Using dynamic contrast estimation to assess amblyopia

Kimberly Meier1
Kristina Tarczy-Hornoch2
Geoffrey M Boynton1
Ione Fine1

1 Department of Psychology, University of Washington
2 Department of Ophthalmology, University of Washington; Seattle Children's Hospital

1. Background

- Intercocular balance or suppression in amblyopia has been measured using a wide variety of stimuli, measurements, and models.
- Most assessments use rivalrous stimuli which do not typically reflect an observer's everyday visual experience. Moreover, most assessments cannot distinguish between attenuation and suppression.
- Previously, we developed an intuitive and robust measure of interocular summation that provides a direct measure of the perceptual experience of the observer during typical non-rivalrous vision. Here, we used this new measure to assess attenuation and suppression in adults with amblyopia.

2. Methods

- History of Amblyopia (n = 19) strabismic, anisometropia, or mixed; M age = 43 years, SD = 21, range 18-75; not all patients presented with ≥ 2 logMAR difference at testing
- Controls (n = 14) M age = 36 years, SD = 18, range 18-69; Normal history of visual function; in order to capture variation, no exclusion criteria for acuity or stereopsis

3. Modeling

Our model parameterized:
- Attenuation as a reduction of stimulus input to the amblyopic eye (kAE).
- Suppression of the amblyopic eye by the fellow eye (kF) and of the fellow eye by the amblyopic eye (kFA), as interocular divisive normalization.

1. Attenuation: \( A_{\text{AE}} = k_{\text{AE}} C_{\text{AE}} + A_{\text{F}} = k_{\text{F}} C_{\text{F}} \)
2. Interocular normalization: \( Z_k = Z_{\text{AE}} = \frac{k_k - Z_{\text{F}}}{-k_{\text{FA}}} \)
3. Linear combination: \( v_{\text{FP}} = Z_k + Z_{\text{AE}} \)

Step 1: Fit data from the monoptic trial portion to estimate weights \( k_k \) and \( k_{\text{F}} \) while fixing \( \mu_k \) and \( \mu_{\text{F}} \) at 0 (effectively a linear combination of weighted input contrasts).

- Normalize by dividing by max(\( k_k, k_{\text{F}} \)) \( k_k \) = fellow eye; \( k < 1 \) is \( k_k \) = amblyopic eye (even in controls)

Step 2: Fit data from the dichoptic (non-monoptic) trial portion to estimate \( \mu_k \), \( \mu_{\text{F}} \), and \( a \) while \( k_k \) and \( k_{\text{F}} \) are fixed

- \( \mu_k \) = the extent to which the signal in fellow is normalized by the signal in amblyopic eye
- \( \mu_{\text{F}} \) = the extent to which the signal in amblyopic is normalized by the signal in fellow eye

To account for idioptics in motor response, a linear mapping function \( k = a + b \cdot \text{delta} \) estimated from response during binocular trial portion was used to translate order to perceived contrast; no difference between groups on any estimates, all \( p \geq 0.40

4. Relationship between attenuation and visual functions

What is the relationship between model parameters and other clinically-relevant visual functions (acuity, contrast sensitivity, stereopsis, and dichoptic letter chart balance point)?
- Visual acuity worse in the amblyopic eye, but not fellow
- Contrast sensitivity worse in the amblyopic eye, but not fellow (area under logMAR).
- Randot circles stereopsis higher (i.e. worse) with amblyopia \( \sigma_\text{AE} = 7.25, p = 0.001 \); \( \alpha = 0.001 \) sec
- Intercocular balance point higher (i.e. greater asymmetry) with amblyopia \( \sigma_\text{AE} = 4.96, p = 0.0002

5. Future directions

- Do observers with non-amblyopic strabismus show low attenuation and high suppression?
- Under rivalrous conditions, will our model show greater suppression in amblyopia than in control observers?
- Because the data we collect in this task are dynamic, we can compare the perceptual timeseries data to neural timeseries data to make predictions about each observer.
- Neuroimaging will allow us to determine whether, and where, cortical activity reflects stimulus input vs. perceptual report (SSVEP data collection underway; functional MRI starts soon).

6. References