Optical Quality of the Eye and Binocular Summation

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Rivalry

Binocular Summation

Suppression

( Monovision )

Binocular Summation Model

Detector summation (Campbell and Green, 1965)

\[ C_{OB} = \sqrt{\text{number of detectors}} \]

Quadratic summation (Legge, 1984)

\[ C_{OB} = \sqrt{C_{OD}^2 + C_{OS}^2} \]

Gain-control theory (Ding & Sperling, 2006; Ding et. al. 2013)

\[
I = \frac{I_{OD}(\mu_d)}{1 + \frac{I_{ES}(\mu_d)}{I_{OS}(\mu_d)}} + \frac{I_{OS}(\mu_s)}{1 + \frac{I_{ES}(\mu_s)}{I_{OS}(\mu_s)}}
\]
Impact of Optical Quality of Each of the Two Eyes on Binocular Summation

- Similar Monocular Optical Quality with Different Magnitude
- Dissimilar Monocular Optical Quality
- Long-term Neural Adaption to Dissimilar Monocular Optical Quality

Binocular visual performance is improved upon higher order aberration correction

Binocular visual benefit is reduced compared to monocular visual benefit.
**Binocular summation is elevated with blur and decreases with improving optical quality**

\[
\text{Binocular summation} = \frac{\text{Binocular visual performance}}{\text{Averaged monocular visual performance}}
\]

- No HOA correction
- SA correction
- Complete correction

Better Optical Quality

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**Dissimilar Monocular Quality**

- Monovision

**Binocular Summation at Resolution**

**Binocular Summation at Contrast Threshold**

- 1.50D anisometropia

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**Through-Focus Image Quality**

*Extending Monocular Depth of Focus with Spherical Aberration*

Traditional Monovision

Modified Monovision

- SA= 0 DE
- SA= 0 NDE
- SA= 0.1 DE
- SA= 0.4 NDE

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**Neural Contribution to Binocular Summation**

- Aberration-free i.e. Neural Contrast Sensitivity Function

Normal Eyes (n=4)

Keratoconus Eyes (n=3)

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**Neural Contribution to Binocular Summation**

- Long-term Adaptation to Dissimilar Monocular Optical Quality

Keratoconus

Monovision

- Bilateral, Asymmetric Slow Progression
- Higher Order Aberration
- Defocus Blur Dissimilar Monocular Blur

Dominant eye

Non-dominant eye

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**Spatial Frequency (c/deg)**

- Normal Eyes
- Keratoconus Eyes

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**Contrast Sensitivity**

- Monocular (better)
- Monocular (worse)

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**Summation Factor**

- Binocular (better)
- Binocular (worse)
**Neural Contribution to Binocular Summation**

Aberration-free i.e. Neural Contrast Sensitivity Function

**Monovision Eyes** (n=2)

- **Binocular**
  - Monocular (better)
  - Monocular (worse)

**Contrast Sensitivity**

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<th>Spatial Frequency (c/deg)</th>
<th>Summation Factor</th>
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**Loss of neural binocular summation is correlated with a degree of optical disparity between the two eyes.**

**Keratoconus Eyes**

- **Worse eye**
- **Better eye**

**Optical quality of the two eyes has the significant impact on binocular summation.**

Long-term visual experience with high interocular optical disparity between the two eyes can alter binocular neural processing, resulting in reduced binocular summation or inhibition.

**Take Home Message**

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