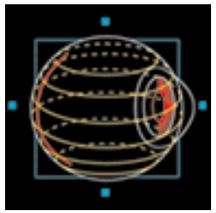
Lateral Interactions in Peripheral Vision



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ABSTRACT

Purpose: When viewed foveally, contrast detection of a Gabor patch (target) is facilitated by collinear, displaced high-contrast Gabor masks (flankers). Polat and Sagi (1994) reported that the same phenomenon occurred in the periphery, but no data was presented. Williams and Hess (1998) found no facilitation in a limited number of conditions tested using a spatial 2AFC paradigm. In the present study, we measured contrast detection in peripheral vision to resolve this conflict in the literature.

Methods: Five normally-sighted subjects participated in temporal and spatial forced choice 2AFC experiments. Experiment 1 examined the effect of eccentric viewpoint (2°, 4°, 6° & 12°) on facilitation using 4 test-flanker distances (2, 4 6 & 8λ, where λ=1/cpd) and a spatial frequency of 2cpd. Experiment 2 examined the effect of spatial frequency (1, 2, 4, 6 & 8cpd). Experiment 3 measured the effect of flanker contrast (10, 20, 40 & 80%). Experiment 4 tested the effect of global orientation of the stimulus pattern (vertical or horizontal). In experiments 2, 3 and 4, eccentricity was 4˚ and test-flanker distance was 4λ.

Results: Facilitation was found to occur in many but not all conditions. Maximum facilitation occurred at a test-flanker distance of 4-6λ, whereas maximum facilitation occurs at 2-3λ in central vision. Facilitation varied between subjects and with spatial frequency. Flanker contrast had no effect over the range evaluated. Equal facilitation was found for both global arrangements of the stimulus pattern.

Conclusion: Facilitation of contrast detection does occur in the near periphery of normally-sighted subjects, although the magnitude of the effect is less than found in central vision. The value of such facilitation for persons with central vision impairment needs to be examined.

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BACKGROUND

- The ability of human observers to detect objects can be modulated by the presence of other objects.
- For instance, laterally displaced Gabor masks (flankers) can facilitate or suppress contrast detection of target Gabor patches in central vision (Polat and Sagi, 1993). Facilitation was maximal at test-flanker distances of 2-3λ, where λ is the carrier period.
- People with central vision loss must use peripheral retina to view objects of interest. In peripheral vision, only low spatial frequencies are detected.
- Less facilitation is found in central vision with lower spatial frequency Gabors (figure 1).

<u>QUESTION</u>: Does facilitation occur in near peripheral vision?

- Polat & Sagi (1994) reported that *facilitation does occur* in peripheral vision (3˚ eccentricity) using a temporal 2AFC, but no data was presented.
- Williams & Hess (1998) reported *no facilitation* in peripheral vision (3˚ eccentricity) using a spatial 2AFC.
- Zenger-Landolt & Koch (2001) found *suppression* in peripheral vision (4˚ eccentricity) using a spatial 2AFC.

<u>ANSWER</u>: Not clear. A limited number of conditions were tested.

PURPOSE: To examine whether facilitation of contrast detection occurs in the near-periphery, using a broader set of spatial conditions than has been used previously.

