Brightness versus apparent contrast 1: Incremental and decremental disks with varying diameter

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Abstract—This study describes the matching of the brightness and of the apparent contrast of foveal disks, presented as an increment or decrement with varying diameter against a 300 cd. m\(^{-2}\) background. If the brightness in the centre of the disks is matched with a constant reference brightness, the well-known spatial Broca-Sulzer phenomenon is obtained. This effect is not found if the apparent contrast of the disks is matched instead. All matching results and detection thresholds indicate that luminance increments and decrements are processed asymmetrically by the visual system: for decrements the threshold curve and curves of isobrightness as well as apparent iso-contrast are all shifted towards larger disk radii relative to those for increments. Two nonlinear single-channel models are tested against the data.

INTRODUCTION

In this study the following three questions are addressed: (1) What is the influence of stimulus size on the perception of aperiodic stimuli if they are presented against a fixed and photopic background? (2) What is the possible difference between matching stimulus brightness at a specific location and matching its global apparent contrast? (3) Is there symmetry or asymmetry in the perception of incremental and decremental stimuli? As stimuli, quasi-static disks with varying diameter were used throughout this study, presented either as an increment or as a decrement against a background with a luminance of 300 cd. m\(^{-2}\).

Varying the diameter of a disk with a constant luminance shows a specific diameter for which its brightness is larger relative to the brightness of smaller and larger disks. This spatial brightness-enhancement or Broca-Sulzer phenomenon is found with a dark background (Hanes, 1951; Glezer, 1965; Hay and Chesters, 1972) and at higher background levels (Higgins and Rinalducci, 1975; Björklund and Magnussen, 1979). The name of this effect is derived from the temporal Broca-Sulzer effect (Broca and Sulzer, 1902; Rinalducci and Higgins, 1971; Magnussen and Glad, 1975; Bowen and Markell, 1980; White et al., 1980; de Ridder, 1987). Spatio-temporal interaction with respect to this effect has also been studied (Arend, 1973; Higgins and Knoblauch, 1977; Bowen and Pokorny, 1978; Drum, 1984). The related Mach-band effect, often thought of as a result of the bandpass behaviour of the visual system, also received considerable attention (e.g., McCollough, 1955; Matthews, 1966; von Békésy, 1968, Bergström, 1973).

Results from some experiments devoted to the temporal Broca-Sulzer effect suggest that luminance increments and decrements are processed asymmetrically by the visual system. Data obtained with pulsed decrements (White et al., 1980) indicate that maximum darkness enhancement occurs for longer durations relative to maximum brightness enhancement. This would imply that the temporal impulse response for
decrements is broader than that for increments. Such a shift has not been observed in the square-wave periodic situation (Magnussen and Glad, 1975). On the other hand, the latter authors conclude that the amplitude gain shows a strong asymmetry. However, one has to be careful in interpreting their data. Graphs are presented in ‘log relative luminance’ (LRL) and amplitude gain is defined in terms of differences of the LRL. If expressed in log luminance increments and decrements, their data show a much less pronounced asymmetry, and incremental gain even exceeds decremental gain.

In the only available study on the spatial Broca-Sulzer effect for decremental disks (Björklund and Magnussen, 1979), experimental data are given in absolute luminances and not in luminance differences with respect to the background as normally used in the case of increments. A curve with unit slope was obtained for small disks, that is, on the basis of log absolute luminance versus log diameter. This conflicts with the often confirmed Ricco’s Law, which implies a reciprocity between the luminance difference with the background and disk area, and therefore pure integration for very small stimuli. However, it can be verified easily that their data, if converted to log luminance decrement versus log area coordinates, show an asymptote with unit slope for small disks. Their data on suprathreshold decremental disks do therefore agree with Ricco’s Law. Moreover, this conversion of their data yields a less-pronounced spatial Broca-Sulzer effect: a smaller dip in the matching curve. The depth of this dip equals 0.2 log unit, which is about half of its magnitude if expressed in log absolute luminance. As for the temporal Broca-Sulzer effect for aperiodic stimuli, a direct comparison of the spatial Broca-Sulzer effects, although measured with different subjects, suggests a strong asymmetry between incremental and decremental stimuli: the darkness-enhancement effect for decrements is found for larger disk radii relative to the brightness-enhancement effect for increments (Higgins and Rinalducci, 1975; Björklund and Magnussen, 1979).

Some of the studies mentioned above were concerned with the question of how the visual system deals with stimuli of opposite polarity. Physiology suggests that brightness and darkness perception is a consequence of the processing by centre-on and centre-off retinal receptive fields (e.g., Krüger and Fischer, 1975; Waesle et al., 1983). Van Erning (1984) measured a significant asymmetry in the size perception of incremental and decremental square patches. Bright patches with a dark surround are perceived to be larger than dark patches with a bright surround. This asymmetry is largest for high contrasts, but vanishes approaching the detection threshold. On the other hand, du Buf (1991) found a pronounced asymmetry between detection thresholds of small incremental and decremental disks. Detection thresholds of small quasi-static decremental disks are much higher than those of incremental disks, whereas detection thresholds of small dynamic disks are symmetrical. Other asymmetries are found with the Hermann grid illusion (Spillmann and Levine, 1971), the Ehrenstein illusion (Spillman et al., 1984; Hamada, 1987), the White effect (White, 1979; Moulden and Kingdom, 1989), and contrast discrimination (Whittle, 1986). Watt and Morgan’s (1985) MIRAGE model exploits the sums of the halfwave-rectified responses of many filters, that is summing all positive parts of the responses and summing all negative parts separately, in order to obtain noise robust and accurate image primitives.

All studies on the spatial Broca-Sulzer effect are related to the perception of