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Do tinted lenses or filters improve visual performance in low vision? A review of the literature

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Abstract

This is a review of studies that have investigated the proposed rehabilitative benefit of tinted lenses and filters for people with low vision. Currently, eye care practitioners have to rely on marketing literature and anecdotal reports from users when making recommendations for tinted lens or filter use in low vision. Our main aim was to locate a prescribing protocol that was scientifically based and could assist low vision specialists with tinted lens prescribing decisions. We also wanted to determine if previous work had found any tinted lens/task or tinted lens/ocular condition relationships, i.e. were certain tints or filters of use for specific tasks or for specific eye conditions. Another aim was to provide a review of previous research in order to stimulate new work using modern experimental designs. Past studies of tinted lenses and low vision have assessed effects on visual acuity (VA), grating acuity, contrast sensitivity (CS), visual field, adaptation time, glare, photophobia and TV viewing. Objective and subjective outcome measures have been used. However, very little objective evidence has been provided to support anecdotal reports of improvements in visual performance. Many studies are flawed in that they lack controls for investigator bias, and placebo, learning and fatigue effects. Therefore, the use of tinted lenses in low vision remains controversial and eye care practitioners will have to continue to rely on anecdotal evidence to assist them in their prescribing decisions. Suggestions for future research, avoiding some of these experimental shortcomings, are made.

Keywords: adaptation, age-related macular degeneration, colour vision, contrast sensitivity, filters, glare, low vision, photophobia, retinitis pigmentosa, rehabilitation, tinted lenses, visual acuity, visual field

Introduction

Tinted lenses are currently used by eye care practitioners to assist people with low vision in maximising use of residual vision, improve visual function, control glare and improve orientation and mobility skills. Tinted lenses are often prescribed to people with various ocular diseases, including age-related macular degeneration (ARMD), retinitis pigmentosa (RP), cataract, diabetic retinopathy, cone dystrophy and oculo-cutaneous albinism. This review will concentrate on studies that have investigated the use of tinted lenses in the rehabilitation of people with visual loss, and highlight areas where more research would be useful. Proposed effects of tinted lenses on progressive eye disease (especially RP) are controversial and will not be discussed here.

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Terminology

Terminology in this field can be confusing. The following definitions are after Millodot (1999). Glare-a visual condition in which the observer feels either discomfort and/or exhibits a lower performance in visual tests. Photophobia-abnormal fear or intolerance to light. Dark adaptation-adjustment of the eye such that after observation in the dark, sensitivity to light is greatly increased. These meanings will be used in the discussion and conclusions sections of this paper, however, it is not possible to determine how these terms were interpreted by the investigators of the various studies described.

Commercially available tinted lenses

Corning photochromic filters

The optical division of Corning Glass developed the Corning photochromic filters (CPF®) range, which is considered by some practitioners to be the gold standard for use in low vision rehabilitation. These tints have been designed, and are marketed specifically, to improve the comfort and visual performance of visually impaired people who suffer from a range of ocular disorders. The tints evolved from research in the late 1970s investigating the possible detrimental effects of visible light on the ocular system.

According to Corning marketing literature, 'short wavelength light has been shown to cause visual discomfort, hazy vision, reduced contrast and prolonged adaptation times'. It is implied that CPF®s can alleviate some or all of these effects by filtering out blue light in the visible portion of the spectrum, 'at the wavelengths that create problems for the photophobic or ageing eye'. They are designed to filter short wavelength light of solar and artificial origin.

A base borosilicate, photochromic glass is used in the manufacturing process. This goes through a firing treatment that changes the chemical structure of the silver halide crystals at the surface of the lens. The tint produced by this 'chemtempering technique' is independent of thickness and is even across the lens surface. A prescription can be ground on to the surface and the lens glazed into a spectacle frame.

There are currently six CPF®s, marketed under the Glare Control trademark (Corning SA, Division Optique, 77167 Bagneaux-sur-Loing, France) each with a different wavelength cut-off level: CPF®450, CPF®511, CPF®527, CPF®550, CPF®527X (improved colour rendition and better cosmetic appearance than the standard CPF®527) and the CPF® GlareCutter™ (improved colour rendition compared with the other filters). The number corresponds to the wavelength in nanometers, above which light is transmitted. See *Table 1* for CPF® characteristics.

Corning recommend certain filters for certain tasks and for certain eye conditions. For example, CPF®450 is recommended for indoor use, for reading, watching TV, VDU and office work, for 'hobbyists' and as a shopping aid; CPF®511 and CPF®527 'have been found to be of benefit by many people who experience visual problems associated with cataract or macular degeneration'. The CPF®s can be glazed into a spectacle frame, with or without side-shields and in a variety of lens forms and materials (see *Table 2* for details). Corning advise that prospective users are given enough time to test the filters and recommend the use of a plano, fixed-tint, plastic clip-on to give the user experience with all the filters, both in and outdoors over a trial period. There are several CPF® facsimiles that are claimed to perform in a similar way to CPF®s, but none have as yet been scientifically appraised.