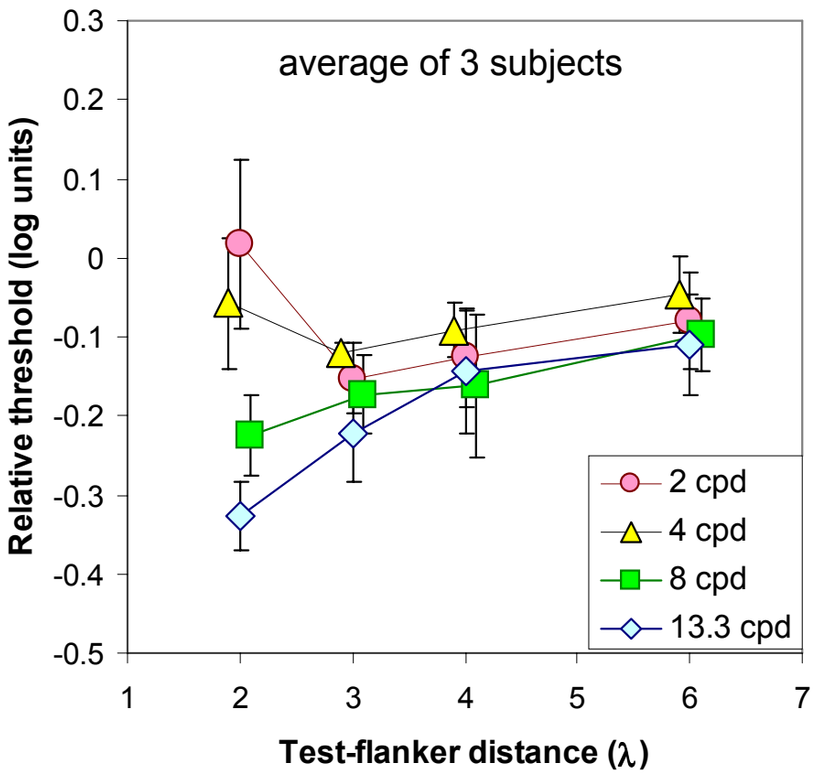

Figure 1. In central vision, facilitation varied with spatial frequency and test-flanker distance. Less facilitation was found at lower spatial frequencies (Woods et al., 2002). Only lower spatial frequencies are available to peripheral vision. Can facilitation occur in the periphery?

GENERAL METHODS

- Contrast detection threshold of a target Gabor patch measured with and without flanking Gabor patches.
- Flankers (40% contrast, except in exp. 3) aligned vertically and equidistant above and below test patch (except in exp. 4).
- Test-flanker distance = center-to-center distance in multiples of λ.
- Target size: $\sigma_x = \sigma_y = \lambda$. Flanker size: $\sigma_x = 0.5\lambda^{\nabla}$, $\sigma_y = \lambda$.
- Each Gabor patch:

$$L(x, y, \theta) = L_0 \left\{ 1 + C \cos\left(\frac{2\pi}{\lambda} \left[(x - x_0)\cos\theta + (y - y_0)\sin\theta \right] \right) e^{-\left[\frac{(x-x_0)^2}{\sigma_x^2} + \frac{(y-y_0)^2}{\sigma_y^2} \right]} \right\}$$

$^{\nabla}$ This flanker width was shown to produce more facilitation at low spatial frequencies (Nugent et al., 2002).

