, an error was scored. A chi-square analysis was performed on the number of errors which occurred per luminance condition and test light position. The distribution of errors was similar to the distribution of increased DTs for both test light position and panel luminance. Thus, significantly more errors ($p < .005$) were made to the more peripheral test lights as well as under the higher luminance conditions. The percentage of errors, disregarding the 0-deg arc test light position and summed across test light positions, increased regularly as a function of luminance; i.e., 8.5 fL (1%), 55 fL (2%), 792 fL (5%), and 6,800 fL (27%).

Each S's daily data were also analyzed in five equal-sized groups. The grand mean for each group was determined for the entire study and for each luminance condition. A progressive decrease in DTs across these five groups might be interpreted as a learning (and lengthened DTs as a fatigue) effect. Neither was found.

DISCUSSION

The distribution of DTs found in this study is similar to those reported elsewhere (Bursill, 1958; Bartz, 1962; Rains, 1963; Kobrick, 1965; Kobrick & Dusek, 1970). The present error analysis showed that Ss frequently and regularly missed test lights at the far periphery and even missed the 0-deg test light (15% at 6,800 fL) which was centered on the search panel. Further experimentation, including eye movement monitoring during the search task, should be conducted to help clarify this finding.

The present panel luminances were shown to produce regular changes in DT in a manner similar to those associated with the presence of an environmental stressor, and attention under these conditions was shown to constrict. This is a finding consistent with Teichner's (1968) theory.

As mentioned earlier, these lengthened DTs and the increased percentage of missed test lights could have serious implications if they occur in a number of real-life situations, particularly those activities which require continued central vigilance as well as peripheral visual detection in the presence of a brightly illuminated panel. Based upon the present findings, it is reasonable to suggest that warning lights should be located within 60 deg of arc or less from the line of sight (along the horizontal meridian) in order to aid detection as fast as possible.

To summarize, it is suggested, on the basis of experimental results, that peripheral visual performance may be impaired during situations of high luminance. This effect, as well as the effect of other stressors, i.e., hypoxia, acceleration, etc., should be taken into account and subsequent research conducted to define the mechanisms which underlie impaired peripheral visual performance as well as to determine how best to counteract this effect.

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