

# Hearts and Minds: Effects of pulse and neural adaptation on aberrations

Laurent Castellucci  
in Fort Lauderdale

IMPROVED wavefront measurement techniques are revealing the subtle effects of factors such as heartbeat and neural adaptation on optical aberrations, reported researchers at the annual meeting of the Association for Research in Vision and Ophthalmology (ARVO).

As wavefront aberrations have become more and more important considerations in refractive surgery, interest has grown in the possible interaction of other factors with those aberrations and visual acuity, noted Pablo Artal PhD.

"From the beginning of using this technology, we have had some indication that perhaps the visual system may be adapting somehow to the particular aberrations," Dr Artal said.

Last year, his group at the University of Murcia in collaboration with David Williams's group at University of Rochester, confirmed this, presenting results using blur-matching that showed the neural visual system is adapted to the eye's particular monochromatic aberrations. These results were published in the *Journal of Vision* (<http://journalofvision.org/4/4/4/>).

But this work left many questions unanswered. For example: for what amount and what types of aberrations can the system compensate? How does it do it? What is the temporal scale of this adjustment?

Some clinicians have suggested in different experiments that the visual system needs months or weeks to adjust to changes in aberrations. Other experiments showed adaptation taking place in only minutes.

"We didn't know exactly what the rate was. If we had adaptation in minutes, we could probably do experiments with adaptive optics. If we had to wait weeks or months, it would not be possible to do these experiments with adaptive optics," Dr Artal said.

Dr Artal's group performed additional experiments using adaptive optics to further explore the temporal dependence of this adaptation process. They used an adaptive optics system to induce wavefront aberrations with associated changes in the point spread function in eight healthy volunteers.

The researchers measured visual acuity through an artificial pupil of 6.0 mm. Volunteers were shown the letter E in one of 4 possible orientations, (to the left, to the right, up, or down). They viewed the stimulus through the adaptive optics system with their own aberrations or with a rotated version of their aberrations. Visual acuity was measured after periods of continuous adaptation to the rotated version of the aberrations.

All of the volunteers had initial logMAR acuities lower than 1.0. After rotating the aberrations 45 degrees, average visual acuity decreased 25%. After 15 minutes of continuous viewing through the rotated aberrations, visual acuity

returned to near normal, with up to 70% of the normal acuity. Recovery increased to near normal total after 25 minutes. Interestingly, in every subject the visual acuity got worse again after 30 minutes.

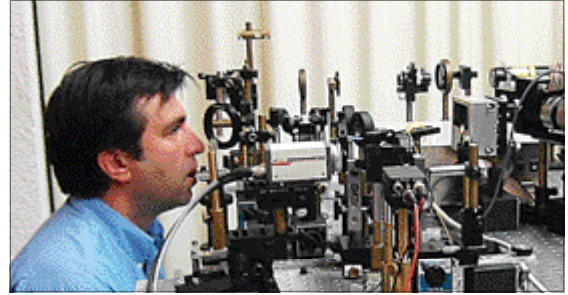
"Each subject does have his or her own values, but you see on average that you have an exponential increase, and at 30 minutes, you get extremely high error bars. We think this can be attributed to them getting tired," Dr Artal said.

Testing in both monochromatic and polychromatic light showed similar results, as did using low contrast VA and blur matching.

Dr Artal suggested that the results follow a double-exponential model, with some rapid decay and then some further decay that continues over longer time.

"We did a nice fitting with one exponential, and it fits very well. But the problem is that because of the one exponential, in about one hour, it projects that you will have recovered your normal visual acuity, but in about three hours, it projects that you will have infinite resolution."

Dr Artal acknowledged that in studies such as prism inversion, patients have taken a day to adapt, which may mean the time needed to adapt may have to do with the type of aberration. More experiments will be needed to address the many questions still unanswered. But all these results may have very important practical applications for refractive surgery in the future, he stressed.



Professor Artal trying his adaptive optics research instrument.

## THE DYNAMICS OF PULSE

The aberrations of the eye themselves display dynamic behaviour. While the cause of the dynamic aberrometric behaviour remains a mystery, there is some correlation with the pulse and eye movements, corneal pulsation, the high frequency component of the microfluctuations in accommodation, and intraocular pressure, noted Karen Hampson of the Imperial College in London.

She attempted to discover more about the links between pulse and RMS (root mean square) error. She measured the wavefront aberrations of five volunteers with a Shack-Hartmann sensor operating at 21.2 Hz. The pulse-pressure wave was simultaneously measured, as was the heart rate variability. Further experiments were carried out on two volunteers in whom the properties of the pulse and heart rate variability were changed to see if corresponding changes

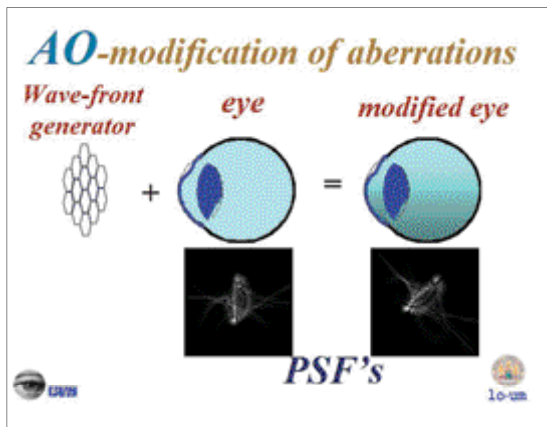
could be observed in the RMS wavefront error. One example included a comparison between a subject holding their breath and breathing deeply.

