28. Ageing and chromatic contrast sensitivity

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Abstract

Chromatic contrast sensitivity (chromatic CS) was measured for 40 subjects aged between 18 and 67 (mean = 37.1). Detection thresholds were determined for an equiluminant sinewave grating for which chroma was modulated along the protanopic axis (0.3–8.1 cpd, 1Hz counterphase modulated). An age-related reduction of chromatic CS was observed for all but the lowest spatial frequencies; i.e. for all spatial frequencies above 2.1 cpd. Age-related changes in spectral properties of the elderly eye were experimentally mimicked but did not reproduce the effects observed in elderly test subjects. Age-related neural changes are discussed.

Introduction

Luminance CS, like other visual performance, e.g. acuity, steropsis, has been shown to decrease with age (e.g. Owsley *et al.*, 1983; Sloane *et al.*, 1988; Tulunay-Keesey *et al.*, 1988). Such changes have been attributed to optical factors, e.g. senile miosis, changes in spectral transmittance of the ocular media, or scattering of the lens, as well as neural changes at the retinal and cortical levels (see Elliot *et al.*, 1990). However, the effect of age on chromatic CS has not yet been investigated, even though a number of studies have demonstrated a general loss in spectral sensitivity (e.g. Werner and Steele, 1988) and a tritanlike worsening in colour discrimination associated with ageing (Ohta and Haruo, 1975). Furthermore, it has been suggested that the parvoceullular pathway may be more affected by ageing than the magnocellular pathway (Elliot *et al.*, 1990; Porciatti *et al.*, 1992) and thus chromatic CS may be more affected by ageing than luminance CS. In order to determine the influence of ageing on chromatic CS, we measured the CS of differently aged observers for heterochromatic, equiluminant sinewave gratings at spatial frequencies between 0.3 and 8.1 cpd.

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Method

Observers

Observers were 40 healthy subjects between 18 and 67 years with no obvious colour vision deficiencies (tested with Ishihara plates and the Farnsworth-Munsell 100–hue test, and with normal or corrected-to-normal visual actuity. The observers were assigned to one of two groups: younger subjects, aged between 18 and 31 (n = 24, mean = 26.0 ± 4.7); and older subjects, aged between 40 and 67 (n = 16; mean = 53.7 ± 10.6).

Experimental apparatus

All experiments were performed in a darkened room. The stimuli for testing chromatic CS were generated on a computer controlled colour monitor using the Moorfield Vision System (Arden *et al.*, 1988). The colour monitor had a 0.31 dot-pitch resolution and was driven at 90 Hz by a graphic card with a 24-bit intensity variation of the primaries. The test program was provided by the computer-graphic software included in the system. Observers were placed 1.5 m in front of the monitor; their head position was not fixed.

Stimuli

The test-pattern was a vertical sinewave grating of 0.3–8.1 cycles per degree (cpd) square wave counterphase modulated at 1 Hz. It subtended 9.5 x 9.5 degrees of visual angle and was surrounded by a homogeneous background of mean luminance (26.5 cd/m^2) and mean chromaticity, both of which were kept constant throughout the experiments. The test-pattern consisted of equiluminous red and green stripes, whose chromatic contrast was varied by choosing colours from the protanopic confusion line. The chromaticities of the extreme colours of the confusion line were: $x_1 = 0.3471$, $y_1 = 0.4838$; and $x_2 = 0.3902$. In order to obtain equiluminance, the relative luminances of the RGB phosphors were first determined individually for each observer by heterochromatic brightness flicker photometry. Contrast was calculated as a percentage of the euclidian distance in the CIE XYZ colour space between the loci of the extreme colours of the protanopic confusion line.

In a second experiment, the effect of ageing on the spectral transmittance properties of the eye was simulated by filtering the stimuli through a long-wavelength filter (Kodak, Wratten No. 81 EF; Figure 1). The filter was placed in lens holders worn by the observers during the experiments. The effect of using this filter is indicated in Fig. 1 by the combined spectral absorbance (●) of the combined long-wavelength filter and a young lens (from Weale, 1988). The combined spectral absorbance is calculated as the log of the inverse of the product of the spectral transmittances of the filter and a younger lens (data taken from Fig. 1). For wavelengths above 400 nm it matches the spectral absorbance of an older lens (from Weale, 1988).

