
The glare effect does not give rise to a longer-lasting afterimage

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Abstract. The glare effect is an illusion in which a region appears self-luminous when flanked by gradients that decrease in luminance with distance from the region (Zavagno, 1999 *Perception* **28** 835–838). This region also appears brighter than a surface of the same luminance. We investigated, using the paradigm of afterimages, whether a low-level mechanism at the level of the retina or LGN could account for this apparent brighter sensation. We first replicated the result from the literature that brighter and longer-lasting physical stimuli generate longer-lasting afterimages. We then compared the glare-effect stimuli with their counterpart controls, and found that the glare-effect stimuli did not give rise to longer-lasting afterimages. This suggests that the apparent brighter sensation of the glare effect is not due to a retinal or LGN mechanism, but must have a cortical origin.

1 Introduction

The glare effect (Zavagno 1999) refers to the visual illusion in which a white region appears self-luminous when surrounded by a decreasing luminance ramp (figures 2a and 2b). This illusion is new and little understood from the perspective that photometric conditions traditionally required for perceiving luminosity are not present in the scene (Ullman 1976; Bonato and Gilchrist 1994). It occurs whenever the brighter end of the luminance ramp approaches or equals the luminance of the white region (Zavagno and Caputo 2001). The degree to which the white region is perceived as self-luminous can be further modulated by the range of the luminance ramp (Zavagno and Caputo 2005). This luminance ramp might therefore mimic natural luminance ramps caused by intraocular light scattering when viewing a real self-luminous light. In fact, in experiments in which thresholds of perceived self-luminosity were measured in glare-effect stimuli presented on a computer monitor, subjects often complained about visual discomfort—noting a disturbing subjective impression of a strong and lasting afterimage, reminiscent of those experienced after a flash of intense light (Zavagno and Caputo 2001). This indicates that the glare effect might be explained by a peripheral, low-level mechanism at the retina or lateral geniculate nucleus (LGN).

Here, by measuring the duration of an afterimage, we provide psychophysical evidence to verify the stage of visual processing in perceiving the glare effect. It has been reported that the duration of an afterimage is positively correlated with its intensity and adaptation time (Granit et al 1930; Feinbloom 1938; Nagamata 1951). For example, an intense light flash, which induced appreciable bleaching (Craik 1940; Brindley 1959; Loomis 1972), gave rise to a long-lasting afterimage. This implies that a flash of light causes a dark afterimage at the retina or LGN (Svaetichin 1956; De Valois 1960). Because the glare effect is perceptually similar to the physical self-luminous light, the pre-cortical account, at the retina or LGN, predicts that a glare-effect stimulus, compared with a control stimulus without self-luminosity, would give rise to a longer-lasting afterimage, when everything else is kept equal. The aim of the current study was to test this prediction of the low-level mechanism.

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We first, in experiment 1, replicated the results from the literature, in order to establish the validity of our experimental paradigm. In experiment 2, we compared the duration of an afterimage generated by a glare-effect stimulus with that generated by a control stimulus. The low-level hypothesis we were testing predicts that the glare-effect stimuli would generate longer-lasting afterimages.

2 Experiment 1

2.1 Method

Two adapting stimuli were used to induce afterimages. Both were squares of identical size ($4.6 \times 4.6 \text{ cm}^2$). One had a luminance of 136 cd m^{-2} , the other 68.4 cd m^{-2} . Each square, with a fixation-cross at the center (luminance 8.5 cd m^{-2} , size 0.46 cm), was shown on a dark computer monitor (0.16 cd m^{-2}). The stimuli were presented either on a Dell Trinitron or a Sony Trinitron GDM-F520 monitor in a dark room. The viewing distance was 57 cm .

In each trial, a subject first fixated at the stimulus square that lasted for either 8, 12, or 16 s. The square then disappeared but the fixation cross remained within a grey background $18.3 \times 18.3 \text{ cm}^2$ in size, and of luminance either 75.7 cd m^{-2} (Dell monitor) or 68.4 cd m^{-2} (Sony monitor). The subject pressed a key on the computer keyboard when the afterimage completely disappeared from the grey background. When ready for the next trial, the subject pressed a key and a new stimulus appeared after 1 s. Both adapting stimuli were presented 10 times in each of the 3 presentation times, amounting to 60 trials in total. The order of the stimulus presentation was randomized.

Seven naive volunteers served as observers. Four of them participated in the experiment with the luminance of the grey background set at 68.4 cd m^{-2} . The other three participated in the experiment with the background luminance set at 75.7 cd m^{-2} . The duration of the experiment was about 30 min.

