Detection symmetry and asymmetry

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Abstract—Experiments were performed on the detection symmetry and asymmetry of incremental and decremental disks, as a function of both disk diameter and duration. It was found that, for a background luminance of 300 cd m\(^{-2}\), thresholds of dynamic (briefly presented) foveal disks are symmetrical for all diameters, and that thresholds of quasi-statically presented disks are symmetrical for large diameters only. Threshold curves of quasi-static incremental and decremental disks are mutually shifted along the log area axis. In order to obtain a better insight into the underlying detection mechanism, additional experiments were performed with halfwave-rectified concentric cosine gratings, i.e. with either incremental or decremental phases. Threshold curves of these gratings proved to be identical, that is independent of polarity, and of the same shape as those obtained with fullwave cosine gratings, though 0.3 log unit shifted in amplitude. The discrepancy between threshold curves of quasi-static disks (asymmetry) and halfwave-rectified gratings (symmetry) is discussed in terms of a multiple-channel theory.

INTRODUCTION

A considerable amount of research has been done on detection thresholds as a function of both stimulus size and duration. There is, however, conflicting evidence concerning the equality of thresholds for luminance increments and decrements if presented against the same background luminance.

Symmetry of incremental and decremental thresholds was found by Blackwell (1946), Vos et al.\(^1\) (1956), Herrick (1956), Rashbass (1970) and Roufs (1974). Incremental thresholds significantly exceeding decremental thresholds were reported by Boynton et al. (1964), Short (1966), Patel and Jones (1968), and Krauskopf (1980). Bowen et al. (1989), exploring modulation thresholds in the case of sawtooth temporal modulation, found a similar difference between rapid-on and rapid-off waveforms (but also symmetry for one subject in case of frequencies above 13 Hz). In most of these studies a stimulus with a diameter larger than 1 deg was typically used [Patel and Jones (1968) also used a diameter of 15 min; Boynton et al. (1964) used a diameter of 10 min], and the difference between incremental and decremental thresholds is reported to decrease for higher background luminances (Short, 1966; Patel and Jones, 1968). In contrast, Herrick (1956) reported an increasing difference for higher backgrounds in the case of one subject.

The reverse, that is decremental thresholds exceeding incremental thresholds, has been reported as well. Novak (1969) found a significantly higher decremental threshold for one subject, and Short (1966) mentions in his section 'Experimental conditions' that decremental flashes with a duration longer than 0.1 s had a higher threshold.

These contradictory results can, perhaps, only be explained by taking all experimental conditions into account: apparatus, viewing, colour, retinal eccentricity, background level, stimulus surround, diameter, duration, as well as the experimental...
method. Unfortunately, the influence of some of these conditions on the results is not clear. For example, Herrick (1956), Rashbass (1970), Roufs (1974), and Krauskopf (1980) all performed basically the same experiment. They measured incremental and decremental thresholds, as a function of flash duration, for stimuli with a diameter equal to or larger than 1 deg typically and presented against a photopic background with a dark surround. Herrick, Rashbass, and Roufs found no significant differences and all threshold curves confirmed Bloch's Law, that is complete temporal integration for short flash durations. Krauskopf, on the other hand, found an asymmetry of about 0.08 log unit and only partial temporal integration for short flash durations. The last author used a CRT display and binocular viewing, whereas the other three authors used a Maxwellian-view optical system that was equipped with an artificial pupil. It is likely that the use of an artificial pupil increases measurement accuracy, but experimental results obtained with different subjects, as reported by some of the authors mentioned above, may differ significantly as well.

In conclusion, there is conflicting evidence with respect to detection symmetry and additional experiments are required to obtain a better insight into the experimental conditions which might lead to some significant asymmetry. In this study we used incremental and decremental disks with varying diameter presented against an extended photopic background, that is using a photopic surround.

For one-dimensional sinewave gratings with varying spatial frequency presented against a photopic background, a high degree of consistency has been found in the shape of threshold curves (Olzak and Thomas, 1986): band-pass in the case of quasi-static and low-pass in the case of dynamic presentation. The shapes of threshold curves for concentric gratings are comparable to those obtained with one-dimensional gratings (Kelly, 1984).

Physiological evidence suggests that luminance increments and decrements are processed by separate neural networks, which differ in amplitude transfer function (gain) as well as in spatial extent (Krüger and Fischer, 1975). The question therefore arises whether psychophysically determined disk thresholds for increments and decrements reflect any asymmetry. Furthermore, it is of interest to study the implications of any asymmetry for the detection of gratings.

To this purpose we introduced halfwave-rectified gratings, to be abbreviated HR gratings in the sequel, which are a result of halfwave rectification of fullwave concentric cosine gratings. These HR gratings consist of periodic luminance increments or decrements, and provide therefore an intermediate condition between disks (aperiodic increment or decrement) on the one hand, and fullwave gratings (periodic increments and decrements) on the other. By studying quasi-static and dynamic thresholds of disks, HR and fullwave gratings under identical experimental conditions, we hope to gain a better insight into the (a)symmetry problem mentioned and the underlying detection mechanism.

APPARATUS AND METHODS

Stimuli were presented on a special-purpose CRT that generates approximately white light. This device has a spiral scan of 256 turns in progressive scan, with a refresh rate of 150 Hz. The homogeneous and steady background luminance of the circular image, subtending 3.3 deg, was 300 cd.m⁻². The radial screen was extended to 6 x 6 deg with an external source of about the same brightness and hue. The barely visible transition between screen and extension was used as an aid in fixating the centre of the screen.