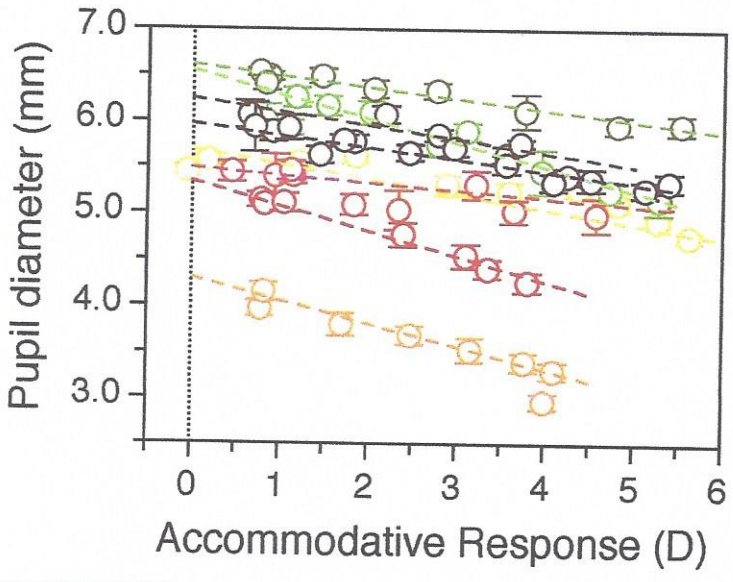
THE PERFECT IMPERFECTION

A changing understanding of emmetropia calls for a revised definition, *writes Ioannis G Pallikaris MD, PhD*

The goal of most forms of cataract and refractive surgery is the achievement of emmetropia, but the very definition of the term "emmetropia" may have to change, in light of the increasing understanding of the complex interaction between the static and dynamic components of the human optical system and their subtler impacts on vision.

British and American dictionaries define emmetropia as the normal refractive condition of the eye when accommodation is relaxed and parallel rays are focused on the retina. What their definitions leave open to interpretation is whether "normal refractive condition" means a condition where all parallel rays of light, central and peripheral, are brought accurately to a focus upon the retina, and also whether such a questionably perfect refractive condition will also be the most satisfying for the individual.



Plainis et al, 2005. Courtesy of Ioannis G Pallikaris MD, PhD

THE MEANING OF THE WORD

When considering a term's definition it can often be helpful to break down the literal meaning of the term, as Antisthenes (ca 445-365 BC) stated: "The principle of wisdom lies in the study of words."

The term emmetropia is a neo-Latin term deriving from the Greek "émmetros", meaning "on measure", with the suffix "-opia" meaning "pertaining to the eye or vision". The Greek metr- particle of the word, as is used in various ways by the ancient authors, can be seen in Plato's quotation of Protagoras in his Theaetetus: "Antropos metron", "Man is the measure (of all things)."

Or as Cleobulus stated, according to Diogenes Laërtius: "Metron Ariston", "Moderation is best."

The term "metron" has also been used by the Greek philosophers since the ancient times to describe certain types of imperfection.

The application of that principle is evident in the architecture of the the Parthenon, which was built in such a way that, upon entering the temple, one would have a perfect anamorphic view of the building's dimensions. The columns appeared to be straight and parallel and the aetoma arranged in a perfect parallelogram.

But, in fact this was an ingenious optical illusion, achieved through the use of what might be considered imperfections, in construction terms. The columns were oval in shape, and the space between them on all sides of the chamber decreased from the centre to the periphery, and the columns were not not aligned in parallel but with a subtle curvature. Together these refinements served to counteract the

naturally-occurring optical illusion that causes long parallel lines to appear to sag in the middle.

PURPOSEFUL IMPERFECTIONS

Vision research has revealed similarly purposeful imperfections in the human optical system, and show that it consists of both static and dynamic components. The challenge of emmetropia is likewise multifactorial in nature.

Among the static elements of the eye's optical system is miosis, which increases the focal range at which a reasonable image quality can be achieved. Studies show that although miosis increases in response to accommodation in a fairly linear fashion, miosis also occurs independently of accommodation.

