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Functional and perceived benefits of wearing coloured filters by patients with age-related macular degeneration

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Background: The aim was to investigate the visual effect of coloured filters compared to transmission-matched neutral density filters, in patients with dry age-related macular degeneration.
Methods: Visual acuity (VA, logMAR), contrast sensitivity (Pelli-Robson) and colour vision (D15) were recorded for 39 patients (average age 79.1 ± 7.2 years) with age-related macular degeneration, both in the presence and absence of glare from a fluorescent source. Patients then chose their preferred coloured and matched neutral density transmission filters (NoIR). Visual function tests were repeated with the chosen filters, both in the presence and absence of glare from the fluorescent source. Patients trialled the two filters for two weeks each, in random order. Following the trial of each filter, a telephone questionnaire was completed.
Results: VA and contrast sensitivity were unaffected by the coloured filters but reduced through the neutral density filters ($p < 0.01$). VA and contrast sensitivity were reduced by similar amounts, following the introduction of the glare source, both in the presence and absence of filters ($p < 0.001$). Colour vision error scores were increased following the introduction of a neutral density filter (from 177.6 ± 60.2 to 251.9 ± 115.2) and still further through coloured filters (275.1 ± 50.8; $p < 0.001$). In the absence of any filter, colour vision error scores increased by 29.1 ± 55.60 units in the presence of glare ($F_{2,107} = 3.9$, $p = 0.02$); however, there was little change in colour vision error scores, in the presence of glare, with either the neutral density or coloured filters. Questionnaires indicated that patients tended to gain more benefit from the coloured filters.
Conclusions: Coloured filters had minimal impact on VA and contrast sensitivity in patients with age-related macular degeneration; however, they caused a small reduction in objective colour vision, although this was not registered subjectively by patients. Patients indicated that they received more benefit from the coloured filters compared with neutral density filters.

Key words: coloured filters, low vision, macular degeneration, tints, visual rehabilitation

Patients with age-related macular degeneration often experience problems with glare, which may be associated with a reduction in visual acuity (VA) and contrast sensitivity.[1] Glare is a phenomenon resulting from increased intraocular light scatter 'veiling luminance'. When it impairs function, this is referred to as disability glare, whereas when only subjective comfort is reduced, it is referred to as discomfort glare. Glare avoidance strategies, advocated for those with age-related macular degeneration, include the use of head coverings, sun visors and tinted spectacle lenses.[2]

There is some controversy as to how dependant intraocular light scatter is on wavelength.[3–6] Recent studies[3,4] confirm Rayleigh's principal that light of shorter wavelengths is scattered more by small particles than light of longer wavelengths. In less pigmented eyes, a red-dominated scatter component is added.[5] Many clinicians believed that low vision patients are generally more sensitive to scatter at the blue end of the spectrum and subsequently that prescribing short-wavelength absorbing filters (SWAFs) reduces the amount of intraocular light scatter.[7,8] Thus, these filters have the potential to reduce the effects of both disability and discomfort glare. Although some studies[9,10] have shown an improvement in contrast sensitivity with these filters, others have found that this only occurred at certain spatial frequencies,[11,12] under photopic conditions[13] and for specific task/background conditions.[14] Other studies have shown that coloured filters did not improve contrast sensitivity[15] and decreasing retinal illuminance reduces VA and contrast sensitivity.[16]

Several studies have investigated the effect of glare on visual functions, through SWAFs. Hammond and colleagues[17] found that glare disability was reduced when SWAFs were used. Neumaier-Ammerer and colleagues[18] concluded that photopic visual functions recorded through clear versus yellow IOLs, in the presence of glare, were similar but that under scotopic conditions, colour vision was reduced through yellow intraocular lenses. No study in the literature appears to have investigated the combined subjective and objective effects of adapting to SWAFs on visual functions in the presence of a glare source. The aim of this study was to compare objectively and subjectively the effect of prescribing, subjectively selected, coloured and transmission-matched neutral density filters on visual functions in patients with age-related macular degeneration.