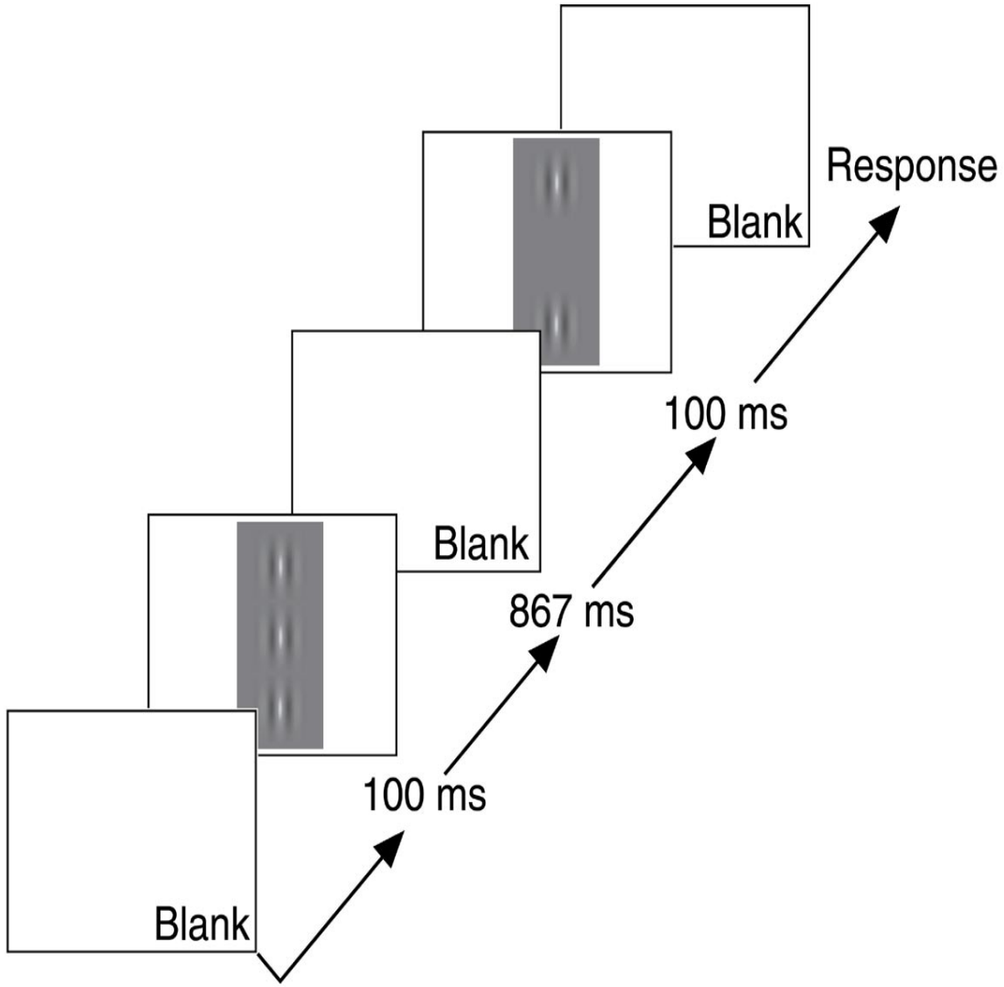

Figure 2. Temporal 2AFC. Each trial consisted of two, 100ms stimulus presentations, separated by an inter stimulus interval of 867ms. Both intervals contained flankers, but only one interval contained the target.

- VisionWorks system & Nanao Eizo monitor [120 Hz, 1024 X 600 pixels, 23.4 by 40cm, 15-bit linear, average luminance 37.5cd/m^2].
- 4 subjects (2 naïve).
- Temporal 2AFC (fig. 2), 3/1 staircase with unequal step sizes. Initial contrast was 25%.
- A staircase included 2 practice + 40 test reversals. Each data point is the average of 3 to 6 staircases per subject.
- Error bars: Standard error.

EXP. 1 - EFFECT OF ECCENTRICITY

QUESTION: 1. Is facilitation found in the near periphery? 2. Is it similar to central vision?

METHODS:

- Eccentricities: 2˚, 4˚, 6˚ and 12˚.
- Test-flanker distances: 2, 4, 6 & 8λ.
- Spatial frequency: 2cpd.
- 4 subjects (2 naïve).

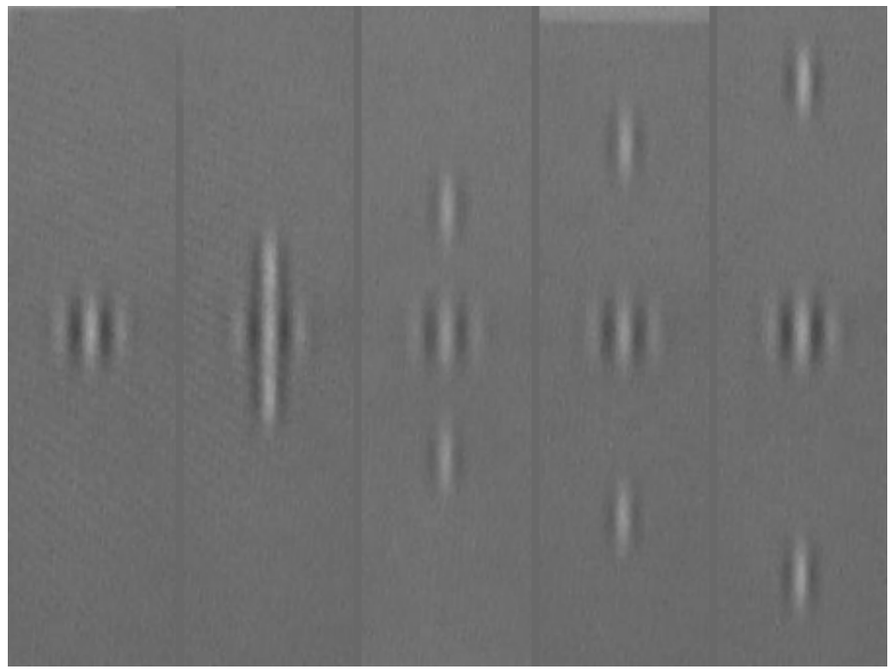

Figure 3. Example images for experiment 1. A small fixation cross to the right of each pattern not shown.

EXP.1 RESULTS

- Facilitation was found for test-flanker distances of 4, 6 and 8λ at eccentricities of up to 6˚.
- Results varied between subjects.
- In central vision at 2cpd, maximal facilitation was found at 3λ (fig.1).

ANSWER: 1.Yes, facilitation was found in periphery to at least 6˚.
2.No, facilitation was about one half that found in central vision (fig. 1).

