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IMPROVING FUNCTIONAL ASPECTS OF AGEING AND SENSORY LOSS

A SIMPLE CLASSIFICATION FOR FUNCTIONAL ASPECTS OF AGE RELATED VISION LOSS

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INTRODUCTION

Historically, two main approaches have been taken in improving age-related vision loss. The medical science approach is to affect or prevent the structural changes that produce age-related eye disease, as for example, in lowering intraocular pressure with drugs as a treatment for glaucoma, or in replacing a cataractous lens with an artificial one. The rehabilitation science approach, on the other hand, is to develop ways to ameliorate the functional consequences of vision loss, generally with vision aids and adaptations. While both approaches are of obvious importance in pursuing the vision problems of an aging society, the present discussion favours the second, more functional approach.

This bias is motivated by the thesis that the myriad structural problems that can and do occur in the aging visual system all produce only three classes of functional changes in how images are formed in the eye, or are processed by the visual apparatus: light loss, image degradation, and dysfunction or damage to receptors or nerve. Solution of visual problems at this level of analysis has the potential to ameliorate the effects of many pathological profiles at once. Lest the reader be sceptical of this 'treat the symptom approach', ponder the enormous benefits of what might be thought of as the first low vision aid the spectacle lens, which ameliorated the image degradation resulting from refractive errors so effectively that, for most people, these errors are no longer considered to be a significant impairment.

The remainder of this paper will further develop this simple taxonomy by briefly outlining the causes, functional effects, and amelioration of each of the three classes of physical functional changes. Only selected effects on visual function are described.

1. LIGHT LOSS

Light loss refers to the condition of having too little light enter the eye for typical visual performance. While even youthful individuals with good vision often experience the effects of reduced illumination when attempting to perform tasks that require more than the available light (such as reading without a lamp at night), we consider light loss to refer to insufficient light entering the eye to perform visually at the level of a typical youthful individual.

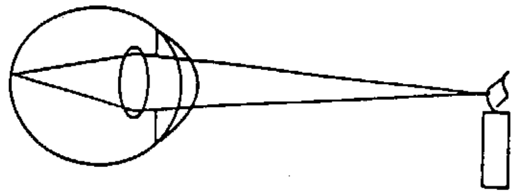
Nearly all older people have significant light loss, and the distinction between what is a normal and what is pathological is not clear cut. However, Weale (1963) has estimated that typically, the light entering the eye of a 60 year old eye is only one-third that of the 20 year old.

1.1 Causes

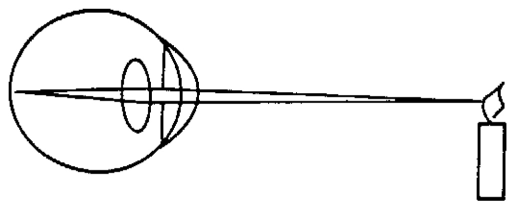
1.1.1 **Miosis** - A main cause of light loss in older people is pupillary miosis, a decrease in the average size of the pupil. Since the pupil limits the amount of light that can enter the eye, a reduction in its average size results in a reduction in the average retinal illuminance impinging on the retinas (see Figure 1). Miosis also results from the use of some drugs used in the treatment of glaucoma.

Caption for Figure 1: A large pupil (a) admits more light into the eye than a small pupil (b). The smaller average pupil size of the older individual (miosis) produces declines in several visual functions.

FIGURE 1



(a)



(b)

1.1.2 Absorption - A second main cause of light loss in older eyes is increased light absorption by the ocular media, especially the crystalline lens. With advancing age, the lens absorbs, and hence filters out, more of the light that passes through it, making it less transparent, much the same way sunglass lenses absorb light that passes through them. One can further distinguish between spectrally uniform absorption, which affects all wavelengths of light equally, and wavelength dependent absorption, in which the lens absorbs more light from some parts of the visible light spectrum. As the human lens ages, short wavelength light tends to be absorbed more than long. The relatively higher passage of long wavelength gives the lens a yellowish cast, and tends to tint the light that passes through it. Both spectrally uniform and wavelength dependent absorption increase with age and are responsible for a significant amount of light loss.

1.1.3 Synergy of Miosis and Absorption - Pupillary miosis and absorption conspire to produce even more light loss than either would by itself. This is because the miotic pupil forces light entering the eye to pass through the thick center of the lens, which absorbs more light than does its thinner periphery.

1.2 Functional Effects

1.2.1 Acuity - Since visual acuity diminishes in low light, (e.g. Shlaer 1937), it is not surprising that ocular light loss produces reduced acuity and impairs performance of tasks that make demands on acuity, such as reading.

