SUB-THRESHOLD BINOCULAR CONTRAST SUMMATION SCALES WITH INTEROCULAR PHASE AND CARRIER ENVELOPE DISPARITY

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Introduction

- Binocular summation is the increased likelihood of detecting a visual stimulus while viewing a target under binocular viewing conditions compared to monocular viewing conditions [1-4].
- A recent study by Raghunandan and Boyak (2018) provided evidence of phase-sensitive and phase insensitive contrast summation that depended on the orientation and carrier frequency of the stimulus grating [5].
- This study provides a more thorough investigation of the interactions between the magnitude of binocular contrast summation, carrier phase-disparity, envelope position disparity, carrier spatial frequency, and carrier orientation .
- The results of this study sheds light on the evolving postulation of dichotomous summative mechanisms that operate in parallel within normal human visual systems [6-7].
- More specifically it elucidates the stimulus characteristics that favor the recruitment of each type of summative mechanism.

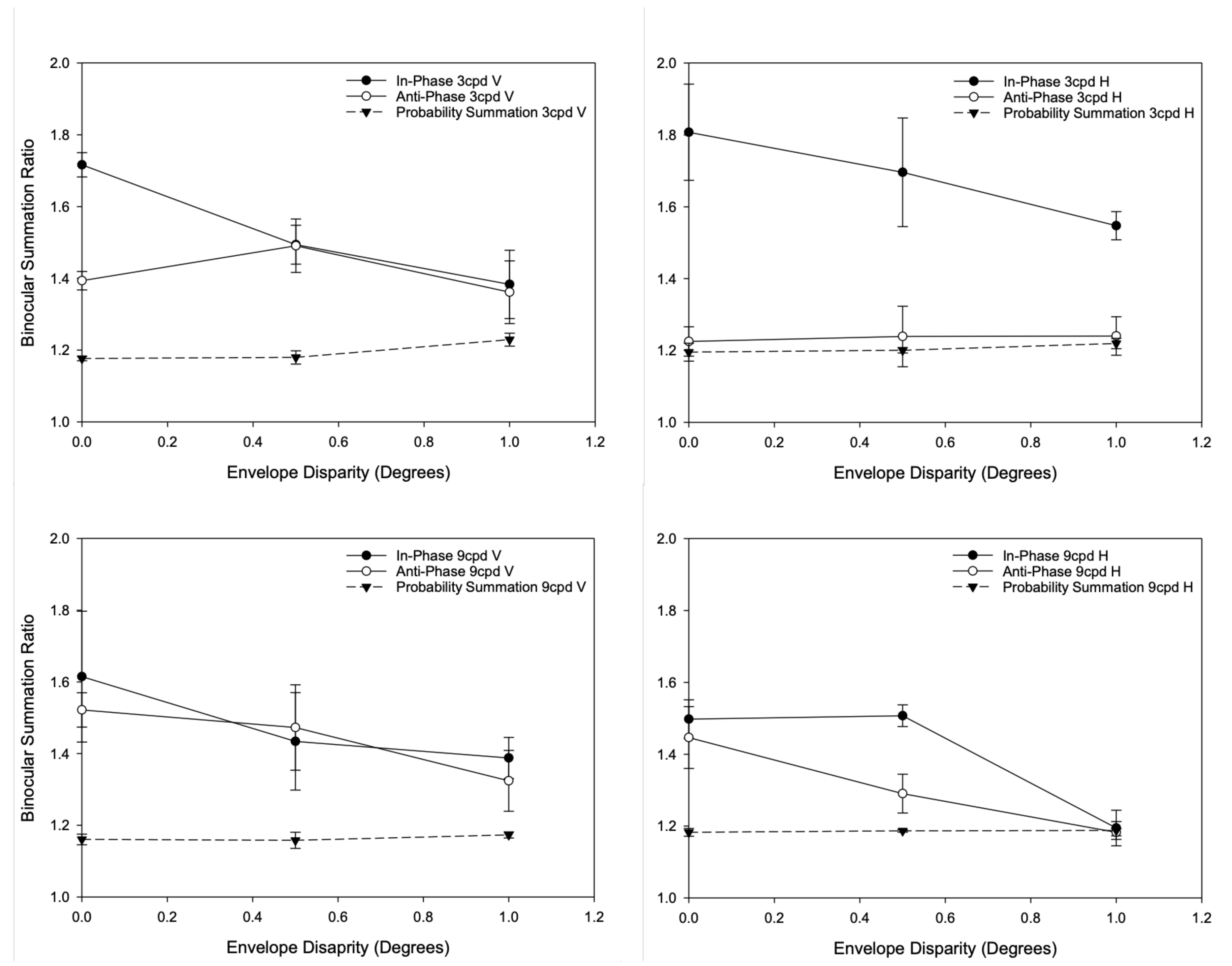
Methods

- Monocular and binocular contrast detection thresholds were measured in 4 observers with normal binocular vision using a two-interval forced choice (2IFC) method presented with a method-of-constant-stimuli.
- Stimuli were Gabor targets ($2.13^0 \times 2.13^0$ carrier cosine grating windowed by a circular Gaussian envelope with a sigma = 0.5^0).
- All stimuli were presented on a linearized Dell CRT monitor interfaced with a VPixx DAC system which allowed 14 BIT grayscale resolution.
- Dichoptic viewing was facilitated by cross polarizes affixed to the monitor and viewing apertures of a Phoropter.
- Independent variables were Gabor carrier spatial frequency (9 and 3 cpd), carrier interocular phase disparity (0, pi radians), carrier grating orientation (horizontal and vertical) , and Gabor envelope disparity (0, 0.5, 1 degree) - creating 24 experimental conditions.
- A complete data set comprised at least 3 detection threshold measures for each of the 24 conditions for each observer.
- A Binocular Summation Ratio (BSR) was calculated for each condition:

$$BSR = \left(\frac{\textit{Mean Monocular Detection threshold}}{\textit{Binocular detection threshold}}\right)$$

