Vision and Aging

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Abstract

Research on aging and vision has increased dramatically over the past few decades. Changes in our visual capacities in later adulthood have the potential to impact our ability to perform common everyday visual tasks such as recognizing objects, reading, engaging in mobility activities, and driving, thus influencing the quality of our life and well-being. Here, we discuss several common visual problems in older adults that cause performance problems in the visual tasks of everyday living and when exacerbated are related to the development of common eye conditions and diseases of aging.

1. INTRODUCTION

How the aging process impacts human visual function is scientifically relevant for several reasons. First, there are many structural and physiological changes in the human visual system from early to late adulthood, such that vision itself—how we see—fundamentally changes in substantive ways as we grow older. Second, these changes in our visual capacities have the potential to impact our ability to perform common everyday visual tasks such as recognizing objects, reading, technology use, mobility activities, driving, workplace tasks, and social engagement. Thus, our quality of life and well-being are directly influenced by the integrity of our vision. Third, the percentage of the population over age sixty in the United States and in many other countries is increasing, and thus, there are public health priorities to serve the eye-health needs of this burgeoning population. Epidemiological studies make it clear that eye diseases and conditions that hamper vision are much more common in the older adult population, as compared to younger age groups. Finally, our theoretical frameworks and models of basic visual processes must account for visual changes over the life span if they are to be scientifically comprehensive and applicable to human existence.

Fortunately, research on aging and vision has increased dramatically over the past 50 years. During these years, there have been many well-written and comprehensive overviews of the field by experts in this area (Faubert 2002; Jackson & Owsley 2003; Jackson et al. 2002; Kline & Schieber 1985; Ordy et al. 1991; Owsley & Sloane 1990; Sekuler & Sekuler 2000a,b; Spear 1993; Weale 1982, 1986; Werner et al. 1990, 2010). The reader is referred to these publications for a diversity of insights and perspectives on the field. Rather than repeating this overview effort yet again, we discuss in this article several common visual problems in older adults that can cause serious performance problems in the visual tasks of everyday living and when exacerbated are related to the development of common eye conditions and diseases of aging. There are many types of visual problems in older adults; however, in the interest of space, we focus on three that, on the basis of previous research, clearly have a noteworthy everyday impact. They are aging-related deficits in spatial contrast sensitivity, scotopic function, and visual processing speed.

2. SPATIAL CONTRAST SENSITIVITY

Spatial contrast is a physical dimension that refers to the light–dark transition at a border or an edge of an image, which marks the existence of a pattern or object (De Valois & De Valois 1988, Owsley 2003, Pelli & Bex 2013). Contrast is defined as the ratio of the difference in the luminance of these two adjacent areas to the lower or higher of these luminance values. The amount of contrast a person needs to see a target is called contrast threshold, and it is typically expressed on a logarithmic_{10} scale. Thresholds can be measured for many different types of psychophysical judgments, such as detection, discrimination, recognition, and identification of targets. Contrast thresholds are often expressed in research as contrast sensitivity, where sensitivity is simply the reciprocal of threshold. When contrast sensitivity is assessed as a function of target size (usually expressed as spatial frequency), the resulting plot is referred to as a contrast sensitivity function. Human contrast sensitivity is best at intermediate spatial frequencies and falls off rapidly with increasing spatial frequency, and more slowly with decreasing spatial frequency.

How does the aging process impact spatial contrast sensitivity? Since the 1980s, many studies have shown that older adults have impaired contrast sensitivity at intermediate and high spatial frequencies under photopic conditions, with the magnitude of deficit increasing with increasing spatial frequency (Derefeldt et al. 1979, Elliott et al. 1990, Kline et al. 1983, Owsley et al. 1983, Tulunay-Keesey et al. 1988). The higher spatial frequency deficit appears to become more accentuated with each advanced decade of age (Owsley et al. 1983), as depicted in **Figure 1**. What