2.2 Result

Figure 1 shows each subject's duration of the perceived afterimage as a function of the stimulus luminance and presentation time. A three-way ANOVA was performed with two within-subjects factors: luminance (high versus low) and stimulus presentation time, and one between-subjects factor: background luminance (68.4 cd m^{-2} versus 75.7 cd m^{-2}). The first two main effects were statistically significant: luminance ($F_{1,5} = 41.53$, $p = 0.001$), and presentation time ($F_{2,10} = 19.84$, $p < 0.001$). The third main effect of background luminance was not significant ($F_{1,5} = 0.004$, $p = 0.95$). There were no significant interactions either. These results concurred with findings in the literature that brighter and longer-lasting physical stimuli generated longer-lasting afterimages.

3 Experiment 2

Having replicated in experiment 1 the finding that a physically brighter or longer-lasting stimulus gives rise to a longer-lasting afterimage, we then studied whether stimuli of the glare effect, which are perceived as brighter (Zavagno and Caputo 2001, 2005), also give rise to longer-lasting afterimages.

3.1 Method

Figure 2 shows two glare-effect stimuli [(a) and (b)] and two controls [(c) and (d)] that were used to generate afterimages. For the cross stimuli [(a) and (c)], the central white square was $4.6 \times 4.6 \text{ cm}^2$, and each of the four arms was $4.6 \times 3.6 \text{ cm}^2$. For the annulus stimuli [(b) and (d)], the diameter of the central white disk was 5.2 cm , and the width of the ring was 3.56 cm . For all stimuli, the luminance gradients ranged from black to white (from 0.76 to 151 cd m^{-2}), and the luminance of the white centers was 151 cd m^{-2} . It should be noted that the average luminance of the annulus ring was different for the glare-effect stimulus and for its control (but see below).