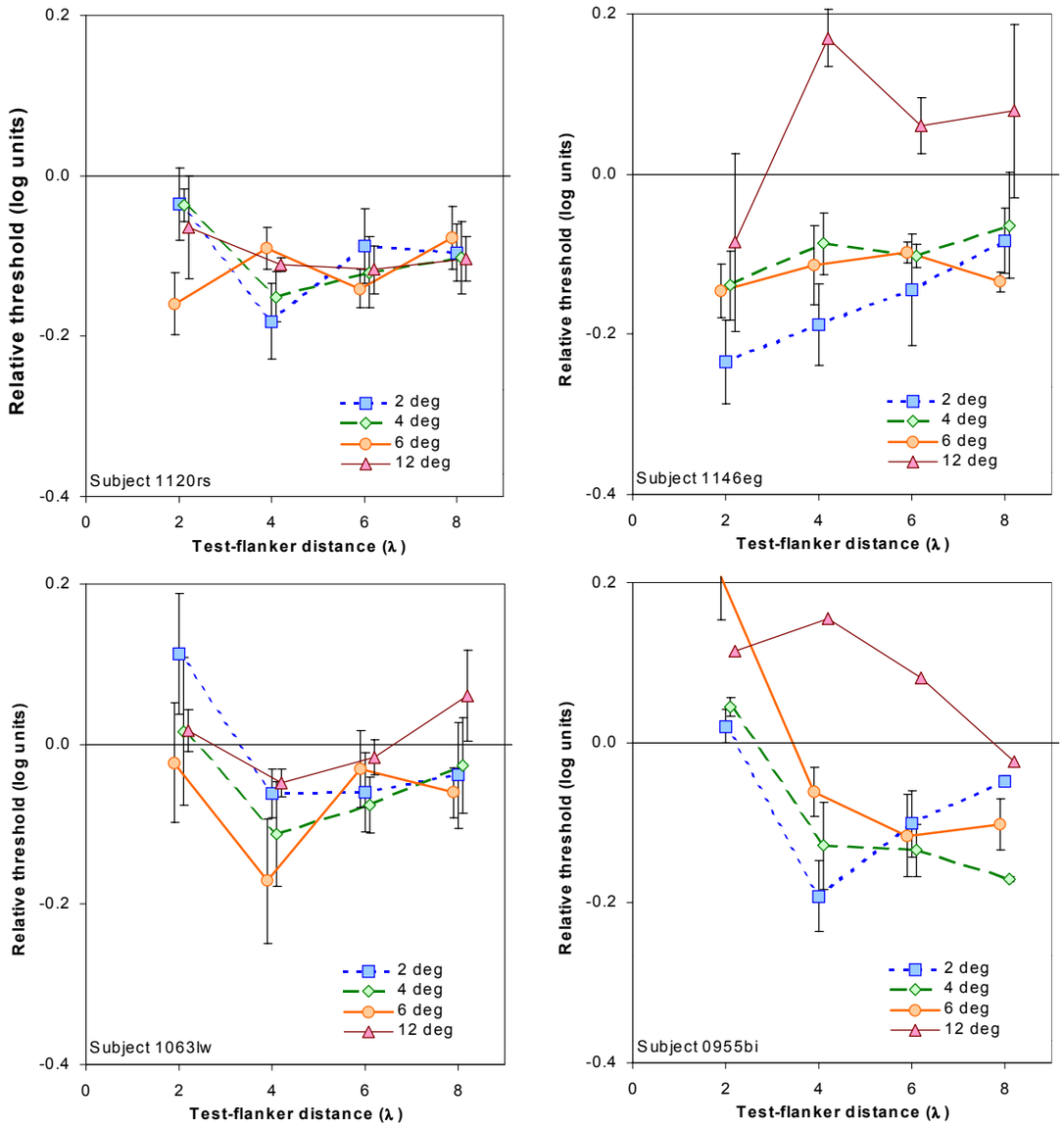

Figure 4. Effect of eccentricity on facilitation for four eccentricities at four test-flanker distances.

EXP. 2 - EFFECT OF SPATIAL FREQUENCY

QUESTION: Does facilitation change with spatial frequency?

METHODS:

- Spatial frequencies: 1, 2, 4, 6 and 8 cpd.
- Test-to-flanker distance: 4λ.
- Eccentricity: 4°.
- 3 subjects (2 naïve).

ANSWER: There was a trend for greater facilitation with decreasing spatial frequency.

