Neural Plasticity Stimulated by Improved Optics in Highly Aberrated Eyes

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Factors Affecting Vision

Neural Adjustments to Image Blur

Short-term adaptation to blur
Webster et al., (2002)

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Short-term adaptation to blur
Webster et al., (2002)
Neural Adjustments to Image Blur

Short-term adaptation to blur
Webster et. al. (2002)

Aberration Subjective Percept
Habitual Rotated

Long-term adaptation to aberrations
Artal et. al. (2004)

Keratoconus subjects for a study on long-term adaptation to the aberration
Pantanelli et. al., Ophthalmology (2007)

Subjective Percept

Normal Keratoconus

- Normally developed visual system unlike amblyopia
- Gradual progression of the disease over years
- Large magnitude of higher order aberrations

I. Phase Compensatory Mechanism

KC eyes with their own habitual aberration

Normal eyes with KC habitual aberrations

Narrowband Stimulus (Single spatial frequency) Contrast Sensitivity
Broadband Stimulus (Multiple spatial frequencies) Visual Acuity

II. Gain Adjustment of Spatial Frequency Channel Mechanism
Sabesan and Yoon, J Vis. (2009)

Full AO Correction i.e. Aberration Free Condition

Neural Plasticity
Re-adaptation to Improved Ocular Optics
Neural Compensation Neural Insensitivity

Adverse effect of neural compensation

Neural Plasticity
Re-adaptation to Improved Optics
“Prosthetic Replacement of the Ocular Surface Ecosystem (PROSE)” provides excellent stability of higher order aberration correction

Sabesan et. al., Optom Vis Sci (2013)

Optical Performance

- 17-22mm diameter
- High oxygen permeability
- State-of-the-art haptic design
- Severe ocular surface treatment

Habitual (Passive) visual experience with improved optics i.e. wavefront-guided PROSE

- Two advanced keratoconic patients
- Severe keratoconus in both eyes
- Spectacle correction in both eyes
- No previous advanced correction

Wavefront-guided PROSE fit

Only spectacle correction
Optical and binocular visual performance follow up with habitual visual experience

Time course improvement of visual acuity with wavefront-guided PROSE

Barbot et. al., Investigative Ophthalmologicae Vis. Sci (2017)

Baseline acuity with conventional PROSE: 20/33

Visual performance improvement with wavefront-guided PROSE (subject #1)

Conventional PROSE Wavefront-guided PROSE at 2 hours Wavefront-guided PROSE at 60 hours

Time course improvement of contrast sensitivity with wavefront-guided PROSE

Visual performance Improvement with wavefront-guided PROSE (subject #2)

Conventional PROSE Wavefront-guided PROSE at 2 hours Wavefront-guided PROSE at 25 hours
Neural Plasticity with Improved Optics and Visual Training

**Improved optics**
Provisioning fine visual details

**Visual training**
Active stimulation

- **Adaptive Optics**
- **Perceptual Learning**

<table>
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<th>Pre-training</th>
<th>Training</th>
<th>Post-training</th>
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<td>VA &amp; CSF with AO in both eyes</td>
<td>Monocular contrast sensitivity at high spatial frequency (24 c/deg) with AO</td>
<td>VA &amp; CSF with AO in both eyes</td>
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5 training sessions over 5 days, 1000 trials / 1 hour each

Visual training with adaptive optics significantly improves contrast sensitivity.

Sabesan et. al., Vision Res (2016)

- **Trained eye** -

$$\begin{array}{c}
\text{Contrast Sensitivity} \\
\text{Spatial Frequency (c/deg)}
\end{array}$$

- S1, moderate KC
- S2, advanced KC

Inter-ocular transfer of the training effect

Sabesan et. al., Vision Res (2016)

$$\begin{array}{c}
\text{Contrast Sensitivity} \\
\text{Spatial Frequency (c/deg)}
\end{array}$$

- S1, moderate KC
- S2, advanced KC

Inter-visual task transfer of the training effect

Sabesan et. al., Vision Res (2016)

$$\begin{array}{c}
\text{Visual Acuity (logMAR)} \\
\text{Trained Eye Fellow Eye}
\end{array}$$

- Trained Eye
- Fellow Eye

Conclusions

- Mechanisms underlying long-term neural adaptation to the eye’s aberrations are
  - Phase compensation (Phase transfer function)
  - Gain adjustment of spatial frequency channels

- The adult human visual cortex has a sufficient degree of plasticity, indicating that providing improved visual input through wavefront-guided correction and/or visual training can recover visual deficits from long-term adaptation to severe optics.

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