Resolution of blur in the older eye: Neural compensation in addition to optics?

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This study examined the roles of pupillary miosis and experience-mediated compensation in older observers’ superior ability to read optically blurred text. The size thresholds of younger and older adult observers for reading common words and identifying line drawings of everyday objects were compared with natural and artificial pupils as a function of systematically varied far letter acuity: best corrected, 20/30, and 20/40. With best corrected letter acuity, younger observers’ size thresholds for reading words were lower than those of older observers with either natural or artificial pupils. In the 20/40 condition, however, older observers’ reading size thresholds with natural pupils were significantly lower than those of the young. No significant age differences were seen at 20/30 or 20/40 on word reading with artificial pupils or on line drawing identification size thresholds with either pupil type. Prior blur experience, as estimated from observers presenting and best optical corrections, was inversely associated with older adults’ word acuity. Pupillary miosis in conjunction with neural compensation appears to account for older observers’ greater ability to read blurred text.

Keywords: visual aging, blur, word acuity, pupillary miosis, neural compensation, artificial pupils


Introduction

Older adults have been shown to be superior to their younger counterparts in identifying optically degraded printed text messages (Kline, Buck, Sell, Bolan, & Dewar, 1999). However, when real and nonsense words are blurred intrinsically via image processing, the age difference is reversed in favor of young observers (Bartel & Kline, 2002). It is unclear, however, if older observers’ superior ability to identify optically degraded text reflects aberration-reducing effects of pupillary miosis, experience-mediated blur compensation, or some combination of the two. This study evaluated the relative importance of these two factors by comparing younger and older observers on the size thresholds for the identification of four-letter words and object line drawings, with and without artificial pupils, as a function of optically varied far letter acuity.

Even well-corrected observers show a progressive age-related decline on acuity (Elliott, Yang, & Whitaker, 1999) and contrast sensitivity for intermediate and high spatial frequencies (Kline, Schieber, Abusamra, & Coyne, 1983; Owlsley, Sekuler, & Siemsen, 1983). Age-related deficits on spatial vision are most pronounced for tasks involving dimly illuminated and/or low contrast stimuli (Schneck, Haegerstrom-Portnoy, Lott, Brabyn, & Gildengorin, 2004). Although increased lenticular opacity and pupillary miosis play significant roles in the decline on spatial vision (Burton, Owlsley, & Sloane, 1993), neural factors may also be implicated (Elliott, Whitaker, & MacVeigh, 1990).

While pupillary miosis reduces retinal illumination, it also enhances image contrast (Owlsley, Sekuler, & Alvarez, 1988; Woodhouse, 1975) and increases depth of field (Winn, Whitaker, Elliott, & Phillips, 1994). Although optical aberrations increase with age for pupils of fixed size, with natural pupils, the MTFs of healthy younger and older eyes are similar and monochromatic wave-front aberrations are actually reduced in the older eye (Calver, Cox, & Elliott, 1999).

Blur, an intrinsic property of retinal images located in multiple depth planes, is exacerbated by the eye’s optical imperfections. Akin to the greater blur tolerance of low-resolution optical systems, Legge, Mullen, Woo, and Campbell (1987) reported that the ability to resist optical blur is inversely related to observer acuity. Increased blur resistance may account for older observers’ superior ability to identify optically degraded words. Kline et al. (1999) compared the ability of younger and older observers to identify standard word-message signs (two to four words) when their Landolt letter acuity was degraded to 20/30 and 20/40 using positive sphere blur. Older observers’ mean size thresholds were lower than those of younger ones in both degraded acuity conditions, significantly so at 20/30. That Landolt acuity better predicted the word size thresholds of younger than older observers led the authors to speculate that older observers’
greater blur experience might account for their superior ability to read blurred text. This hypothesis was tested in a second experiment that compared the word size thresholds of younger and older observers for reading standard and novel word messages with acuity degraded to 20/30 or 20/40. Size thresholds were significantly lower in the 20/40 condition among older observers for both the standard and novel stimuli, suggesting that older observers’ blur tolerance occurs at the level of letter identification. The optical and/or neural factors that might account for this effect, however, are unclear.