Some correlations were observed between the aberrations and some components of the pulse and heart rate variability. However, the particular frequencies and aberrations varied widely from person to person, with no apparent causal relationship. For example, the study showed no real contribution to the RMS error from holding one's breath or changing heart rate.

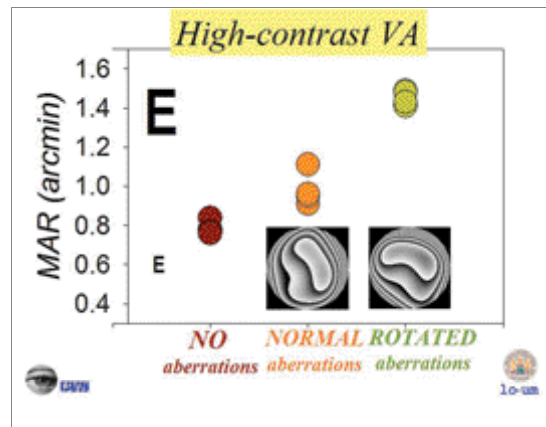
"The pulse is not sufficient to account for the shape of the power spectrum of the RMS wavefront error. So while pulse plays a role in the dynamic characteristics of the higher-order aberrations, it can't account for all of them," she said.

pablo@um.es

Karen.hampson@imperial.ac.uk



Schematic example of how adaptive optics can be used to modify the eye's aberration

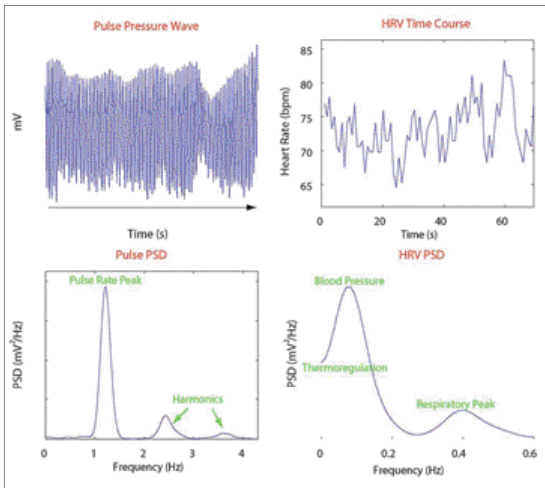


Visual acuity with normal and rotated aberrations. The same amount of aberrations that are unfamiliar (rotated) reduced visual acuity.

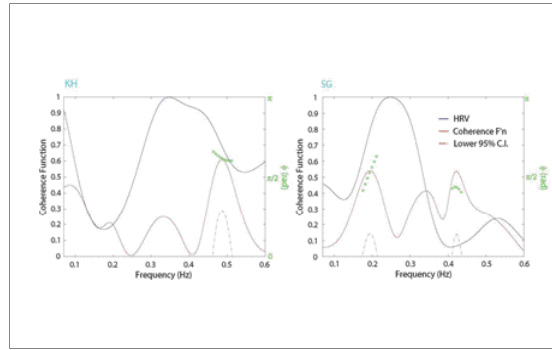
You can get an update on the clinical applications of wavefront sensing at the ESCRS Congress in Paris.

Events include: the Workshop in Visual Optics on Sunday 19th September; and the ESCRS symposium "Using Wavefront Technology To Maintain The Physiology Of The Cornea" on Tuesday 21 September

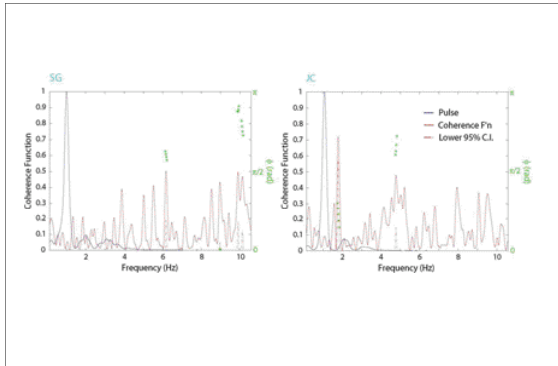
Courtesy of Karen Hampson



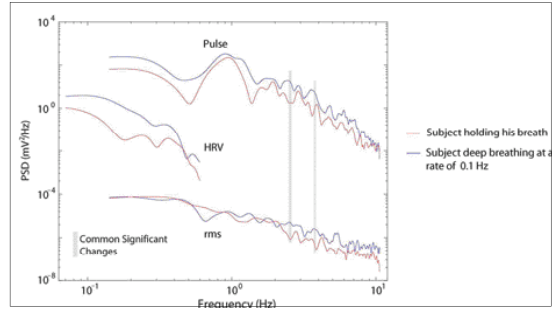
All pulse data for one subject



Coherence function for the HRV and rms waveform error for two subjects.



Coherence function for the pulse and rms waveform error for two subjects.



Comparison of rms waveform error, pulse, and HRV PSD for one subject deep breathing and holding their breath.