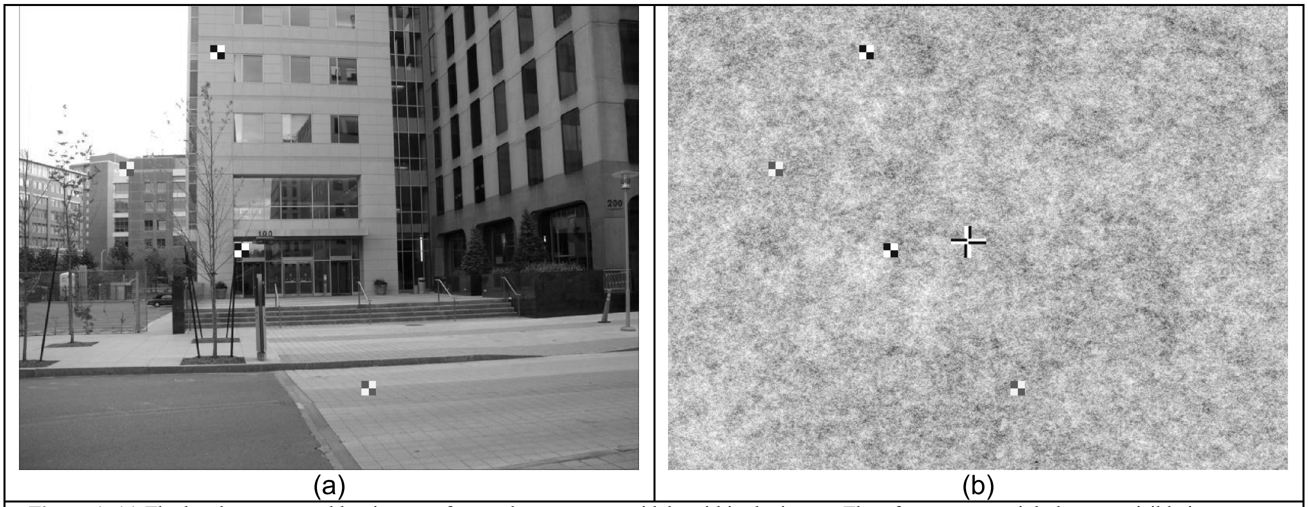
Supplementary Material
Object Detection in the Ring Scotoma of a Monocular Bioptic Telescope

eBackground Images:
The large areas of varying contrast, luminance and clutter (masking) in street scene photographs could dramatically alter the difficulty of the detection task (as illustrated in eFigure 1 and noted in pilot experiments). Natural scenes, despite their wide variety, have fairly consistent statistical features.[1] The radially average amplitude spectrum is relatively consistent across images[2], falling approximately as $1/f^n$ where n is approximately 1 yet varies between 0.8 and 1.5.[3] The 1/f noise has a similar amplitude spectrum to natural scenes but no longer looks like a natural scene, as there are no recognizable objects, edges or contours and the statistical characteristics are more uniform across the image. Therefore, we used a spatial noise background to represent the more complex visual conditions encountered in real-world bioptic use. In pilot experiments we found that our checkerboard test stimuli were too easily detectable on 1/f noise. Therefore, to avoid ceiling effects, we adjusted the slope of the noise image to $1/f^{0.75}$ which increases energy at the higher spatial frequencies and thus increases target masking and the difficulty of the task.

In a small study (n = 4) we evaluated whether binocular rivalry due to differences in magnification (non-magnified fellow eye view vs. magnified telescope eye view) occurred on noise images as well as natural scenes. We found no significant difference in rivalry rate between the noise background and the natural scene when viewing through a 3x monocular bioptic telescope (difference of only 2-3 changes in 2 minutes of viewing; Mann-Whitney U =8.0, p=1.0). Perception changes between the magnified and unmagnified views were as noticeable with noise images as they were with natural images.


(a) (b)

eFigure 1: (a) The local contrast and luminance of natural scenes vary widely within the image. Therefore a target might be very visible in one area but much less visible in another, which could affect detection rates. (b) The $1/f^{0.75}$ noise background used in this study with passive fixation target (2.9° cross). Two examples of 95% contrast stimuli (1°) and 75% contrast stimuli are shown. Targets of equal size and contrast are almost equally visible across the noise image but not across the street image.

ePerimetry Target Stimuli:
The selection between 75% and 95% stimulus contrast was made based on pilot trials with each patient to avoid ceiling and floor effects. Two conditions were used in the pilot trials: active fixation on noise background with bioptic and passive fixation on noise background without bioptic. Since all comparisons between conditions were within subjects, the use of different targets for different subjects did not affect our analysis.