If based on an age-related optical change such as pupillary miosis, older observers’ greater ability to resolve blur may not extend to stimuli degraded by image processing. Bartel and Kline (2002) evaluated this possibility in a comparison of younger and older observers’ ability to identify low-pass filtered images of real words, nonsense words, natural scenes, and famous faces. Younger observers were better than older ones in identifying real and nonsense words; no age difference was seen on the scene or face identification tasks. The authors suggested reduced spherical aberration and enhanced depth of focus due to pupillary miosis (Winn et al., 1994) in combination with prior experience might account for older observers’ superior ability to identify blurred text. Consistent with this suggestion, Nio et al. (2000) have shown that the age-related decline on contrast sensitivity is greater at optimal focus than with positive defocus. The authors attributed this outcome to age-related changes in the optical media.

It is known that short-term exposure to unfocused images can enhance uncorrected acuity as well as contrast sensitivity (e.g., Mon-Williams, Tresilian, Strang, Kochhar, & Wann, 1998; Rosenfield, Hong, & George, 2004) and that perceived focus is affected directly by prior adaptation to blurred or sharpened images (Webster, Georgeon, & Webster, 2002). Webster et al. (2002) concluded that blur adaptation reflects cortically mediated, spatially selective contrast gain control. Artal et al. (2004) found that binary-noise images that recreate an observer’s own higher order aberrations are judged as sharper than rotated versions of the same images. These and related findings (e.g., Chen, Artal, Gutierrez, & Williams, 2007; George & Rosenfield, 2004) are consistent with the conclusion that neural adaptation derived from long-term visual experience can compensate for the eye’s optical aberrations.

To estimate the relative importance of the optical and neural contributions to age differences in the resolution of blurred stimuli, the present study compared the size thresholds of younger and older observers for identifying words and line drawings of common objects with natural and artificial pupils across three induced acuity levels: best corrected, 20/30, and 20/40. It was expected that word size thresholds with degraded acuity would be lower for older observers, more so with natural than artificial pupils (i.e., an age by stimulus type by pupil interaction).

In that age-related long-term neural compensation should be more evident for familiar than novel stimuli, greater age differences were anticipated for words than line drawings.

### Methods

#### Participants

Two age groups, each composed of 12 healthy volunteers (6 men and 6 women), participated in the study: a younger group (mean age = 26.9 years, range: 21 to 36 years) and an older group (mean age = 72.7 years, range: 61 to 80 years). The young participants were university student volunteers; the older participants were recruited from the laboratory’s established long-standing pool of healthy community-resident volunteers. Mean presenting acuity in the best eye was better for the younger observers ($M = -0.108$ logMAR; range: 0.0 to $-0.155$ logMAR) than the older ones ($M = 0.013$ logMAR; range: $-0.155$ to +0.176 logMAR), $t(22) = 2.72$, $p < 0.05$. Mean best corrected acuity in the better eye was better for the younger group ($M = -0.125$ logMAR; range: 0.0 to $-0.301$ logMAR) than the older group ($M = -0.046$ logMAR; range: 0.0 to $-0.125$ logMAR), $t(22) = 2.55$, $p < 0.05$. The dioptric difference between the presenting and best acuity refraction was virtually the same ($p = 0.92$) for the younger ($M = 0.60$ D, range: 0.0 to +1.5 D) and older ($M = 0.64$ D, range: 0.0 to +3.5 D) participants.

None of the participants reported a chronic visual disorder or the use of a medication for a visual disorder. Two elderly participants had prior cataract surgery with IOL implantation (both about 2 years prior to the study). Three elderly men reported cardiovascular diseases and one elderly woman reported mild type II diabetes. None of the younger participants reported any general health problems.

The mean education levels of the younger (17.3 years, range: 15 to 19 years) and older participants (15.7 years, range: 12 to 22 years) did not differ significantly, $t(22) = 1.63$, $p > 0.05$. Testing was conducted in accord with an institutionally approved protocol for full informed consent.

#### Apparatus and materials

**Vision measures**

Letter acuity was measured at 6.1 m for each eye to the nearest $-1.0$ logMAR using a custom high-contrast Landolt-C chart. As recommended (e.g., Bailey & Lovie, 1976), the acuity targets were equally legible, each row contained the same number of targets (five), and inter-target spacing was one target width. The white-area
background luminance of the chart was 60 cd/m^2. Acuity was measured as the smallest size at which orientation of all targets on the row was reported correctly. Initial prescriptions for best acuity were determined using a Canon R-22 Autorefractor and then refined manually with an American Optical Master Phoropter. The phoropter was also used to determine the additional positive sphere blur needed to degrade acuity to 20/40 (0.301 logMAR) and 20/30 (0.176 logMAR) for a single line of five black-on-white Snellen letter targets presented via a Bausch and Lomb Accu-Chart 3 projector (white-area luminance 22 cd/m^2). Monocular far (3.1 m) contrast sensitivity for sinusoidal gratings at 1.5, 3.0, 6.0, 12.0, and 18.0 cpd for the eye with best acuity was measured using the Vistech VCTS 6500 chart.