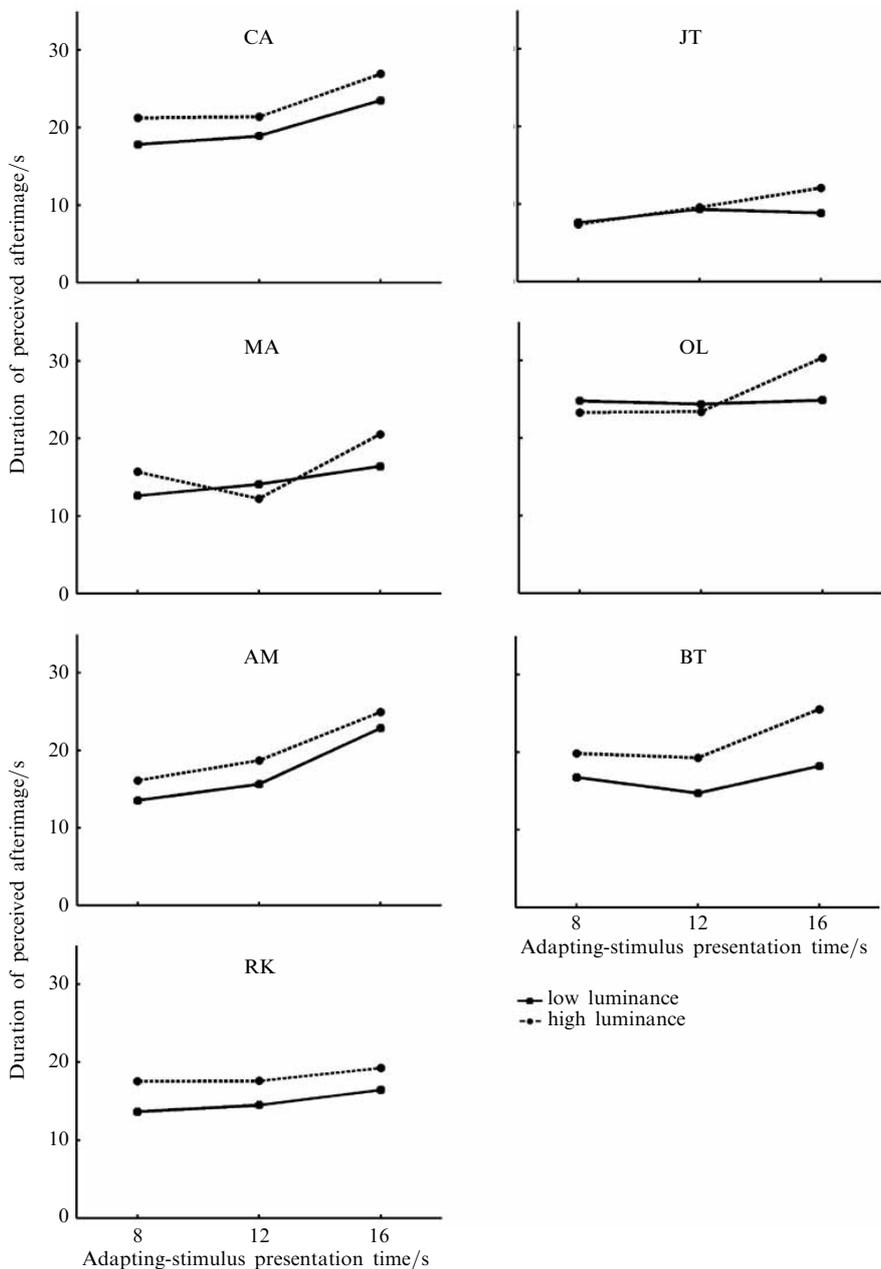


Figure 1. Duration of the perceived afterimage per subject as a function of the stimulus presentation time and stimulus luminance. CA, JT, MA, and OL were tested with the background luminance of 68.4 cd m⁻²; AM, BT, and RK were tested with the background luminance of 75.7 cd m⁻².

In order to compare fairly between the glare stimuli and their controls, we concentrated on the afterimages of the central regions (in figure 2, the central squares on the left, and the central disks on the right). To clearly distinguish the afterimages of the central regions, we used a textured grey background (line width 0.03 deg, orientation 45°, inter-line distance 0.14 deg), with a 'hole' in the middle that corresponded to the shape of the central region (figure 3). The textured background had a luminance of 75.7 cd m⁻²

