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Metacontrast target detection under light and dark adaptation*

DEAN G. PURCELL†
University of Arkansas, Fayetteville, Ark. 72701

ALAN L. STEWART
New York University, New York, N.Y. 10003

and

ROBERT L. BRUNNER
Purdue University, Lafayette, Ind. 47907

Two experiments investigated the influence of light and dark adaptation on forced-choice target detection under conditions of metacontrast. U-shaped masking functions were found under both adaptation conditions. The U minimum occurred at shorter Δt values under dark adaptation than under light adaptation. Light adaptation increased target detection under some conditions.

Boynton & Kandel (1957) determined that light adaptation could reduce the effectiveness of a masking flash. The present experiments investigated the influence of light adaptation on metacontrast.

EXPERIMENT I
Method

Subjects

Seventeen undergraduates participated in the experiment as a requirement of their introductory psychology course.

Apparatus and Procedure

The adaptation, target, and masking fields were square, subtending 3 deg on a side. The adaptation field was either light or dark as conditions required. This field contained the fixation stimulus. The fixation stimulus consisted of four 1-min dots arranged in a diamond pattern. Each dot was 60 min from the center of the field. Under conditions of dark adaptation, the dots were red. Under light adaptation, the dots were black. In the light-adapted condition, the luminance of the preexposure field was 20 fL. This field was illuminated continuously except when the target and mask were presented. In the dark-adapted condition, the adaptation field was dark. The target field contained a black disk with a diameter of 24 min. The onset of the target immediately followed the offset of the adaptation field. The luminance of the target field was 20 fL. This field was exposed for 20 msec. The black target disk reflected 2.4 fL. The onset of the mask field was delayed from the onset of the target field by Δt values of −20, −21, −25, −35, −50, and −80 msec. The mask field contained two black annuli, separated by 90 min of arc, center to center, and oriented to the left and right of the center of the masking field. The inner diameter of each ring was 24 min and the outer diameter was 34 min. The luminance of the mask field was 20 fL. This field was exposed for 20 msec. The black annuli also reflected 2.4 fL. Under Δt values longer than −20 msec, the target and mask onsets were separated by an interstimulus interval (ISI). Under light adaptation, the ISI was illuminated at 20 fL. Under dark adaptation, the ISI was dark. The Ss were instructed to look at the center of the fixation field, which corresponded to a point halfway between the two rings in the masking field. On any given trial, the target disk was positioned so that upon simultaneous exposure of target and mask, the target appeared to fit snugly inside one or the other of the rings. All viewing was monoptic with the right eye. The S's task was to indicate in which ring the black disk appeared, guessing if necessary. Each S was tested on both light and dark adaptation under six Δt values, 25 trials per condition, for a total of 300 trials per S.

Ss were tested at all Δt values under a given condition of light or dark adaptation before going on to the remaining conditions. For each S, the order of testing on light- or dark-adapted Δts was randomly determined. The order of presentation of Δt values within a condition of adaptation was also randomly determined for each S. Ss were adapted to the prevailing condition, light or dark, for 10 min prior to testing. Ss practiced the experimental task during the adaptation period. Practice was conducted at a Δt of −200 msec until the S made 20 consecutive correct localizations or detections. The S initiated each trial by pressing a thumb switch. Each session took approximately 1 h.

Results and Discussion

Figure 1 presents the results in mean percent correct for conditions of light and dark adaptation. Repeated measures analysis of variance showed significant main effects for adaptation, $F(1,16) = 12.9$, $p < .01$, and Δt, $F(5,80) = 3.1$, $p < .025$. A separate analysis of the light-adapted condition also demonstrated a significant main effect of Δt, $F(5,80) = 2.69$, $p < .05$. A t test was performed to verify the existence of a drop in target detection as Δt was increased from −25 to −35 msec in the light-adapted condition. The t test on the percent correct target detection showed this decrease to be statistically significant, $t(16) = 2.75$, $p < .01$. Further determination of the characteristics of the masking