Size thresholds for words and objects

Minimum target size thresholds were established for six words and six black-on-white line drawings of common objects (see Figure 1). The word stimuli were the most common English four-letter words (Arial font) that begin with a different letter (About, Inc., 2004): THAT, WITH, HAVE, FROM, SOME, and YOUR. The object line drawings were of a Car, Chair, Cup, Key, Scissors, and Telephone. The stimuli, presented on a Sony 19-in. high-resolution monitor controlled by an Apple G3 computer, were viewed monocularly from 6.1 m through the phoropter using a natural pupil or a 3-mm artificial pupil. The untested eye was occluded with a translucent fogging lens to reduce intermittent blurring and fluctuations in vision associated with opaque occluders (Wildsoet, Wood, Maag, & Sabdia, 1998).

Testing procedures

After refractive correction for best acuity (sphere and cylinder), the positive sphere power needed to reduce acuity to 20/40 (0.301 logMAR) and 20/30 (0.176 logMAR) was determined for the eye with the best acuity. Starting +3.0 D above the power for best corrected acuity, the

<table>
<thead>
<tr>
<th>Words</th>
<th>Line drawings</th>
</tr>
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<tbody>
<tr>
<td>HAVE</td>
<td><img src="image" alt="Car" /></td>
</tr>
<tr>
<td>FROM</td>
<td><img src="image" alt="Key" /></td>
</tr>
<tr>
<td>SOME</td>
<td><img src="image" alt="Cup" /></td>
</tr>
<tr>
<td>THAT</td>
<td><img src="image" alt="Scissors" /></td>
</tr>
<tr>
<td>WITH</td>
<td><img src="image" alt="Telephone" /></td>
</tr>
<tr>
<td>YOUR</td>
<td><img src="image" alt="Chair" /></td>
</tr>
</tbody>
</table>

Figure 1. The test stimuli: six words and six object line drawings.
blur needed for 20/40 and 20/30 was determined by decreasing the sphere power in 0.25-D and then 0.125-D steps as the designated acuity line was approached. Blur threshold for each acuity level was the maximum sphere power at which at least three of the five Snellen letter targets were identified correctly. This procedure was carried out for the natural and then for the artificial pupil condition. Contrast sensitivity for the eye with best acuity was then measured in order of the lowest to highest spatial frequency.

Size thresholds were established for words (letter height in arcmin) and object line drawings (area in arcmin^2) by progressively increasing stimulus size in 5.2% (0.059 dB) steps. To minimize apparatus reconfiguration and task duration, size thresholds were tested in six (i.e., 3 acuity by 2 pupil) trial blocks. Test order was counterbalanced by assigning one participant in each age by sex group to one of six randomized trial-block orders. Testing was self-paced in a single session of approximately 90-min duration.

### Results

An alpha level of 0.05 was adopted for all significance tests; Bonferroni corrections were used to control the error rate for multiple comparisons. Possible violations of the assumptions of homogeneity of covariance in the split-plot analyses of variance (ANOVA) were controlled using the Greenhouse–Geisser adjustment.

#### Acuity induction

An Age (2) by Pupil (2) by Acuity (3) split-plot ANOVA on word size thresholds (letter height in arcmin) showed significant effects for pupil type, \(F(1, 22) = 15.54, p < 0.05\), and acuity, \(F(2, 44) = 114.65, p < 0.05\), but not age group, \(F(1, 22) = 0.02, p = 0.90\) (see Figure 2). The pupil and acuity effects were embedded in higher order interactions: pupil by age, \(F(1, 22) = 8.57, p < 0.05\), pupil by acuity, \(F(2, 44) = 7.49, p < 0.05\), and age by acuity by pupil, \(F(2, 44) = 3.87, p < 0.05\). In the best acuity condition, the size thresholds of younger observers were lower than those of older observers in the natural, \(t(22) = 2.60, p < 0.05\), and artificial pupil conditions, \(t(22) = 3.63, p < 0.05\). No significant age differences were seen at 20/40 for either pupil condition, nor at 20/40 condition with artificial pupil. With natural pupils, however, the older observers’ size thresholds in the 20/40 condition were below those of their younger counterparts, \(t(22) = 1.99, p < 0.05\) (see Figure 2).

