Technological environments for visual independence in later years

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H. Bouma, R.A. Weale, C. McCreadie. Technological environments for visual independence in later years. Gerontechnology 2006; 5(4):187-194. The increasing number of older people with minor or major visual impairments calls for further efforts in Research, Design, Development, and Distribution (RDDD) to maximise independence in private and public space. In order to promote enhancement and satisfaction of life for the potential target group, prevention of age related eye diseases comes first, closely followed by compensation of diminished visual functions. The main domains of daily life may require different solutions; in particular mobility is largely dependent on the whole visual field, while recognition depends rather on fine resolution in the centre of the visual field. The rapid progress of technology presents both increased visual demands and enhanced options for visual independence. A bird's eye view is offered on the ageing eye and on eye diseases that tend to come with increasing age. Next, the different visual requirements of daily tasks are introduced with an emphasis on reading. Finally, the specific contributions to the special issue are introduced: review on technical aids, visualisation of visual impairments, evaluation of accommodating implant lenses, visual requirements of light emitting diodes, and visual requirements for walking. Best practices concern: legibility requirements, exposing illegible printings, nutrients that contribute to the prevention of age-related eye disease, and a proposal of a user interface for a smart cane.

Keywords: independence, low vision, technological environments

Gerontechnology is concerned with older people living in a dynamic society full of technological and informational innovations. Demographic projections for most industrialised and industrialising countries show that by 2020 those over 65 will constitute about a quarter of the population. This population ageing is taking place in a time of great technological innovation. Such innovation has the potential to greatly lessen the potentially adverse impacts of some of the symptoms of biological ageing and age-related disease such as impaired or deteriorating mobility, vision, hearing, and memory loss. Technology has the power to preserve autonomy and independent living - outcomes viewed as desirable by society and individuals alike. This special issue of Gerontechnology is concerned with how technological advancement can enhance independence and quality of life by diminishing potential and actual effects of visual impairment and associated limitations. We discuss certain preventive and compensatory measures, as well as relevant innovations in the public infrastructure. Quality of life and personal fulfilment can be greatly enhanced by lessening the effects of visual impairment - when visual restrictions do not necessarily lead to 'visual handicap', as they no longer operate to define individuality and existence.

The main relevant domains of life to be considered are as follows: (i) Health and self-esteem; (ii) Housing and daily living; (iii) Mobility and transport; (iv) Communication and governance; (v) Work and leisure. The main purposes of technological innovations are: (a) Enhancement and satisfaction of life; (b) Prevention of diseases and of inhibitory environmental conditions, and increased participation of normal life; (c) Compensation and assistance; (d) Care support and organisation. Domains and purposes together define an earlier proposed impact matrix to serve as a general framework for gerontechnology[1].

The causes of visual impairments are to be found in general ageing processes of portions of our visual system including some that belong to the domain of age-related pathology. Therefore we first provide a brief reminder of how vision works and how it can go wrong; also how attention to lighting may alleviate some of the problems encountered during the later years of life or, perhaps, in connection with eye diseases[2]. This ought to provide a framework suitable for the task in hand. General effects of ageing are a certain slowing of neural functions including those serving the visual system.

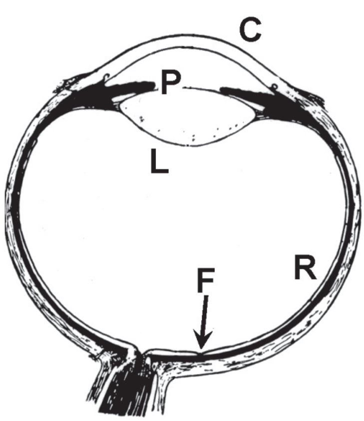

Figure 1. Section through the adult eye; cornea C, pupil P, lens L, and retina R with the small pit: the fovea F. Below on the left is the optic nerve that guides the signals to the brain. The six eye muscles have been omitted

THE AGEING EYE

For good reasons the eye has been compared to a camera. Like the latter, the glossy cornea (*Figure 1, C*) and the usually invisible lens (L) combine to project an image of the outside world on the retina (R). A tear film over the cornea makes for a smooth transparent surface, although with ageing tear production may become too high. The coloured iris controls the size of the pupil (P), which, as a diaphragm, controls the amount of light reaching the retina.

