Perception, 2007, volume 36, pages 791 – 794

DOI:10.1068/p5785

Last but not least

Abstract. Gori and Stubbs (2006 *Perception* **35** 1573 – 1577) have published some visual illusions elicited in observers who fixate very blurred disks while they move their head towards and away from them. We interpret these illusions as afterimages. We support this with examples of eccentric, colored, and striped afterimages.

Afterimages and the Breathing Light Illusion

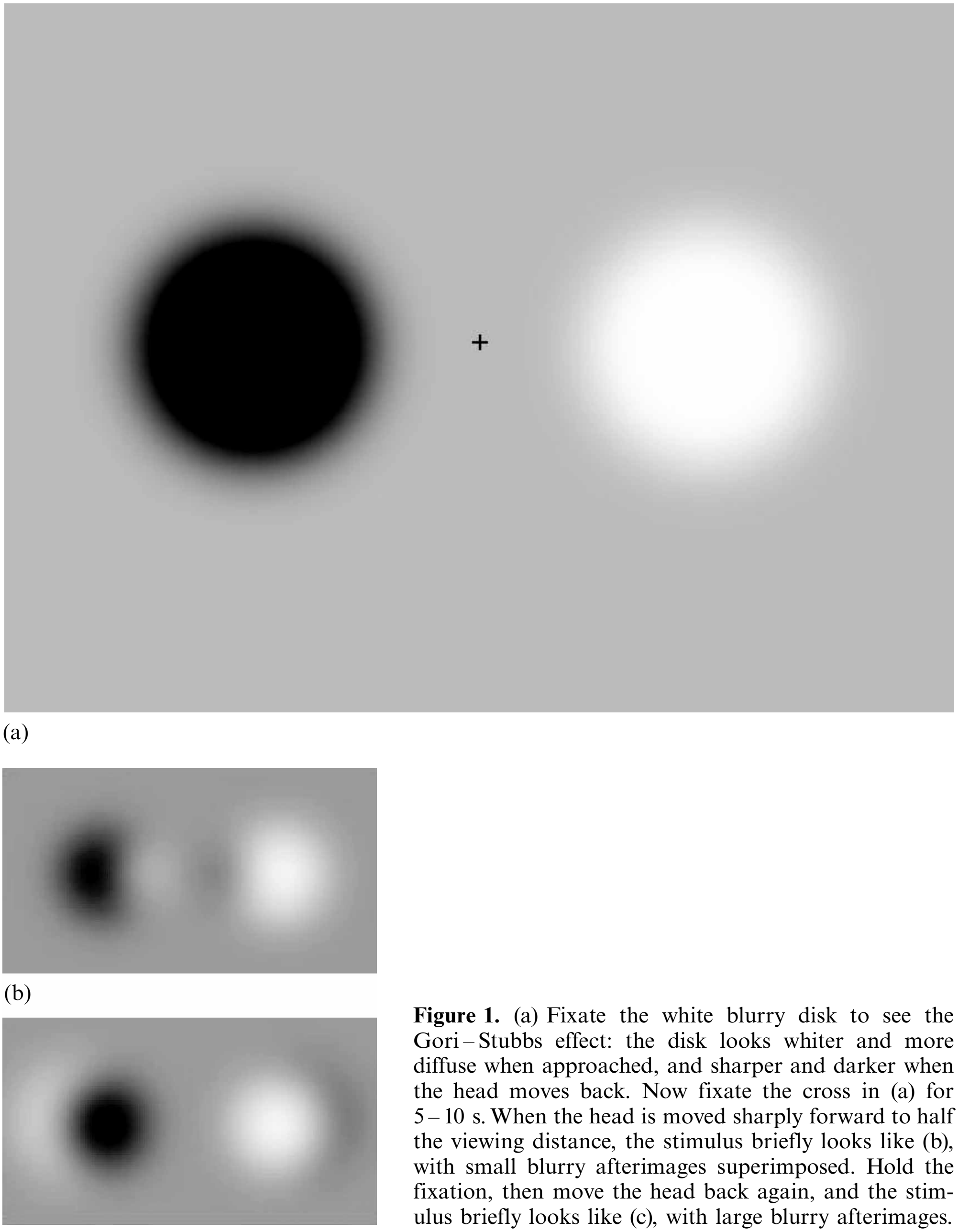
Gaze at the blurry white disk in the right hand half of figure 1a [resembling figure 1 in Gori and Stubbs (2006): see color version of this figure on our website http://www.perceptionweb/misc/p5785]. Approaching this pattern by moving one's head towards it makes the disk appear to become larger, more diffuse, and filled with white. On receding from it, the disk's center remains white but the remainder appears smaller, darker, and sharper.