METHODS

All review patients scheduled to attend the Low Vision Clinic at the Royal Victoria Hospital, Belfast, between July 2006 and January 2007, who were over the age of 50 years, had a primary diagnosis of stable (atrophic) age-related macular degeneration and whose VA had remained stable over at least the previous year were invited to participate in the study. The atrophic form of age-related macular degeneration included patients with both dry age-related macular degeneration and those with a disciform scar resulting from previous neovascular age-related macular degeneration. Patients with active neovascular age-related macular degeneration were excluded. Patients with a history of degenerative neurological conditions were excluded from the study. Those identified (n = 197) were sent a large-print information letter by post in advance of their low vision review appointment. This letter detailed the aims and objectives of the study and invited patients to take part. Of the 74 (38 per cent) who gave consent, 39 (53 per cent) self-reported at least moderate discomfort glare symptoms, had stable vision and were deemed fully eligible to take part in the study. The average age of the patients was 79.1 ± 7.2 years (range 61–94 years) and the majority (n = 28, 72 per cent) were female. Eight subjects (21 per cent) were severely sight impaired (VA of 1.3 or worse logMAR) and three (eight per cent) sight impaired (VA 0.6 or less to 1.0 logMAR).[19]

Binocular baseline visual function data comprising of VA (at 3.0 metres using the Bailey–Lovie logMAR Chart), contrast sensitivity (at 1.0 metre using the Pelli-Robson Chart) and colour vision (at 50 cm in a D65 light box, using the Jumbo D15) were recorded both in the presence and absence of a glare source. The ambient indoor lighting was fluorescent.

Colour vision error scores were calculated using a standardised D15 scoring method.[20] A higher score indicates poorer colour vision. Subjects wore their distance prescription for all visual function measurements. The glare source was provided by an angle-poised lamp (IBJ Danmark model 871), positioned such that the fluorescent strip bulb was parallel to the plane of the subject's face at a vertical elevation of 10° for all clinical tests. This glare source had a luminance in excess of 20,000 cd/m^2. In the case of VA and contrast sensitivity, the lamp to eye distance was one metre, whereas to facilitate work within the light box, the distance was reduced to 30 cm for colour vision testing.

Following the collection of baseline data, a range of coloured filters (green, amber, orange and yellow) of medium spectral transmission (NoIR light transmission filters [LTF], NoIR Medical Technologies, South Lyon, MI, USA) were trialled in random order inside the clinic. These colours were chosen, based on the results of a pilot study conducted by the authors and following a review of previous studies on filter colours.[7,9,11,13–15,21–22]

Subjects were given the opportunity to trial the filters both indoors and outdoors, (although it was not possible to standardise for weather conditions) prior to selecting their preferred colour. Having chosen their preferred filter colour, subjects were presented with three filters of identical hue, of high (53.0 ± 2.4 per cent LTF) medium (20.4 ± 4.5 per cent LTF) and low (8.6 ± 1.8 per cent LTF) spectral transmission (measured using a Cary 2300 spectrophotometer between 400 and 700 nm, Table 1). Subjects were provided with their filter colour and intensity of choice and a transmission-matched neutral density filter. Binocular VA, contrast sensitivity and colour vision measures were repeated in the presence and absence of a glare source, through the preferred colour filter and the matching neutral density filter. VA and contrast sensitivity charts consisting of different letter combinations were used for each assessment to minimise learning effects.

Subjects were provided with a pair of filters (neutral density and coloured) for a four-week period and advised to use them in the order specified for two periods of two weeks according to a randomised cross-over design. The filters (both coloured and neutral density) took the form of wrap-around non-prescription shades with a brow bar and side shields. The best fitting frame was selected from the two sizes available, achieving an acceptable fit in all subjects and allowing any habitual refractive prescription to be worn beneath. They were instructed to wear the filters in a variety of situations, such as indoors, outdoors, in cars and in shops. The second pair of filters were not revealed to the patient until after the telephone questionnaire on the first pair had been completed at the end of the initial two weeks.

The telephone questionnaire (Table 2) conducted by a masked researcher consisted of questions relating to daily living activities graded on an ordinal scale. The questions used were based on questions relevant to filter use and glare from existing quality-of-life questionnaires.[14,23,24]

A three-way analysis of variance (ANOVA) mixed model of the effect of filter type and the presence of glare was performed on all VA, contrast sensitivity and colour vision data (SPSS v15: SPSS Inc., Chicago, IL, USA). Wilcoxon signed rank tests were performed on subjective telephone questionnaire data.

