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The scientific work of Lucie Sawides


Lucie Sawides

I received my Engineering Degree (2005) in Opto-electronics from ENSSAT (Ecole Nationale Supérieure des Sciences Appliquées et de Technologies, Lannion, France) and my MS degree (2006) in Lasers, Materials and Biomedical Optics from the University Pierre et Marie Curie, Paris VI (France).

In March 2006, I joined the Instituto de Optica, Consejo Superior de Investigaciones Científicas (CSIC), Madrid, Spain, to carry my predoctoral research under the supervision of Prof. Susana Marcos, in the field of visual optics.

In particular, at the CSIC Visual Optics and Biophotonics Laboratory, we have developed an adaptive optics system, with a Hartmann-Shack wavefront sensor, a magnetic deformable mirror for the measurement and real time correction of ocular aberrations, combined with psychophysical channels. Using this instrument, we have explored the effects of optical aberrations on visual performance, and the role of neural adaptation to aberrations in visual perception.

While low order aberrations (i.e. astigmatism and defocus) are normally corrected with spectacles or contact lenses, an ultimate challenge is the customization of the correction by compensating also for High Order Aberrations (HOA). Adaptive Optics (AO) allows to appropriately control the blur level of the retinal image, resulting in a powerful technique to directly test visual functions, such as visual acuity as well as daily tasks (sharpness assessment of natural images and face recognition), under perfect optics and investigate neural adaptation to the blur produced by the optics of individual eyes.

Effect of ocular aberrations on Visual Functions

The image formed by the eye's optics is inherently blurred by aberrations (low and high order aberrations) specific to the individual's eyes. Correcting ocular aberrations improves visual acuity significantly at most luminances and contrast polarities (i.e. black letter on white background and vice versa). Besides, this improvement in visual acuity was well correlated with the improvement of optical quality. When using natural images, the subjective impression of sharpness increased dramatically when correcting aberrations and the familiar face recognition (although not facial expression recognition) improved systematically in almost all subjects [1]. These results led to a new question, i.e. to which extension subjects are adapted or can adapt to low and high order aberrations.

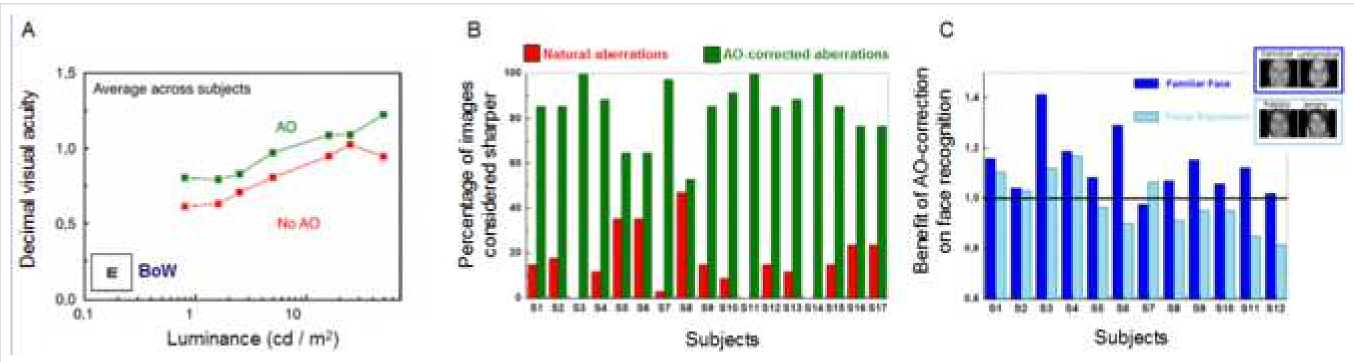

Figure 1: A. Improvement of visual acuity at different luminances, with black letter on white background (BoW), with Adaptive-Optics (AO) correction of aberrations. B. Percentage of images considered sharper under AO correction and natural aberrations. C. Benefit of AO correction of aberrations on familiar face and facial expression recognition.

Short-term adaptation to low and high order aberrations.

Adapting to blurred or sharpened images alters the perceived focus of subsequently viewed images and shifts the perceived focus point to more blurred or sharpened level. Based on this paradigm, we developed new psychophysical experiments in collaboration with Prof. Michael Webster, from the University of Nevada, Reno, USA, to explore short-terms adaptation to blur produced by low order aberrations (optically generated by convolution with the point spread function from combinations of astigmatism and defocus) [2] and to high order aberrations (where images were blurred by scaled increases or decreases in the subjects natural HOA) [3]. We found that a brief exposure (typically 1 minute) to blurred images changes the perception of the subsequent images. Adaptation to horizontal blur caused isotropically blurred images to appear vertically biased and viceversa and the perceived focused point was shifted toward the adapting level of blur produced by the scaled HOA. These strong meridional aftereffects suggested that previous experience to aberrations have an impact on the visual response.

