Transient glare: its effect on the lower threshold of motion

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Abstract: We measured the lower threshold of motion (LTM) of suprathreshold gratings as a function of spatial frequency and contrast, for both transient glare and no-glare conditions. A two alternatives forced choice paradigm, using the method of constant stimuli, was adopted to measure the LTM. The LTM occurs at constant velocity. This velocity threshold is higher for transient glare condition than for no-glare condition. We found that the sudden onset of glare increases LTM over the whole range of contrasts. We believe the effect of transient glare sources on the lower threshold of motion is due to the transient loss of sensitivity.

OCIS code: (000.330) Vision and Color (330.4150) Motion Detection (330.1800) Contrast Sensitivity

References and links

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1. Introduction

The vertebrate visual system detects and analyses patterns of light distributed in time and space that, in naturally occurring images, cover an extremely large dynamic range of energy. To be capable of light detection at extremely low levels of energy and yet also be capable of analysing the spatial distribution of light at very high energies, the visual system has the capacity to modify its behaviour as needed. This capacity is referred to as visual adaptation. Most of these processes take place in the retina. The purpose of adaptation is to keep the retinal response to visual objects approximately the same when the level of illumination changes (for reviews see, for example, Shapley and Enroth-Cugell)[1].

Temporal characteristics of adaptation have been explored extensively [2]. In one of the most influential of these experiments on dynamics, Crawford [3] measured the increment threshold for a brief light test presented before, during and after the presentation of a larger background light (which he called conditioning field). He found that the test threshold was highest near the onset of the conditioning field and the threshold decreased substantially over the next 200 msec or so. More recently, this effect was investigated by Bichao *et al.* [4] who explored the phenomenon, using glare as an indirect conditioning field. They found that their results were qualitatively similar to Crawford's results. It is well documented that transient backgrounds are more efficient in raising detection thresholds that are steady backgrounds of the same intensity [5-7].

These investigations approach the dynamics of light adaptation at the threshold. However, the changes in the conditions of adaptation can also play a fundamental role in the visual task when images are suprathreshold. For example, an object with high contrast can be disguised by the surroundings and become conspicuous due to its movement with respect to the surroundings [8]. Our ability to perceive motion of objects and to extract information about object velocity is a fundamental visual process. Does the visual system lose ability to detect motion by the rapid changes in the conditions of adaptation?

Our search of literature so far has uncovered no studies on the influence of the dynamics of light adaptation on the thresholds of motion. This paper reports lower threshold of motion (LTM) as a function of spatial frequency and contrast, for temporally windowed sine gratings for both no-glare and transient glare conditions. This study extends the transient effects of brief flashes and glare sources to motion perception.

2. Methods

2.1 Glare

A glare source was used as an indirect conditioning field. Glare was generated using an incandescent lamp located 10º away from the line sight and was onset 100 msec before the effective stimulus presentation. The onset of the incandescent lamp is not abrupt, it has a time constant of 50 msec, thus, the effective delay between glare and stimulus presentations, is 50 msec. Onset and offset of the glare source was under direct computer control. Figure 1 shows a scheme of the stimulus and glare presentation in an interval of a trial. The upper curve represents the modulation of contrast and the lower one, glare intensity.

Under the glare condition, an intraocular forward scatter produces a retinal veiling illuminance from the glare source. The retinal contrast of the stimulus is thus reduced, and a quantifiable glare effect may be measured. The effective retinal contrast can be calculated adding an equivalent veiling luminance to the minimum and maximum luminance in Michelson grating contrast (Cg), the resulting formula being:

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$$C_R = C_g \left(\frac{Lm}{Lm + Lv} \right) \quad (1)$$

where Lm is the mean luminance on the screen and Lv is the equivalent veiling luminance which was determined by the empirical formula:

$$Lv = k \frac{Eg}{\theta^n} \quad (2)$$

where Eg is the illuminance produced by the glare source on a point in the middle of the eyes, θ is the angle between line sight and glare source and k and n are constants whose values are 10 and 2 respectively for $\theta > 5^{o}$ and young adults [9]. The value of Eg used in this work was 60 lx consequently, the value of Lv was 6 cd/m^2.

