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BCLA CLEAR Presbyopia: Definitions

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ABSTRACT

Presbyopia is often the first sign of ageing experienced by humans. Standardising terminology and adopting it across the BCLA CLEAR Presbyopia reports, improves consistency in the communication of the evidence-based understanding of this universal physiological process. Presbyopia can be functionally and psychologically debilitating, especially for those with poor access to eyecare. Presbyopia was defined as occurring when the physiologically normal age-related reduction in the eye's focusing range reaches a point that, when optimally corrected for far vision, the clarity of vision at near is insufficient to satisfy an individual's requirements. Accommodation is the change in optical power of the eye due to a change in crystalline lens shape and position, whereas pseudo-accommodation is the attainment of functional near vision in an emmetropic or far-corrected eye without changing the refractive power of the eye. Other definitions specific to vision and lenses for presbyopia were also defined. It is recommended that these definitions be consistently adopted in order to standardise future research, clinical evaluations and education.

1. Overall purpose

A key role of consensus reports is to promote consistency in the use of the terminology and definitions relevant to the topic. This reduces confusion, enhances clear communication and generates more homogeneous data for synthesis in epidemiology studies and in recommending management approaches (Fig. 1).

2. Presbyopia

Presbyopia is more than just functional near visual loss or a decline in the crystalline lens' ability to accommodate. As presbyopia is derived from Ancient Greek πρέσβυς translated into Latin (présbus, "old man") and ωψ (ops, "eye" or to "see like") [2], a definition, centred on the patient's functional experience to fit this etymology has been proposed. Here, "*presbyopia occurs when the physiologically normal age-related reduction in the eye's focusing range reaches a point that, when optimally corrected for distant vision, the clarity of vision at near is insufficient to satisfy an individual's requirements*" [3,1]. The definition acknowledges that presbyopia is defined by the impact of the tasks that an individual conducts rather than physiological ocular changes in isolation. Hence, this review assimilates the contemporary evidence-base concerning correction strategies and their impact on presbyopia. Despite not explicitly defining presbyopia as relating to the inability to perform near tasks, some authors have argued that presbyopia is a medical condition and a disease [4]. A recent ophthalmic consensus group proposed the average characteristics related to mild, moderate and advanced presbyopia based on the near add requirement, distant corrected near vision and Jaegar equivalent in photopic and mesopic conditions, behavioural adjustments, age and refractive error considerations; the rationale to this mainly clinical measurement-based approach was to "facilitate consistency between healthcare practitioners and their ability to best match patients to the optimal treatment", but this needs to be task demand and environment specific [5].

Presbyopia can be divided into two types: 'functional' presbyopia describes the situation whereby the person has vision of < N8 (approximately 0.4 logMAR) at near that can be restored to better than this with near addition lenses, but does not include moderate myopes

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who can read without the aid of spectacles; whereas 'objective' presbyopia occurs when a person is fully corrected for distant vision, but reduction in accommodation has resulted in a near vision of < N8 [6].

3. Pseudo-accommodation

Pseudo (meaning 'not genuine' or 'fake') and accommodation (defined as the change in optical power of the eye from a change in crystalline lens shape and position) have been combined to explain improved near vision as a result of the depth of focus of the eye which does not arise from active accommodation. It is the "attainment of functional near vision in an emmetropic or distant-corrected eye without changing the refractive power of the eye." It is usually used to account for the reading ability of an eye corrected with a monofocal lens and may occur when the pupil is very small thus increasing the depth of field or as a result of spherical aberration or astigmatism induced by corneal incisions made to insert an intraocular lens [7].

Pseudo-accommodation (also termed 'apparent accommodation' [8]) is typically applied to cases when no objective accommodation is expected, for example after monofocal intraocular lens implantation cataract surgery [9], although it has been suggested to be created by progressive addition lenses [10,11]. While true accommodation is assessed by the difference in spherical equivalent between far and near viewing, the dynamic range of focus [12] or range of clear focus (the sum of true and pseudo-accommodation) is determined by an amplitude of accommodation, defocus curve or optical transfer function focus [13] (see BCLA CLEAR Presbyopia: Evaluation and diagnosis report) [14]. For far corrected presbyopes it has also been calculated as the reciprocal of the reading distance (in metres) minus the minimum reading addition [15]. Factors affecting pseudo-accommodation are pupil size, astigmatism (principally against the rule), corneal higher order aberrations and neural tolerance to blur [16–18,13]. Pseudo-accommodation is essentially the same as the subjective depth of [clear] focus.