#### Contrast sensitivity

An Age (2) by Spatial Frequency (5) split-plot ANOVA on the contrast sensitivity data showed a significant age deficit, \(F(1, 22) = 16.27, p < 0.05\), as well as an effect for spatial frequency, \(F(4, 88) = 46.49, p < 0.05\). The spatial frequency by age interaction was not significant. Independent \(t\)-tests showed that sensitivity values for younger observers exceeded those of the older at all five spatial frequencies (\(p < 0.05\)).

#### Size thresholds for words

An Age (2) by Pupil (2) by Acuity (3) split-plot ANOVA on word size thresholds (letter height in arcmin) showed significant effects for pupil type, \(F(1, 22) = 15.54, p < 0.05\), and acuity, \(F(2, 44) = 114.65, p < 0.05\), but not age group, \(F(1, 22) = 0.02, p = 0.90\) (see Figure 2). The pupil and acuity effects were embedded in higher order interactions: pupil by age, \(F(1, 22) = 8.57, p < 0.05\), pupil by acuity, \(F(2, 44) = 7.49, p < 0.05\), and age by acuity by pupil, \(F(2, 44) = 3.87, p < 0.05\). In the best acuity condition, the size thresholds of younger observers were lower than those of older observers in the natural, \(t(22) = 2.60, p < 0.05\), and artificial pupil conditions, \(t(22) = 3.63, p < 0.05\). No significant age differences were seen at 20/40 for either pupil condition, nor at 20/40 condition with artificial pupil. With natural pupils, however, the older observers’ size thresholds in the 20/40 condition were below those of their younger counterparts, \(t(22) = 1.99, p < 0.05\) (see Figure 2).

#### Size thresholds for line drawings

Size thresholds for line drawings were calculated as the minimum rectangular area in arcmin^2 (i.e., height × width in arcmin) at which each object could be identified correctly. An Age (2) by Pupil (2) by Acuity (3) split-plot ANOVA indicated that thresholds varied inversely with acuity, \(F(2, 44) = 39.87, p < 0.05\), and were worse with natural than artificial pupils, \(F(1, 22) = 7.32, p < 0.05\). Both main effects, however, were embedded in an acuity by pupil interaction, \(F(2, 44) = 4.67, p < 0.05\). As shown in Figure 3, the difference between natural and artificial pupils increased as acuity was degraded. Dependent \(t\)-tests indicated that the artificial pupil threshold advantage was significant at 20/40, \(t(23) = 2.50, p < 0.05\), but not at 20/30. Although the mean size thresholds for identifying object line drawings were lower for older observers in the 20/40 natural pupil condition, the age

<table>
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<tr>
<th>Acuity</th>
<th>Natural pupil</th>
<th>Artificial pupil</th>
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<tr>
<td></td>
<td>Young</td>
<td>Old</td>
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<tr>
<td>20/30</td>
<td>1.10</td>
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<tr>
<td>20/40</td>
<td>1.40</td>
<td>0.97</td>
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Table 1. Net positive sphere add (D) beyond best acuity correction for 20/30 and 20/40 acuities for young and old observers with natural or artificial pupil.
Visual predictors of size thresholds

The relationships between best corrected acuity and the size thresholds for words and object line drawings in the best acuity condition were examined using Pearson correlations. While generally positive, the correlations between word size thresholds and Landolt acuity ($r$ range: 0.53 to 0.67) were not significant after Bonferroni correction for either age group regardless of pupil condition. Younger observers’ thresholds for identifying object line drawings in the best acuity condition were related significantly to their best corrected acuity with natural pupils ($r = +0.74, p < 0.05$) but not with artificial pupils. Among older observers, however, acuity was not related to object size thresholds for natural ($r = +0.19, p = 0.56$) or artificial pupils ($r = +0.12, p = 0.71$).

The correlations between mean and peak contrast sensitivity and size thresholds for words and objects were

Figure 2. Mean word size thresholds (arcmin) for the (A) natural and (B) artificial pupil conditions as a function of age group and acuity level.
determined for each age group for natural and artificial pupils in each of the three acuity conditions. Although the relationships between word size thresholds and mean contrast sensitivity varied considerably across the six acuity pupil conditions, after Bonferroni correction, none were significant for either age group. Line drawing thresholds were related to peak contrast sensitivity among older observers only with an artificial pupil at 20/30 acuity ($r = 0.72$, $p < 0.05$); none of the other possible relationships between contrast sensitivity and line drawing thresholds reached significance in either age group.