All study procedures were approved by the local research ethics committee and adhered to principals inherent in the Declaration of Helsinki. Informed consent was obtained from all patients prior to participation, after explanation of the nature and possible consequences of the study.

RESULTS

Almost half of the subjects expressed a preference for an amber filter (46.2 per cent chose this colour). Of all the subjects who chose the amber colour, 77.8 per cent chose medium intensity (Table 1).

The results for VA, contrast sensitivity and colour vision measures recorded through coloured filters, the neutral density filters and in the absence of any filter are presented in Table 2. VA and contrast sensitivity through the chosen coloured filter (Table 2) were similar to those recorded without any filter but were reduced by the matched neutral density filters ($F_{2,68} = 5.8$, $p = 0.005$; $F_{2,75.23} = 22.8$, $p < 0.001$, respectively). Following the introduction of a glare source, VA scores decreased by an average of 0.05 ± 0.01 logMAR ($p < 0.001$) under all three conditions, correlating to a 2.5 letter loss on the logMAR chart. The introduction of a glare source also resulted in a marked reduction (0.22 ± 0.10 log units) in contrast sensitivity in all three groups ($F_{1,160} = 109.7$, $p < 0.001$).

Mean colour vision error scores were increased by the neutral density filter

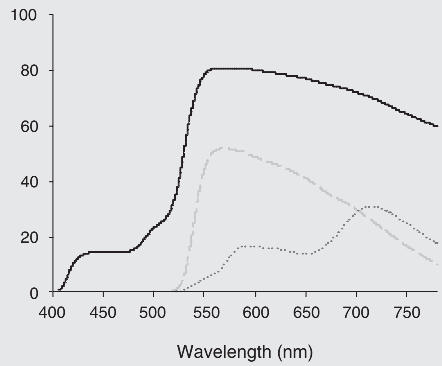
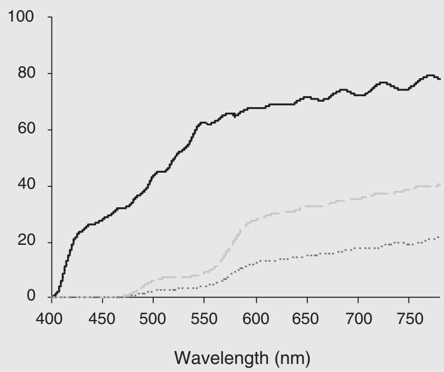
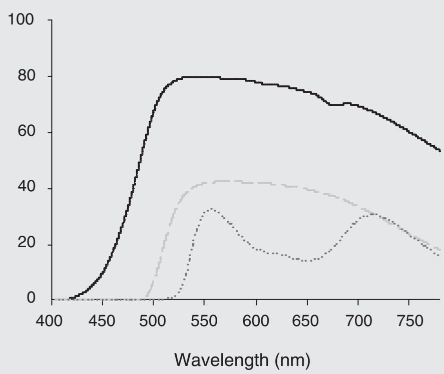
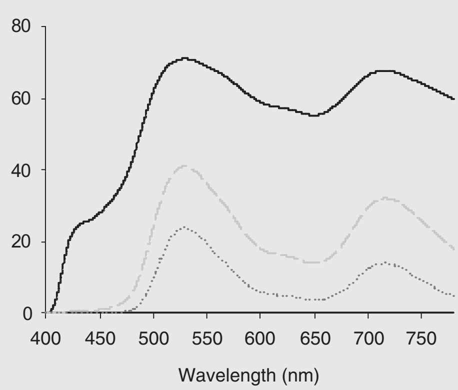
Filter transmission		Number of patients preferring
50.9% (high) 23.6% (medium) 8.1% (low)		7 5 0
51.6% (high) 15.3% (medium) 7.1% (low)		3 14 1
55.7% (high) 24.7% (medium) 11.8% (low)		2 1 2
51.4% (high) 17.8% (medium) 7.6% (low)		0 3 1