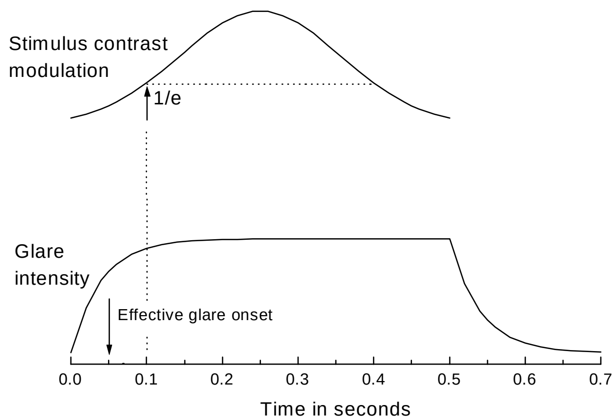

Fig.1. Stimulus and glare presentation in time. The stimulus contrast is modulated with a Gaussian function whose time constant is 0.150 sec. The time course of glare follows a logarithmic law and was obtained measuring the voltage produced by light on a photodiode, using a LeCroy digital oscilloscope.

2.2 Stimuli

Stimuli were luminance gratings displayed on a Eizo T560i-T monitor at a field rate of 120 Hz. Patterns were generated using an RGB framestore which was part of a purpose built display controller, the Cambridge Research System's VSG 2/3. VSG 2/3 has two palette chips operating in parallel. Adding together the two palette outputs with different gains, a higher resolution output is obtained. This operating mode produces the effect of 12 bits of grey level resolution per pixel, which was used to give more precise control of contrast.

Stimuli were presented within a circular patch, the diameter of which subtended 4 deg at the 2 m viewing distance. The mean luminance of the display (grating and background) was 2 cd·m^{-2}. The gratings were vertical sinusoidal modulations of luminance generated using the method previously described by Cox and Derrington [10].

The gratings were displayed during 500 msec. The contrast of these patterns was controlled by a gaussian function of time in order to avoid transient effect in the stimulus presentation. Its standard deviation or time constant was 150 msec. We express the effective duration of the stimulus as twice the standard deviation (standard criteria: 1/e of maximum contrast).

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2.3 Subjects and tasks

Two observers took part in this experiment, one of the authors and one naive as to the purpose of the study. Both observers were experienced in visual motion experiments. The screen was viewed foveally and binocularly, with the head positioned on a chin-rest and with natural pupil and accommodation.

The influence of transient glare on the lower threshold of motion was analysed for a direction-of-motion discrimination task. In the discrimination task, the stimulus was presented in two intervals; in one interval, chosen at random, the stimulus moved to the right, in the other, it moved to the left. The observer's task was to indicate, by pressing a key, the interval in which the grating had moved to the left.

A temporal two-alternative forced-choice paradigm using the method of constant stimuli was used to measure the psychometric functions, relating performance to temporal frequency. To calculate thresholds, we fitted Weibull functions to percent-correct responses distributions. The Weibull function has valuable theoretical properties and is extensively used in vision research (for a review, see: Macmillan & Douglas Greelman)[11].

In each block of trials a set of 7 stimuli was used. Each stimulus was used a total of 25 times in each of 2 the blocks of trials. Before each session, the observers were required to fixate the line sight on the screen set at 2 cd/m^2 for 5 min.

3. Results and discussion

3.1 LTM vs. Spatial Frequency

We measured the lower threshold of motion as a function of spatial frequency (1-8 c/deg), for glare and no-glare conditions. The contrast of the grating (*Cg*) was 25%. The glare illuminance (*Eg*) was 60 lx, which produces an effective retinal contrast of 6.25%. It was calculated using Eq. (1) and (2).