We present several demonstrations that support an afterimage interpretation. The supplementary material (see http://www.perceptionweb/misc/p5785) also illustrates a colored afterimage, together with blurred disks of opposite polarity that in denying afterimages also abolish the motion illusions.

A few seconds' fixation with the head at a fixed distance from the pattern in figure 1a adapts the observer to the luminance of the initial stimulus. Moving the head sharply forwards whilst fixating the cross generates a novel effect: two small illusory blurry disks are briefly perceived. A small blurry white dot appears on the inner edge of the black dot at 3 o'clock, whilst a small blurry black dot appears on the inner edge of the white dot at 9 o'clock. An additional pause serves to re-adapt the observer to the close-up view of the stimulus. Then, moving the head backwards produces a large white flare on the outer edge of the black dot at 9 o'clock, and a large black flare on the outer edge of the white dot at 3 o'clock. Figures 1b and 1c show an artist's impression of how these afterimages look. They are clearly generated by the stimulus where changes in luminance are strongest. Changes are smaller than the stimulus when the head moves forward and larger when the head moves back.

Figures 2a and 2b explain these results for a fixated white disk with a Gaussian luminance profile. Figure 2a shows a narrow spatial luminance profile at time T1 when the head is far away, and a broader luminance profile at time T2 when the head is closer. In figure 2b the afterimage from T1 is superimposed on the stimulus at T2, and vice versa. These afterimage profiles are drawn with dashed lines. The resulting perceived profiles, drawn with thick lines, are differences of Gaussians (DoGs). The upper profile, when the head is far away at T1, has the familiar Mexican-hat profile, with the spot apparently sharpened up, and in the lower profile, when the head is in the near position at time T2, the central bright area enlarges and the spot appears diffuse and blurry. This matches the observed percepts. Thus the combination of the stimulus with its own differently sized afterimage leads to increased spatial differentiation when the head is far away and increased spatial summation when the head is close in.

With eccentric fixation upon the cross, and the white disk to the right of fixation, the afterimage from T2 will be shifted laterally upon the stimulus at T1, and vice versa. Figure 2c shows the displaced afterimage profiles drawn with dashed lines, and the outcomes drawn with thick lines: the observer sees the white disk as composed of two blurry spots of different sizes side by side, one light and one dark. This also matches the percepts reported.



(a)

(b)

(c)

Figure 1. (a) Fixate the white blurry disk to see the Gori–Stubbs effect: the disk looks whiter and more diffuse when approached, and sharper and darker when the head moves back. Now fixate the cross in (a) for 5–10 s. When the head is moved sharply forward to half the viewing distance, the stimulus briefly looks like (b), with small blurry afterimages superimposed. Hold the fixation, then move the head back again, and the stimulus briefly looks like (c), with large blurry afterimages.

Spatial luminance ramp. In figure 3, a spatial luminance ramp translates horizontally. This light-to-dark ramp is equivalent to an extreme close-up of the right-hand edge of a very blurred light disk on a dark surround. When a fixation point such as the tip of a pencil is moved to the right across this figure, the whole stimulus appears to become much darker and to move strongly to the left, through a greater distance than the fixation shift (Anstis 1967, 1979, 1986; Arnold and Anstis 1993; Cavanagh and Anstis 1986). Moving the fixation back to the left gives the ramp an apparent lightening and an exaggerated motion back to the right. Figure 2 shows what is happening. Figure 2d shows the luminance profile of the ramp at times T1 and T2, and

