Enhancing the Visual Environment for Older and Visually Impaired Persons

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This article provides guidelines for making the environment more visually accessible to seniors with low vision and with visual declines typical of older age. These include typographic modifications to documents and signage, and enhancements of color and contrast. In addition, a tutorial introduction to how vision declines with age, describing the major determinants of object visibility, is given.

Key words: *low vision, vision and aging, vision impairment*

Declining visual function is a natural part of aging. How do we best design environments for people with the typical visual decline that we accept as normal, and for those with low vision, to best optimize the ability of seniors to use visual information? Below we outline some guidelines that may make special sense in older peoples' homes, and in other facilities, such as assisted care facilities and nursing homes. The emphasis is on providing practical information, but a little bit of technical information about how vision declines will be necessary background.

We begin with a brief description of how vision declines and subsequently outline what can be done to ameliorate the decline with environmental modifications. Obviously, when addressing the needs of a particular older individual, medical and rehabilitative interventions must be addressed as well. Our focus in this article is on the many interventions that can be applied at the level of environmental design, where the design is intended to include older people.

HOW VISION DECLINES WITH AGE

Here are several causes of the decline of visual function with age:

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- Our crystalline lenses, the focusing optical elements near the front of the eyes, invariably lose elasticity causing nearly of us to need additional refractive power to perform close tasks such as reading, as we age. Typically our ability to focus our eyes to within arm's length is reduced by age 50, when most of us require the use of reading glasses. (Those with near-sightedness, or myopia, may, instead of reading glasses, need to take off their myopic corrective spectacles, which optically does much the same thing as reading glasses.)
- The crystalline lenses also become increasingly yellow and become less transparent with age, admitting less light into the eye (especially in the short wave end of the wavelength spectrum), and reducing the sharpness and contrast of the retinal image.
- The reduced transparency of the lenses also means that light is scattered to some degree within the eye. Practically, this means that when viewing brightly lit scenes, older people may experience what is known as *disability glare*, a reduction in visibility due to *too* much light.
- Our pupils become smaller with age, again reducing the amount of light that enters the eye, making the world somewhat dimmer, and reducing our ability to discern fine details and to discriminate colors.
- Our risks for eye conditions that lead to low vision and blindness increase, and these risks accelerate with each decade over 60. The conditions include macular degeneration, glaucoma, cataract (often inoperable), and diabetic retinopathy. All of these conditions can affect our visual acuity, a measure of the smallest (retinal image) object sizes we can see effectively, and our *contrast sensitivity*, a measure of the lowest contrasts we can see (see "Lighting and Contrast" section below). Many of these disorders have highly variable end stages so that in the later years there is an enormous range of visual capacity, ranging from almost normal to completely blind. Visual acuities may range, for example, from 20/40 to immeasurably low.

Variability in visual function of older people makes the designer's task difficult, because an enormous range of visual capabilities must be accommodated. For example, it would be helpful to make environmental signs readable to people with as wide a range of visual acuities as possible, but the approximate range of text sizes (after magnification) required by people's visual acuity ranging from 20/20 to 20/1000 varies by a factor of 50. And visual function varies in other ways in addition to acuity, such as color and contrast perception, visual field, speed of visual processing, and attentional factors.

At the same time as risk for vision loss is on the increase, risk for nonophthalmologic medical conditions also increases and accelerates, including stroke, Alzheimer's disease and other dementias, and conditions that limit mobility and independence, so that well into late adulthood, comorbidity with visual decline is more the rule rather than the exception.

We now turn to the most important determinants of visibility: lighting and contrast and retinal object size.

MAJOR DETERMINANTS OF VISIBILITY

Lighting and contrast

The amount of light illuminating a visual scene and contrast of the objects in that scene are the most important variables affecting detectability and discriminability of visual objects. We all know intuitively that good illumination is necessary for optimal visual performance; when reading small print, we naturally seek better illumination if we cannot make out the letters and words, and illumination seems dim. But few people have a good intuitive notion of contrast, even though contrast is just as important in determining visibility of visual objects.

Contrast is always defined as some kind of luminance (or reflectance) ratio. One common definition is $C = (L_{max} - L_{min})/L_{max}$, where L_{max} and L_{min} are maximum and minimum luminance (or light levels), respectively, in a scene. Contrast by this definition varies between 0, when there is no difference between maximum and minimum light levels in the scene (ie, $L_{max} - L_{min} = 0$), and 1.0, where the minimum light level is zero (ie, $L_{min} = 0$). Note that contrast will be exactly the same regardless of the overall amount of illumination. Thus, black (L_{min}) text against a bright white (L_{max}) background may have the same contrast value regardless of whether room lights are on high, or are dimmed to almost imperceptibly low levels. So even objects that contrast with their backgrounds maximally ($C = 1.0$) will be imperceptible if there is insufficient illumination.

Conversely, we may also consider extremely bright scene light values with little contrast, such as seeing a sheet of white paper in sunlit snow. Here the low contrast may be the limiting factor where illumination is obviously sufficient. In summary, while to a degree lower contrasts can be compensated for by high illumination and vice versa, we need both good contrast *and* good illumination to see optimally. Thus, rather counterintuitively, *contrast* and illumination level are quite independent of one another, but both are essential for good visibility.