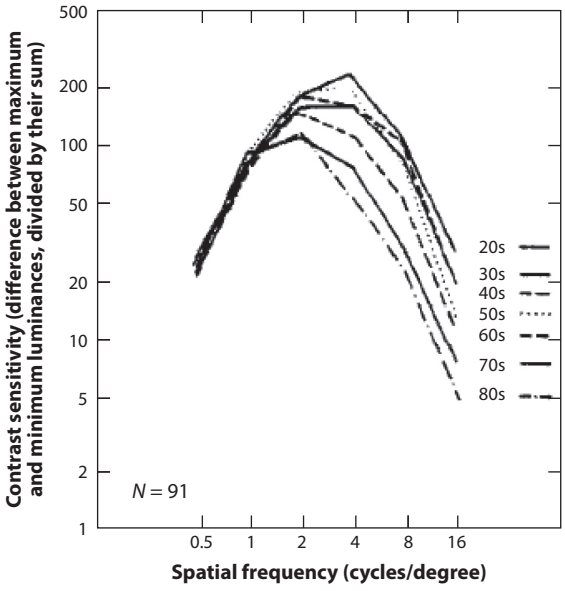

Figure 1

Spatial contrast sensitivity for each decade of age during adulthood. With increasing age, intermediate and high spatial frequency deficits become larger. Adapted from Owsley et al. (1983), with permission from Elsevier, copyright 1983.

mechanisms could be contributing to older adults' loss in spatial contrast sensitivity? It was initially thought that older adults might set a more cautious or conservative decision criterion for acknowledging that they see the target pattern, particularly at higher spatial frequencies where the target's bars are very narrow. However, older adults' spatial contrast sensitivity deficits are present even when criterion-free methods of threshold estimation are used (Elliott et al. 1990, Higgins et al. 1984).

Optical characteristics of the eye as we grow older play a major role in reducing contrast sensitivity in older adults. Retinal illuminance in older eyes is reduced because of pupillary miosis (reduction in pupil size as one ages) (Loewenfeld 1979) and the increased optical density of the crystalline lens (Pokorny et al. 1987, Said & Weale 1959). There is also increased intraocular light scatter and optical aberrations in the aging eye that can reduce image contrast (Artal et al. 2003, Glasser & Campbell 1998). Research has indicated that optical characteristics of older eyes are largely responsible for older adults' spatial contrast sensitivity deficits at photopic light levels. When the optical performance of the human eye was compared for younger and older adults using an apparatus to measure the modulation transfer function, there were lower values of modulation in the older eyes (Artal et al. 1993, Guirao et al. 1999). This lower modulation difference was similar to the psychophysically measured loss in spatial contrast sensitivity in older adults as compared to younger adults from previous work (Owsley et al. 1983). That older adults' loss in spatial contrast sensitivity under photopic conditions is largely optical in origin was also established through psychophysical studies using laser interferometry to bypass the optics of the eye in generating targets on the retina. These studies found that older adults exhibited either no loss in contrast sensitivity (Dressler & Rassow 1981, Kayazawa et al. 1981) or a very small loss (0.1–0.2 log units) (Burton et al. 1993) when the interference fringe targets are utilized. In older adults, this small loss in so-called neural contrast sensitivity accounted for less than half of the photopic contrast

sensitivity loss at higher frequencies when sensitivity was measured using conventional viewing techniques where the optics of the eye are not bypassed (Derefeldt et al. 1979, Elliott et al. 1990, Kline et al. 1983, Owsley et al. 1983, Tulunay-Keesey et al. 1988), implying that optical factors are major contributors to spatial contrast sensitivity deficits in older adults at photopic levels. Neural changes in the aging visual pathways can have a role (Spear 1993), although their role is likely very minor when compared against the optical properties of the aged eye (Owsley 2011).

Although spatial contrast sensitivity impairment is present to some degree in most older adults, it is accentuated in those with clinically significant cataract (Adamsons et al. 1992, Elliott et al. 1989, Rubin et al. 1993). Age-related cataract formation is a gradual process of increasing opacification of the crystalline lens during the aging process. Thus, all older adults have some degree of cataract because the process starts earlier in adulthood. For this reason, it is unclear when exactly the cataract nomenclature should be most properly applied. Clinically, an older adult is said to meet the diagnostic criteria for cataract in the United States when visual symptoms start to interfere with the visual activities of daily living (e.g., reading, driving). At that time, cataract surgery becomes a possible intervention that could be reimbursed by third-party payers (i.e., insurance, Medicare).