UVShield® and NoIR® filters

NoIR Medical Technologies (South Lyon, MI, USA) market two types of filter for use in low vision; the UVShield® and the NoIR® filter. According to the

Table 1. Transmission details for CPF® range (from Corning marketing material)

	CPF®450	CPF®511	CPF®527	CPF®550	CPF®527X	GlareCutter™
Wavelength cut-off (nm)	450	511	527	550	–	–
% Light transmission (lightened state)	67	44	32	21	33	18
% Light transmission (darkened state)	19	14	11	5	15	6
Absorption % in darkened state						
Minimum UVB	100	100	100	100	100	100
Minimum UVA	97	98	98	99	98	98
Blue light	95	98	98	98	98	98

Table 2. CPF lens forms, power ranges and materials (from Corning marketing material)

Lens form	Refractive index	Spherical power range (DS)	Cylindrical power range (DC)	Addition (DS)
Single vision	1.50 glass	+6.00 to –8.00	Up to 4.00	–
Single vision	1.80 glass	+6.00 to –23.00	Up to 4.00	–
C28 bifocal	1.50 glass	+6.00 to –8.00	Up to 4.00	0.75–4.00
Progressive	1.50 glass	+6.00 to –8.00	Up to 4.00	0.75–3.50
Fixed tint clip-on	1.50 plastic	Plano	Plano	–

manufacturer's marketing literature, the UVShield® provides protection for 100% UV and visible light and the NoIR® filter eliminates near infrared, 100% UV and 'provides visible light protection, for maximum eye comfort'. At the time of writing there are 22 UVShields® and 12 NoIR® filters. Constructed from polycarbonate, they retain their original shape and will not stretch or deform with use. Supplied in large fitover moulded form, with wide temples that double as side-shields, and made from the same material with the same colour as the front. The design helps to shield the eyes from light incident from above and that reflected from below and allows a wide field of view. During the manufacturing process an ultraviolet and infrared absorbing chemical is blended with polycarbonate before it is moulded into the final product. A hard-coated version is available.

From discussions with several low vision specialists, it seems that the current mode of determining whether tinted lenses will be of benefit to a particular person is to have a brief indoor clinic based trial, with a plano plastic fixed tint CPF® clip-on or a UVShield® or NoIR® fitover. An objective improvement in visual acuity (VA) or contrast sensitivity (CS) is tested for, and a subjective opinion obtained from the user in terms of effect on glare and photophobia. This is usually followed by an outdoor trial, where emphasis is placed more on subjective opinion rather than any objective measures. For those subjects that demonstrate a clinic based objective or subjective benefit, CPF® plano plastic clip-ons are loaned for a more prolonged real world trial period of 3 to 6 weeks. If after the real world trial a CPF® is deemed beneficial by the user, the option is given of having this made up as a prescription spectacles with glass CPF®s or purchasing a plano clip-on. With UVShield® and NoIR® fitovers, because the cost to the person is relatively lower, these are usually supplied immediately following a successful clinic based indoor or outdoor trial. Some eye care practitioners consider the supply of tinted lenses in this non-scientific manner unsatisfactory. This review of the literature was conducted to determine if other, more scientific approaches had been described and could be adopted for clinical practice.

Method of literature search

Literature selection for this article was based on a MEDLINE search covering the past 30 years for all articles, using key word combinations including low vision, tinted lenses, filters, eye disease, glare, photophobia, adaptation, CPF, UVShields®, NoIR®, coloured lenses and luminance. The database search produced several papers that described investigations into the use of tinted lenses as a method of improving visual function in low vision. The reference lists of these papers were then hand searched for other relevant items. Here, studies have been divided into those that used mainly objective outcome measures and those that used mainly subjective outcome measures in the determination of effects of tinted lenses on visual performance. Those studies with an objective outcome measure have been further divided according to the measure used, for example, the effect of tinted lenses and filters on VA.

Objective outcome measures

Visual acuity

The literature search located six papers that reported a positive effect of tinted lenses on VA. Lynch and Brilliant (1984) compared the effects of CPF®550 and a 20% transmission neutral density (ND) filter on the VA of 16 RP subjects. CPF®550 improved VA in 24 eyes, one decreased, and in seven it remained unchanged. Eight eyes that had improved VA with the ND filter had even greater improvement with the CPF®550. Improvements were significant at the 0.01 confidence level using the correlated *t*-test formula. Similarly, Tupper *et al.* (1985) found that tinted lenses could improve VA in low vision. They assessed the effects of CPF®550 on VA for 39 cataractous eyes; VA was determined first without a filter, with CPF®550 alone, with CPF®550 and an overlying sheet of translucent dark red acetate with a central 6.5 mm clear hole, and finally with the aid of the red acetate alone. Tests were conducted with and without a glare source. In the non-glare situation subjects with cortical spokes, nuclear sclerosis, or both, averaged a 15% increase in VA with CPF®550, which increased to 40% when the dark red acetate filter with a 6.5-mm viewing aperture was added. With the glare source, those with cortical, nuclear, combined and posterior subcapsular changes demonstrated a 70% improvement with the CPF®550 alone, and 95% when used with the red overlay. As well as increasing letter contrast, Tupper *et al.* postulated that as CPF®550 transmitted only 21% of incident light, the retina received less light, causing the pupil to dilate, enabling subjects with central opacities to view around the obstruction. The red acetate probably worked by filtering peripheral extraneous light.