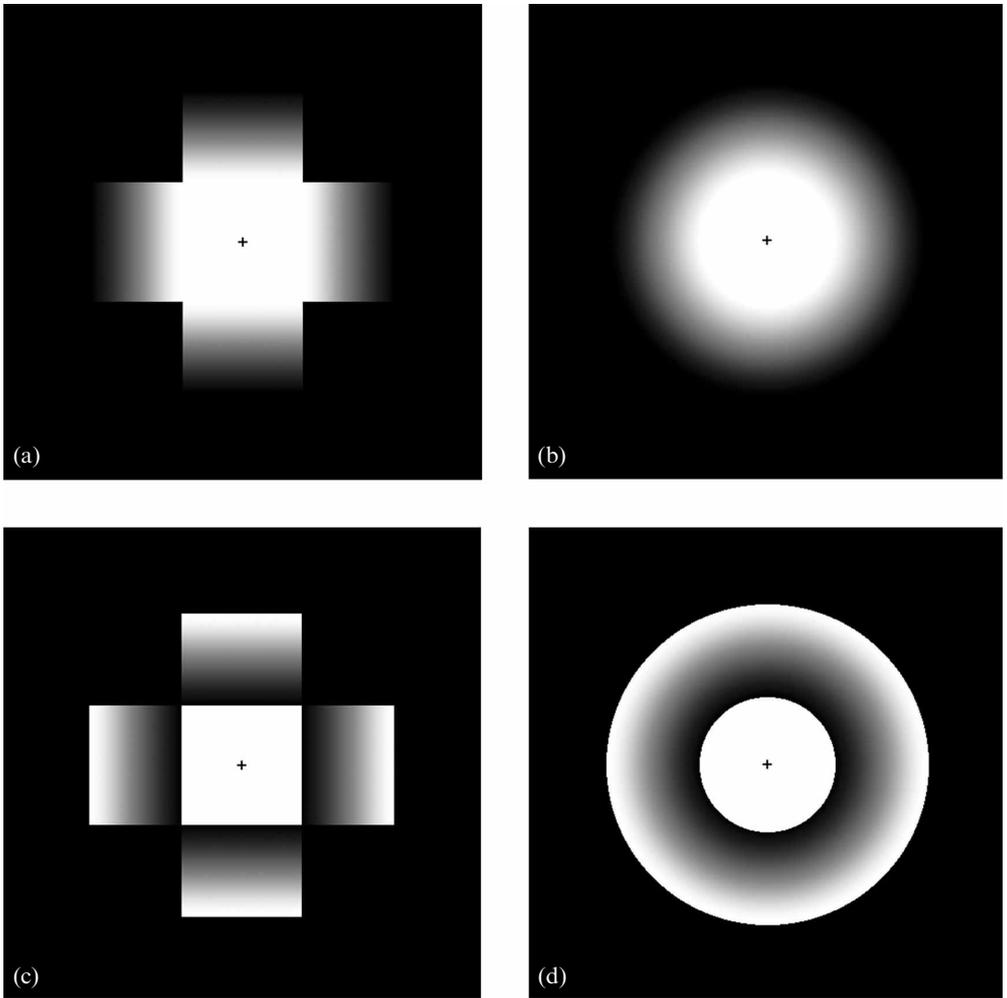


Figure 2. (a) and (b) The glare-effect stimuli; (c) and (d) the corresponding controls.

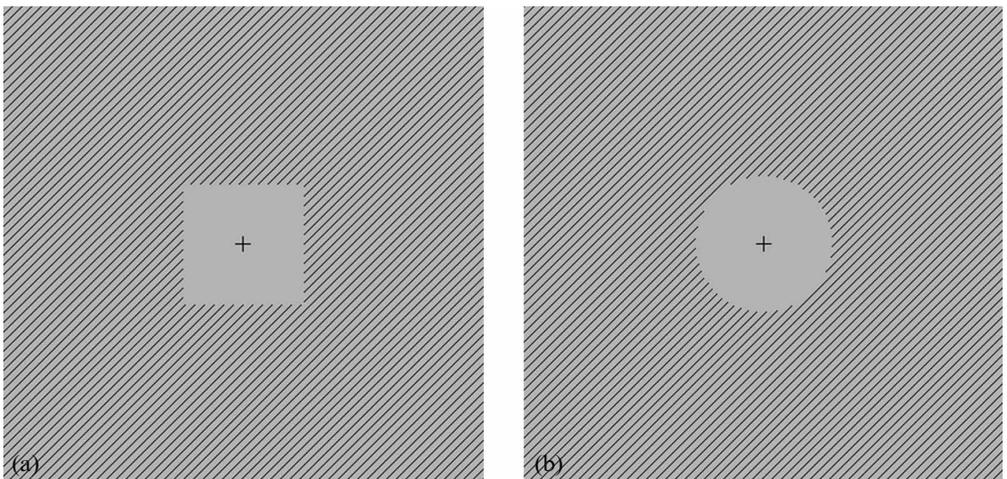


Figure 3. Images presented after the adapting stimuli, in which afterimages were perceived: (a) after adapting to the cross stimulus; (b) after adapting to the annulus stimulus.

and a size of $18.3 \times 18.3 \text{ cm}^2$. This luminance was the same as one of the grey backgrounds used in experiment 1 and run by three subjects. The ‘hole’ (square or disk) was slightly larger (by 0.03 deg of visual angle) than the targeted adapting region. The stimuli were presented on a Sony Trinitron GDM-F520 monitor in a dark room.

Each of the 4 stimuli was shown 3 times for each of the 3 presentation times (8, 12, or 16 s), amounting to 36 trials in total. Two authors, DZ and ZL, and two naive subjects participated. The procedure was otherwise identical to that in experiment 1.

3.2 Results

Figure 4 shows each subject’s duration of the perceived afterimage as a function of the stimulus presentation time. A three-way ANOVA was performed with the following within-subjects factors: stimulus presentation time (8, 12, or 16 s), glare versus control, and stimulus (cross versus annulus). As expected, there was a main effect of stimulus presentation time ($F_{2,6} = 11.22$, $p < 0.005$). This suggests that a longer-lasting stimulus gave rise to a longer-lasting afterimage (11.57 s, 14.04 s, 14.15 s). Interestingly, the control stimuli gave rise to afterimages that were lasting longer than the glare stimuli (14.11 versus 12.40 s; $F_{1,3} = 10.91$, $p < 0.05$). This suggests not only that the glare-effect stimuli did not give rise to longer-lasting afterimages, but also that this result was not due to the lack of statistical power. No other effect was statistically significant. In particular, the main effect of stimulus (cross versus annulus) and the interaction between stimulus and glare (glare versus control) were not significant ($F_{1,3} < 1$). This indicates that although the annulus stimuli (glare versus control) had unequal average luminance (unlike the square stimuli), the effect was negligible.

