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Action of Red-sensitive Colour Mechanism on Blue-sensitive Colour Mechanism in Visual Masking

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Action of red-sensitive colour mechanism on blue-sensitive colour mechanism in visual masking

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Abstract. In the visual masking effect, metacontrast, the perceived brightness of a flash of light is reduced by the presentation of a second flash in an adjacent region of the visual field. A metacontrast masking interaction between different colour mechanisms is examined in the present study. The spectral compositions and intensities of the stimuli are chosen so that the first (test) flash preferentially stimulates the blue-sensitive colour mechanism and the second (masking) flash preferentially stimulates the red-sensitive colour mechanism. Elevation in test-flash threshold is measured as a function of delay in presentation of the masking flash and an interaction effect shown to occur at both positive and negative masking-flash delays.

In a series of papers [1–4], Stiles developed a theory of colour-response mechanisms which was based on measurements with the two-colour threshold method. In these measurements it was supposed that these mechanisms operated independently of one another. Subsequent investigations by a number of authors using other stimulus conditions showed that in some cases [5–9] this independence of mechanism function is preserved, and that in other cases [10–17] it is not. This note is concerned with the effect of one colour mechanism upon another in the masking phenomenon known as metacontrast [18–20], where the perceived brightness of a flash of light (the test flash) is reduced if it is followed a short time later by a second flash (the masking flash) in an adjacent region of the visual field. Metacontrast masking depends not only on the geometry and time course of the stimuli [18–20], but also on the properties of the receptor mechanisms stimulated [21, 22].

Alpern and Rushton [5] performed a metacontrast experiment in which the test-flash threshold was determined as a function of the luminance of the masking flash, the interval between the onsets of the flashes being fixed. They showed that the red, green, and blue-sensitive mechanisms (Stiles' π_5, π_4 and π_1 mechanisms respectively) did not interact. In similar study, however, Yellott and Wandell [15] obtained results indicating that metacontrast masking does not necessarily take place within a single π mechanism. In the present work a metacontrast interaction between two different colour mechanisms is shown explicitly. The test flash is made to preferentially excite the blue-sensitive π_1 mechanism and the masking flash made to preferentially excite the red-sensitive π_5 mechanism. The elevation in test-flash threshold is determined as a function of the time-lag between the onsets of the flashes.

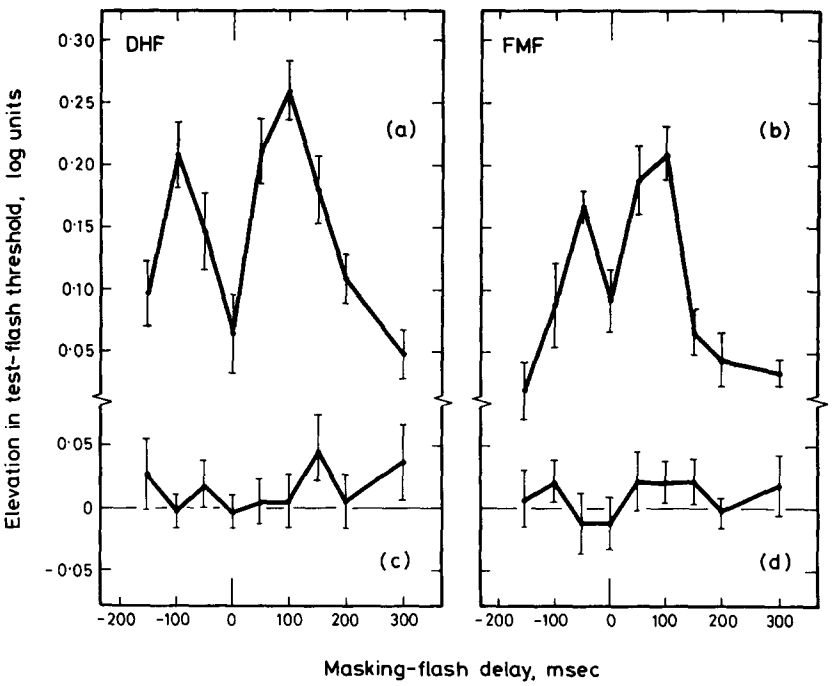
The apparatus and methods of the present experiment are similar to those of two earlier investigations into rod-cone metacontrast [21, 22]. A 5-channel Maxwellian-view optical system, with a tungsten-halogen lamp, was used to produce the stimuli. The disc-shaped test flash (diam. 0·6°) was presented on a steady disc-shaped conditioning field (diam. 0·7°), and the annular masking flash (i.d. 0·8°, o.d. 1·2°) was presented on a steady annular conditioning field (i.d. 0·7°, o.d. 11·0°). The stimuli were all concentric and appeared centred about a point 1·0° to the left of a small fixation point. The durations of the flashes, controlled by electromagnetic shutters, were each 25 ms. The subject, using the right eye, viewed the stimuli through a 2 mm artificial pupil. A dental bite-bar was used to steady the head.

