Visual improvement of perceptual learning based on adaptive optics system for human eyes

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Purpose

Higher order aberrations correction can benefit the visual function of human eyes on adaptive optics system [1], what can we do to achieve this benefit out of laboratory? We combined higher order aberrations (HOAs) correction [1,2] and perceptual learning (PL) [3,4] to gain persistent visual improvement.

Methods

All the subjects were arranged into 3 groups randomly. Group1 were trained at cut-off spatial frequency (spatial frequency when contrast threshold at HOAs corrected condition is 0.4) with HOAs corrected by adaptive optics [2]. Observers in Group2 were trained at cut-off spatial frequency without HOAs corrected. Observers in Group3 were trained a using a spatial frequency which while being optimal in terms of HOAs corrected sensitivity was sub-optimal in terms of perceptual training. The experiment in each group consistent of four consecutive stages: pre-training practice stage (2 days), pre-training test stage (2 days), training stage (10 days) and post-training test stage (2 days). For each subject, only one eye was used in the experiment, the other eye was covered by an opaque fabric. The tested eye with normal or corrected to normal vision was selected randomly for each observer. Contrast sensitivity, defined as the reciprocal of contrast threshold for detecting a sine-wave grating with 79.3% accuracy, was measured at spatial frequencies 0.6, 1, 2, 4, 8, 16, 24, 36 on the adaptive optics system. Each training session consistent of seven blocks of 90 trials each and lasted about 50min. Subjects could take an optional rest after finishing one block.

Results

Significant improvement of contrast sensitivity function was found in Group1 and Group2, but not in Group3.

In Group1, average improvement of contrast sensitivity at the trained spatial frequency is 5.39dB; average magnitude of contrast sensitivity improvements across observers and spatial frequencies is 3.11dB.

In Group2, average improvement of contrast sensitivity at the trained spatial frequency is 3.42dB; average magnitude of contrast sensitivity improvements across observers and spatial frequencies is 1.31dB.

We found much less improvement in Group3, which were trained at a lower spatial frequency, indicate that just a HOAs-corrected environment is necessary but not sufficient; training at a near-cutoff spatial frequency is also required.

Training also significantly improved visual acuity in Group1, but not in Group2 and Group3. All subjects in Group1 have visual acuity improvements after training, that were retained for at least 5 months (4 subjects in Group1 has visual acuity retested 5 months after training). Average improvements of visual acuity in Group1 was 2.32dB (or 31%)

Conclusions

We find larger training improvements (contrast sensitivity as well as visual acuity) in normal adults whose HOAs have been corrected using adaptive optics compared with those without such optical correction. We conclude that after the critical period, the visual areas of our brain still have considerable plasticity but the extent of the visual improvement that can be induced by perceptual learning is limited by the optical quality of the eye. If the higher order aberrations are corrected, the full extent of brain plasticity can be uncovered with resultant supernormal vision.

Our demonstration of enhanced visual plasticity in the adult not only offers hope for the effectiveness of new therapies applied in later life to redress brain dysfunction resulting from anomalous visual development earlier in life but also shows that "supernormal" vision is achievable through the combination of recent advances in our understanding of optics and brain plasticity.

References

1. Yoon, G.-y. and D. R. Williams (2002). "Visual performance after correcting the monochromatic and chromatic aberrations of the eye." J. Opt. Soc. Am. A 19(2): 266-275.

2. Li, S., Y. Xiong, et al. (2009). "Effects of Monochromatic Aberration on Visual Acuity Using Adaptive Optics." Optometry and Vision Science 86(7): 1-7.

3. Hubel, D. H. and T. N. Wiesel (1970). "The period of susceptibility to the physiological effects of unilateral eye closure in kittens." J Physiol 206(2): 419-436.

4. Fiorentini, A. and N. Berardi (1980). "Perceptual-Learning Specific for Orientation and Spatial-Frequency." Nature 287(5777): 43-44.

5. Huang, C. B., Y. Zhou, et al. (2008). "Broad bandwidth of perceptual learning in the visual system of adults with anisometropic amblyopia." Proc Natl Acad Sci U S A 105(10): 4068-4073.