1.2.2 Contrast Sensitivity - Light loss produces significant reductions in our ability to detect small light intensity differences in visual patterns, especially fine patterns (Devalois et al, 1974). Low levels of contrast, where one region of an image may differ little in its gray scale value from its neighbouring region, become difficult to discern (this is true for youthful individuals with excellent vision as well, under conditions of reduced illumination), and may cause special visual difficulties with relatively low contrast images such as curbs and shaded objects such as faces.

1.2.3 Color Discrimination - Wavelength dependent light absorption may affect the ability to discriminate differences in hue. Short wavelength light, which appears blue in isolation, is increasingly attenuated by the lens with advancing age. This may be one reason why color discriminations that young observers make by comparing relative amounts of short and longer wavelength lights, are impaired in older observers. However, spectrally uniform light loss may also produce age-related losses in color discrimination (Knoblauch et al, 1987), since at lower luminances bluish and yellowish hues become less distinct (this is known as the Bezold-Brucke effect). These troublesome color discriminations generally correspond to evaluating the relative amounts of blue and yellow sensation in a given patch of color.

1.2.4 Glare - Individuals with light loss tend to have problems with the type of glare that is occasionally referred to as blinding glare. Blinding glare can arise from the sudden change from a state of low light adaptation to exposure to bright light, as most of us experience when exiting a dark movie theatre into daylight. Since lowered average retinal illumination results in a lower average level of light adaptation, relatively intense lights more often reduce visibility and make vision uncomfortable in people with a light loss problem.

1.3 Amelioration

1.3.1 Individuals with light loss should arrange, when possible, to compensate for their lower retinal illumination with higher environmental illumination, especially in performing tasks that require high resolution (like reading) and high contrast sensitivity.

1.3.2 Where possible, higher contrast patterns (like black against white) should be selected in the home, especially for items where safety is an issue, e.g. stair carpeting, stove knobs, etc.

1.3.3 Where color is important for its information value, differences in hues should be chosen to avoid particular color combinations. Specifically, blue against green, and yellow and orange against white should be eschewed.

1.3.4 White blue tinted filters may, under some circumstances, compensate for color discrimination losses produced by wavelength dependent light absorption, they increase light loss further, and should be avoided.

2. IMAGE DEGRADATION

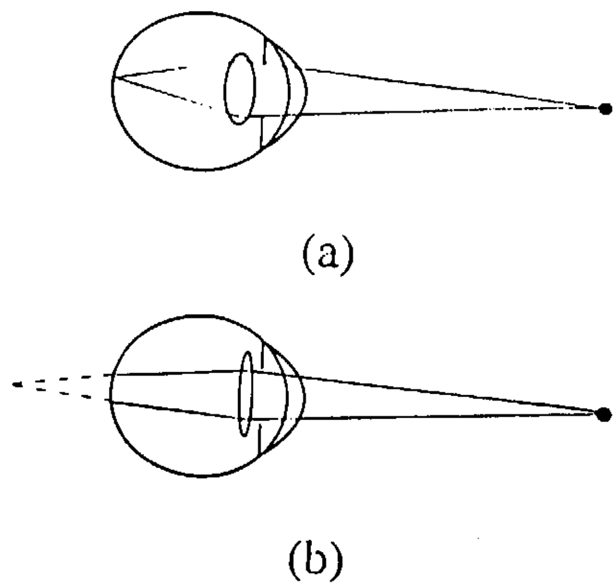
Image degradation refers to any condition in which, due to optical factors, light quanta fall on a non-optimal retinal location, or are too spread out. Image degradation is usually accompanied by blur and loss of image contrast.

2.1 Causes

2.1.1 Defocus - All refractive errors result in the condition of defocus, where rays of light emanating from individual points in space converge to a plane either closer or more distant than the retina (see Figure 2). Since these rays intersect the retina either in front of or behind their convergence (focal) point, they are spread out, and hence appear blurred in the same way as a film projector that is out of focus. Nearly everyone experiences reduced ability to accommodate, or focus the lens to near distance, with increasing age. This condition is referred to as presbyopia. Cataract extraction inevitably produces some refractive error, whether it be from lack of lens (aphakia), or from residual error associated with an intraocular lens implant (pseudophakia).

Caption for Figure 2: In the young eye (a), lens shape changes dynamically in order to focus images of nearby objects on the retina. The older eye loses its elasticity and with it, the ability to bulge sufficiently to focus the image of nearby objects. Images, which would be in focus somewhat behind the eye (dashed lines), become spread out on the retina.

