Adaptive Optics as a tool to study changes in the perceived neutral point after correction of astigmatism

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Purpose

Previous experiments have shown that the perception of focus changes after adaptation to a blurred or sharp images[1]. Shifts in the perception of neutral focus point (toward images with horizontal or vertical blur) have also been reported after adaptation to images artificially degraded with vertical/horizontal astigmatism[2]. Adaptive Optics is an ideal tool for testing neural adaptation effects, as images can be simulated on the retina without interactions of the natural aberrations of the subjects. Adaptive Optics has been used in studies suggesting the role of neural adaptation to high order aberrations in keratoconus eyes[3], rotated aberrations[4], and combinations of coma and astigmatism[5] in visual performance. In this study we evaluated neural adaptation to astigmatism by testing whether non-corrected astigmats shift their perceived neutral point before and after adaptation to astigmatic correction, while the High Order Aberrations are corrected with Adaptive Optics.

Methods

A custom-developed Adaptive Optics (AO) system was used to measure and correct the subject's aberrations. The main components of the AO system, described in detail in previous publications [2, 6-7], are a Hartmann-Shack wavefront sensor (composed by 32x32 microlenses, with 3.6mm effective diameter and a CCD camera; HASO 32 OEM, Imagine Eyes, France) and an electromagnetic deformable mirror (MIRAO, Imagine Eyes, France) with 52 actuators, a 15-mm effective diameter and a 50µm stroke. Illumination comes from a Super Luminescent Diode (SLD) coupled to an optical fiber (Superlum, Ireland) emitting at 827 nm. The stimuli were presented on a CRT monitor (Mitsubishi Diamond Pro 2070) through the Badal and AO mirror correction. Stimulus display was controlled by the psychophysical platform ViSaGe, (Cambridge Research System, UK). The Hartmann-Shack system, deformable mirror, and closed-loop correction were controlled with custom software in C++.

Experiments were performed on five habitually non-corrected astigmats (>0.75 D), and five emmetropes (control group) .Experiments were performed before prescription of astigmatic correction (in the astigmatic group) and after 2 hours, and 1 week of astigmatic correction wear. All experiments were performed with naked eyes, where the astigmatism and high order aberrations of the subject were corrected with the AO-mirror and defocus with a Badal system. Test images were generated by varying the magnitude of astigmatism over $\pm$2 µm, varying defocus to maintain constant blur. Images (1.98º) were blurred following the subject's axis of natural astigmatism (in the astigmatic group), and from horizontal to vertical axis (in the emmetropic group). Images were presented on a CRT monitor, viewed monocularly through the adaptive-optics system. A two Alternative Forced Choice procedure, based on quest algorithm, was performed to estimate the perceived neutral point, i.e. the stimulus that appeared isotropic to the subjects, by responding if the image appears oriented along or perpendicular to a certain axis (axis of natural astigmatism for astigmats or horizontal/vertical for emmetropes).

Results

The two groups show differences in their performance both in the first session, and between sessions, after the astigmatic groups have been wearing the astigmatic correction.

Emmetropic subjects show only minor shifts in the perceived isotropic neutral point (with respect to isotropically blurred images) and, in the most part, do not show significant changes in the perceived isotropic neutral point between sessions. Prior to correction, habitually non-corrected astigmats shifted their perceived neutral point toward the axis of their natural

Astigmatism (by 0.24µm of Astigmatism on average). After correction, their perceived neutral point shifted to more isotropically blurred images. This behavior is more pronounced subjects with their axis along the horizontal and vertical meridians than for subjects with oblique Astigmatism (Fig.1)

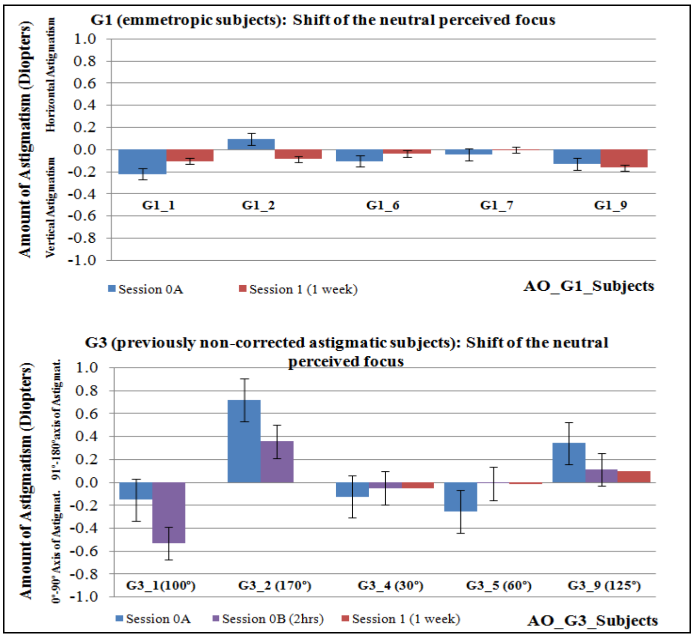

Fig. 1. Shift of the neutral perceived focus for both Groups: Emmetropic (G1, upper panel) and initially non corrected Astigmatic (G3, lower panel) subjects. Values in parenthesis for G3 subjects represent Zero in the vertical axis indicates isotropically blur images, while positive values represent horizontal astigmatism (or closer to horizontal in oblique astigmatism) and viceversa for negative values. Data for the session prior to astigmatic correction wear in astigmatic patients (session 0A, blue), 2 hours after correction wear (session 0B, purple) and after 1-week (session 1, red) are shown. Emmetropic subjects do not show relevant shifts of the perceived neutral point. Prior to correction, astigmatic subjects shift their perceived neutral point toward the axis of their natural astigmatism. Except for subject G3_1, following adaptation to their astigmatic prescription, the perceived neutral point shifts towards more isotropically oriented images.

Conclusions

(1) Adaptive Optics is an excellent tool to test for the role of neural adaptation in visual perception.

(2) Our results support that non-corrected astigmats are naturally adapted to their astigmatism, and that adaptation to astigmatic correction shifts perception of neutral focus.

References

1. Webster, M.A., M.A. Georgeson, and S.M. Webster, Neural adjustments to image blur. Nat Neurosci, 2002. 5(9): p. 839-40.
2. Sawides, L., et al., Visual performance with real-life tasks under adaptive-optics ocular aberration correction. J Vis, 2010. 10.
3. Sabesan, R. and G. Yoon, Visual performance after correcting higher order aberrations in keratoconic eyes. J Vis, 2009. 9(5): p. 6 1-10.
4. Artal, P., et al., Neural compensation for the eye's optical aberrations. J Vis, 2004. 4(4): p. 281-7.
5. de Gracia, P., et al., Visual acuity under combined astigmatism and coma: optical and neural adaptation effects. J Vis, 2011. 11(2).
6. Gambra, E., et al., Accommodative lag and fluctuations when optical aberrations are manipulated. J Vis, 2009. 9(6): p. 4 1-15.
7. Marcos, S., et al., Influence of adaptive-optics ocular aberration correction on visual acuity at different luminances and contrast polarities. J Vis, 2008. 8(13): p. 1 1-12.