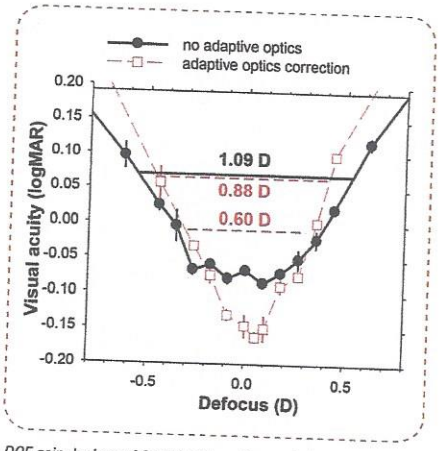
Other static components of human vision include bifocal elements, which divide the focus into two disparate peaks, each with reduced image contrast, and aberrations (in particular spherical aberration) which can contribute to increased depth of focus at the expense of image quality.

Correcting higher-order aberrations increases peak visual or optical performance, but results in a more rapid loss of performance away from the in-focus condition. Adaptive optics systems which incorporate a Hartman-Shack sensor into a phoropter could offer personalised correction with a broader range of focus.

DYNAMIC COMPONENTS

When aiming for emmetropia it is also important to have regard for the dynamic aspects of vision which have a continual and variable impact on the eye's degree of focus and aberration profile, and which also play an important role in an individual's visual perception.

Optical dynamic components are mostly related to the stability and accuracy of the accommodative response. The fluctuation of accommodation in response to visual



DOF gain, by loss of 0.07 line in snellen scale in non-adaptive optics (AO) corrected vs AO corrected eye

stimuli has its lowest amplitude when the eye is focused at infinity but there is considerable variation among individuals.

During accommodation, spherical aberration (Z40) tends to move to negative values, causing a lag in the defocus effect. When accommodation is relaxed the reverse occurs, enhancing the return to an unaccommodated state. Coma-like aberrations (Z3-1, Z31) on average change to positive values. Other dyamic changes in the optical system include saccadic ocular movements, artefacts introduced by blood flow or other metabolic process.

In summary, the eye is a dynamic system which scans the subject continuously in 3D and shows complex behaviour. Dynamics of ocular aberrations are random and as yet unpredictable. These dynamics introduce noise when estimating a wavefront and an average of several measurements should always be used to minimise these effects. There are many other sources of error, none of them well understood.

I furthermore propose that the dictionary definition of emmetropia should be rewritten, based on the ancient meaning of the word and also on our evolving understanding of ocular dynamics and visual function. The definition I suggest is as follows: "Emmetropia is the refractive state in a healthy eye in which any individual achieves the perfect visual function."

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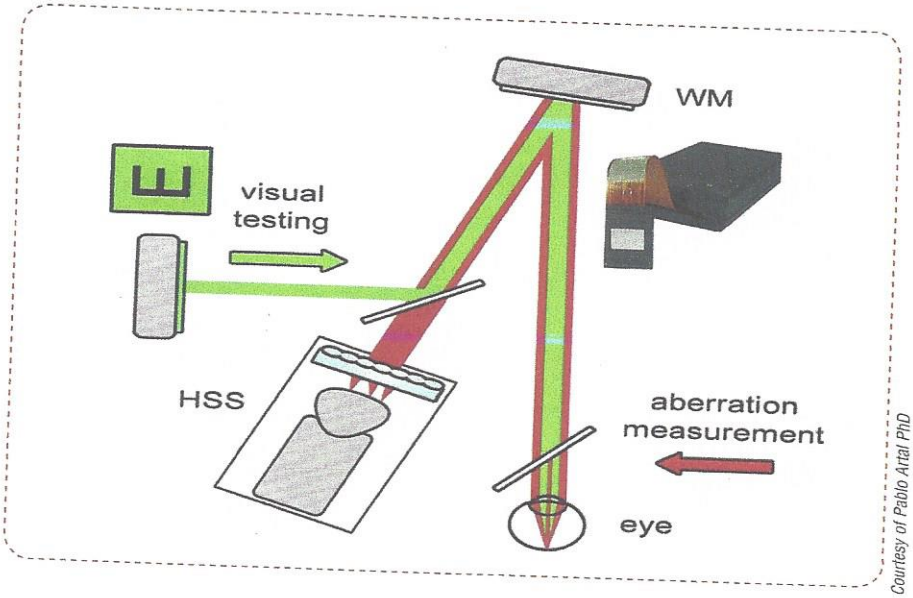

Courtesy of Pablo Artal PhD