4. Simultaneous vision

A simultaneous vision correction is one that contains two or more optical zones with refractive powers to focus objects at two or more distances on the patient's retina. The term appears to have been coined by Erickson and colleagues in the 1980's and applied to concentric bifocal lenses [19,20]. By design, simultaneous vision creates the superimposition of a more in-focus image with a more blurred image. As the images are not focused on the retina simultaneously, it has been suggested that the terminology 'simultaneous images' is not accurate, but it is still used by standards organisations [21].

Original simultaneous vision designs incorporated two concentric zones, with the central zone smaller than the entrance pupil so that light could pass through both zones. First generation simultaneous vision soft contact lenses had either a distant-centre: near-surround or near-centre: distant-surround design [22,23] (see BCLA CLEAR Presbyopia: Management with contact lens and spectacle report) [24]. Other designs were aspheric and diffractive [22,23]. The principle was subsequently applied to intraocular lenses [25,26] (see BCLA CLEAR Presbyopia: Management with intraocular lenses report) [27] and corneal inlays [28] (see BCLA CLEAR Presbyopia: Management with corneal techniques report) [29].

5. Distant, intermediate and near vision

A measure of uncorrected or corrected vision (or visual acuity) is a relevant functional outcome in presbyopia research. Visual acuity is measured at a range of distances that are broadly categorized as *far, intermediate* and *near*, according to the distance between the object being viewed and the eye. While 'distance vision' is often used to describe viewing far objects, distance has a dual meaning as both (a) a length of space between two points and (b) a far-off position, hence 'distant' or "far" vision is more appropriate terminology.