Cataract causes visual impairment by accentuating the loss in spatial contrast sensitivity (Adamsons et al. 1992, Elliott et al. 1989, Rubin et al. 1993), although it also can reduce spatial resolution (decreased acuity) and increase glare problems. Cataract hampers driver safety and performance. Older drivers with clinically significant cataract are 2.5 times more likely to have been involved in a recent vehicle collision (Owsley et al. 1999). Contrast sensitivity impairment is primarily responsible for this elevation in collision risk (Owsley et al. 2001c). Furthermore, cataract surgery and intraocular lens implantation, which improve contrast sensitivity, lower the collision rate of older drivers with clinically significant cataract by 50% as compared to the collision rate for those who do not have cataract surgery (Owsley et al. 2002a). On-road driving performance also improves after cataract surgery, and improved contrast sensitivity mediates this effect (Wood & Carberry 2006). Ambulatory function and postural stability in older adults are also negatively impacted by contrast sensitivity loss; hip fractures are more likely in those with contrast sensitivity impairment (Cummings et al. 1995), as are disturbances in postural stability (Elliott et al. 1995, Lord et al. 1991, Lord & Menz 2000, Turano et al. 1996). Older adults' reading problems are accentuated by contrast sensitivity impairment (Crossland & Rubin 2012). Even when older adults have good acuity, their reading speeds for very small and very large characters are slowed compared to young adult readers, which is attributable to their contrast sensitivity impairment (Akutsu et al. 1991). Furthermore, for older adults with contrast sensitivity deficits caused by cataract, their reading accessibility index is reduced in terms of average reading speed to print sizes that are readily accessible because of their vision limitations (Calabrese et al. 2016).

In summary, spatial contrast sensitivity impairment is a common and almost inevitable part of aging. It is due primarily to aging-associated changes in the optical properties of the eye, including the increasing optical density of the crystalline lens as we age, although aging-related neural factors may play a minor role. When the increased lens optical density progresses to the point of interfering with the visual tasks of daily living, it is designated as clinically significant cataract. Contrast sensitivity deficits caused by cataract increase motor vehicle collision and fall risk, hamper postural stability, and reduce reading rate and accessibility.

3. SCOTOPIC FUNCTION

Scotopic visual function is vision under very low luminance conditions, specifically when the background adaptation level is $10^{-3.5}$ cd/m^2 or lower (Le Grand 1972). Scotopic vision is exclusively mediated through rod photoreceptors. Older adults are more likely to cite vision problems at night

and under low luminance conditions, compared to younger adults, as revealed by questionnaire studies and structured focus groups (Kline et al. 1992, Kosnik et al. 1988, Mangione et al. 1998, Owsley et al. 2006b). These visual complaints cover many kinds of low luminance activities—for example, night driving, reading menus in dimly lit restaurants, and getting around in poorly illuminated environments. Older adults' low luminance vision problems have a psychophysical basis. Many studies going back several decades have shown that older adults have decreased light sensitivity in the dark under steady-state conditions (i.e., after they have adapted to darkness), and this deficit is larger than their light sensitivity under photopic (daytime) conditions (Birren & Shock 1950, Gunkel & Gouras 1963, Jackson & Owsley 2000, Jackson et al. 1998, McFarland et al. 1960, Owsley et al. 2000b, Robertson & Yudkin 1944, Steven 1946, Sturr et al. 1997). Although increased optical density of the aged crystalline lens and pupillary miosis contribute to their scotopic threshold elevation, these optical factors are not primarily responsible for this sensitivity loss, with approximately a half log unit elevation in threshold or more remaining after these factors are taken into account (Jackson et al. 1998, Sturr et al. 1997). It is important to consider possible neural mechanisms underlying older adults' scotopic deficit. By age sixty to seventy, the density of rod photoreceptors decreases dramatically in the macula as indicated by studies on donor retinas (Curcio et al. 1993, Gao & Hollyfield 1992). However, scotopic sensitivity loss in older adults occurs in retinal areas where there is negligible rod loss; also, scotopic sensitivity loss is not accentuated in the areas of heightened rod loss. This pattern of results suggests that a simple rod loss explanation by itself cannot account for older adults' sensitivity impairment in the dark (Jackson et al. 1998). Furthermore, there is little change in the amount of rod photopigment, rhodopsin, throughout adulthood (Liem et al. 1991, Plantner et al. 1988, van Kuijk et al. 1991).