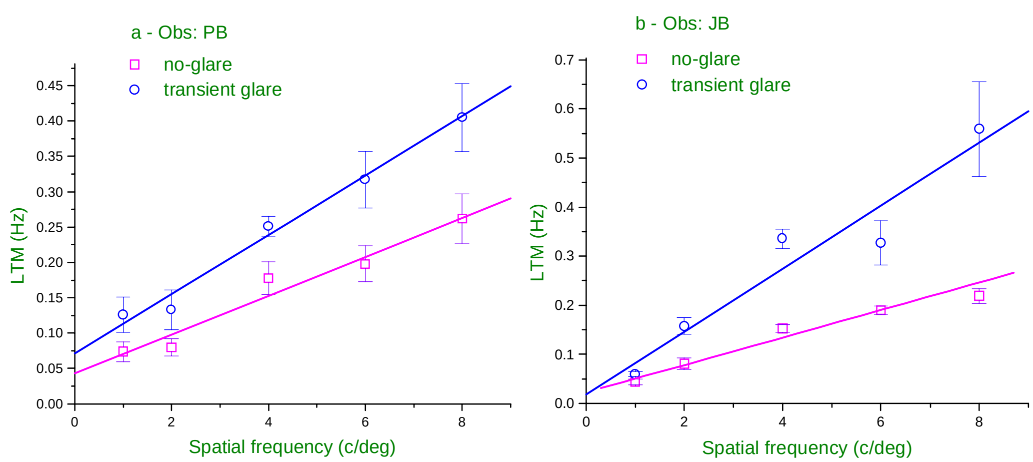

Fig. 2. Lower threshold of motion as a function of spatial frequency for no-glare and transient glare conditions. The LTM increases with the spatial frequency in a linear form for both situations. Velocity threshold obtained with transient glare is greater than that obtained without glare.

Figures 2(a) and 2(b) show, for both observers, LTM as a function of spatial frequency. Results show a linear increase of the LTM with the spatial frequency, as was previously showed by Johnston and Wright [12] for several values of eccentricity. Data were fitted with

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straight lines by the least square method obtaining correlation coefficients greater than 0.92. A statistical analysis (ANOVA) was carried out to check the validity of coefficients A (ordinate for fs=0) and B (slope). This analysis indicates that coefficient A is zero with a significance level of 0.05 whereas the probability that coefficient *B* was zero is less than 0.009. Assuming the functions are linear and pass through 0.0, the slope of these curves denotes the velocity threshold.

The finding that threshold occurs at constant velocity shows LTM depends on a critical displacement of the grating within temporal constraints, as was shown by Boulton [13]. This would mean that transient glare increases the displacement threshold.

The main result of this experiment is that the transient glare increases this threshold. We think that this increment in threshold could not be explained by the difference of retinal contrast because we are working in a range of retinal contrasts where the LTM is almost independent from contrast [12,14,15].

3.2 LTM vs. Contrast

In this experiment we measured the lower threshold of motion for no-glare and transient glare conditions, as a function of retinal contrast. In order to check whether the contrast reduction due to glare can explain the increase of LTM, stimuli had the same retinal contrast for both conditions. This means that for each measured point the grating contrast value used for transient glare condition was four times greater than the corresponding value used for no-glare condition, according to the Eq. (1) and (2). We checked a wide range of retinal contrasts (2-25%). The experiment was carried out using a spatial frequency of 1 c/deg, for observer JB, and a spatial frequency of 4 c/deg for observer PB.

Results can be seen by referring to figures 3(a) and 3(b), which plot, for both observers, the LTM as a function of retinal contrast.