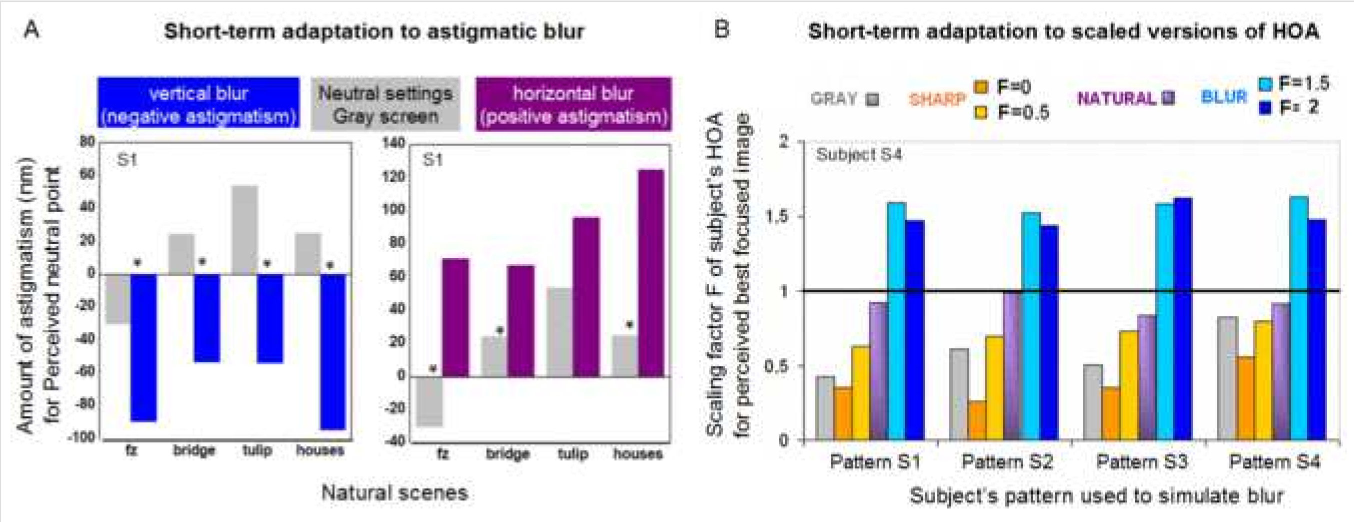

Figure 2: A. Short-term adaptation to astigmatic blur, perceived neutral point was shifted to more vertically oriented image after adapting to a vertical blur (and vice versa for horizontally blurred images). Black stars show significant differences before (gray) and after adaptation. B. Short term adaptation to scaled versions of subject's High Order Aberrations (HOA). The perceived best-focused image was shifted toward the adapting level of blur produced by the scaled HOA.

Subjects are naturally adapted to the retinal blur produced by their ocular aberrations

We asked whether spatial coding in the visual system is matched to the native blur specific to an individual's HOAs by investigating long-term adaptation to the blur produced by the optics of the eye. Adaptive Optics allow us to cancel the natural aberrations of all subjects, exposing observers to identical aberration patterns and ensuring that any difference across subjects would arise from their own neural processing and their prior neural adaptation. Retinal blur was manipulated by projecting degraded images with known HOAs where realistic blur of different amounts and forms was computer simulated (we used convolved images with the optical point spread function to represent the retinal image quality) using real aberrations from a population. Our results provide strong evidence that spatial vision is calibrated for the specific blur levels present in each individual's retinal image as, for the majority of observers, the level of blur perceived as best-focused was closely predicted by the magnitude of the native blur present in their eyes [4].

However, this does not preclude the possibility that the adaptation can also selectively adjust for some differences in the orientation of HOA pattern. To isolate the effect of specific features of the HOA pattern, retinal blur was instead maintained at a constant level equal to each subject's natural blur (in terms of strehl ratio) where only the shape of the corresponding point spread function (PSF) varies. Observers judged the best-focused image from 100 pairs of images blurred by different patterns of HOA (one image of the pairs was blurred by a reference pattern, the other was blurred by a randomly selected pattern over 100). Our findings support some bias (but not strong) to the specific features of individual's own HOA pattern [5] as the percentage of the images that were judged as best-focused was not systematically higher when filtered with the subject's own patterns.