The effect of prior blur experience on word acuity with natural pupils was estimated initially by determining correlations between word size thresholds and an observer’s presenting correction. Among younger observers, presenting correction was associated nonsignificantly with higher word size thresholds for both 20/30 ($r = +0.35$) and 20/40 ($r = +0.21$). Among older observers, however, the presenting correction was inversely related to word thresholds, significantly so for 20/40 ($r = -0.59$, $p < 0.05$). The significance of this age reversal in the 20/40 condition was confirmed by an $r$-to-$z$ transform ($z = 1.69$, $p < 0.05$). The relationship of the difference between observers’ presenting and best correction and their word size thresholds showed a similar age reversal. For younger observers, a greater difference between the presenting and best correction was associated nonsignificantly with elevated word size thresholds, $r = +0.13$ and $r = +0.49$ for 20/30 and 20/40, respectively. Among older observers, however, the corresponding correlations ($r = -0.22$ and $r = -0.21$) showed a nonsignificant inverse relationship between the presenting/best dioptric difference and word acuity. $R$-to-$z$ transforms revealed that this age reversal in the direction of this relationship was also significant for the 20/40 acuity condition ($z = 1.69$, $p < 0.05$).

**Discussion**

With letter acuity degraded optically to 20/40, older observers’ word acuity with natural pupils was superior to that of their younger counterparts. Age, however, exerted no systematic effect on word acuity through an artificial pupil, or on the size thresholds of object line drawings for either pupil type. Older observers’ ability to identify blurred text appears to involve both age-related optical change and experience-mediated neural compensation.

The well-documented age deficit on contrast sensitivity among healthy observers (e.g., Kline et al., 1983; Owsley et al., 1983) was observed in the present study. As in some prior studies (Gagnon & Kline, 2003; Sloane et al., 1988), an age deficit on contrast sensitivity was apparent at low as well as intermediate and high spatial frequencies.

For both age groups, the level of dioptric blur needed to degrade acuity to the 20/30 and 20/40 levels was greater with artificial than natural pupils (Table 1), likely reflecting the reduction in spherical aberration associated with a smaller pupil (Legge et al., 1987; Winn et al., 1994). The same factor could also account for the finding that size thresholds for both words and line drawings were generally lower with artificial than natural pupils. Unlike
Kline et al. (1999) who did not find significant age difference, older observers needed less spherical blur than younger ones to reduce their best acuity to 20/30 and 20/40. Although the reasons for this difference are not clear, it may reflect our older observers’ worse corrected acuity, in combination with the lower chart luminance level used in the present study (22 versus 65 cd/m²). It is well recognized that age deficits on acuity are exacerbated by reduced luminance (e.g., Taub & Sturr, 1991).

With better corrected acuity than their older counterparts, it is not surprising that younger observers’ size thresholds for reading words and identifying line drawings in the best corrected acuity condition were generally lower than those of older observers. While reading and line drawing thresholds increased for both age groups when letter acuity was degraded, as hypothesized, the thresholds were affected differentially by age and pupil condition. Consistent with prior research (Kline et al., 1999), older observers’ word reading thresholds with natural pupils were lower than those of younger ones, under degraded acuity, significantly so in the 20/40 condition (Figure 2). This age effect appeared due to older observers “outperforming” their induced 20/40 letter acuity rather than inadequate reading performance by the young adults. Younger observers’ mean letter height threshold for reading in the 20/40 condition was equivalent to a resolution letter acuity of 0.314 logMAR (or 20/41.2), whereas older observers’ threshold corresponded to a resolution acuity of 0.225 logMAR (or 20/33.7). Relative to the natural pupil, a 3-mm artificial pupil in the 20/40 condition caused a considerably greater reduction in word reading threshold (2.26 versus 0.35 arcmin) in younger than older observers. In fact, the reading threshold of young observers with an artificial pupil in 20/40 letter acuity was similar to that of the older observers with either pupil type. This finding implicates pupillary miosis’ contribution to the age-related increase in blur tolerance (Nio et al., 2000). The effects of a smaller pupil on depth of focus and spherical aberration may also help explain why the reading thresholds of both age groups were better than those to be expected from letter acuity alone. This could be clarified by measuring observer pupil size at the test luminance, it is a limitation of the current study that it did not.