Detail is resolved in the first stage by the retinal photo-receptors, which convert light into electric nerve signals that, after local processing, speed to the brain. The two types, called by their microscopic appearance rods and cones, fulfil different functions. The rods operate at low light levels and convey merely difference in the amount of light they receive (scotopic vision). In contrast, the cones are concerned with detail and colour, and are active in daytime (photopic vision). Operationally the photoreceptors can be compared to the well-known pixels. More pixels per unit area, and hence better resolution of fine detail are characteristic of the cones rather than the rods. The cones are particularly dense in a small central area of the retina: the macula and at its very centre the fovea (F). In the fovea, young eyes can distinguish a visual angle of 0.5-1.0 minute of arc in standard optotypes with proper illumination (visual acuity 2.0-1.0). For older persons, visual acuities are somewhat lower, say between 1.0 and 0.6, and illumination level is more critical. At intermediate light levels where both rods and cones are active, vision is called mesopic. Obviously, in evening and night conditions, vision will be less acute.

Matters of focus

The images formed by cornea and lens have to focus with great precision just on the retina, not in front of, or behind it. Failure is referred to as ‘refractive error’, and can generally be remedied with glasses. However, the eye lens itself can partly change focussing: this is called accommodation. It is one of the earliest to fail on our passage along the phenomena of ageing, and is called presbyopia (Gr. *vision of the elderly*). It occurs in hot countries much earlier than in temperate ones where it starts affecting reading typically in the forties or early fifties. As the large recent migrations have shown, the condition exhibits assimilation to new climates: second generation immigrants adjust the age of onset of presbyopia to that prevalent in their families’ new abodes. Because the presence of presbyopia is universal, it is now looked upon as a normal physiological development, and not as pathological.

Presbyopia is corrected by means of reading glasses that need checking from time to time because the condition may show progress. Also, one has to know where the reading glasses are kept when not worn, for the prevention of domestic accidents. There are alternatives in the form of bifocals, progressives, and other types of reading glasses. However, they tend to be expensive, and not everyone can get accustomed to their use. People who are short-sighted may not need reading glasses but rather glasses for distance vision at all ages.

Lighting

Whereas the young pupil diameter may be as large as 7 mm (area about 40 mm^2), that of older healthy eyes will go down to 2 or 3 mm (5 mm^2). This lowers the light level of retinal images, as does increased light absorption in the ageing eye lens. If the lens clouds in the centre, the effect is worse. Substantial higher task illumination is needed to secure easy vision; higher contrast also helps. A small pupil size increases the depth of focus of the retinal image, which is an advantage in focusing.

Cataract

This is the name given to a clouding of the lens. It is age-related, usually develops slowly, and sometimes accompanies diabetes. In most cases, it can be remedied by means of a relatively simple operation, involving the removal of the lens, and replacing it with a plastic implant.

All cataracts involve a loss of acute vision and increased haze and glare; this is how an individual notices that something is wrong. The problem is caused by irregularities or deposits in the lens, which impede the smooth passage of light rays. Peak-caps may be of considerable help on sunny days. Increased lighting in the home should never be directed at the eyes themselves, but should always be task-orientated. Because it is the white portions that are causing light scattering, white texts on a dark background may be better legible than the usual black texts on a white background.

The other relatively frequent age-related conditions are glaucoma and age-related maculopathies, which involve the retinal seeing mechanism itself.

Glaucoma

This condition can exist in one of two different forms. One, angle-closure glaucoma, is painful, and, paradoxically, is hence to be preferred to the other, namely primary open-angle glaucoma. This is surreptitious, because the patient is alerted to its existence only when the visual apparatus has suffered damage, which is, at present, unfortunately irreparable. In general, the condition is accompanied by a rise in the intra-ocular pressure. The latter has evolved for the eye to maintain its spherical shape which permits it not only to move freely in the orbit, but also to maintain the shape of the outer glassy cornea which assists in the focussing process. It is an excessive pressure which may turn out harmful because it leads to damage of the pathway conveying the electrical impulses from the retina to the brain, thereby initiating blindness.

Drugs can be prescribed for the pressure to be maintained at a safe level once glaucoma has been diagnosed. In most cases these lead to a reduction in the size of the pupil as well. A treated glaucoma patient's pupil may be 1.5 mm in diameter (about 2 mm^2) as compared to some 7 mm (40 mm^2) of a young eye. Thus, a constricted glaucomatous pupil will transmit only one twentieth of the light transmitted by the youthful healthy one. The situation may be considerably aggravated if a cataract co-exists with the glaucoma.

Age-related macular disease (AMD)

In a maculopathy such as AMD the function of the macula will slowly be gravely impaired if not altogether abolished. While not leading to total blindness, it is likely to be accompanied by a reduced ability to read, engage in close work, recognise faces, etc. The origin of AMD is suspected in an insufficiency of local anti-oxidants, and there is a genetic factor. Magnification may be of help and individual lighting levels are desirable[3]. Reports of partial cures have recently been published: they may be generally available in a few years' time. Moreover, certain nutrients have recently been reported to delay the development of AMD.