Lighting can be controlled in the environment for the older person, with fixture lighting, lamp lighting, handheld illuminated magnifiers, and placement of objects relative to natural light entering through windows. Since lighting considerations are addressed elsewhere in this feature issue, we note here only that sufficient lighting is 1 of 2 *necessary* conditions for good object identification and for fine detail vision. Below, in the "Color and Contrast" section, we focus on the practicalities of making effective contrasts for older and visually impaired people.

Retinal object size

The size of an object on the retina is another major determinant of visibility and identifiability. When we view a small object, such as a penny, from a few inches away, its image is very large on our retinas, but if we view it from several hundred feet away, where its size on the retinas is tiny, it may not be perceivable at all. Similarly, we may be able to read large text at arm's length, but not small. Both of these are examples of the importance of retinal object size in visibility. The (retinally) smallest standard object that we can identify is a measure of our *visual acuity*. Most major age-related vision disorders reduce visual acuity.

We can enhance function for those with reduced visual acuity through several means. First, magnification devices are used to increase retinal object size. Older people with vision problems should obtain optometric vision rehabilitation services in order to be prescribed the most appropriate magnification devices to accomplish the task they want to accomplish. A second means is simply moving closer to an object. For example, a sign (eg, indicating the location of a restroom) can be approached to a closer distance to increase its retinal size. In terms of environmental design, the most important way to allow the use of this means of increasing retinal object size is to allow a free walking path to the sign, so that the sign is approachable and viewable from a close distance. A third means is increasing the physical size of the object. For example, signs with larger text are more legible for most people with visual impairment than those with smaller text.

PRACTICAL GUIDELINES IN DESIGNING FOR OLDER AND VISUALLY IMPAIRED PERSONS

The above background material should lay the groundwork for the practical principles to follow. Keeping in mind that good lighting that illuminates objects and avoids glare is essential (see the article by sloane at al in this issue), the remaining sections detail some guidelines to follow in aspects of design other than lighting.

Typography

Typography can affect legibility and appears to have an even greater impact on legibility in visually impaired people than in able-sighted people. The principles below apply to documents and to environmental signage alike. Most of these are detailed in a brochure available from Lighthouse International,[1] also available at http://www.lighthouse.org/print_leg.htm.

Point size

A printer's point is equal to 1/72.27 in (computers usually define a point as 1/72 in), so a 12-point font has roughly a height of 12/72.27 in. Point size refers to overall size of letters, but most people (and computers) use this to refer only to the vertical size of the font. It is obvious that font point size strongly affects legibility, since we use optical magnification and large print to make text larger and hence more readable, and often measure visual function and legibility by minimum readable size (ie, acuity). What is less well known is that the point size of a font is not really a fixed or objective measure of any dimension of the font, so different fonts may have very different sizes even if they have the same nominal point size. Computer typography is changing this somewhat—it is now fairly conventional in computer typography to use the point size to characterize the sum of the height of the tallest (uppercase) letter and the lowest descender, for example, the minimum vertical size needed to set the font without successive lines overlapping.

Use the largest font size for documents and signage you can afford. Obviously there are limits as to how much "real estate" you can afford to devote to an environmental sign, and there are limits as to how many pages you can afford to devote to a document. A good rule of thumb to ensure that older and visually impaired readers will be able to access your document is to use 16- or 18-point text. For signs, use the largest text size that is feasible, keeping in mind that it is more important to allow sign readers to approach signs at a close distance than it is to make the sign text large.

X-height

X-height is, quite literally, the height (in absolute measure, such as printer's points, or relative measure, such as a percentage of the point size of the font) of a lowercase "x." It characterizes the height, and generally the size of the body of most lowercase characters. That size, of course, affects how legible a font is, in the same way that the overall size of letters does. Because most of the information distinguishing lowercase letters is in the letter body, x-height is probably a better indicator of lowercase font legibility than is overall point size.

When producing a document or a sign that is made of lowercase or mixed-case letters, consider the x-height of the letters, which is generally more important than the font size.

Letter aspect ratio

Letter aspect ratio refers to the ratio of width to height of characters in a font and should be measured using a symmetrical character like an "O" or "H." Aspect ratio can be seen as the relative horizontal-to-vertical magnification of letters. But, if one keeps point size (a vertical-only measure) constant, aspect ratio really refers to the width, or fatness of the characters. Expanding characters horizontally generally makes them more legible because it is a form of magnification[2]; however, like most things that enhance legibility, a large width-to-height ratio prints fewer characters on a line and, as a consequence, is more expensive to print.

Interletter spacing

Spacing between letters has a very significant impact on legibility, especially at small sizes relative to a person's visual acuity.[3,4] Since people with low vision are often reading close to their acuity limit (ie, with little acuity *reserve*), adding additional space between letters is particularly advantageous to them.[5] Again, printing costs may increase, because there are fewer characters on each line.

