Is astigmatism, spherical, or other high-order aberrations used for detecting the sign of defocus?

Marín-Franch I[1,2] (ivan.marin@uv.es)
Del Águila-Carrasco AJ[1], Bernal-Molina P[1,2], Kruger PB[3], Esteve-Taboada JJ[1], Montés-Micó R[1], López-Gil N[2]

[1] Optometry Research Group, Universitat de València, Valencia, Spain; [2] Ciencias de la Visión research group, Universidad de Murcia, Murcia, Spain; [3] State University of New York, College of Optometry, New York, NY, USA

Purpose

Retinal images with the same magnitude but opposite sign of defocus are different in presence of even-order aberrations such as astigmatism or spherical aberration [1,2,3]. Then, these aberrations are potential cues for accommodation, but, is the eye using them to decode the sign of defocus? We tested if the visual system uses these aberrations to accommodate monocularly to moving monochromatic stimuli.

Methods

Five subjects were presented a Maltese cross spanning 1° of visual angle in a monochromatic microdisplay (550 ± 5 nm) through a Badal system that changed the target vergence sinusoidally at 0.2Hz during 50 seconds (10 cycles) between −1 D to −3 D from each subject's far point. Target's luminance was 125 cd/m² and it was seen through a 4-mm artificial pupil. Aberrations were measured using a Shack-Hartmann sensor at a vergence of −2 D and manipulated with a deformable mirror before measurements of dynamic accommodation started (Figure 1).

Amplitude and phase in the accommodation response were calculated from the dynamic accommodative response under 4 conditions, each repeated 6 times. The conditions were the eye's natural aberrations, all aberrations corrected except defocus and astigmatism, all aberrations corrected except defocus and 4th order spherical aberration, and all aberrations corrected except defocus. An example is shown in Figure 2.

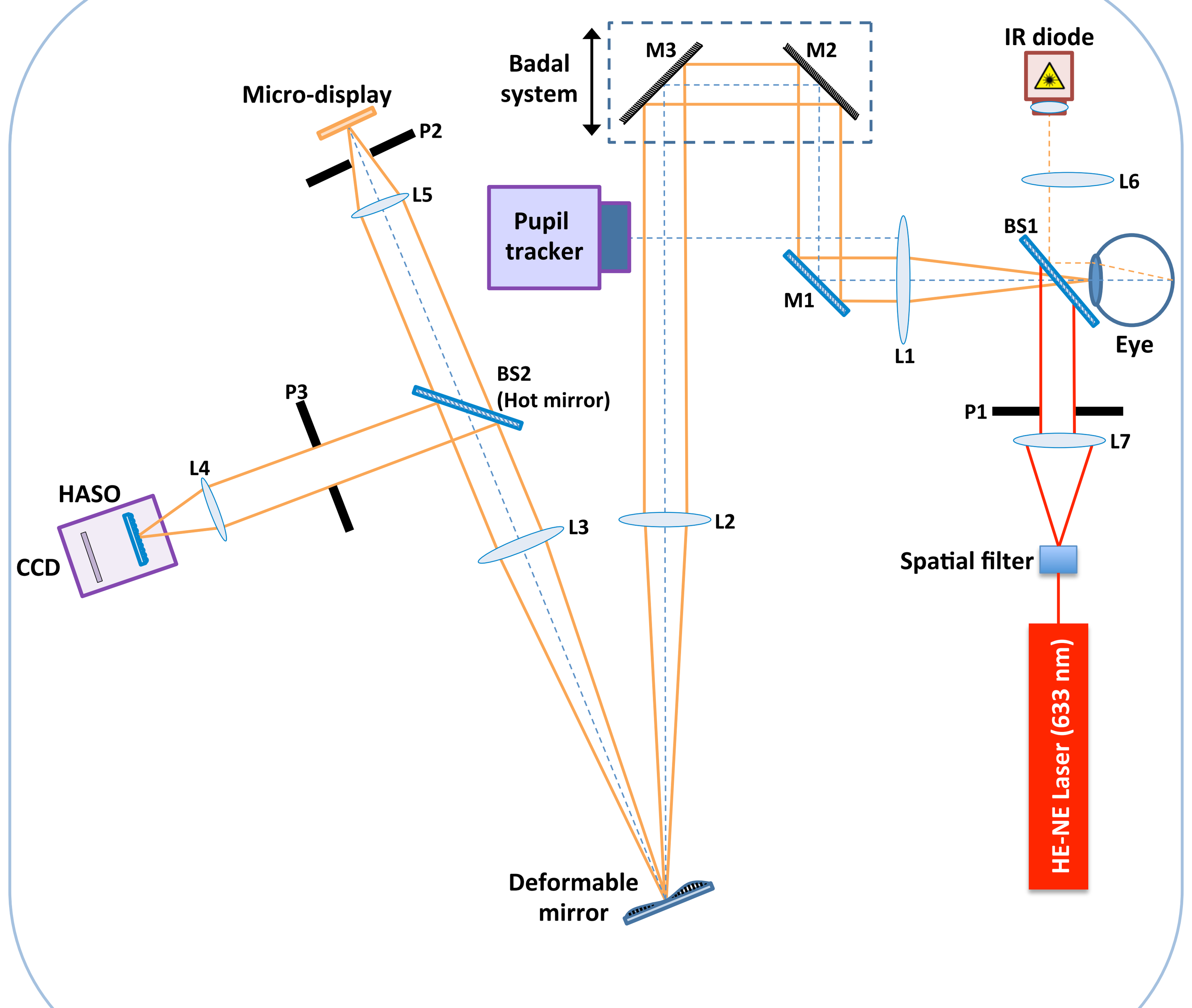

Figure 1. Optical set-up "MurciAO"