Theme

Vision and hearing are the two outstanding communication inputs. Among communication problems of old age, visual difficulties from eye diseases are common. Progress in medical technology has been impressive in preventing the diseases and their consequences, through lens implantation, laser treatment, and specific nutrition. Technical means of compensation have also progressed, through special spectacles, object enlargement on monitor screens, closed circuit TV systems, speech synthesis, and better illumination. Technology has, however, also caused setbacks such as by the advent of graphic interfaces in computers or by increased glare problems by bluish car lamps, necessitating compensation by yellowish spectacle glasses. This brief summing-up indicates the important role of technology in dealing with visual problems of old age.

Orientation and recognition

Two basic functions of vision are orientation and recognition. In visual orientation, the whole visual field is involved both for analysing, segmenting, and comprehending the outside world including the analysis of movements in the visual field or movements of the retinal image following from eye and head movements. Detail vision for the recognition of objects has a secondary role to play. Retinal field defects will hamper visual orientation. Visual orientation is also challenged in cases of night-blindness: a decreased sensitivity of low-intensity, scotopic vision or a delay in reaching scotopic sensitivity after exposure to medium or high light levels.

In visual recognition, detailed vision in the central visual field is of primary importance, with a secondary role for visual orientation. For reading, it is not just the fovea that is involved in recognition but also the adjacent area called parafovea. Unlike the fovea proper, which in reading covers a few letters only, the parafovea is characterised by strong interference ('crowding') between visual objects such as letters and words, largely towards the foveal direction[4,5]. In reading, eye fixations jump forward in units of 1-2 words at a time and the brain integrates the subsequent information in a fluent understanding. For the easy finding of the beginning of each next line of print, more remote portions of the retina have to be used. The conclusion is that a low visual acuity has serious consequences for visual recognition in general and reading in particular. Larger print may be necessary, but the reading rate will usually be sub-normal.

All five major domains of daily life as set out in the impact matrix[1] rely on both visual orientation and recognition, with mobility being greatly dependent on orientation, and communication on recognition, for example, of text, human faces, and TV images.

Technology

Normal vision, without specific restrictions, has already been served by technology for a long time. Historically, illumination at night was probably one of the first means for augmenting vision, followed by optical technologies for improving and enlarging the retinal image, by spectacles, microscopes, telescopes, and binoculars. More recently, electronic technologies have resulted in substantial progress in visual displays, from large ones, like public information boards and computer or television screens, to small ones like palm tops and mobile phones. Lamps have become smaller and more efficient. In many areas there has been impressive technological innovation that has changed and will continue to change society. For many older people with normal vision, it is quite a challenge to remain integrated in society by making full use of the latest technology. The challenge is even greater if visual functions gradually diminish.

Visual independence

This special issue is about technologies for maintaining visual independence in later years. Visual independence may be defined as the ability to live and act as a full and active member of present society despite possible visual restrictions. For the latter, normal visual functions of the majority of the population are taken as the basis, in particular as to visual acuity (say, at least 0.5), contrast vision, an undamaged visual field, and only tolerable amounts of glare. Certain colour defects occur rather frequently in the male population at large, but do not seem to be a problem for older people in particular. Colour plays an important part in structuring the visual space and consequently in visual orientation. Technology may come as an individual aid, but often requires a public infrastructure in society for proper functioning. This is why the 'environment' may play such a decisive role. Such environment may be a general one for all people or a specific one for people with visual impairments. Table 1 provides an overview of certain technologies serving aging people in two main domains of daily life.

Following the special issue of Gerontechnology on driving in old age[6], the present issue will illuminate certain other relevant developments.

The present issue

Review of visual aids

Rapid progress in technology has been beneficial for the compensation of visual impairments. This is true in the age-old field of enlarging images and also in newer fields such as speech technology for the automatic reading of texts, and radar and GPS technology for navigation. The review paper by Neustadt-Noy[7] summarises present options for daily situations with a hopeful look toward options still round the corner. The selection of the proper aid suited for any desired task of the individual may present a problem in itself for which professional help may be needed. Also learning to use it on a daily basis requires a sustained effort and sometimes professional guidance. Protection of existing suppliers by bureaucratic procedures has impeded new products from reaching the target group rapidly and at a reasonable price. The spectrum of social security provisions in various countries is to be tuned to the new technological options for independence of individual people with visual impairments.