The spectral compositions of the stimuli and conditioning fields, chosen on the basis of data given in [3, 23], were controlled by interference filters (Balzers, type B40, half bandwidths not greater than 12 nm). The masking flash was 664 nm and its conditioning field 465 nm ; the test flash was 421 nm and its conditioning field a mixture of 620 nm and 576 nm (' auxiliary ' and ' main ' fields respectively [3]). From threshold-versus-radiance (t.v.r.) and field spectral sensitivity curves [3], determined for each observer in preliminary experiments, the luminances of the conditioning fields were set so that at increment threshold the test flash preferentially stimulated π_1 and the masking flash, fixed 0·6 log units above increment threshold, preferentially stimulated π_5. The specificity of these stimuli for the selected mechanisms is discussed later. (Typical retinal illumination level of the mixed test-flash conditioning field was 2·3 log td and that of the masking-flash conditioning field 1·5 log td.)

At the beginning of each session the subject dark-adapted for 10 min and then set the masking flash level 0·6 log units above increment threshold. For each fixed interval between the onsets of the test flash and masking flash, the subject adjusted the luminance of the test flash with a neutral density wedge until the flash was just detectable. The final threshold setting was approached from below. Each measurement was preceded and followed by a separate determination of the test-flash threshold without the masking flash. Elevation of test-flash threshold above resting level was specified by the difference between the wedge reading obtained with the masking flash and mean of the two readings obtained without. There were two observers.

Figures (*a*) and (*b*) show data obtained by subject DHF (the author) and subject FMF. The elevation in threshold of the 421 nm test flash due to the 664 nm masking flash is plotted as a function of the time-lag between the stimulus onsets. Each point in (*a*) represents the mean of six readings and in (*b*) the mean of eight readings. The vertical bars show ± 1 S.E.M. Positive time-lags indicate that the masking flash follows the test flash, and negative time-lags that the masking flash precedes the test flash. There is an obvious masking effect of 0·26 log units for DHF at 100 ms and 0·21 log units for FMF at 100 ms, and a smaller effect of 0·21 log units for DHF at -100 ms and 0·17 log units for FMF at -50 ms. These threshold elevations are all statistically highly significant ($P < 0{\cdot}001$), and the increased thresholds are of the same order of magnitude as the masking flash used to induce them. The existence of a masking effect at both positive and negative onset delays has been reported in several other studies [21, 22, 24].

It might be hypothesized that the suprathreshold 664 nm masking flash



Elevation in test-flash threshold as a function of delay in presentation of a masking flash. Data in (*a*) and (*b*) are for a 421 nm test flash and a 664 nm masking flash ; data in (*c*) and (*d*) are for a 421 nm test flash and a 429 nm masking flash equivalent to the 664 nm flash with respect to the blue-sensitive π_1 mechanism. All flash durations were 25 ms. Each point represents in (*a*), (*c*) and (*d*) the mean of six determinations, and in (*b*) the mean of eight determinations. The vertical bars correspond to ± 1 S.E.M. Observers : DHF and FMF.

excites the π_1 mechanism directly in the surround, and that the elevations in test-flash thresholds depicted in figures (*a*) and (*b*) are the result of masking solely within the π_1 system. This hypothesis was tested by a replication of the original metacontrast experiment, but with the 664 nm masking flash replaced by a 429 nm flash that in the surround had the same effect on π_1. (This equivalence of the two flashes with respect to π_1 was determined by a field-sensitivity measurement [3, 23]. The 429 nm equivalent flash was found to be subliminal.) If the observed masking effects are in fact a consequence of this putative within-mechanism interaction, then this interchange in masking flashes should give rise to the same elevations in test-flash threshold as the time-lag between stimulus onsets is varied. The results of this experiment are shown, for each subject, in figures (*c*) and (*d*). Each point is the mean of six readings, and the vertical bars show ± 1 S.E.M. At no time-lag, except possibly that of 150 ms for DHF (figure (*c*)), is there a significant elevation in test-flash threshold ($P > 0{\cdot}1$). The elevation at 150 ms for DHF may be significant ($0{\cdot}1 > P > 0{\cdot}05$), but its magnitude (0·05 log units) is negligible relative to the threshold elevations obtained with the 664 nm masking flash (figure (*a*)).

A second control experiment, analogous to the one preceding, was carried out to verify that the masking effects shown in figures (*a*) and (*b*) did not arise

through direct excitation by the 664 nm flash of the green-sensitive π_4 mechanism. The results of this experiment were similar to those shown in figures (*c*) and (*d*), and confirm that the 664 nm flash acts through excitation of π_5 alone.

One other possible interpretation of the main results is that the 421 nm test flash is not preferential to the π_1 mechanism. This hypothesis was tested in the following way. The 421 nm test flash, set at increment threshold, was replaced by a 516 nm flash, equivalent with respect to π_4, and then by a 653 nm flash, equivalent with respect to π_5. Each of these replacement flashes was found to be subliminal. At increment threshold, therefore, the 421 nm test flash is specific to π_1, and any elevation in the 421 nm test-flash threshold must entail an elevation in the threshold of π_1.

It follows from the above control experiments that the data in figures (*a*) and (*b*) evidence a real masking action of π_5 on π_1. The opposite effect, that is the masking action of π_1 on π_5 is being investigated.

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