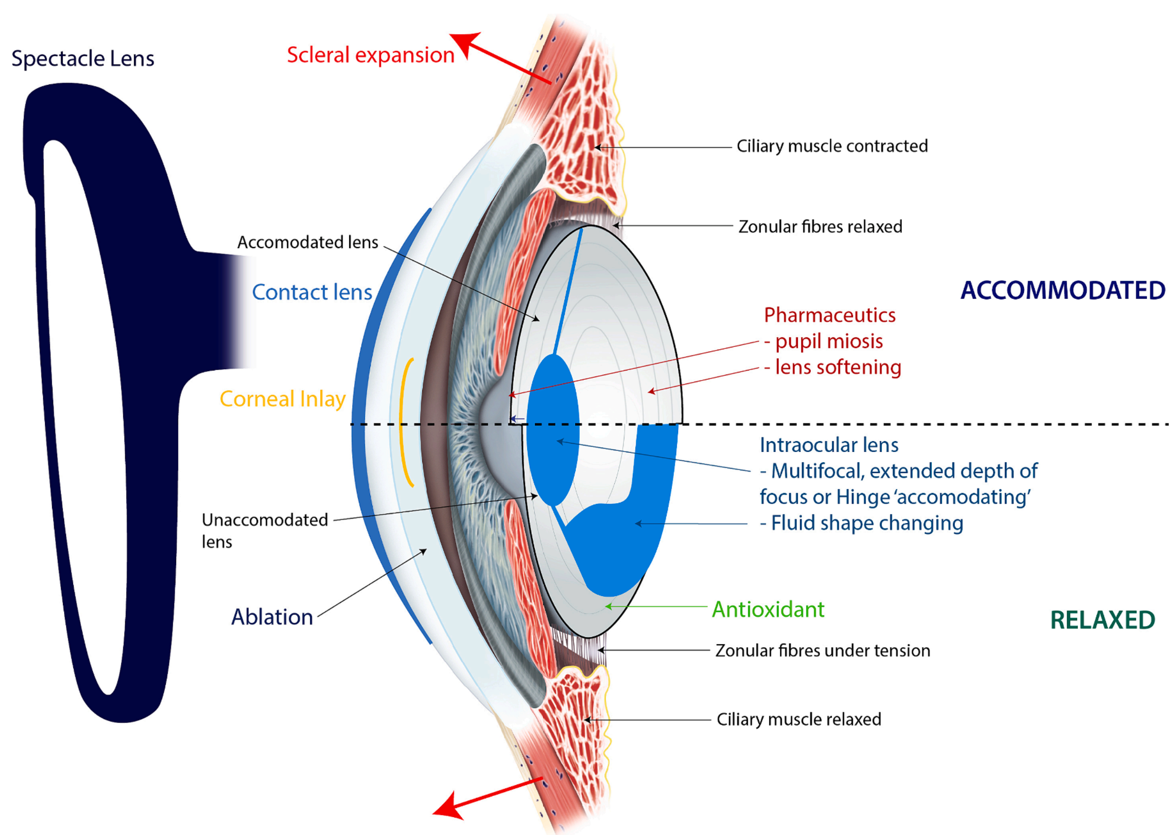

Fig. 1. Treatments for presbyopia and their location / point of action © Aston University 2022 [1].

5.1. Distant / far (distance) vision

Far vision assessment seeks to determine the resolving capability of the eye in its unaccommodated state (i.e. when gazing at a far distant target). In current clinical research settings, visual acuity is routinely evaluated monocularly and/or binocularly, almost exclusively with standardized Early Treatment of Diabetic Retinopathy Study (ETDRS) charts, while traditional Snellen charts with non-standard progression of letter size are less commonly used [30,31]. Visual acuity outcomes are reported as the logarithm of the minimum angle of resolution (logMAR), or less commonly as the Snellen equivalent.

In the clinical setting, the furthest distance practically used to test far vision is 6 m (or 20 ft), that gives rise to the standard notation of 6/6 (based on metres) or 20/20 (based on feet) corresponding to the 1 min of arc resolution expected of the normal eye. Where such a testing distance is impractical in the modern office setting, a 6 m testing distance can be simulated by use of a mirror placed at 3 m reflecting a chart in the same plane as the eye of the observer (Fig. 2).

Facilitated by the advent of computerised and projected charts, shorter testing distances than 6 m are most commonly employed, with chart letter sizes calibrated accordingly. Such non-standard distances for vision measurement described in the literature relating to presbyopia correction, include 3 m [32], 4 m [33–37], and 5 m [38,39] (Fig. 2). Measuring at distances as short as 1 m with compensating lenses has been shown to accurately reflect standard 6 m visual acuity [40]. In some instances, no testing distance is stated explicitly [31,41]. Given the breadth of testing distances reported in the literature, a default testing distance of 6 m cannot be assumed where it is not otherwise stated. This highlights the importance of explicitly stating all testing distances when publishing study outcomes.

By virtue of target placement being closer than infinity (where no accommodation would be induced), a chart placed at 6 m induces accommodation of 0.17 D in an emmetropic eye. Being less than the smallest lens increment that is generally used when correcting refractive error, the impact of this level of accommodation is most often disregarded. No compensation in refractive correction appears to have been considered in the presbyopia literature including assessment guidelines [42,43], even with shorter distances where 3 m, 4 m, and 5 m testing distances result in induced accommodation of 0.33 D, 0.25 D and 0.20 D, respectively; however, industry standards often include this requirement. It is unclear from the academic literature whether compensatory lenses for the accommodative demand allows distant visual acuity to be measured on charts closer than 6 m, although a space-saving chart study suggests this may be the case [40]. One conference proceedings article assessed this in 45 individuals aged 16 to 66 years old, but measurement was subjective, noisy and the study unmasked [44]. The convention of pushing plus when refracting a patient may influence the need for correcting for non-infinite distances. Far vision could therefore be defined as a distance at which the accommodative demand is less than 0.25 D.