Computer simulation

It is difficult for people with normal vision to imagine what people with visual restrictions can or cannot see. So far, this has been tried by intuitive means, showing, for example, a black part of the visual field in case of non-functioning parts of the retina. However, we know that non-functioning parts of our retina, such as in the 'blind spot' do not look black but just non-existent, making it even difficult to convincingly demonstrate that each of us possesses such inconspicuous blind spots. Following earlier efforts in simulating colour deficiencies, the article by Hogervorst and van Damme[8] extends the methodology to simulate visual restrictions on an experimentally founded methodology. Since the relevant software can be freely downloaded, this has the potential to become the preferred standard in all requirements for public infrastructure, for which certain visual limits should be defined within which people with visual restrictions can be served. Moreover, the software permits responding to individual visual requirements as well.

Implant lenses with accommodation

Medical technology is of basic importance in dealing with visual restrictions, witness lens implants and laser treatments. The field is so specialised that we tend to leave it to ophthalmologic specialists. While the technical specialities of lens plastics and operation procedures can be left to the professionals, the functional aspects deserve a broader attention. The paper by Koopmans and Kooijman[9] in the present issue discusses whether lens implants can be made to restore the natural eye accommodation that starts to diminish rather early in life until it virtually disappears around the age of 50.

Light emitting diodes (LED)

We are experiencing rapid progress in illumination technology, both as regards displays (LCD) and also lamps (efficiency, optics). LEDs are new lamps of such efficiency that battery or solar cell operation has become an option. This also requires new thinking about spectral efficiency for the eye and colour rendering. To diminish glare, the intensity of short (bluish) wavelength light should probably be moderated for older people. The paper in this issue by Yamagishi, Kawasaki, Yamaba, and Nagata[10] presents preliminary research in this new field.

Visual navigation in walking

Just walking around requires orientation and navigation that is largely visually mediated. The peripheral field of view is of utmost importance, and if it fails for whatever reason, a remaining sharp peephole vision offers only limited help. Whereas this belongs to general knowledge, the precise information about absolute and relative movements that our low-acuity visual system utilises in orientation and navigation remains to be specified. The short paper by Itoh[11] presents a contribution to our knowledge. This should help to specify the functionality of navigation aids and also to guide the design of public spaces.

Legibility practices
Three best practices are considered in the present issue. One by Weale and McCreadie[12] concerns requirements of texts intended to be read by an unspecified general public. Size of lettering and contrast are the most relevant features. It would be a good thing if a general requirement were that people with a visual acuity of, say, 0.3 and above, should be able to read a given text without special optical aids. The sad truth is that the know-how to make this happen, while available for a long time, is not often put in practice. This makes it relevant to renew our efforts to disseminate such knowledge so that it is utilised in new applications such as in credit cards, palm tops, and medical information.

Preventive nutrition
Another best practice paper has to do with nutrients that increasingly appear to influence the ageing process, and in particular diseases that have tended to belong to the class of ageing diseases without known cause and without known treatment. The basic role of antioxidants in influencing ageing processes in our body has been recognised for some time, but applications have often remained rather general and vague. Now it has been shown convincingly that certain nutrients have a preventive influence on age- related macular degeneration, one of the threatening eye diseases of old age so far without effective treatment. It may be expected that the increased attention to nutrients influencing the ageing process will bear more fruit in the coming years. This new hope is the main reason for reviewing a recent important paper on the prevention of AMD[13].

Table 1. Selection of technologies supporting visual functions as part of the matrix depicting technology gains for different domains of daily life[1]; Italics = not yet available; Between square brackets = unsuitable for most older persons with vision restrictions

Technology gains	Domains of daily life	
	Mobility & Transport	**Information & Communication**
Enhancement & Satisfaction	Electronic keys Good street illumination *I-cane (GPS/radar)*[12]	Mobile phone Spoken books (CD) Text-to-speech
Prevention & Engagement	UV protection Healthy nutrients[14] Large dark peak (cap, hat) Lens implants[9] Pavement indicators[11]	Normal letter size[13] (>1.5 mm at 40 cm) High contrast lettering[13] Focussed task illumination[3,10] Lens implants[9]
Compensation & Assistance	Tactile pavement indicators Telescopes[7] Radar (Ùltra-cane)[7] Ultrasound (Mini-guide)[7] Talking signs *Retinal implants*	Reading glasses Optical magnifiers[7] Electronic magnifiers[7] (CCTV; displays) [Braille (displays, books)][7] Speech-to-text
Care support & Infrastructure	Low vision simulator[8] UFOV tests[6] Glare meter 'C-Quant'[15]	Training environment[7]

User interface concept of a smart cane

A smart cane for navigation has become feasible because of GPS and radar technology. A new user interface of such a concept cane has recently been described[14].

The special attention to the theme will continue in future issues where we hope to have contributions on subjects such as speech technology, on navigation aids, and on retinal implants for restoring vision.

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