

The Global Need for Refractive Correction

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Abstract

The simplest way to get an estimate of the global need for corrective eyewear is to look at what fraction of a developed world population wears or has some form of vision correction, and then extrapolate. This fraction is about one half to two thirds of the population for the USA, Western Europe, Japan etc. This figure is interesting because it is for populations where access to vision correction is in effect not significantly limited by access to professionals or money.

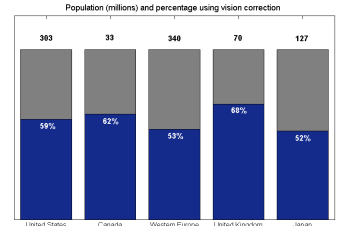
Another way of looking at the problem is to take a "typical" distribution of refractive error, and use a theoretical correspondence between refractive error and achievable acuity. Choosing a pupil diameter then leads to a minimum size "focus" of, for example, a distant point object on the retina, by simple optics. Interestingly, for an emmetropic eye, the minimum "spot" is a diffraction pattern of the pupil, but once some defocus is introduced, we get a situation where the "spot" on the retina can be found to reasonable accuracy – for a given pupil diameter – by simple geometric optics. Choosing a pupil diameter, using a "typical" distribution of refractive error, and setting an acuity criterion, then enables us to estimate the fraction of that population who will be able to see to that acuity.

A WHO working group which studied the need for corrective eyewear concluded in 1987 that "the sight of one-fifth of the population could be improved by the use of spectacles, including the sight of about 10% of schoolchildren". Using the procedure we suggest here, that estimate can be interpreted in terms of an implied acuity criterion in that study.

Corrected vision in the developed world

In countries where access to eyewear and eyecare professionals is not limited i.e. the US, the UK, Europe, Japan etc., between 50% and 70% of the population have some form of vision correction^{1,2}.

These are populations where one might assume that most of those that "need" vision correction have it.



Optical limitations for the resolving ability of the eye

- If the eye were perfect one would expect to get a nice sharp image on the retina. In reality this does not happen for two reasons:

- diffraction of light by the pupil margin
- the defocus produced by ametropia

Diffraction

- If one observes a point source, the extent of the blurred image arising from diffraction depends upon the pupil diameter (d) and the wavelength of light λ (Rayleigh criterion: $1.22\lambda/d$)
- Thus, for an emmetropic eye with a pupil diameter of 4mm, and yellow light (wavelength 590nm), the minimum spot size on the retina corresponds to an angular resolution of a little over half a minute of arc. Detail finer than this cannot be resolved.

Defocus

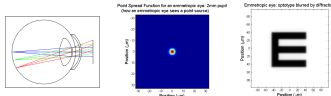
- If the eye is ametropic the degree of blurring – and hence the subject's best achievable acuity – is determined by defocus. There is thus a relationship between refractive error and visual acuity*

Relationship between visual acuity and refractive error

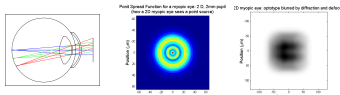
- It is also clear from simple "ray optics" that the amount of blur of the image on the retina is determined by the iris diameter – as well as the magnitude of the subject's myopia³.
- It follows that for any given population, if we know the distribution of refractive error, we know in principle the distribution of achievable acuity.

*this relationship does not necessarily hold for individuals with an amplitude of accommodation sufficient for hyperopia