Results

- The results from 4 subjects were pooled and are presented graphically below.
- Mean BSR values (+/- 1 SEM) for in-phase (filled symbols) and anti-phase (unfilled symbols) conditions are graphed below for two spatial frequencies and 3 envelope disparities.
- The predictions of probability summation are indicated as dashed lines with filled triangles.
- A two-way repeated measures ANOVA was completed for each set of data *.



Summary of Main Results

1. High spatial frequency gratings (9cpd) were more likely to display summation behavior consistent with position sensitive processing ($p < 0.05$*) and not phase-sensitive processing ($p > 0.08$*).
2. Low spatial frequencies (3cpd) displayed behavior consistent with phase sensitive mechanisms, regardless of the direction of relative disparity ($p < 0.01$*).
3. BSR decreased with increasing position disparity of the envelope whether mediated by the phase-sensitive or the position-sensitive mechanism ($p < 0.05$*).

Conclusions

- The results of the current study imply that both phase-sensitive and phase-insensitive mechanisms operate in parallel within the contrast summation domain.
- At this point of reporting, this is the first report providing evidence that the recruitment of phase-sensitive or phase-insensitive mechanisms depends on the spatial frequency and perhaps the orientation of the carrier grating.
- The authors speculate that the final binocular contrast detection threshold depends on a weighted combination of activity between the phase-sensitive and phase-insensitive mechanisms.
- The goal moving forward is to develop an algorithmic model of how these two distinct mechanisms interact to produce binocular contrast summation that scales with spatial frequency, direction of disparity and envelope disparity.
- The hope of applying this research lies in establishing a more complete model of neural summation in the normal human binocular system. This more complete model may then be used to assess the underlying nature of functional deficits endemic to individuals with abnormal binocular systems. It may also allow for the study of the fundamental deficits underlying seemingly idiosyncratic presentations of amblyopia.

References

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