Table 1. Spectral transmission characteristics of the four coloured filters used in this study. The three lines (upper—solid black, medium—dashed grey and lower—dotted dark grey) on each graph illustrate the spectral characteristics of the three different filter transmissions available in each colour. The numbers on the left indicate the mean spectral transmittance for each filter, whereas those on the right identify the number of patients who specified a preference for individual filter types.

compared to no filter and reduced further by the coloured filters ($F_{2,107} = 122.7$, $p < 0.001$). Bland–Altman analysis demonstrates marked inter-subject variability (Figure 1). The introduction of a glare source had minimal effect on colour vision results recorded through either a neutral density or coloured filter; however, under unprotected (no filter) conditions, colour vision error scores increased by 29.1 ± 55.6 units, when a glare source was introduced ($p = 0.02$, $F_{2,107} = 3.9$).

The coloured filters provided the greatest benefit when distinguishing facial features, making objects stand out from one another, moving from a dark to a bright environment, watching television and participating in outdoor activities; however, coloured and neutral density filters hindered vision for reading tasks and crossing the road on a bright day (Table 3). On questioning, no patient reported a disturbance of colour vision with either filter.

DISCUSSION

This study has shown that coloured filters, which absorb visible light of particular wavelengths, are superior to corresponding neutral density filters of matching transmission. They are able to reduce discomfort glare in those with age-related macular degeneration without affecting either VA or contrast sensitivity. As expected, differential absorption across the visible spectrum causes colour vision to be distorted.[21,24,25] This was partly due to the reduction in spectral transmission as the neutral density filters also affected colour perception.

Interestingly, when colour vision was examined in the presence and absence of glare, the introduction of the glare source

	Visual acuity (logMAR)		Contrast sensitivity (log units)		Colour vision (total error score)	
Filter	Without glare	With glare	Without glare	With glare	Without glare	With glare
None	0.75 ± 0.39	0.80 ± 0.33	0.96 ± 0.34	0.69 ± 0.50	177.60 ± 60.20	206.70 ± 58.60
Coloured	0.77 ± 0.32	0.82 ± 0.31	0.92 ± 0.34	0.72 ± 0.37	275.10 ± 50.80	273.50 ± 58.60
ND	0.87 ± 0.37	0.91 ± 0.33	0.70 ± 0.44	0.52 ± 0.41	251.90 ± 115.20	262.70 ± 59.50

Table 2. Mean (±1 S.D.) visual acuity, contrast sensitivity and colour vision total error scores with and without a glare source for the no filter, coloured and matched neutral density (ND) filters, n = 39

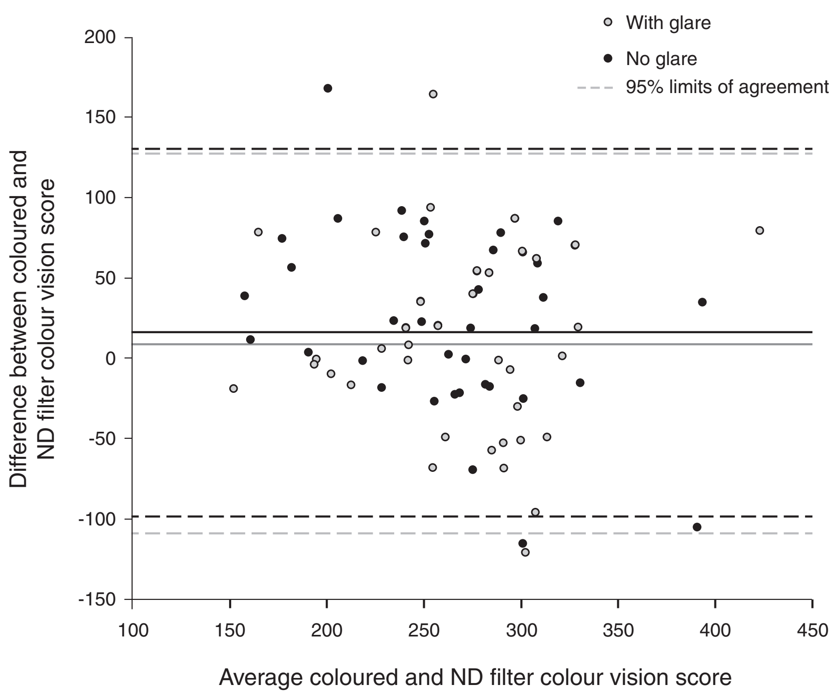


Figure 1. Comparison of the colour vision error score, when subjects wore their preferred coloured filter compared to the equivalent transmission neutral density filter, n = 74

did not significantly affect the colour vision error score, when either the coloured or ND filters were worn. This finding suggests that, although both filters reduced the subjects' colour discrimination, their ability to reduce light scatter prevented further colour deterioration, when a glare source was added.