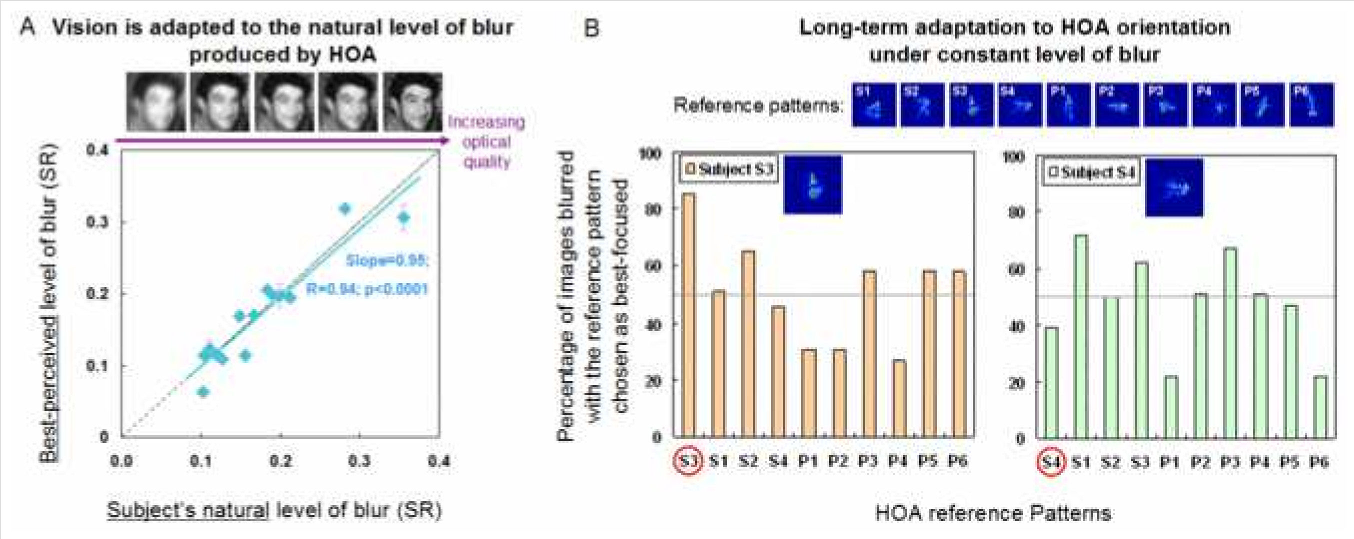

Figure3: A. Long-term adaptation to the level of blur produced by the High Order Aberrations of individual eyes: correspondence between the image quality perceived as best-focused and the retinal image quality produced by the aberrations of the subjects. B. Long-term adaptation to the subject's high order aberrations orientation, under constant level of blur: percentage of images blurred with each of the 10 reference patterns illustrated by the corresponding Point Spread Function, PSF, (including the subject's PSF (S1-S4) and other 6 additional HOA patterns P1-P6).

The codification of internal blur thus seems to be highly driven by the overall amount of blur and partially biased by blur orientation. Other patterns are frequently identified as better focused than the native pattern, although these generally show similar orientation that the native pattern.

These studies have led to new experiments to investigate the time-scale of adaptation to astigmatism and to its correction with spectacles, and the adaptation to new presbyopia correction solutions.

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Selected publications

1. L. Sawides, C. Dorronsoro, P. de Gracia, M. Vinas, M. Webster, S. Marcos (2012) Dependence of subjective image focus on the magnitude and pattern of High Order Aberrations. JOV 12(8):4, 1-12.
2. L. Sawides, P. de Gracia, C. Dorronsoro, M. Webster, S. Marcos. (2011) Vision is adapted to the natural level of blur present in the retinal image. PLoS ONE ,6 (11), e27031.
3. L. Sawides, P. de Gracia, C. Dorronsoro, M. Webster, S. Marcos. (2011) Adapting to Blur produced by ocular high order aberrations. JOV 11(7):21, 1-11.
4. L. Sawides, S. Marcos, S. Ravikumar, L. Thibos, A. Bradley, M. Webster. (2010). Adaptation to astigmatic blur. JOV 10(12):22, 1–15.
5. L. Sawides, E. Gambra, D. Pascual, C. Dorronsoro, S. Marcos. (2010) Visual performance with real-life tasks under Adaptive-Optics ocular aberration correction. JOV 10(5): 19, 1-12.

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