There is growing evidence that older adults' scotopic dysfunction stems from an aging-related disturbance in the visual cycle, the biochemical pathway responsible for rhodopsin regeneration. The visual cycle includes the production of 11-*cis*-retinal from retinoid and the subsequent regeneration of rhodopsin. Slowing of the visual cycle results in a prolongation of dark adaptation kinetics. Psychophysical dark adaptometry techniques and biological modeling of the resulting data have been highly developed and estimate the time constants associated with the visual cycle by measuring the recovery of light sensitivity after exposing the photopigment to an intense light that bleaches the photopigment (Alpern 1971, Barlow 1972, Hecht et al. 1937, Lamb & Pugh 2004, Rushton & Powell 1972). Research has shown that older adults experience substantial delays in adapting to darkness (Jackson et al. 1999), as shown in **Figure 2**, exhibiting an increase in the time constants for the second and third components of rod-mediated dark adaptation (Lamb & Pugh 2004, Leibrock et al. 1998), which signifies slowing in rhodopsin regeneration. Results obtained through rod densitometry (Liem et al. 1991) are consistent with the psychophysical findings. The dark adaptation delays faced by older adults are noteworthy (e.g., adjusting to a dark indoor environment after being outside on a sunny day; searching for an object in a dark closet or drawer). For example, the time taken for seventy-year-olds to reach prebleach light sensitivity is over 10 min longer than for those in their twenties. Slowed dark adaptation in older adults increases their risk for falls (McMurdo & Gaskell 1991) and the likelihood they report visibility problems at night (Owsley et al. 2006a,b).

Research on the aging retina suggests that slowed dark adaptation in older adults may stem from a number of aging-related changes in the retinal pigment epithelium (RPE)–Bruch's membrane complex, such as progressive thickening of Bruch's membrane (Bird 1992, Feeney-Burns & Ellersieck 1985, Newsome et al. 1987), accumulation of extracellular material including cholesterol between the RPE and Bruch's membrane (Curcio et al. 2001, Pauleikhoff et al. 1990), reduced hydraulic conductivity of Bruch's membrane (Starita et al. 1996), and changes in the structure of RPE cells (Kornzweig 1979). These changes likely compromise metabolic exchange by causing

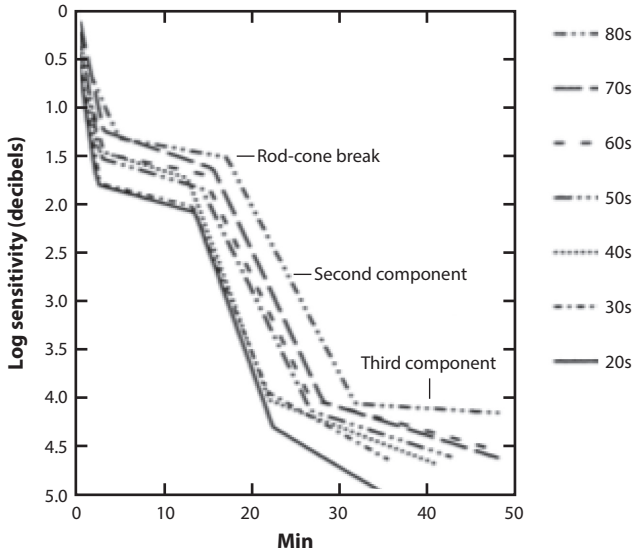

Figure 2

Dark adaptation as a function of decade of age during adulthood for persons in normal retinal health. The rod-cone break and the second and third components of rod-mediated dark adaptation are shown in the plot. Note that the functions shift to the right with increasing decade, indicating a slowing in the rate of rod-mediated dark adaptation during aging. Adapted from Jackson et al. (2002), with permission from Elsevier, copyright 2002.