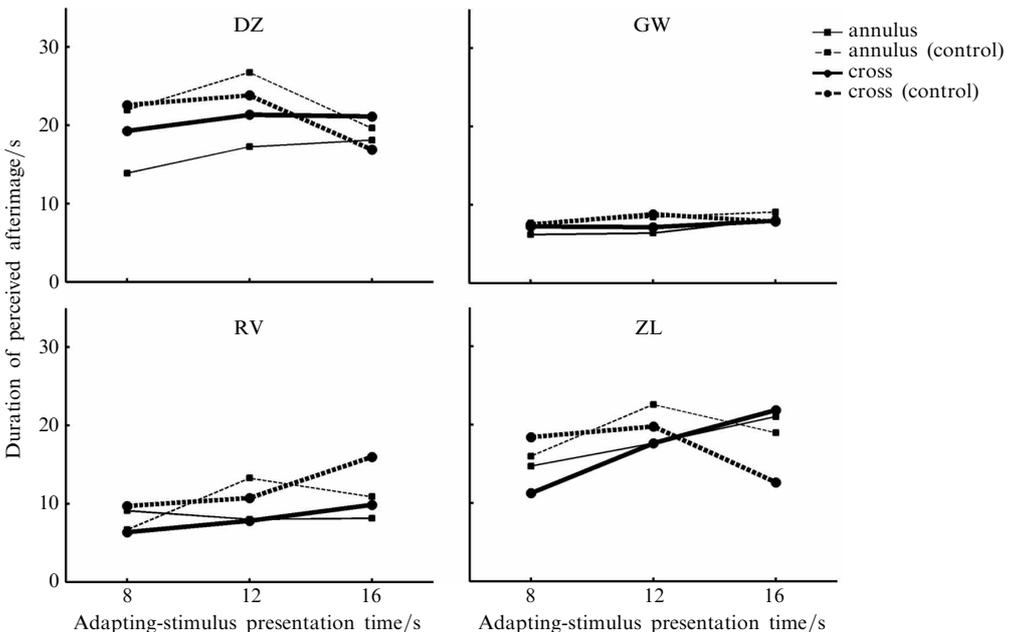


Figure 4. Duration of the perceived afterimage for each subject as a function of the stimulus presentation time. DZ and ZL are the authors.

4 Discussion

The result that the glare-effect stimuli gave rise to significantly shorter-lasting afterimages indicates that there is sufficient statistical power already from the four subjects. Consequently, our conclusion that the glare-effect stimuli did not give rise to longer-lasting afterimages is not based on a null result, but on a statistically significant and

opposite one. The reason for this opposite result, we believe, is the substantial ease in perceiving the afterimage of a control stimulus relative to perceiving its glare-effect counterpart. As can be seen in figure 2, the boundary of the central region of the control stimuli had the highest contrast, whereas that of the glare-effect stimuli had the lowest contrast. Consequently, it is easier to detect the fading away of the afterimage of a control stimulus because of its high contrast boundary against the grey background. In comparison, the afterimage of a glare-effect stimulus, because of the low contrast of its boundary, is harder to discriminate from its grey background. So subjects may tend to see an afterimage of a glare-effect stimulus disappear faster than that of a control, with a constant detection threshold.

To conclude, our result suggests that the subjective sensation of a brighter glare-effect stimulus is not due to a low-level mechanism, eg at the retina or LGN. It is likely that this illusory sensation is due to an association process that links the stimulus pattern of a possible light source, or the glare, to a protection reflex against strong illumination. Our data therefore suggest that the glare effect is likely to occur at cortical stages of visual processing, which implies that luminance ramps play a crucial role in brightness assignments at the cortical level. This hypothesis does not support theories on perceptual luminosity based on a threshold-ratio principle, according to which a surface appears self-luminous only when its luminance is above that of a surface perceived as white within the same visual scene (Bonato and Gilchrist 1994, 1999), but is consistent with previous studies on perceptual afterimages (Loomis 1972; Virsu and Laurinen 1976; Anstis et al 1978; Shimojo et al 2001). Concerning the problem of white as an anchor for luminosity perception, recent empirical studies on the glare effect have shown that the apparent luminosity of the illusion was independent from perceived white (Zavagno et al 2004; Zavagno and Caputo 2005). The cortical-origin hypothesis is instead consistent with other psychophysical findings that suggested that luminosity thresholds depended on figural salience (Bonato and Cataliotti 2000). The cortical-origin hypothesis is also consistent with a recent functional magnetic resonance imaging (fMRI) study suggesting that an area in the human posterior occipito-temporal sulcus is involved in luminosity processing (Leonards et al 2003).

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