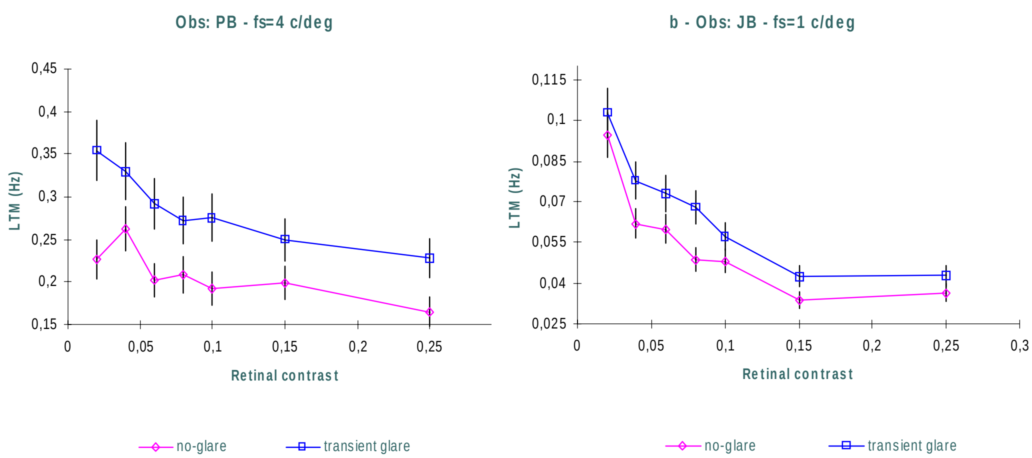

Fig. 3. Lower threshold of motion as a function of retinal contrast, for no-glare and transient glare. Figures show that the no-glare curves are moved up by transient glare.

A number of authors [12,14,15] have reported that the beneficial effects of increasing contrast only occur at very low contrast. Nakayama and Silverman [15] suggest that these effects indicate a saturating non-linearity in the motion detectors, and have used the function to describe the response/contrast function of the cortical cells used by Albrecht and Hamilton [16], to calculate the effective contrast. We obtained similar results. However, we found that the independence of LTM from contrast begins at higher values, probably because we have worked in a scotopic-mesopic range and in the above mentioned papers photopic ranges of adaptation were used.

The main result of this experiment is that the transient glare moves up the whole curve almost uniformly. This result means that the increase of LTM can not be explained by the retinal contrast reduction due to glare but by the transient characteristics of glare.

We carried out a subsidiary experiment using a spatial frequency of 8 c/deg and the same glare intensity. We found that steady glare does not increase the LTM as the transient glare does. This result is consistent with those found with controlled retinal contrast since the steady glare also reduces retinal contrast.

3.3. Motion mechanism or adaptation problem?

Considering the approach of Nakayama and Silverman [15], we believe the effect of transient glare sources on the lower threshold of motion would be due to the increase of the minimum contrast threshold for discrimination-of-motion direction (*Tq*). The minimum contrast threshold (*Tq*) corresponds to the contrast threshold for a displacement of phase of 90º. They found that, if a stepping sinusoidal grating is represented in a polar form (see figure 4), the motion threshold measured in terms of the displacement of phase (ϕ_m,), corresponds to the angle for which the projection of the effective contrast vector *Ce* is equal to *Tq*. This is shown in Eq. (3):

$$\phi_m = arcsin\left(\frac{Tq}{Ce}\right) \tag{3}$$

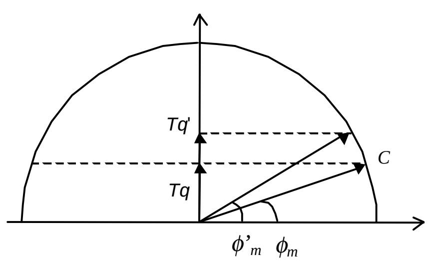

Fig. 4. Polar representation of a sinusoidal grating. The length of the vector denotes the grating contrast, the change in position is denoted by the angle ϕ, and *Tq* represents the quadrature contrasts.

Therefore, for a given grating contrast, if *Tq* increases, the displacement threshold will be greater.

It is worth noting that there is no evidence to suppose that the increase in LTM under transient glare condition is due to a motion mechanism since the velocity threshold is increased keeping the linearity with the spatial frequency. Moreover, as the transient glare moves up the whole LTM vs contrast curve almost uniformly, we would rather think this is a problem of transient adaptation.

As was discussed in the introduction, the sudden onset of a conditioning field, in this case produced by a glare source, produces a transient loss of sensitivity. This loss of sensitivity increases the contrast threshold for discrimination-of-motion direction therefore the LTM increases.

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