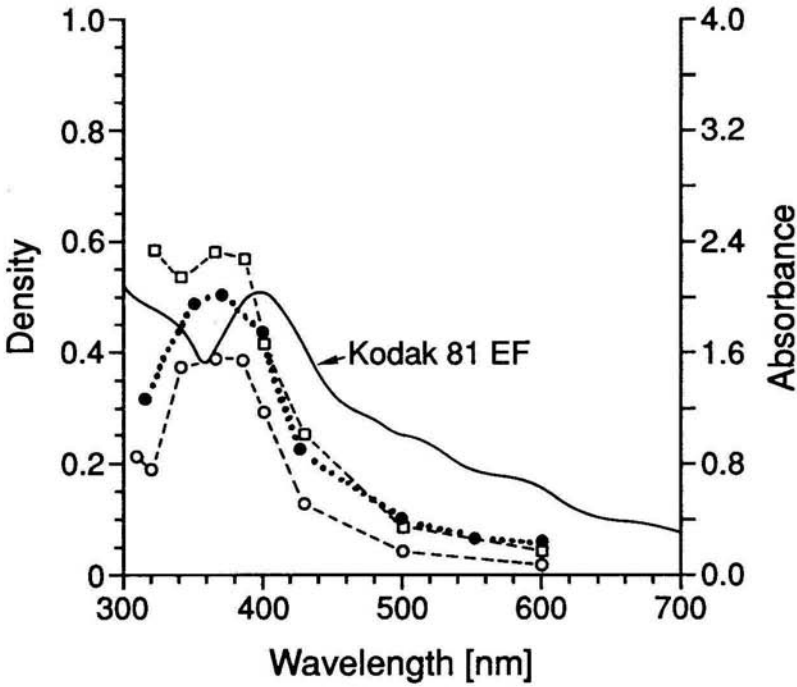

Fig. 1. Age mimicking long-wavelength filter (Kodak Wratten No. 81EF). Functions of spectral absorbance of the lenses of a 13-year-old (o) and a 63-year-old person (□) are marked by dashed lines (according to Fig. 1 in Weale, 1988). The spectral absorbance of the combined long-wavelength filter and younger lens is given by ●. Note that the left ordinate (density) refers to the long-wavelength filter, the right ordinate (absorbance) to the lenses and the combined long-wavelength filter and younger lens.

Experimental procedure

Each test session was preceded by a heterochromatic flicker photometry test. In the contrast experiments, chromatic contrast was determined by means of detection thresholds for the grating, which were measured in a double staircase manner. Threshold was defined as the contrast that allowed a 70% probability of correct answers (Arden *et al.*, 1988). All tests were performed binocularly and for central vision.

Results

The effect of ageing on chromatic CS is demonstrated in Figure 2 where contrast detection thresholds for a 4.1 cpd grating are given as a function of age. The curve has a correlation coefficient of 0.92. In Figure 3, the chromatic CS for spatial frequencies between 0.3 to 8.1 cpd is compared for a group of younger