FIGURE 2



(a)

(b)

2.1.2 **Scatter** - When small particles in the ocular media refract light rays in random directions, light is said to be scattered. The crystalline lens, in particular, scatters light increasingly in the later years of life. Severe light scatter by the lens is known as cataract. The scattering particles give the lens a cloudy, or milky appearance. As with lens absorption, there are spectrally uniform and wavelength-dependent forms of light scatter. The former, known as Mie scatter, arises from particles that are larger than a wavelength of light. The latter is known as Rayleigh scatter, and arises from particles that are smaller than a wavelength of light. Like wavelength- dependent absorption, Rayleigh scatter also affects short wavelength light more than long. (The sky is blue because of Rayleigh scatter). It is not clear how much intraocular light scatter is of the wavelength-dependent sort.

2.1.3 **Fluorescence** - As the size of the lens increases with advancing age, which it does with advancing age, it accumulates substances which fluoresce. These substances absorb light at invisible ultra-violet wavelengths while emitting light at a different, visible, wavelength. The light emissions of this fluorescence are random in direction, do not contribute coherently to retinal imagery, and hence have effects similar to those of scatter.

2.1.4 **Prismatic Effect** - While quite uncommon, cataracts involving only a portion of the lens can produce a secondary image that is superimposed on the primary retinal image.

2.2 Functional Effects

2.2.1 **Acuity** - Defocus and scatter, while blurring the retinal image in quite different ways, both reduce the ability to visually resolve fine spatial patterns, because they both spread or smear light.

2.2.2 **Contrast** - Contrast, especially in the fine structure of spatial patterns. Scatter may add stray light uniformly to the retinal image, producing a veiling or disability glare, under conditions of high illumination.

2.2.3 **Monocular Diplopia** - Result from incomplete cataracts can be confusing and troublesome.

2.3 Amelioration

2.3.1 Spectacles and contact lenses are a highly effective means of correcting refractive errors. While correction of age-related refractive errors with spectacle lenses and lens implants brings images at the refraction distances in clear focus, the presbyope and the corrected aphake still experience a limited depth of focus relative to the younger individual.

2.3.2 Magnification of images by optical, electronic, or 'page-to-nose' means may increase functional acuity since magnification transforms the fine details of patterns into larger, more detectable forms.

2.3.3 Presenting a test as white characters on a black background (reversed contrast) enhances reading performance in most individuals with glare from scatter, since less light enters the eye and is available for scattering.

2.3.4 Control of illumination can be critical for effective visual performance in individuals with glare resulting from scatter. The scattering condition, usually a cataract, absorbs so much light that the individual suffers from light loss. Yet the addition of light to ameliorate the light loss may reduce visibility by degrading the image with scattered light. Such individuals see best only within a small range of illumination and contrast. Tinted lenses and sunglasses are one means of illumination control.

2.3.5 Tinted lenses that selectively filter out wavelength and ultraviolet light can be useful for reducing the effects of wavelength-dependent scatter and fluorescence. However, it is unclear how much these particular effects contribute to image degradation in aging and diseased eyes.

3. RECEPTOR AND/OR NERVE DAMAGE OR DYSFUNCTION

This class of physical-functional change refers to any kind of age related problem in retinal production of neural impulses in response to light, or in transmission of those impulses from the retina to the brain. Pathological causes will not be described here since there are so many physiological conditions that can lead to receptor and nerve damage and dysfunction, and since knowledge of the causes yields little insight into effects on visual function and amelioration. There is evidence that in the absence of specific identifiable pathology, aging also produces measurable diffuse losses in neural efficiency (see Werner et al, 1990 for a review).