Pupillary miosis, however, does not appear to account fully for older observers’ ability to identify blurred text. First, neither acuity nor contrast sensitivity significantly predicted word thresholds for either age group regardless of viewing condition. Second, if miosis benefited older observers’ ability to identify blurred stimuli, the effect might be expected to be as robust for line drawings as for text, but it was not. Third, unlike their younger counterparts, the strength of the older observers’ presenting optical correction was inversely rather than directly related to word acuity. Finally, and perhaps most importantly, prior blur experience, as estimated from the difference between an observer’s presenting and best correction, was also related inversely to older observers’ word size thresholds. These findings suggest that neural compensation (Artal, Ferro, Miranda, & Navarro, 1993) also plays a role in the age-related increase in older observers’ ability to identify blurred text.

It has been shown that short-term exposure to unfocused images can enhance uncorrected acuity as well as the contrast sensitivity of young adult observers (Mon-Williams et al., 1998; Pesudovs & Brennan, 1993; Rosenfield et al., 2004). Webster et al. (2002) demonstrated that brief adaptation (3 min) to blurred or sharpened images (faces, edges, natural scenes) strongly biased observer focus preferences in the direction of the adapting stimulus. The authors suggested that adaptation to blur reflected spatially selective cortical contrast gain control.

Previous research has also provided evidence for long-term neural adaptation to blur. Rosenfield et al. (2004) had moderate myopes view far stimuli for 3 h with and without refractive correction. Measurement of high-contrast letter acuity at 30-min intervals showed significant gains in acuity in the absence of refractive correction that could not be attributed to change in refractive error. Also suggestive of long-term adaptation differences, George and Rosenfield (2004) found that low-contrast (2.5% to 16%) grating acuity improved more among myopes than emmetropes over 2 h of adaptation to 2.5-D fogging lenses.

Artal et al. (2004) proposed a cortical mechanism that uses visual experience to adapt the neural system to the eye’s optical aberrations. In support of this hypothesis, they found that binary-noise images generated with adaptive optics to recreate the observer’s own higher order aberrations were judged to be sharper than rotated versions of the same images. Similarly, Chen et al. (2007) found optimal image quality occurred when some of an observer’s higher order optical aberrations were left uncorrected. Both findings imply enduring neural adaptation effects that originate in long-standing visual experience.

Although long-term neural adaptation to blur among older observers has not yet been demonstrated conclusively, there is evidence that the neural responses that underlie adaptation to transient blur are intact in the older visual system (Elliott, Hardy, Webster, & Werner, 2007). Elliott et al. (2007) noted that suprathreshold contrast matching functions show little evidence of age-related loss and hypothesized that neural adaptation may be the foundation for perceptual constancy with age in spatial vision. To test this hypothesis, they compared younger and older observers on judgments of the focus of natural scenes after adaptation to 2 min of varied levels of image blur or sharpening. A small but significant age difference in the level of blur perceived as “best focus” suggested a routine difference in the long-term blur experience of each group. That, coupled with the absence of an age difference in the magnitude of the blur aftereffect, led the authors to conclude that the neural processes that mediate adaptation to blur remain intact with aging. More recently, Pérez, Manzanera, and Artal (2009) have provided evidence that
the normal age-related increase in positive sphere aberration can compensate for the adverse effects of light scatter on retinal image contrast.

**Conclusion**

This study showed that pupillary miosis contributes to the ability of older observers to “outperform” their younger counterparts and their own induced letter acuity in reading blurred text. In the latter, older observers are unlike younger ones whose visual acuity is a good predictor of reading acuity (Chung, Jarvis, & Cheung, 2007). The stimulus-specific nature of this ability (i.e., greater for text than novel line drawings) suggests the additional involvement of neural compensatory mechanism. The compensation observed here is generally consistent with the suggestion by Artal et al. (2004) that the brain can manage a number of different point-spread functions if it has sufficient experience with each of them. Such experience might well originate in older observers’ familiarity with stimuli viewed through a progressively fixed-focused (i.e., presbyopic) optical system and increasing in spherical aberration.

Our results are consistent with those from previous research showing evidence of visual plasticity among healthy aged adult observers (e.g., Artal et al., 2004; Elliott et al., 2007). How visual experience interacts with age in affecting plasticity, however, remains to be determined. Research on the effects of adaptive optics with observers of varied age could enhance our understanding of experience-mediated neural compensation. So too would an evaluation of the extent to which short-term blur experience might ameliorate younger observers’ deficit in reading blurred text. By advancing our understanding of observers’ ability to cope with optical change, such research could also be of practical significance. For example, it would be useful to determine if performance on real-world tasks could be improved by blur training or through designs that optimize the discriminability of stimuli by maximizing the uniqueness of their low-pass optical profile.

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