Proportionality of spacing

Fixed and variable (also called *proportional*) spaced fonts differ in the amount of horizontal space occupied by each character. With variable spacing, characters generally take up only the amount required by the character form, so, for example, a lowercase "i" takes up far less space than an uppercase "W." With fixed spacing, all characters take up the same amount of space—generally the width of the widest letter (usually the "W"). Fixed space fonts are a good deal more legible at small character sizes (relative to acuity). But it appears that it is not really the proportionality of the font that is important—the legibility advantage can be fully accounted for by the fact that the *average* interletter spacing is greater in fixed than variable-spaced fonts.[3,6]

Stroke width

This variable refers to the thickness of the strokes making up the letters, and, in general, bolder strokes are more legible. However, when strokes become too bold, the letter forms "fill in" and become less legible. The important point is that thin-stroked fonts are considerably less legible than thick-stroked fonts of the same size.

Although taking up slightly more space, bolder, thicker-stroked letters are more legible in both signs and documents.

Outline vs filled

Outline fonts, in which the "ink" has been removed from the interior of letter strokes, is far less legible than filled fonts of the same size,[7] and should be avoided for use by the older and low-vision reader.

Serifs

Serifs are the little "feet" that punctuate the ends of strokes on most lowercase and some uppercase letters of seriffed fonts. Our research has recently shown that fonts with serifs have a minuscule advantage in legibility over sans serif fonts, but that the advantage is wholly accounted for the small increase in interletter spacing that fonts with serifs must have to avoid "collisions" with neighboring letters.[8] This advantage is so small, however, as to have virtually no impact on one's decision as to whether to select a seriffed or sans serif font. Both can be highly legible.

Letter case

The common wisdom, aesthetics, and a good deal of research from cognitive science suggest that words composed of lowercase letters are more easily identified than those composed of uppercase, because word shape is more distinctive. Our recent results, however, indicate that uppercase characters are more legible than lowercase, for both normal and low-vision readers, in terms of both minimum discriminable size (acuity) and reading speed. The reason is simple: when equated for point size, uppercase letters are simply bigger!

Familiarity

Standard roman and sans serif fonts are much more legible than ornate, nonstandard, or decorative fonts, for both documents and environmental signage. Letter forms should be simple and easily recognizable, avoiding special effects such as drop shadows and three-dimensional. Letterforms that are the most common are those with which we have the most familiarity, and are hence the easiest for us to identify.

Color and contrast

Color is used primarily in 2 ways in environmental and document design. First, it may be used to enhance the aesthetic value of an environment or document. Second, colors may have a semantic value. For example, we associate "safety yellow" stripes, for example, on stair treads to signal potentially hazardous conditions.

Since objects are distinguished from their backgrounds largely on the basis of color, however, the designer should take into account the color contrasts in an environment, and ensure that they are adequately accessible to the population they are trying to serve.

The most accessible or distinguishable color contrast is always bright white against very dark black, and some people argue that the designer of environments and documents for visually impaired persons should confine designs to black and white because it maximizes the detection of objects. The approach we espouse is rather that designers must be given flexibility so that esthetics and semantic values of colors may be retained, while giving designers the tools to ensure effective contrasts.

We have developed a set of 3 principles of color contrast design that we believe to be useful in ensuring that contrasts are relatively accessible. First, we propose that designers should always strive to maximize lightness contrast whenever attempting to design for older and visually impaired persons, where lightness can be thought of roughly as the "gray value" of a particular color. If a very light color contrasts with a very dark color, lightness contrast will be high.

Second, we propose that designers should select light colors either from white, or from colors that reflect predominantly midspectral hues from the rainbow such as yellow or green. Similarly, dark colors should be selected either from black, or from colors that reflect predominantly colors from the spectral extremes of the rainbow, such as red, blue, and purple. The rationale for this principle is fairly technical and is beyond the scope of this article, but the interested reader may consult Arditi and Knoblauch.[9] To give a brief and approximate explanation, this principle seeks to ensure that colors from the extremes of the spectrum, which are vulnerable to perceptual darkening, are used in situations in which such darkening would not reduce effective contrast.

Third, we propose that designers should select hues that are very dissimilar. Thus, rather than selecting red to contrast with purple (which is itself a mixture of red and blue), the designer should select hues that are themselves very different, such as red and green, or blue against yellow.

These 3 principles are detailed, along with explanatory material for the designer, in a brochure that is available from Lighthouse International,[10] and also is on its Web site: http://www.lighthouse.org/color_contrast.htm.

In closing this section, we note another way, in addition to esthetics and semantic value, that color might be used in designing environments for older people, especially those with cognitive decline: Color can be used to make parts of the environment more distinctive and hence serve the function of landmarks. For example, having rooms painted in different colors helps make those rooms more identifiable and hence more useful as landmarks that can help in spatial orientation.

SUMMARY

Designing with the older and visually impaired person in mind requires consideration of the natural or typical effects of aging on vision as well as the high prevalence of age-related visual disorders and comorbidities. The visual world needs to be well-lit, contain high contrasts of objects against background, and often requires larger retinal object sizes for small visual objects such as text.

There are quite a few ways to enhance the accessibility of the visual world. Some of the most effective for the designer are in enhancing typography of signs and documents, and in prudent selection of color contrasts.

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