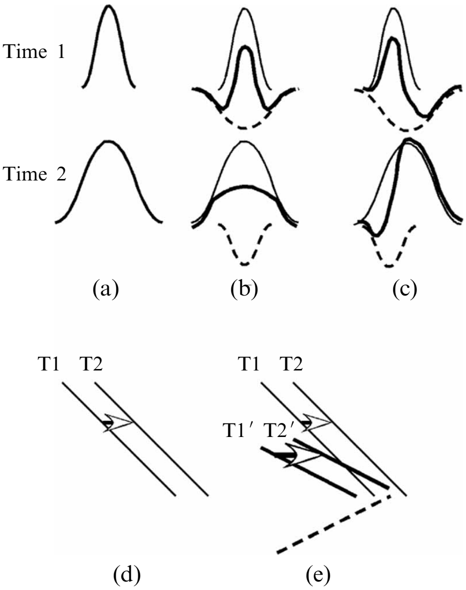


Figure 2. Hypothetical retinal images of blurry patterns. (a) A blurry disk fixated from far away at time T1 and from half the distance at time T2. (b) The disk at T1 has the afterimage from T2 (dashed lines) superimposed, yielding a difference-of-Gaussians combined retinal image (thick lines) that looks sharp and dark; and vice versa, which looks white and diffuse. This accounts for the Gori – Stubbs effect. (c) During eccentric fixation, the afterimages are no longer centered on the stimuli, but offset, giving the percepts diagrammed in figures 1b and 1c. (d) The spatial ramp shown in figure 3. Shifting the gaze slightly to the left shifts the retinal image to the right (black arrow). (e) Superimposing the afterimage from the ramp makes the effective spatial ramp shallower. Result: The perceived motion of the ramp during an eye movement is exaggerated (thick arrow).

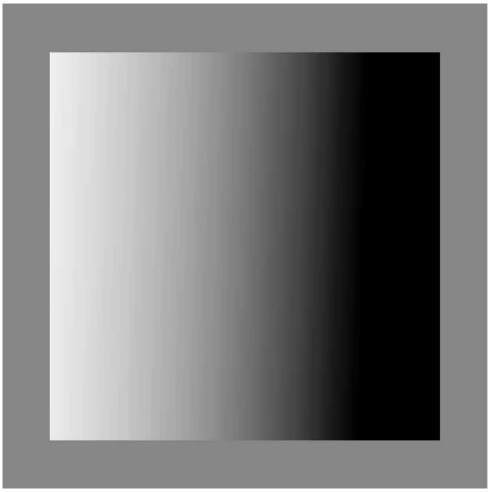


Figure 3. Fixate for a few seconds a pencil point held near the center of this spatial luminance ramp. Now move the pencil point and the gaze to the right. Result: The spatial ramp appears to get darker, and move strongly to the left, through a greater distance than the pencil point. See text.

the displacement to the right is seen correctly. In figure 2e, the afterimage of the ramp (dashed lines) is subtracted from the luminance profiles at times T1 and T2, making the resultant profile (thick lines) shallower. Consequently, the amplitude of the perceived motion is increased, as shown by the thick arrow. This may be related to the illusory motion of static luminance gradients that are viewed peripherally (Fraser and Wilcox 1979).

Striped afterimages. Figure 4a shows a blurred disk filled with a vertical grating, like a very large Gabor patch. When this pattern was fixated, and then the head moved toward or away from it, a ghostly pattern of vertical bars was briefly visible, 5 or 10 times coarser than the bars of the grating. These illusory bars were moiré fringes, resulting from a spatial beat or interaction between the original stimulus and its slightly larger or smaller afterimage. Figure 4b shows similar moiré fringes as the physical result of superimposing two identical patterns, one being 20% larger than the other.