a diffusion barrier between the choroid and photoreceptors, causing a localized scarcity of vitamin A, important for rod photoreceptor health (Dowling & Wald 1958, Kemp et al. 1988). A psychophysical experiment in older adults supports this explanation (Owsley et al. 2006a). Older adults' dark adaptation was measured before and after they received a 30-day, high-dose course of retinol (preformed vitamin A). Those receiving the retinol course had rod-mediated sensitivity recovery that was faster than that of a placebo-control group. Although this study does not provide direct evidence of an in vivo localized nutritional deficiency, it does highlight a possible pathway by which rod dysfunction and degeneration could occur during retinal aging and why dark adaptation is delayed in older adults.

As discussed above, older adults, even when in normal macular health, have delayed rod-mediated dark adaptation. A recent study showed that for some—approximately 20%—of these older adults, dark adaptation is severely delayed, much more so than the delay exhibited by their age-mates (Owsley et al. 2014). Interestingly, those older adults with severe dark adaptation delays were more likely to have several risk factors for age-related macular degeneration (AMD) (Owsley et al. 2014), specifically, elevated C-reactive protein (Seddon et al. 2004), a history of alcohol abstention or heavy use (Chong et al. 2008), and high blood pressure (Chakravarthy et al. 2010). Previous work also demonstrated that those older adults with early and intermediate AMD have exacerbated delays in rod-mediated dark adaptation compared to those in normal macular health (Dimitrov et al. 2008; Jackson et al. 2014a,b; Owsley et al. 2001a; Steinmetz et al. 1993). These findings lead to the question of whether delayed rod-mediated dark adaptation in older adults in seemingly normal macular health is a functional biomarker (i.e., a risk factor) for the development of early AMD. A prospective study (Owsley et al. 2016) enrolled a large sample of older adults ($N = 325$) in normal macular health (i.e., they did not have AMD in either eye). Rod-mediated dark adaptation was measured at baseline, and then the older adults were assessed three years

later for the presence of AMD. After adjustment for age and smoking (established and strong risk factors for AMD), those with abnormal dark adaptation at baseline were approximately two times more likely to have AMD by the time of the follow-up visit three years later, compared with those who had normal dark adaptation at baseline. These findings support accentuated slowing in rod-mediated dark adaptation as a functional biomarker for AMD, the leading cause of irreversible vision loss in older adults in the United States.

In summary, older adults, even when in apparently good eye health according to standard clinical diagnostic criteria, exhibit scotopic dysfunction. This dysfunction manifests itself as both a loss of steady-state light sensitivity under scotopic conditions and also as a delay in rod-mediated dark adaptation. Older adults notice these visual disturbances as evidenced by their citing them as visual problems in questionnaires and focus group discussions. In addition, their scotopic dysfunction interferes with their performance of everyday visual activities in low luminance environments. Those older adults whose delayed dark adaptation is particularly severe (approximately 20% of the population studied) also had other risk factors for AMD, the leading cause of blindness in older adults in the United States. Furthermore, those with these abnormal delays were twice as likely to have AMD several years later as compared to those without the abnormal delays, which suggests that this scotopic dysfunction is a functional biomarker for the future development of AMD.