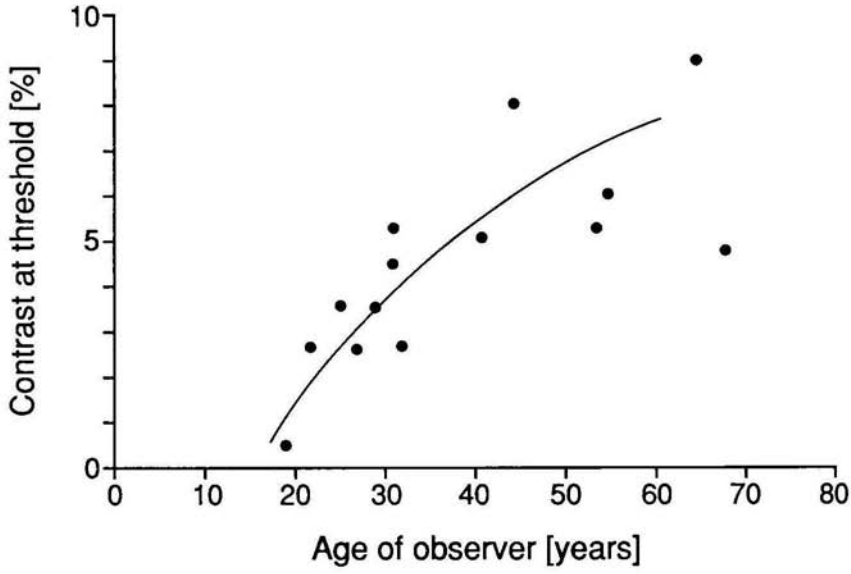

Fig. 2. Detection thresholds for a 4.1 cpd chroma modulated red/green sinewave grating (1 Hz counterphased) as a function of the observers age. Correlation coefficient = 0.92; regression coefficient = 0.67.

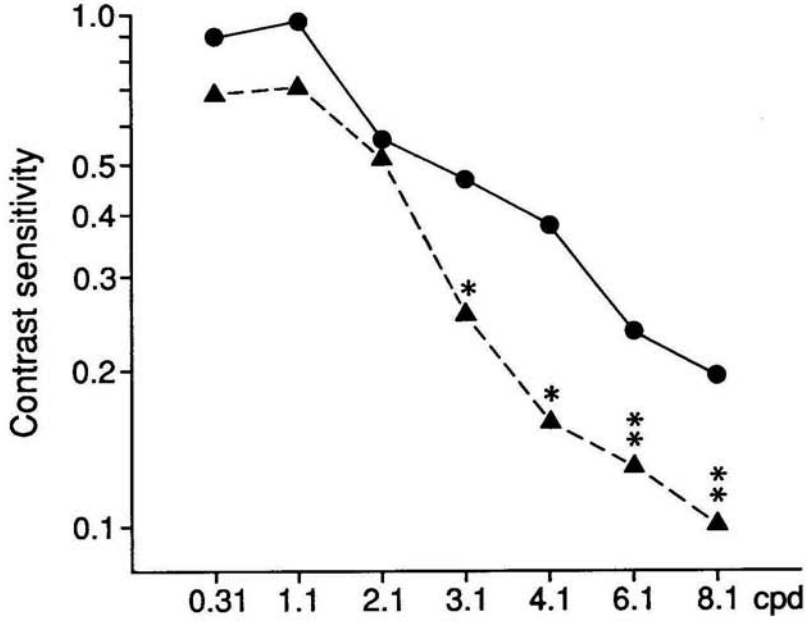

Fig. 3. Chromatic CS (1/threshold) for a chroma modulated red/green sinewave grating as a function of spatial frequency in observers aged between 18 and 31 (●; n = 14) and observers aged between 40 and 67 (▲; n = 8). Significant differences between the groups of older and younger observers are indicated by asterisks (t-test; ★★ for $p < 0.001$ and ★ for $p < 0.01$).