Subjectively, patients did not report colour distortion effects with the coloured filters and preferred the tinted lenses to the matched neutral density filters. There may have been some neural adaption to the colour distortion noted on the clinical test, when the lenses were initially trialled. It would have been interesting to measure the colour distortion again clinically at the end of the two-week trial to determine whether the colour error score also improved.

Although no improvement in visual function was observed clinically, the ability of the coloured filters to reduce discomfort glare without actually degrading image quality made them the favourable choice. The statistically significant change in VA (of 0.05 logMAR, $p < 0.001$), equivalent to 2.5 letters, was smaller than the variability of repeated measurements of VA previously reported by Kiser and colleagues[26] and as such the clinical significance could be questioned. Leat, North and Bryson[3] similarly concluded that improved clinical performance is not essential for subjects to gain improved comfort. Eperjesi, Fowler and Evans[27] reviewed the literature on tinted lenses in low vision and observed that few studies have related objective and subjective results.

While patients generally preferred the coloured filters compared with transmission-matched neutral density filters, a baseline quality-of-life questionnaire would have allowed the magnitude of the benefit to be compared to habitual visual satisfaction. Compliance with filter use was not specifically examined, as the purpose of the study was to directly compare SWAFs and neutral density filters. The filters used in the current study cover those previously shown to benefit patients with age-related macular degeneration[11,14] but other tints may be of benefit to specific patients. The indoor lighting used for testing was fluorescent. Although this may have had an impact on initial filter choice, it could be considered to be realistic to low-vision filter prescribing in a clinical setting.

The current study differs from previous studies, as it attempted to assess the potential benefits of coloured lenses compared to neutral density transmission-matched filters, binocular objective and subjective assessments of vision, patients with age-related macular disease and real-world adaptation to filter introduction. These differences are likely to account for the more defined benefits of coloured filters found compared to some previous studies; however, patients should always be warned of the reduction in light reaching the retina when wearing filters.[4] The subjective rating of the benefits and limited range of colours and transmissions selected in this study (Table 3) open the potential for clinicians to offer discomfort and disability glare protection to patients with age-related macular degeneration as part of their standard package of care.

	Coloured filter	ND filter	Significance
How much have the filters helped with: Greatly (4), Slightly (3), Not at all (2), Worse (1):			
Distinguishing facial features	2.70 ± 0.81	2.35 ± 0.92	0.03
Making objects stand out from one another	3.00 ± 0.78	2.65 ± 0.92	0.05
Comfort on bright sunny days	2.80 ± 1.10	2.60 ± 1.00	0.47
Comfort when moving from a dark to a bright room	3.20 ± 1.20	2.90 ± 1.10	0.04
Vision when moving from a dark to a bright room	3.00 ± 1.00	2.60 ± 1.10	0.02
Vision when moving from a bright to a dark room	1.90 ± 1.00	1.50 ± 0.70	0.04
How did the filters affect your ability to: Much easier (5), Easier (4), No difference (3), Difficult (2), More difficult (1):			
Watch television	3.11 ± 1.85	2.35 ± 1.86	0.04
Read indoors	1.57 ± 1.19	1.54 ± 1.19	0.56
Read outdoors	1.59 ± 2.13	0.30 ± 0.97	1.00
Shopping	1.59 ± 2.13	1.62 ± 2.15	0.71
Crossing road on a bright day	2.43 ± 2.33	1.32 ± 1.99	0.24
Do outdoor activities	4.60 ± 0.80	3.90 ± 1.50	0.01

Table 3. Telephone questionnaire and response average, standard deviation and significance (Bonferroni correction for multiple Wilcoxon test p < 0.005). The significance values relate to the difference in rating between the coloured and neutral density (ND) filter.

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