4. VISUAL PROCESSING SPEED

The term visual processing speed refers to the amount of time needed to make a correct judgment about a visual target or event. These judgments can be made with reference to many types of visual tasks, including detecting the presence of a target, discriminating among targets, recognizing a target as familiar, identifying what a target is, indicating its spatial location, and making other types of decisions about complex events (Julesz & Schumer 1981; Neisser 1964, 1967; Sternberg 1969; Treisman & Gelade 1980). It was observed several decades ago that slowing in visual processing speed is one of the most robust behavioral phenomena of human aging (Birren & Fisher 1991). Deficits in many cognitive domains (e.g., working memory, visual attention, associative learning, executive function) in older adults otherwise in good health (i.e., free of diagnoses of eye disease and dementia) were associated with a slowing in visual processing speed (Salthouse 1991, 1995, 1996, 2004, 2005), leading to the conclusion that a generalized slowing in information processing during aging most likely played a significant role in many aging-related cognitive impairments. Yet it is important to emphasize that whether older adults actually experience visual slowing depends on a variety of task characteristics, such as stimulus configurations, task demands, consistency of response, and practice (Anstey et al. 2003, Ball et al. 1988, Cosman et al. 2012, MacDonald et al. 2003, Madden 2001), and thus, slowed processing speed in older adults is not inevitable and ubiquitous. In fact, there are wide individual differences among the elderly. Population-based research has shown that although some older adults exhibit slowed visual processing speed, others have rapid processing speed times (Owsley et al. 2013, Rubin et al. 2007), similar to those of young adults.

Older adults commonly report difficulties in visual tasks of everyday living that involve visual clutter, secondary task demands, and time sensitive responses (Ball et al. 1990a, Kosnik et al. 1988, Sloane et al. 1992). These difficulties often cannot be attributed to visual sensory impairment such that in many cases, the older adults citing these problems have normal visual sensory status. Over the past few decades, laboratory techniques for measuring visual processing speed under divided attention conditions and among visual distractors have been developed, particularly for use in research on older adults. Ball and colleagues (Ball et al. 1988; Edwards et al. 2005a,b, 2006; Sekuler & Ball 1986) have developed a commonly used visual processing test in aging research that

incorporates divided attention and visual distractors under brief stimulus conditions, which they termed "the useful field of view." They drew on prior work by Sanders (1970) on the "functional field of view" and Verriest and colleagues (Verriest 1983, 1985) on the "occupational field." Ball and colleagues (1988) defined the useful field of view as the spatial area over which useful information can be acquired rapidly without the use of eye or head movements (within one fixation). There is commercially available software for a version of the useful field of view test called UFOV®, but many laboratory-specific versions have been developed by individual investigators over the years.

Useful field of view tests usually have several component subtests, as summarized in detail elsewhere (Edwards et al. 2005a, 2006; Owsley 2013; Wood & Owsley 2014). Stimulus displays are presented for very brief durations (e.g., ≤500 ms), and targets are typically designed to be visible and discriminable even to persons with minor visual impairment (Owsley et al. 1995). The initial task consists of a center task only in which the observer is asked to simply discriminate whether the target presented at fixation was either of two targets. Target display duration is manipulated. The second subtest involves the same center task, but the observer is also presented a peripheral target simultaneously; in the most recent version of the test, peripheral targets are presented at 10° eccentricity. The observer is asked to not only perform the center task but also indicate the radial direction of the peripheral target, which could be located at any of eight radial directions. Subtest three is identical to subtest two except now the peripheral target is presented such that it is embedded in distracting stimuli (see **Figure 3** for an illustration). There is also a fourth subtest in the UFOV test software that is similar to the third subtest except the discriminability of the targets in the central task is more difficult. Performance in the current version of the commercially available software is defined as an observer's minimum duration for correct central