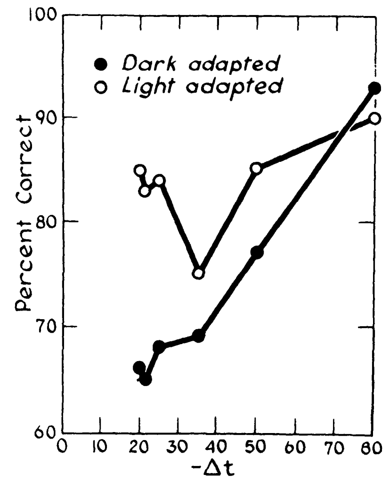

Fig. 1. Mean percent correct target detection at six Δt values for the light and dark conditions of Experiment I.

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†Requests for reprints should be sent to D. G. Purcell, Department of Psychology, University of Arkansas, Fayetteville, Ark. 72701.

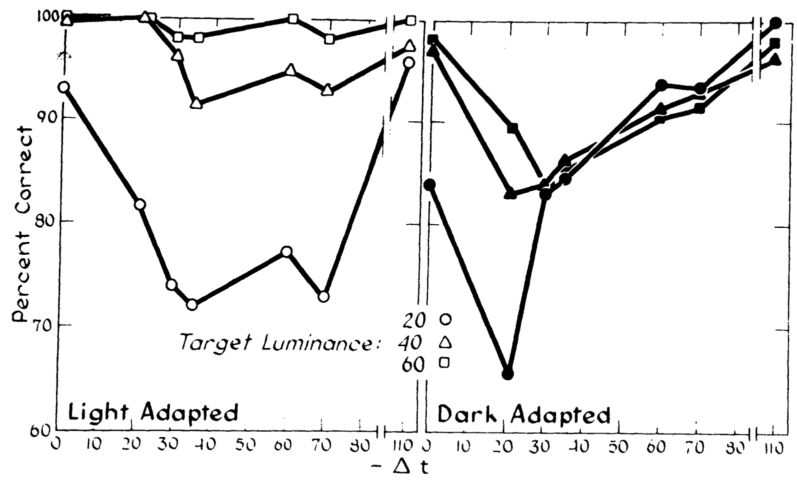

Fig. 2. Mean percent correct target detection at seven Δt values, under three levels of target luminance, for the light and dark conditions of Experiment II.

functions were made by adjusting first- and second-degree polynomial equations to give lines of best fit to the data points, as represented in Fig. 1 (Dixon, 1967). It was found that under light adaptation, the quadratic component accounted for 28% of the variance and the linear, 33%. Under dark adaptation the quadratic accounted for 1.8% of the variance and the linear, 98% of the variance. The results of the analysis of variance on the light-adaptation conditions considered together with the results of the t test and curve fitting all indicate a strong nonmonotonic component to the light-adapted masking function.

EXPERIMENT II

To test the hypothesis that dark adaptation shifts the U minimum toward shorter Δt values, a Δt value of zero was included in Experiment II. The zero Δt value allowed an assessment of the maximum effect of luminance-summation contrast-reduction on target detection. Three levels of target energy were employed to test the hypothesis that increases in target energy will reduce target report (Purcell, Stewart, & Dember, 1969). An artificial pupil was used to control pupil size under light and dark adaptation.

Method

Subjects

Five trained, paid Ss participated in Experiment II.

Apparatus and Procedure

The apparatus and procedure were the same as in Experiment I, with the following exceptions. A 3-mm-diam artificial pupil was used in all conditions. The masking field luminance was 40 fL. The adaptation field in the light-adapted condition was 40 fL. In the dark-adaptation condition this field was not illuminated. Three levels of target field illumination were tested. These were 20, 40, and 60 fL. Values of Δt equal to 0, –20, –30, –35, –60, –70 and –110 msec were presented to each S in a different random order, with data gathered in two different blocks of 25 responses each. Ss were light or dark adapted for 10 min, and only one adaptation condition was run for each S during one session.