eProcedure:
Of the 13 stimulus presentations, 12 were shown only to the fellow eye, and one was shown only to the telescope eye (whether or not the telescope was present). The latter control stimulus was included to verify that the telescope eye did <u>not</u> detect in the area of the ring scotoma when using the bioptic (none of the control stimuli were seen). The control stimuli were not included in the analyses. Due to the asymmetry in the field of view through each shutter lens, the control stimulus was presented in a different location from the 12 test stimuli. The boundary of the shutter lens of the telescope eye did not extend much beyond the field of view through the bioptic, especially for patients with a small interpupilary distance. Before

each of the scored tests started, kinetic perimetry was used to quickly verify that there had not been a shift of the ring scotoma due to head movement (if the telescope was being used) or the area occluded by the shutter-lens housing. This ensured that the stimuli lay within visible locations (visible to the fellow eye) corresponding to the ring scotoma.

The total number of stimulus presentations to the fellow eye (n=60) was chosen to enable a reliable measure of detection performance to be determined while ensuring that the duration of each test condition would not be too long and tiring for the participants. The number of stimuli locations was chosen based on the limited amount of space available in which to present stimuli, and kept constant at 12 locations for each subject for consistency. Eccentricities of the stimulus locations varied slightly across participants and were chosen based on their central scotoma size and shape and their PRL location and the seeing area of the fellow eye. The minimum eccentricity was slightly smaller for patients using the DVI bioptics than those using the Ocutech bioptic (6.9° vs. 7.7°), the difference was statistically significant (Mann-Whitney U=9.0, p=0.047). There was no significant difference in maximum eccentricity between those using DVI and Ocutech bioptics (12.3° vs. 13.0°, Mann-Whitney U=17.0, p=0.338) and no significant difference in average eccentricity (9.6° vs. 10.3°, Mann-Whitney U=17.0, p=0.338). Average stimulus eccentricity was also not significantly correlated with detection performance in any of the 8 conditions (Spearman's rho, p>0.235). Note that since all the main analyses were within subjects, these differences do not matter.

16 participants were able to complete all 8 test conditions in one visit, with a break after the 4th condition, while one performed just 4 conditions per visit, spread over two visits.

eBioptic Telescopes:

The ring scotoma size of a bioptic telescope is theoretically determined by the power of the bioptic multiplied by the nominal field of view. For the participants in the study, our field of view measurements were smaller than the reported values for the 2 types of bioptics used and the ring scotomas were larger than the theoretical value. To determine why this may be the case, we obtained measurements from normally sighted subjects. We found the field of view and ring scotoma size to change with the type of target and background used. When measured on a gray background with the 2 stimuli used in the study, the field of view and ring scotoma size were similar for normally sighted subjects and participants (75% contrast Ocutech 13.9° field of view, 52.1° ring scotoma size DVI 8.1°, 38.3°; 95% contrast Ocutech 13.4°, 48.2° DVI 8.2°, 38.2°). However, when using a high contrast white stimulus on a black background, the field of view (Ocutech 15.6°; DVI 9.6°) and the ring scotoma (Ocutech 35.7°; DVI 33.2°) were comparable to the theoretical size.

The bioptic user group included: 3 participants who used their bioptic weekly; 2 who used their bioptic at least once a month; 1 who used her bioptic less than monthly; and 1 who rarely used his bioptic but used a handheld telescope multiple times per day.

ePerimetry Apparatus:

An InFocus DepthQ projector (Lightspeed Design, Inc., Bellevue, WA) incorporating an 800x600 pixel DLP chip projected the background, fixation, and target stimuli onto a 1.6x1 m rear projection screen at a 120 Hz frame rate. A custom Windows XP application running on a CyberPower (CyberPowerPC.com) system with an Athlon II X2 250 Black processor and an HP (Palo Alto, CA) using a RADEON Quadro FX3700 video card generated the images. The video card provided a square wave signal that alternated level with alternate frames, which was used to open and close the right and left shutters of Cambridge Research Systems (Rochester, Kent, UK) FE-1 liquid crystal shutter goggles. The goggle shutters were synchronized with alternate frames projected at 120Hz so that each eye received 60 frames per second. The participants used a hand-held button to signal detection of the target stimulus directly to the computer. The operator's console displayed a polar grid representing a conventional perimetry plot, in addition to various mode and parameter settings. The operator selected the background, fixation, and stimulus parameters, as well as the eye or eyes to which each was shown.

eReferences:

1. Field DJ. Relations between the statistics of natural images and the response properties of cortical cells. *Journal of the Optical Society of America Part A, Optics and Image Science.* 1987;4:2379-2394.
2. Geisler W. Visual perception and the statistical properties of natural scenes. *Annu Rev Psychol.* 2008;59:167-192.
3. Tolhurst DJ, Tadmor Y, Chao T. The amplitude spectra of natural images. *Ophthalmic Physiol Opt.* 1992;12:229-232.