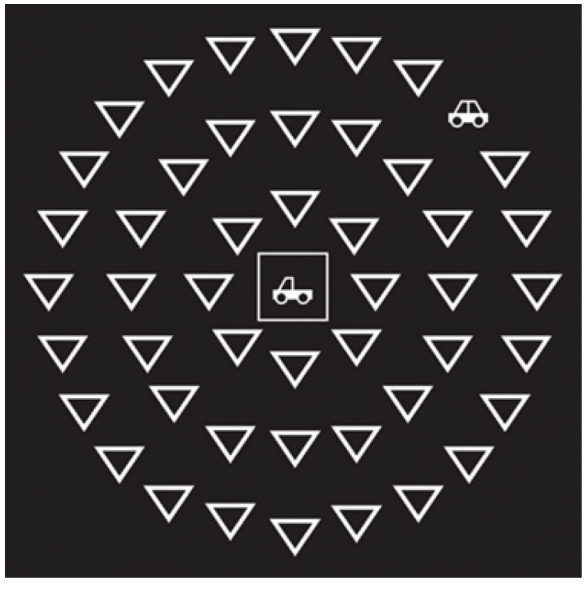

Figure 3

The stimulus display used in subtest three in useful field of view (UFOV®) testing. The participant's primary task is to identify whether the center target is a car or truck and also to identify the radial direction of the peripheral target (a car). The initial task consists of a center task only where the observer is simply asked to discriminate whether the target presented at fixation was either of two targets. The display contains an array of triangles serving as distracting stimuli. See text for more detailed information about useful field of view testing. The Visual Awareness Research Group Inc. has given permission to reprint the picture of subtest three of the UFOV.

task performance 75% of the time for each of the subtests, with thresholds ranging from 16.67 to 500 ms. Thus, visual processing speed is characterized by these minimum duration thresholds in each task. Many older adults have higher duration thresholds, signifying slower visual processing speed, although as mentioned earlier, there are wide individual differences among the older adult population.

The properties of the useful field of view are not fixed but depend on the situation (stimulus configuration and task demands). For example, its properties, such as the size over which the perceiver can rapidly respond, depends on the presence of a foveal stimulus—a more or less difficult task to perform at fixation—the presence or absence of visual distractors, and the distractor's similarity to the target of interest (Bergen & Julesz 1983, Bloomfield 1972, Drury & Clement 1978, Engle 1977, Ikeda & Takeuchi 1975, Leibowitz et al. 1955, Treisman & Gelade 1980, Williams 1982). Important for our discussion here is that compared to younger adults, older adults are more likely to be hampered (i.e., they need more time to make visual judgments) by brief stimulus presentations, the addition of secondary tasks, and distractors (Ball et al. 1988, Cerella 1985, Edwards et al. 2006, Plude & Hoyer 1981, Rabbitt 1965, Scialfa et al. 1987, Sekuler & Ball 1986).

What possible mechanisms underlie older adults' slowed visual processing speed in tasks such as the useful field of view? Older adults with slowed visual processing speed in tasks involving central target discrimination and peripheral target localization tend to also have problems with attentionally disengaging from a cued location (Cosman et al. 2011). This finding is consistent with other work that has highlighted aging-associated problems with disengaging and shifting attention (Castel et al. 2003). Other researchers have suggested that older adults' slowed visual processing speed in useful field of view tasks stems from inefficiencies in visual processing and visual search, thereby slowing processing speed, which thus increases the time needed to complete the task (Cosman et al. 2011, Lunsman et al. 2008, Owsley et al. 2000a, Seiple et al. 1996, Sekuler et al. 2000, Vance et al. 2007). Thus, contrary to how the underlying mechanisms were originally conceptualized (Ball et al. 1988, 1990b), older adults' fundamental problem in performing useful field of view tasks most likely does not stem from a constriction or shrinkage in the size of the attentional or functional field, but it is more likely because of inefficiencies in visual search and problems with attentional disengagement, which in turn slow the visual processing time needed to complete the task at hand. Thus, the evolution in the UFOV metric from the size of the useful field of view (as in the original work) to a visual processing speed metric (i.e., minimum duration threshold), in the more recent research, is appropriate (Owsley 2013).

Another explanation suggested for slowed visual processing speed in useful field of view tasks is that older adults' increased time needed to complete visual tasks, as compared to young adults' time needed, is attributable to differences in speed-accuracy trade-off (Ratcliff et al. 2000, 2001). In this view, older adults have longer response times when making decisions about visual targets because they are more concerned about accuracy and thus have a more conservative approach (i.e., they take more time to make a decision and respond). Although speed-accuracy trade-off differences between young and older adults may contribute to slower response times in older adults in laboratory paradigms where reaction time is the dependent measure, this explanation does not apply to tasks in which duration thresholds are the dependent measure and subjects can take as long as they would like to respond (Owsley 2013).