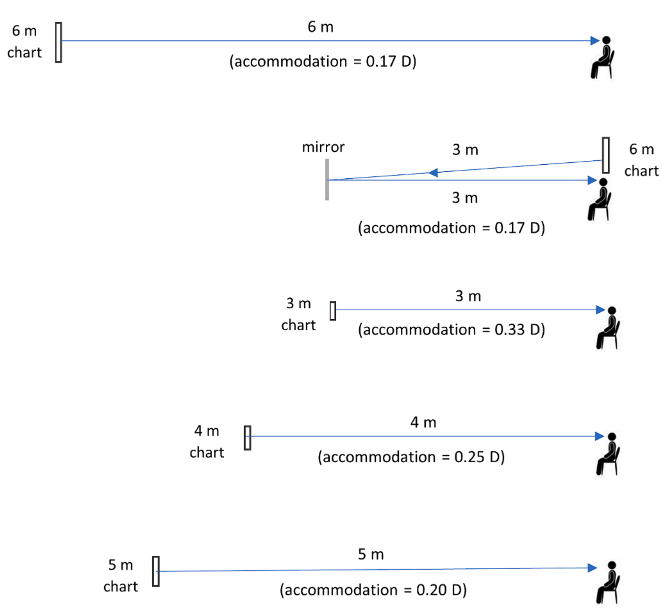

Fig. 2. Testing options used to measure far vision. Chart labels indicate testing distance for which chart is calibrated, and the values in parentheses denote the accommodation required to focus on the target. (m = metres, D = dioptres).

5.2. Intermediate vision

Intermediate vision that is relevant to tasks positioned further from the eye than conventional reading material, such as computer screens or dashboards, is typically measured, with or without distant refractive correction, over a range of distances between 50 cm and 1 m [45–48,34,49–52,31,41,32,35,36,38,37]. The most common two distance selections are between 70 and 80 cm and between 60 and 66 cm, although some researchers report intermediate vision outcomes at three distances [34,51,31]. Vision at a fixed intermediate distances is most frequently measured for comparative purposes, but vision assessed at a 'preferred distance', where participants can adjust the reading distance according to personal comfort, may also be reported [50,41], as a measure of 'real-world' functionality. ETDRS acuity charts, calibrated for the appropriate distance, are commonly used [46,34,35]. Where far vision is typically reported both monocularly and binocularly, intermediate and near vision are most often assessed only binocularly. Considering intermediate distance is usually associated with computer screen use which ranges from 35 to 70 cm for a laptop and 45 to 80 cm for a computer monitor [53], a standard distance of 60 cm seems appropriate (despite 80 cm being commonly used as it is dioptrically midway between optical infinity and 40 cm), with intermediate vision defined as a distance at which the accommodative demand is between 0.5 and 2.0 dioptres.

5.3. Near vision

Near vision is generally measured with a reading chart positioned between 30 and 40 cm, consistent with an usual adult reading distance for handheld reading paper and digital tasks [53]. The most commonly reported distance for measurement of near vision in presbyopia research is 40 cm [46,47,34,50,41,32,35,38,37,39], although 35 cm [45,48], 33 cm distances [46,47] and 30 cm [34,36] are also reported, as well as the patient's preferred reading distance [50]. Most frequently, studies report near vision at a single distance [45,48,32,35,36,38,37,39], but, in some cases, near vision outcomes are reported for two different distances [46,47,34,50]. As is the case for intermediate vision, near vision is most often assessed binocularly. Near vision assessed in the presbyopia literature has been specified using British N notation [32], the Jaeger system [30] and other near vision charts [31], but due to the lack of consistency [54], most commonly in recent research, it is assessed using near ETDRS, capital letter, acuity charts [55]. More detailed reading performance can be evaluated with the MNRead [56] or Radner [57] charts with automated versions available which control / monitor the reading distance and delivers automated calculation of reading speed as well as logarithmic reading acuity [58,50,41]. Paper reading tasks are held at 25 to 55 cm and smartphones or tablets, at 30 to 60 cm [53], so a standard distance of 40 cm seems appropriate, with near vision defined as a distance at which the accommodative demand is more than 2.0 dioptres. 'Functional vision' refers to how well an individual performs while interacting with the visual environment [59], so assessment involves the time or ability to accurately complete simulated or real-world tasks.

6. Near effective refractive error coverage (near eREC)

eREC is defined as the proportion of the population that has received the required refractive correction with a good-quality outcome. Hence near eREC is an important epidemiological marker, used by organisations such as the World Health Assembly, to assess regional access to presbyopia correction (see BCLA CLEAR Presbyopia: Epidemiology and impact report) [60].