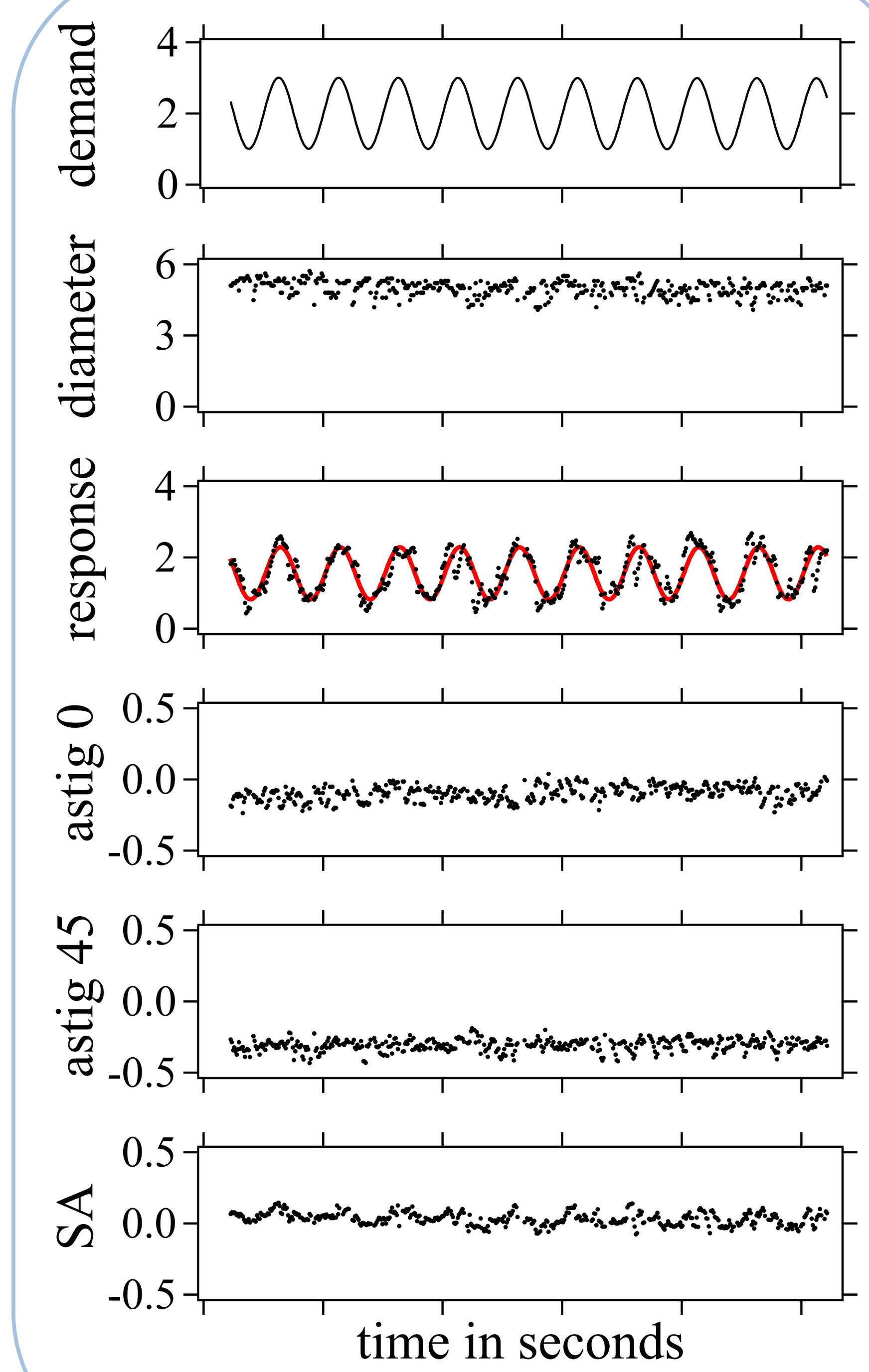

Figure 2. examples

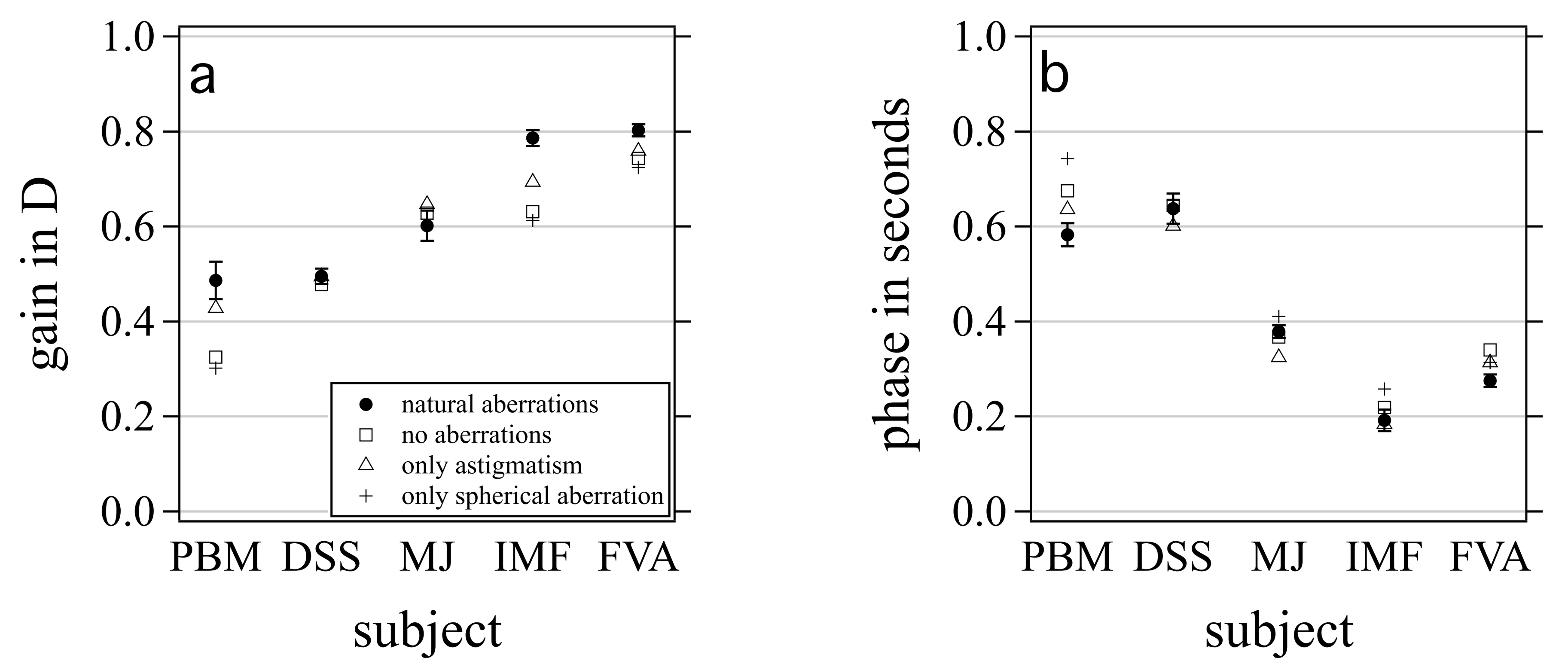

Figure 3. Gain (a) and phase (b) for the 5 subjects

Results

Figure 3 shows mean gain and phase over the 6 repetitions for all 5 subjects and 4 conditions.

The mean response amplitude (and standard deviation) with natural aberrations was 0.63 D (0.15 D). The mean phase was 0.41 s (0.19 s). For 3 out of 5 subjects, there were changes in amplitude and phase in all conditions compared to those for natural aberrations. These subjects had astigmatisms with magnitudes of 0.27 μm (±0.03), 0.33 μm (±0.02), and 0.43 μm (±0.04), and spherical aberrations of −0.04 μm (±0.003), −0.09 μm (±0.02), and 0.08 μm (±0.01), respectively. For these 3 subjects, the mean changes in amplitude and phase were −0.02 D and 0.01 s for astigmatism alone, −0.08 D and 0.08 s for spherical aberration alone, and −0.06 D and 0.05 s for the completely corrected eye. The spherical aberration condition had the smallest amplitude and greatest phase.

Conclusion

Three out of 5 subjects in this study got a better response with natural aberrations, which may indicate that they are used as cues for dynamic accommodation. Astigmatism seemed an important cue for 2 of those 3 subjects, whereas spherical aberration was not for any of them.

References

1. N. López-Gil, et al. Effect of coma and trefoil on dynamic accommodation. Vis. Res. 47 (6), p.755-765, Mar 2007.
2. L. Thibos, et al. "Spherical Aberration and the Sign of Defocus". Optom. Vis. Sci. Nov;90(11):1284-9.
3. Kruger, P.B. (2012). Cues for Accommodation. Chapter in Presbyopia: origins, effects and treatment. Eds. Pallikaris, I., Charman, N. & Plainis, S., Slack Press.

Funded by:

SAF2013-44510-R

European Research Council
ERC-2012-StG-309416-SACCO

This poster was awarded an IMC travel award. Del Águila-Carrasco is funded by Atracció de Talent (UV-INV-PREDOC14-179135)