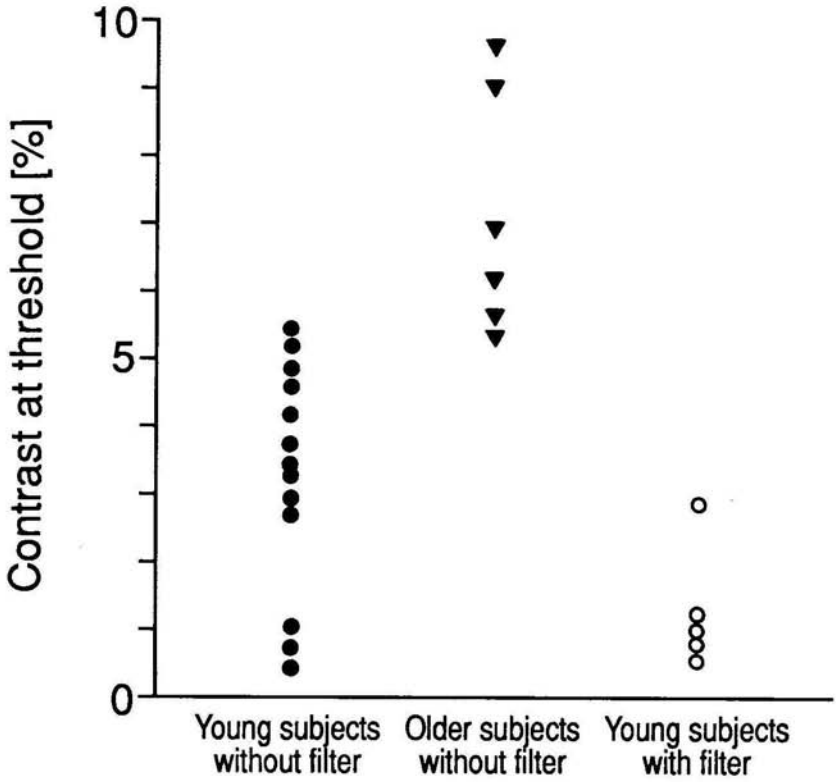

Fig. 4. Individual results for observers younger than 30 years with (○; n = 5) and without (●; n = 15) age mimicking long-wavelength filter. The results of observers older than 40 are also shown (▼; n = 8). Same experiment as described in Figs. 2 and 3.

(aged 18 to 31; ●) and older observers (aged 40 to 67; ▲). The chromatic contrast detection thresholds of the older group are significantly increased for all spatial frequencies higher than 2.1 cpd and the fall off of the function is steeper.

In order to simulate age-related changes in ocular spectral transmittances we had several observers, younger than 28 years, repeat the experiments while viewing the gratings through an age-mimicking longwavelength filter (see Fig. 1). As can be seen in Figure 4, chromatic CS is not reduced by this procedure.

Discussion

What is the possible origin of the observed age related decrease of chromatic CS (Figs. 2 and 3)? Retinal blur, caused by cataract or poor refraction, has been found to be a critical factor influencing luminance CS but not chromatic CS (Seim and Valberg, 1993). Reduced accommodation of the elderly eye cannot

account for a reduction of chromatic CS, since the distance between the monitor and the observers was 1.5 m which is beyond the accommodation range. Senile miosis, and the changed spectral properties of the optical media, reduce retinal illumination on average by 3 times (Weale, 1963) and lead to a decline in luminance CS. This is particularly so for higher spatial frequencies (Kulikowski, 1971; Owsley *et al.*, 1983). The observed reduction in chromatic CS in elderly observers may therefore be related to such changes in retinal illumination. However, our simulation of the aged optical media by means of a longwavelength filter in younger observers did not produce a similar reduction in chromatic CS (Fig. 4) and, therefore, the observed chromatic CS loss cannot be traced back to a decrease in retinal illumination in the aged eye. This is consistent with the observations of Owsley *et al.*, (1983) and Sloane et al., (1988) and suggests that additional neural changes must be taken into account. For example, a random cell loss within the visual pathway, as has been suggested by Weale (1975) for luminance CS loss, may also explain the pronounced chromatic CS loss at higher spatial frequencies. Chromatic CS reduction in the elderly may also be due to changes in transmitter efficiency as has been reported for the dopaminergic and GABA-ergic system (Carlsson and Winblad), 1976; Carlsson, 1987). It is interesting to note that luminance CS in elderly people can be enhanced by the dopamine agonist piribedil (Corbe *et al.*, 1992). Furthermore, impaired colour vision (Price *et al.*, 1992) and a similar selective reduction of luminance CS for medium and higher spatial frequencies, if modulated with 1 Hz temporal frequency (Bodis-Wollner, 1990), has been found in patients with Parkinson's disease. Further investigations should help clarify the relation between the level of dopamine/GABA and luminance and chromatic CS loss in the elderly.

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