7. Presbyopia lens terminology

Various terms have been applied to lenses designed to compensate for reduced accommodative amplitude, which are often overlapping in meaning (such as the catch-all term 'multifocal') and are often not well defined. The number of discrete focal distances incorporated are described as, for example, a mono-, bi-, tri- and quadra- focal. As 'glasses' refers to the material, 'spectacles' is the preferred terminology. 'Occupational' and 'reading' spectacles are task orientated, but do not describe the optics incorporated into the lens and hence are not informative terms.

7.1. Progressive addition lenses

The term progressive addition lens was used in the first peer-reviewed papers evaluating these designs [61,62], although other terms including progressive addition multifocal lens [63–65], varifocal spectacle lenses [66] and progressive powered lenses [67] have been described. Regardless, progressive addition lens is the most widely used term, including in clinical trials of these lenses for myopia control [68]. Progressive addition lenses have been defined as "multifocal lenses employing a class of surfaces that provide a continuously smooth increase in positive focal power"[69], however, this also describes aspheric lenses, hence a better definition is a 'spectacle lens with a corridor of increasing power between a far and near zone.'.

Typically, the curvature of the front surface gradually increases from a minimum value within the far distant zone to a maximum value within the near zone, thus providing the desired near addition power. This gradual increase in curvature produces a channel of progressively increasing positive power, thus an intermediate zone of variable power. These three zones are bordered by regions of undesirable, but unavoidable defocus and astigmatism. The continuous changes in power are achieved by higher order aberrations, primarily a balance of trefoil and coma [70,71], but there is a continuous, near vertical locus of spherical points, referred to as the 'umbilic'.

The creation of a smooth continuous surface is achieved by incorporating various amounts of surface astigmatism, generally oriented at an oblique axis, in the lateral regions of the lens surface. The Minkwitz theorem states that astigmatism perpendicular to the 'umbilic' changes twice as quickly as the rate of change of power along the umbilic [67]. 'Soft' (compared to 'hard') progressive addition lenses have relatively low amounts of unwanted astigmatism and a relatively long distance between the distant and near centres of the lens.

Historically, progressive addition lenses were manufactured with the progressive optics on the front surface, and the final spherocylindrical power created by a customized back surface. Recently, digital lens surfacing has allowed the introduction of lenses with the progressive surface and the astigmatism both on the back surface [71]. State-of-the-art (free-form) designs now incorporate complex optical geometry on both surfaces in order to minimize spatial distortion and improve patient acceptance.

7.2. Varifocal

In the case of spectacle lenses, a varifocal lens, although a brand name, is synonymous with progressive addition lens [66,72]. For other corrections, the term varifocal has a different meaning. An early aspheric simultaneous vision soft contact lens was referred to as a concentric varifocal [73]. Subsequently, they were defined as involving "a smooth, rotationally symmetric, gradation of power from the centre to the edge of the optical zone of the lens, produced by the use of a continuous aspheric surface (conicoidal or polynomial) which has no lenticulation or power-zone junctions"[74]. In the context of LASIK presbyopia correction, varifocal is used to describe the induction of spherical aberration by non-spherical ablation profiles [75]. Given the optical design of a 'varifocal' spectacle lens is very different from that of a 'varifocal' contact lens, the term might be best avoided.

7.3. Aspheric lenses

Aspheric lenses have a power profile that changes graudually and generally symmetrically between the centre and the periphery. As a result, these lenses increase the depth of clear focus. Bi-aspherics (aspheric near and peripheral far zones [76]) have been applied to corneal ablation profiles [77,78].

7.4. Diffractive optics

Diffractive (Fresnel or Phase Fresnel) lens designs consist of concentric echelettes (teeth), which spread incident light waves, causing optical interference which create multiple focal diffraction maxima planes; the width of the steps govern the magnitude of the near addition [79]. Trifocal diffractive designs have been created through steps alternating in height [80–82]. The diffractive zero order allows the majority of the light to focus for far vision; as the intermediate additions 2nd order maxima is twice the near additions 1st order maxima, it contributes to a typical near focal distance.

8. Presbyopia amelioration technology

Arguably, no current presbyopia management approach 'corrects' presbyopia as task performance cannot be restored to that achieved by the pre-presbyopic, health eye. Hence 'presbyopia amelioration' may be better terminology.