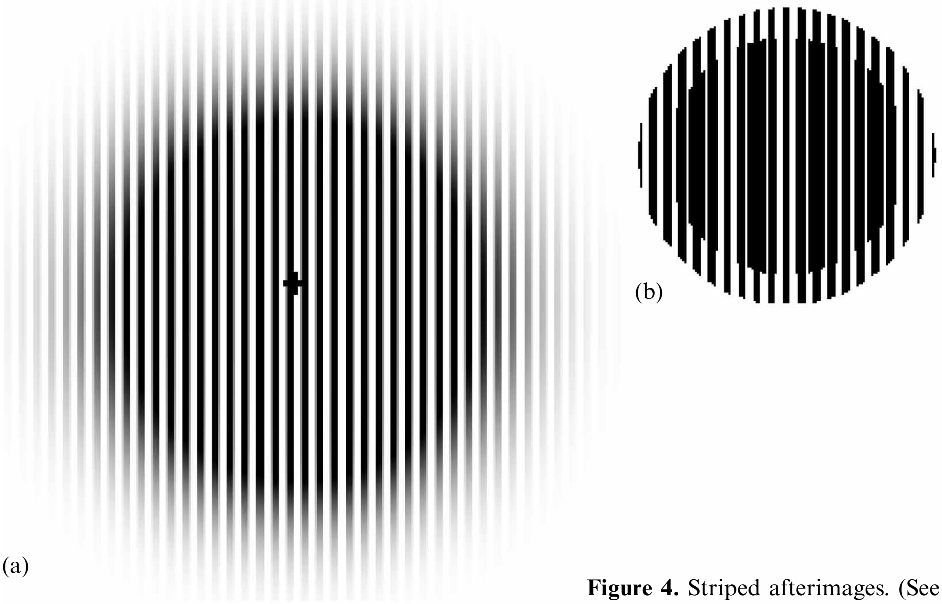


Figure 4. Striped afterimages. (See text.)

Note that all these illusions are greatly enhanced by adapting to the static luminance pattern for a few seconds before the movement as predicted by our afterimage assumption. This adaptation increases the sensitivity to small local changes in luminance elicited by head movements. Consequently, transient aftereffects appear, whose contrast polarity is opposite to that created by the local changes in luminance.

Acknowledgments. SA was supported by a grant from the UCSD Academic Senate. Thanks to Christopher Tyler for suggesting the afterimage explanation, and to Lothar Spillmann and an anonymous referee for helpful suggestions and discussions.

Stuart Anstis, Simone Gori¶, Christian Wehrhahn§

Department of Psychology, University of California San Diego, 9500 Gilman Drive, La Jolla, CA 92093-0109, USA; e-mail: sanstis@ucsd.edu; ¶ Dipartimento di Psicologia Generale, Università degli Studi di Padova, via Venezia 8, I 35131 Padua, Italy; e-mail: simone.gori@unipd.it; § Department of Neurophysiology, Max-Planck-Institut für biologische Kybernetik, Spemannstrasse 38, D 72076 Tübingen, Germany; also The Salk Institute, 10010 North Torrey Pines Road, La Jolla, CA 92037, USA; e-mail: christian.wehrhahn@tuebingen.mpg.de

References

Anstis S M, 1967 "Visual adaptation to gradual change of intensity" *Science* **155** 710 – 712

Anstis S M, 1979 "Interactions between simultaneous contrast and adaptation to gradual change of luminance" *Perception* **8** 487 – 495

Anstis S M, 1986 "Recovering motion information from luminance" *Vision Research* **26** 147 – 159

Arnold K, Anstis S, 1993 "Properties of the visual channels that underlie adaptation to gradual change of luminance" *Vision Research* **33** 47 – 54

Cavanagh P, Anstis S M, 1986 "Brightness shift in drifting ramp gratings isolates a transient mechanism" *Vision Research* **26** 899 – 908

Fraser A, Wilcox K J, 1979 "Perception of illusory movement" *Nature* **281** 565 – 566

Gori S, Stubbs D A, 2006 "Last but not least: A new set of visual illusions—the Dynamic Luminance-Gradient Illusion and the Breathing Light Illusion" *Perception* **35** 1573 – 1577

Krauskopf J, 1967 "Heterochromatic stabilized images: a classroom demonstration" *American Journal of Psychology* **80** 634 – 637

Please note: Supplementary material is on our website, as mentioned on the first page of this article.

ISSN 0301-0066 (print) ISSN 1468-4233 (electronic)

PERCEPTION

VOLUME 36 2007

www.perceptionweb.com