Slowed visual processing speed in older adults has been shown to be associated with a number of everyday visual task performance problems in older adults, even after adjustments for cognitive status and visual sensory deficits. Older drivers with slowed visual processing speed are at increased risk for motor vehicle collision involvement (Ball et al. 1993, 2006; Cross et al. 2009; Owsley et al. 1998a,b; Rubin et al. 2007); they also exhibit problems in on-road driving performance (Wood

et al. 1993) and driving tasks in a driving simulator (Rizzo et al. 1997). Slowed processing speed in older adults is also associated with a number of mobility and physical activity problems, including those related to ambulatory mobility (Owsley & McGwin 2004), limitations in the extent of travel into one's community (Stalvey et al. 1999), reduced participation in household and physical activity (Roth et al. 2003, Sims et al. 2000), an increased fall risk (Huisingh et al. 2014, Margolis et al. 2002, Sims et al. 1998), and increased time to perform visual activities of daily living (e.g., finding an item on a shelf) (Edwards et al. 2005b, Owsley et al. 2001b, 2002b). Furthermore, slowed processing speed is often observed in mild cognitive impairment (Bublak et al. 2011, Makizako et al. 2013), which is viewed as a transitional state from normal cognitive aging to Alzheimer's disease and other forms of dementia (Flicker et al. 1991, Morris et al. 2001).

In summary, slowed visual processing speed is a common problem in older adults, even when visual sensory status and cognitive status are normal. It has been estimated that approximately 25–30% of older adults have slowed visual processing speed (Owsley et al. 2013, Rubin et al. 2007). Research suggests that aging-associated visual processing speed slowing is attributable to inefficiencies in visual search and problems with attentional disengagement. Many everyday visual performance problems experienced by older adults, such as those experienced in driving and ambulatory mobility tasks, participation in physical activities, and the performance of everyday tasks in a time-sensitive fashion, stem at least in part from older adults having slow visual information processing speed.

5. CONCLUSIONS

In this overview of vision and aging, we have discussed three common visual problems that older adults typically experience—impaired spatial contrast sensitivity, scotopic sensitivity loss and delayed rod-mediated dark adaptation, and slowed visual processing speed. Although not all older adults will experience deficits in these visual functional domains to the same degree, most older adults are likely to experience one or more of these disturbances in vision. These visual deficits cause problems in the performance of everyday visual tasks, including reading, ambulatory mobility activities, and driving. In addition, in their more severe forms, these aging-related visual disturbances can be signs of the emergence of visual pathway conditions and diseases common in the elderly.

SUMMARY POINTS

1. Spatial contrast sensitivity impairment is a common and almost inevitable part of aging.
2. Contrast sensitivity deficits caused by cataract increase motor vehicle collision and fall risk, hamper postural stability, and reduce reading rate and accessibility.
3. Older adults exhibit visual dysfunction at night and under low luminance conditions, including a loss of steady-state light sensitivity under scotopic conditions and a delay in rod-mediated dark adaptation.
4. Older adults with serious delays in dark adaptation are at increased risk for age-related macular degeneration, the leading cause of irreversible vision impairment in older adults.
5. Slowed visual processing speed is a common problem in older adults, even when visual sensory status and cognitive status are normal.
6. Slowed visual processing speed in older adults is associated with increased risk for motor vehicle collision involvement, falls, and problems in performing everyday activities in a time-sensitive fashion.

FUTURE ISSUES

1. Can ophthalmic interventions, be they medical or surgical, improve contrast sensitivity or slow its progressive loss in older adults such that they experience improvements in the performance of the visual activities of daily living?
2. Can rod-mediated dark adaptation be a useful functional outcome measure when one is evaluating interventions to prevent age-related macular degeneration or slow its progression?
3. Are there training strategies to speed up visual processing in older adults that lead to practically significant gains, and not just statistically significant gains, in the visual performance of everyday tasks?

DISCLOSURE STATEMENT

Cynthia Owsley is a patent holder for the patent "Method and apparatus for the detection of impaired dark adaptation" (#20090153802, #20110007276, and #20110141437) and has received research funding support from Genentech.

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