8.1. Apodisation

Apodisation is the modification of lens optical shape with the pupil size, to alter the proportion of optical area within the pupil focused at far and near, such as distributing more light to near vision when a patient's pupil is small and to far vision when their pupil is larger [83].

8.2. Extended depth of focus / field

Due to the adverse effects of lens multifocality, such as dysphotopsia and a reduction in contrast sensitivity [3], lenses with a lower near power addition compared to the full near correction, which create a single elongated focal point, rather than several foci, to enhance depth of focus, have become a popular approach particularly for intraocular lenses (see BCLA CLEAR Presbyopia: Management with intraocular lenses report) [27], with the 'extended depth of focus' or 'extended depth of field' terminology adopted since the 2010's [84]. Extended depth of field describes objects which you can see clearly in front of you (lifestyle benefit, so linked with the definition of presbyopia) whereas extended depth of focus (exploited by a lens optic) describes what is happening at the retina.

8.3. Accommodating lens

The term 'accommodating lens' has been widely employed in the intraocular lens literature [85]. These lenses attempt to exploit the action of the ciliary muscle which remains functional throughout life [86]. Most employ the 'focus shift' principle whereby the design of the lens haptics causes forward movement of the lens optic in response to ciliary muscle contraction, which in turn causes a modest increase in the positive power of the system [87–96]. Variants of accommodative lens optics include designs where ciliary muscle activity causes the displacement of the two refractive elements of the intraocular lens [97] or a steepening of lens surface curvature [95,98], again leading to an overall increase in positive power. Another approach is an intraocular lens which can be filled with a flexible silicone-based polymer during implantation and may function like a pre-presbyopic crystalline lens [99]. Other lens types contain silicone-based liquid which permits a degree of surface deformation during the action of the ciliary muscle, causing a change in power [100–103]. Although the degree of optical performance of 'accommodating' intraocular lenses is disputed [104], the term has been employed in the literature to denote devices which seek to provide a change in *overall optical power as a consequence of the action of the accommodative apparatus of the eye* – typically presumed to be a response to ciliary muscle contraction - and distinct from other, fixed, presbyopia solutions such as multifocal lenses. From a grammatical standpoint, the ubiquity of the term 'accommodating' appears somewhat erroneous and 'accommodative' is a purer description. Likewise, the term 'disaccommodation' to indicate the relaxation of accommodation [105,106] incorrectly implies this has an active mechanism and 'lenticular relaxation' would be more appropriate.

8.4. Monovision, mini-monovision and modified monovision

Definitions of monovision (also known as blended vision) in the ophthalmic literature seem to be consistent and state it as being *a technique used to compensate for presbyopia by fully optically correcting one eye for distance [far] vision and the other eye for near vision* [107]. Definitions have appeared in peer-reviewed publications, especially review papers and the earlier reports relate to contact lenses only [108], whereas later articles include cataract and refractive surgery [109], particularly laser vision correction [110].

Monovision induces anisometropia (a significant difference in refractive error between the two eyes) with a consequent reduction in stereopsis. To address this, mini-monovision aims to *restrict the level of anisometropia to only one dioptre* (the far vision eye is still fully corrected). This allows patients to maintain better stereopsis, but often requires additional spectacle wear for certain near tasks [111]. Reducing

Table 1
BCLA CLEAR Presbyopia definitions.