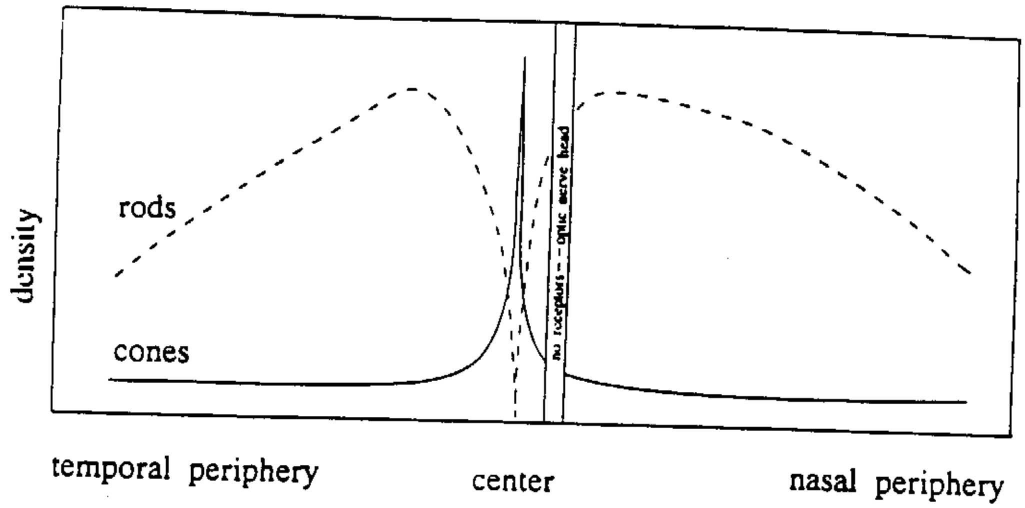
3.1 Functional Effects

There is some evidence that age-related declines in visual function are greater than can be accounted for by the optical factors described in sections 1 and 2. Therefore, part of the declines observed in acuity, contrast sensitivity, and color discrimination may be due to neural losses. How much can be attributed to neural factors is still very much an open research question.

Neural losses from disease, however, invariably produce defects of the visual field, which are generally local areas of blindness or reduced visual sensitivity called scotomas. Surprisingly, scotomas may often go unnoticed by the individual with field defects until much of the visual field is lost. (There is a normal scotoma in the visual field of all human eyes, where the optic nerve makes its entry into the eye). What distinguishes the functional effects of one pattern of scotomas from another is their size, and even more importantly, their location. This is because different regions of the retina are specialised for different visual functions. An understanding of the functional effects of visual field defects requires a brief examination of some retinal anatomy.

Figure 3 illustrates the distribution of the two visual light receptor types (the receptors produce neural impulses in response to light) across a cross-section of the retina. The rod receptors, most numerous in the mid periphery of the visual field have very high sensitivity, and are thus well suited for night vision. (This is why a star is more detectable if one aims the eye slightly away from it). The rod system, however, does not signal information about color. From this, it is easy to see why peripheral visual field defects cause problems with night vision. Since the periphery also has the portions of space immediately to our sides and on the ground directly in front of us, peripheral defects may also cause problems with mobility.

FIGURE 3



Caption for Figure 3: Schematic representation of receptor density for cones (solid line) and rods (dashed line) across the retina. The nasal periphery lies closer to the nose, while the temporal periphery lies closer to the ear.

The cone receptors, on the other hand, which have lower sensitivity and are for use in daytime light levels, mediate color vision and are highly concentrated in the central retina, allowing us to resolve the fine details of visual images. When we attend to an object, we reflexively move our eyes so that its image falls in the central visual field. For these reasons, central field defects cause dramatic losses in visual acuity, resolution, and color perception. Eye movements made to inspect an object are especially frustrating, since such movements only serve to make the object less visible.

Finally, central field defects invariably result in problems with glare, since there are few receptors that are suitable for daylight levels of illumination. In this case vision must be mediated by the higher sensitivity rods, and since the rods are saturated with light, they are unable to effectively signal the changes in light level over space or time, that they are able to at lower light levels.

3.2 Amelioration

3.2.1 **Magnification** - Magnification by any means usually provides functional relief to those with central field defects because it allows the image to be resolved by more peripheral retina, which has lower visual acuity.

3.2.2 **Minification** - Minification can, in limited circumstances, be useful to those with only central visual field remaining. The theory is that by compressing a wider angle view of the world into a smaller image, peripheral objects are more likely to be detected. In practice, the sacrifice in central visual resolution that comes about with minification, greatly reduces its benefits.

3.2.3 Illumination Control - Tinted lenses, sunglasses, and reduction of lamp intensities, can all reduce the glare that arises from loss of cone function when central visual fields are dysfunctional.

3.2.4 Eccentric Fixation - With central field loss, individuals perform high resolution tasks best when they can relocate the image of an attended object, say, a word, to the most central peripheral region with healthy retina. Some individuals train themselves to use one healthy peripheral location quite consistently, relative to the use of randomly chosen peripheral areas, improving performance of tasks like reading.

CONCLUSION

The goal of this paper has been to produce a simple classification of the physical causes of age related declines in vision at a level that allows the identification of optical and physiological factors with particular vision rehabilitation strategies. Some effects on visual function have been identified with each physical cause, but the list is incomplete, both so as to simplify the discussion, and because the effect of age on many visual functions has yet to be measured. The three categories of causes of vision decline, however, would seem to be sufficiently broad to encompass most effects on visual function that are likely to be encountered.

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