Results and Discussion

The repeated measures analysis of variance disclosed significant main effects of Δt, $F(6,24) = 7.4$, $p < .001$, and target luminance, $F(2,8) = 210.25$, $p < .001$. The analysis also disclosed two-way interactions of Δt by Adaptation, $F(6,24) = 5.78$, $p < .01$, Δt by Target Luminance, $F(12,48) = 5.30$, $p < .001$, and Adaptation by Target Luminance, $F(2,8) = 26.68$, $p < .001$. There was also a three-way interaction of Δt by Adaptation by Target Luminance, $F(12,48) = 9.02$, $p < .001$.

Again the characteristics of the masking functions were determined by fitting polynomial equations to the masking functions. Under light adaptation with 20-, 40-, and 60-fL targets, the quadratic component accounted for 84.47%, 64.81%, and 34.76% of the total variance, respectively. By comparison, the linear component accounted for only 6.14%, 1.56%, and 3% of the total variance. Under dark adaptation with 20-, 40-, and 60-fL targets, the quadratic component accounted for 0.05%, 27.75%, and 54.8% of the total variance. The linear component accounted for 52.29%, 15.8%, and 8.84% of the total variance.

Adaptation state had several effects in Experiment II (see Fig. 2). With the exception of the 20-fL-target condition, target detection was highest under light adaptation. Under light adaptation, target detection was also relatively constant, from the U minimum of –35 msec out to –70 msec. However, under dark adaptation, the U minimum was shifted to –20 msec, and target detection changed rapidly out to –70 msec. These differences in the U function are not predicted by present theories of metacontrast (see Bridgeman, 1971; Weisstein, 1968).

Increases in target energy generally served to increase target detection. This was not so for dark-adapted Δt values greater than –20 msec.

GENERAL DISCUSSION

Experiments I and II provide evidence that disk-annulus metacontrast, force-choice detection functions can be U-shaped under both light and dark adaptation. This finding, and the finding of Cox & Dember (1972), contradicts the speculation that U-shaped masking functions are not to be found when a forced-choice detection task is employed (see Bridgeman, 1971; Eriksen, Becker & Hoffman, 1970; Kahneman, 1968; Schurman, 1972). Experiments I and II also indicate that light adaptation can, under certain circumstances, increase target detection. This finding is consistent with the argument that light adaptation can reduce the influence of luminance summation on masking (see Eriksen, 1966). It is also consistent with the idea that light adaptation reduced the mask's efficiency by reducing the magnitude of the neurological "on-response" it produces (see Boynton & Kandel, 1957). Both of these hypotheses of backward masking assume that the target and the mask sum together or are integrated in the visual system. As such, neither of them predicts U-shaped or masking functions. The possibility is suggested that temporal integration mechanisms may determine absolute levels of masking, but not necessarily the shape of the masking function.

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Detection of single letters and letters in words with changing vs unchanging mask characters*

W. K. ESTES, ELIZABETH L. BJORK†, and EDITH SKAAR
Rockefeller University, New York, New York 10021

With a forced-choice procedure and tachistoscopic displays, accuracy of identification was compared for letters presented alone vs the same letters embedded in words or in nonword letter strings. The advantage for single letters over letters embedded in words or nonwords was found to depend jointly upon characteristics of the pre- and postmasks and change vs no change in mask characters in nontarget locations at the onset of single letter displays.

In contrast to the finding of Reicher (1969) and Wheeler (1970) that letters are better identified when embedded in words than when presented alone, several more recent studies (Bjork & Estes, 1973; Massaro, 1973; Thompson & Massaro, 1973) have reported a single letter advantage. All of these studies utilized tachistoscopic presentations with similar exposure durations, but there has been one principal difference in procedure. In the studies showing a word advantage, the target letters for a trial have been indicated to the S by means of a postexposure cue, whereas in the studies showing a single-letter advantage, the target letters have been known in advance and held constant over a block of trials. It has been suggested (Bjork & Estes, 1973; Massaro, 1973) that the latter procedure provides stricter control of effects of redundant information from word contexts at the decision level.

However, there are also differences between the two basic procedures which might operate at the perceptual

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†Now at the University of Michigan.