Term	Definition	Notes	
Presbyopia	Occurs when the physiologically normal age-related reduction in the eye's focusing range reaches a point that, when optimally corrected for far vision, the clarity of vision at near is insufficient to satisfy an individual's requirements		
Accommodation	The change in optical power of the eye due to a change in crystalline lens shape and position		
Pseudo-accommodation	Attainment of functional near vision in an emmetropic or far-corrected eye without changing the refractive power of the eye	Subjective depth (range) of (clear) focus	
Simultaneous vision correction	Correction that contains two or more optical zones with refractive powers to focus objects at two or more distances on the patient's retina		
Monovision (blended vision)	Fully optically correcting one eye for far vision and the other eye for nearer vision		
Mini-monovision	Restricting the level of monovision-induced anisometropia to 1.0 dioptre	Partial monovision should be avoided	
Modified-monovision	When only one eye is fitted with a multifocal lens or the two eyes are fitted with multifocal lenses with different focal planes.		
Near effective refractive error coverage	The proportion of the population that has received the needed near refractive correction with a good-quality outcome.	Note the quality of the outcome needs to be assessed	
Vision	**Far / distant**	Far vision at a distance at which the accommodative demand (incident vergence) is less than 0.25 dioptres	Standardisation at 6 m
	Intermediate	Intermediate vision at a distance at which the accommodative demand is between 0.5 and 2.0 dioptres.	Standardisation at 60 cm
	Near	Near vision at a distance at which the accommodative demand is more than 2.0 dioptres.	Standardisation at 40 cm
	Functional	How well an individual performs while interacting with the visual environment	
Apodisation	Modification of lens shape to alter the proportion of optical area within the pupil, as it changes size, that is dedicated to far and near focus		
Lenses	**Multifocal**	Overarching term for a lens with optics that create multiple focal planes	
	Progressive addition	Spectacle lens with a corridor of increasing power between a distance and near zone	Varifocal is a brand name
	Aspheric	Lens with a power profile changing smoothly and symmetrically between the centre and the periphery.	
	Diffractive	Lens with echelettes which spread incident light waves, causing optical interference which creates multiple focal diffraction maxima planes	Also called Fresnel or Phase Fresnel lens designs
	Extended depth of focus	Reduced near addition lenses, which create a single elongated focal point, rather than several foci, to enhance depth of focus	
	Accommodative	A lens that can change in overall optical power as a consequence of the action of the accommodative apparatus of the eye	Avoid 'accommodating' lens or 'disaccommodation'

the reading addition in the near eye to lower the magnitude of the anisometropia is defined as partial monovision (although this term is seldom used) and has also been labelled as modified monovision [112], but this leads to confusion with other definitions of modified monovision [113].

Modified monovision is stated as *where one or both eyes are made multifocal*, (here, if both eyes are given a multifocal lens then the near adds are different for the two eyes [113]), or when only one eye is fitted with a multifocal lens or the two eyes are fitted with multifocal lenses with different focal planes. This has also been termed as enhanced monovision [112], although this term is rarely used for this purpose.

9. Conclusions

By standardising terminology (Table 1) and adopting it, not just across the BCLA CLEAR Presbyopia reports but more broadly, this will improve consistency in the communication of the evidence-based understanding of this important condition, which is often the first sign of ageing experienced by humans and can be functionally and psychologically debilitating (BCLA CLEAR Epidemiology and impact of presbyopia report), especially for those with poor access to eyecare. It is recommended that these definitions be consistently adopted in order to standardise future research, clinical evaluations and education.

10. Disclosure

James S. Wolffsohn has received grant funding from Alcon and Rayner, is a paid consultant for Alcon, Atia Vision and Bausch + Lomb, and has stock ownership in Wolffsohn Research Ltd. Shehzad A. Naroo has received unrestricted grant funding from Lenstec, Teleon Surgical and Topcon Europe. Mark A. Bullimore provides consultancy to Alcon Research, Bruno Vision Care, CooperVision, EssilorLuxottica, Euclid Vision, Eyenovia, Genentech, Johnson & Johnson, Lentechs, Novartis, Paribas, Sydnexis, Vyluma, and has stock ownership in Ridgevue Publishing and Ridgevue Vision and has received honoraria from Broadcast Med, CooperVision, EssilorLuxottica, Euclid Vision, Johnson & Johnson, Oculus, TreeHouse Eyes and EssilorLuxottica. Leon Davies provides consultancy to Novartis Pharmaceuticals. Cristina Schnider is a retiree, stockholder and paid consultant for Johnson & Johnson Vision and a paid consultant for Lentechs and Lenz therapeutics. Philip B Morgan has received honoraria from Alcon, Bausch + Lomb, CooperVision, Menicon and Johnson & Johnson Vision and grant funding from Alcon, Bausch + Lomb, Clearlab, CooperVision, Daysoft, Johnson & Johnson Vision, Mark'Ennovy, Menicon and Visco Vision. Jennifer P. Craig and Maria Markoulli have no declarations of competing interest.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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