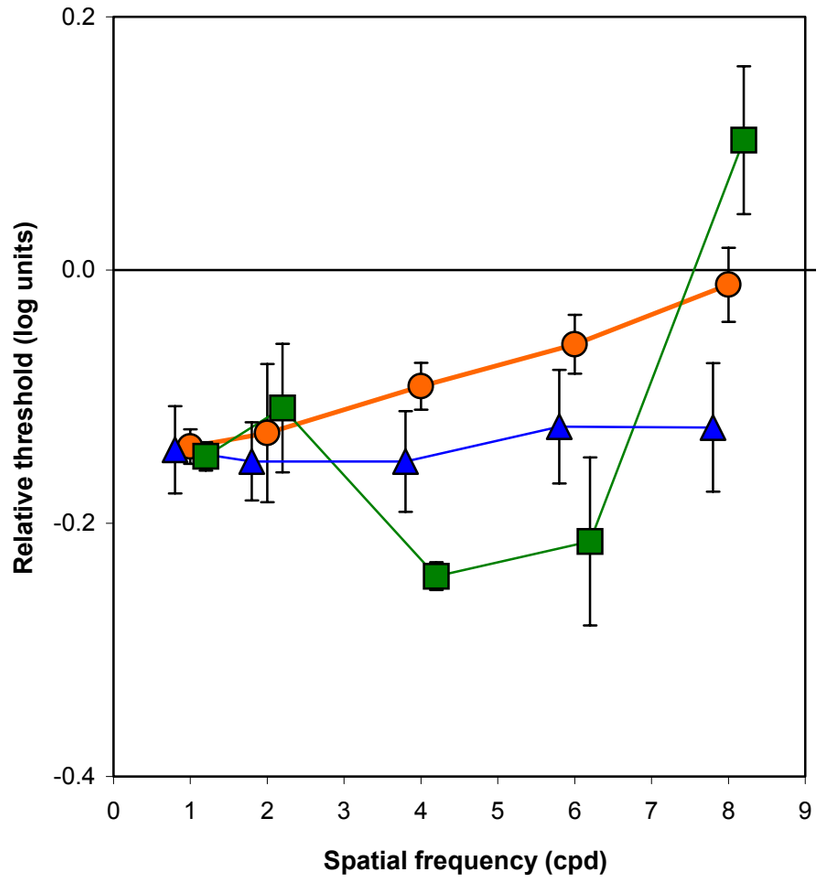

Figure 5. Facilitation was found for all three subjects up to 6 cpd.

EXP. 3 - EFFECT OF FLANKER CONTRAST

QUESTION: Does flanker contrast Matter?

METHODS:

- Flanker contrasts:10, 20, 40 and 80%.
- Eccentricity: 4˚.
- Test-to-flanker distance: 4λ.
- Spatial frequency: 2cpd.
- 3 subjects (2 naïve).

ANSWER: No, facilitation independent of contrast over the range tested.

