Anisotropy of perceptual filling-in at the blind spot

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We found an anisotropy of perceptual “filling-in” at the physiological blind spot. The stimulus was a pair of lines presented for 200 ms with one line on each side of the blind spot. The length of the lines extended gradually whenever an observer pushed a key on a computer keyboard. The observer’s task was to report whether the line appeared ‘complete’ or ‘gapped’ when compared to a reference line presented simultaneously to the temporal retina. The independent variable was the orientation of the line. The results with 9 observers showed that the minimum length of the line for perceptual filling-in increased systematically as the orientation of the lines changed from the horizontal to the vertical. We suggest that this anisotropy is due to the elliptic shape of the receptive fields of the binocular neurons that contribute to perceptual filling-in at the blind spot.

Key words: anisotropy, perceptual filling-in, blind spot

Introduction

The blind spot is an area of the retina where photoreceptors are not present. But we do not perceive any gap in the visual field which corresponds to the blind spot even in monocular vision. This is because the visual system complements a lack of visual input at the blind spot: a phenomenon which is called perceptual filling-in. When a pair of lines is presented, with one line on each side of the blind spot, we perceive a continuous line. This perceptual completion of the line requires the lines to be a sufficient length. Recently Okuma et al. (2001) have reported that the minimum length of the lines which is required for perceptual filling-in depends on their orientation: that is, shorter horizontal lines were required for perceptual filling-in, than were required when the lines were vertical. The present study investigated the anisotropy of perceptual filling-in at the blind spot by changing the orientation of the lines from 0 degrees (horizontal) to 90 degrees (vertical).

Method

Observers Nine observers with normal or corrected-to-normal visual acuity, participated in the experiment.

Stimuli and Apparatus The stimuli used in the experiment are illustrated in Figure 1a. The stimulus was a pair of lines which were presented with one on each side of the blind spot of the right eye. A reference line, which was a continuous line, was presented to the temporal retina with equal retinal eccentricity, and was used as a criterion on which to judge perceptual filling-in of the blind spot. Both lines were presented for 200 ms and their length was gradually extended whenever the observer pressed a key of the computer keyboard. The width of both lines was 1.7 degrees and the luminance of both lines and the background were 0.3 and 78.1 cd/m², respectively. The stimuli were presented on a 19-inch color monitor (IIYAMA MA901U). A computer (FMV ME 3/507) controlled the presentation of the stimuli and recorded the responses of the participants.

Procedure Before the experimental trials the region of the blind spot in the right eye of each observer was measured. Each observer was asked to fixate on a displayed fixation point, and to press a key of the keyboard until the gapped line appeared as a continuous line in the same manner as the
The orientations of the lines were 0, 30, 60, 90, 120, and 150 degrees. The observer performed 36 trials (6 orientations in each of 6 sessions). In each session the 6 orientations of the line were presented in a random order for each observer. The experiment was conducted in a darkened room and the distance between the display and the eye of an observer was 30 cm. The observer's head was stabilized with a bite-board and their left eye was occluded.

**Results and Discussion**

The experiment demonstrated an anisotropy of perceptual filling-in at the observer's blind spot: that is, the minimum length of the line for the perceptual filling-in changed as a function of the line orientation. Figure 1b shows the means and standard deviations of the minimum line length for perceptual filling-in, averaged over the 9 observers, and plotted as a function of the orientation. The results of a one-way repeated measure ANOVA indicated that the effect of the orientation of the line was statistically significant ($F(5, 40) = 4.06, p < 0.005$). Multiple comparison tests also revealed that the minimum line length was shorter when the line was oriented at 0 degrees than when the line was oriented at 60, 90, or 120 degrees. These results clearly indicate that in the anisotropy of perceptual filling-in the minimum line length increases in a systematical manner from the horizontal to the vertical orientations.

The anisotropy found in the present study may be due to the elliptic shape of the receptive fields of the binocular neurons in V1 that contribute to perceptual filling-in at the blind spot (Komatsu, Kinoshita, & Murakami, 2000). These neurons tend to have very large elliptical receptive fields with a horizontal axis longer than the vertical axis.

**References**