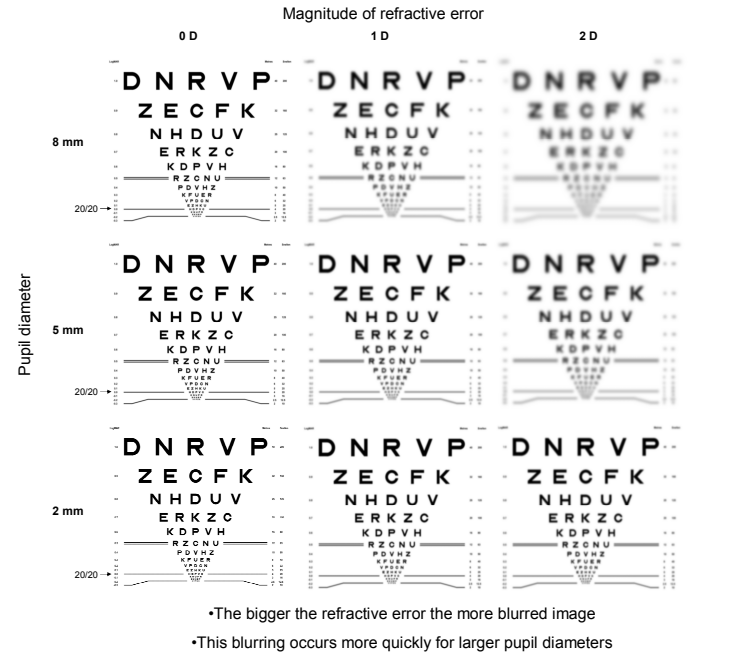
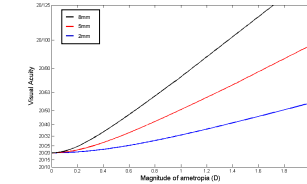
Effect of diffraction on image formation in the emmetropic eye



Effect of defocus and diffraction on image formation in the myopic eye



The relationship between the magnitude of ametropia and visual acuity for different pupil sizes (Smith, 1991)



How to estimate the global need

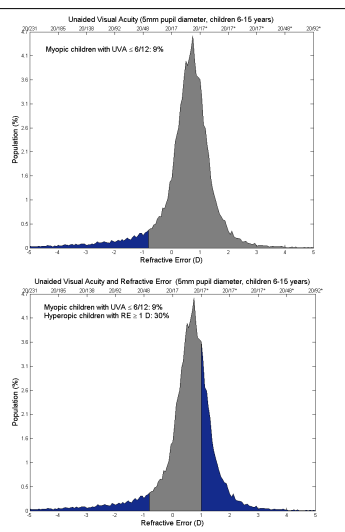
To estimate the need for refractive correction, we need

- A distribution of refractive error
- An assumed pupil diameter
- An acuity criterion

- An acuity criterion is appropriately defined in relation to a specific task
- We can conveniently use driving as such a task in which case it is the vehicle licensing authorities that set the criterion
- For example, in the US one is required by law to read a standard sized number plate which corresponds to a visual acuity of at least 2 minutes of arc (20/40 Snellen acuity)^{4,5}.
- Distributions of refractive error vary from one population to another and as yet there are no complete global statistics for adults
- For children, however, there has been a large population based study of 38,000 subjects in several countries⁶⁻¹⁰.
- One can use this data to estimate:

- the percentage of myopes not satisfying the acuity criterion (9%)
- the percentage of hyperopes not satisfying the acuity criterion or, in the case of children⁶, an arbitrary refractive error criterion (1D hyperopia) criterion (30%)

*where the amplitude of accommodation is sufficient to compensate for some degree of hyperopia

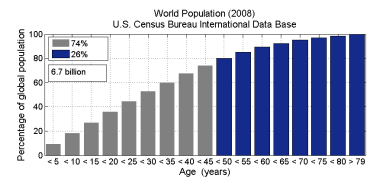


What about presbyopes?

The method of relating refractive error to visual acuity can also be applied to presbyopes

Given that the focal length of the presbyopic eye is fixed, the vast majority of presbyopes need corrective eyewear

If we assume everyone over the age of 45 is presbyopic, this alone implies that in excess of one fifth of the world's population requires vision correction



Conclusion

Given the 20/40 visual acuity criterion, and excluding non-presbyopic adults, the table above indicates that at least 33% of the world's population could benefit from vision correction

Although the distribution of refractive error in the non-presbyopic adult population (approximately 3.1 billion people) is currently unknown, a conservative estimate of the need for vision correction in this age group would be 30% (930 million). This corresponds to 14% of the world's population.

Our final estimate for the global need for vision correction is at least 47%. This figure is in fair agreement, but still lower than, the fraction of people known to be wearing corrective eyewear in the developed world.

We suggest that a further global study should be carried out on adults so as to refine the estimate presented here.

		Population in age group (millions)	People requiring vision correction (millions)
Children (age < 16 years)	Myopic	1,830	165 (9%)
	Hyperopic		= 650 (30%)
Non-presbyopic adults (16 >= age > 45 years)		3,154	Unknown
Presbyopes (age >= 45 years)		1,720	> 1,380 (> 80%)
Total			> 2,195

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