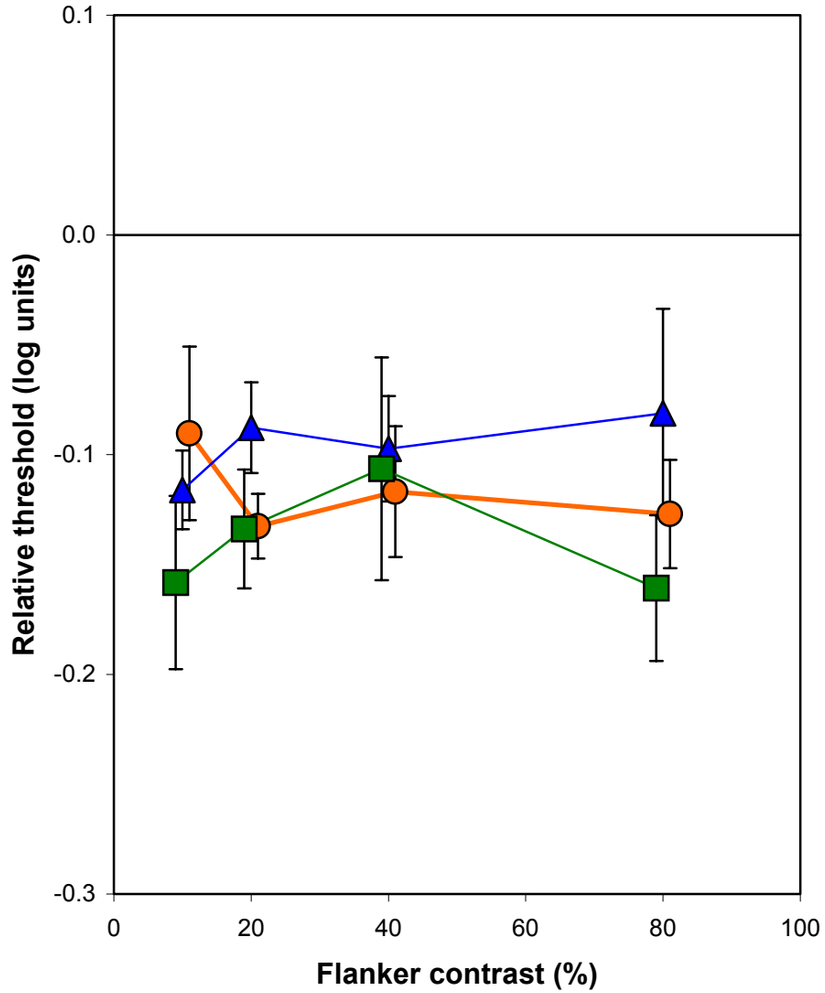

Figure 6. Facilitation for three subjects at four flanker contrasts.

EXP. 4 – EFFECT OF GLOBAL ORIENTATION

QUESTION: Is facilitation found for horizontally aligned stimuli?

METHODS:

- The stimulus arrangement was collinear, either vertical or horizontal (fig. 7 inset).
- Eccentricity: 4˚ to the left (vertical) or 4˚ below (horizontal) (fig. 7 inset).
- Test-flanker distance: 4λ.
- Spatial frequency: 2cpd.
- 3 subjects (2 naïve).

ANSWER: Yes.

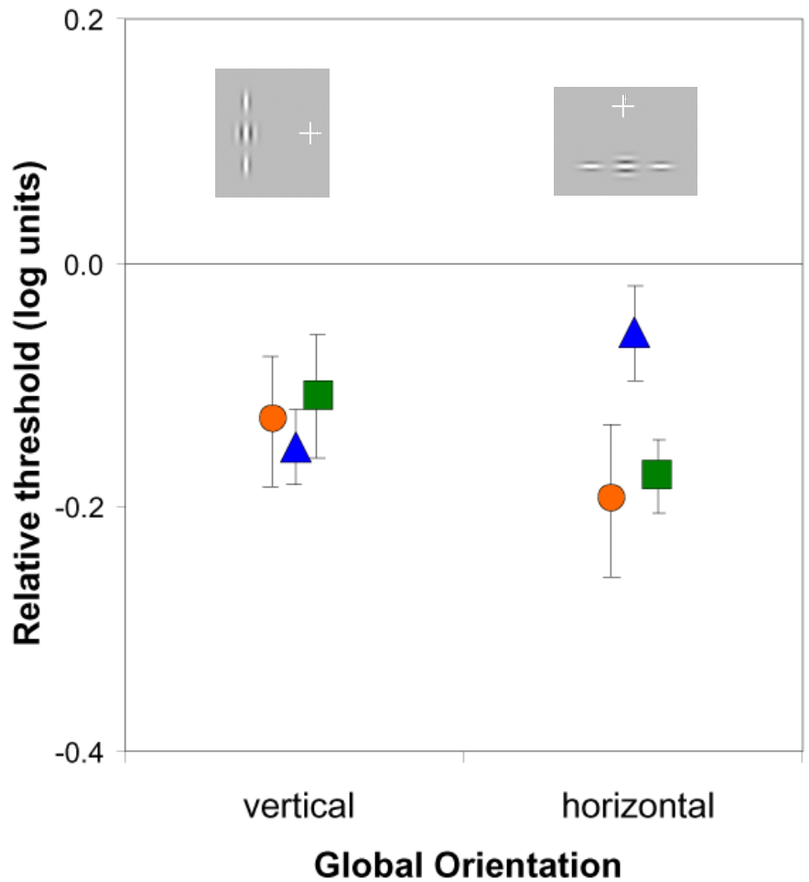

Figure 7. Facilitation for three subjects at two orientations.

CONCLUSIONS

- Facilitation was found in the near periphery.
- Facilitation roughly half that found in central vision.
- Facilitation varied with spatial frequency and between subjects.
- Patients with central vision loss would be expected to demonstrate facilitation with similar patterns presented to their PRL.

ACKNOWLEDGMENTS

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