Leat *et al.* (1990) also included a glare source to assess the effects of tinted lenses and filters on visual performance for 44 low vision subjects (various pathologies). Grating acuity was measured with and without filters (CPF®550, CPF®527 and CPF®511 and various ND filters) and then with and without a glare source. Under non-glare conditions, 48% of subjects showed no improvement with CPF®s or ND filters, 20% improved with both types of filter, 27% improved with CPF®s but not with the ND filters. Only 4.5% showed an improvement with the ND filter alone. It was concluded that subjects with an anterior segment or preretinal component to the ocular condition are most likely to benefit from the use of short-wavelength filters, probably because of a reduction of the abnormal scatter of these wavelengths within the eye. Both Tupper *et al.* (1985) and Leat *et al.* (1990) demonstrated that a glare condition could isolate more people who may benefit from tinted lenses or filters. However, Van den Berg (1990) noted that a red filter (no other details provided) did not decrease light scatter when compared with white light or green filters for one RP subject with cataract. Similar results were found for other RP subjects and for those with just cataract. The use of a red filter to decrease intraocular light scatter was not indicated.

Van den Berg (1990) noted that red glass filters (no other details provided) resulted in an improvement in VA for 18 RP subjects. Tests were performed monocularly, with and without a preferred red filter. Learning and fatigue effects were controlled by assessing VA without a filter, with a filter, and again without. Zigman (1990) found VA improved for all five low vision subjects (ARMD or cataract) in his study when using a polycarbonate filter with absorption below 480 mm (no other details provided). Four age-related normal controls also demonstrated a one line VA improvement with the filter. Rosenblum *et al.* (2000) developed four tints and noted their effects on visual performance for a variety of ocular conditions. Fifteen adult subjects with cataract were assessed with a yellow filter (50% transmission at 490 nm), 13 aphakic subjects with a second yellow filter (50% transmission at 445 nm), 42 subjects who had oculo-cutaneous or oculo albinism with an amber filter (17% transmission at 560 nm) and 27 subjects with congenital macular dystrophy were assessed with an orange filter with transmittance above 520 nm (percentage transmission at this wavelength not given). Monocular VA increased with the yellow lenses by 43% for the cataract group, 12% for those with albinism, 19% for the aphakics and 11% for those with congenital macular dystrophy. The authors suggested that VA improved with the filter in aphakia by reducing chromatic aberration; in congenital macular dystrophy by a reduction in photophobia and for those with albinism by a reduction of intraocular light scatter. The main conclusions drawn from the study were that filters could have a positive effect on visual function associated with ocular disease and that each type of ocular pathology probably required a filter with a specific spectral absorption curve.

Seven papers were located in the literature that reported neutral or negative effects of tinted lenses and filters on VA in low vision. Bailey *et al.* (1978) assessed monocular reading acuity (RA) and reading speed (RS) using Bailey–Lovie near word reading cards for nine subjects with cataract, and nine normal subjects with simulated cataract. Different near charts with the same features but containing different words were used to prevent learning effects. Six yellow filters were used: Roscolene theatrical lighting filters (nos 805 and 806) placed as overlays on the transilluminated charts; a yellow trial case lens of unidentified origin; Kodak Wratten filter no. 21 placed in Halberg clips mounted over spectacle lenses; NoIR® fit-over (no model details provided); amber slip-in filters (no other details provided). Trials were also conducted with three ND filters (75, 50 and 12.5% transmission). All subjects read aloud with each filter in turn and the time taken to complete a line of six words at each size level was noted. Cataract subjects in general demonstrated a small reduction in RA with all filters, but this was not statistically significant at the 95% confidence level (apart from the NoIR® filter). The simulated cataract group showed a statistically significant decrease in RA for all but the Roscolene no. 805 filter at the 95% confidence level; the greatest decrease occurred with the NoIR® filter. The ND filters all produced a reduction in RA for both groups. By comparing reductions produced with the ND filters to those with the yellow filters, both averaged and individual data showed that the yellow filters marginally reduced RA because of the reduced illuminance rather than because of their colour.

Silver and Lyness (1985) attempted to ascertain whether 27 RP subjects who experienced ‘light related problems’ preferred to wear red photochromic lenses rather than lenses with broadly similar fixed tints. They used a single-masked randomised controlled trial. Each subject was supplied with both filters and initial preference was recorded. Subjects used one filter for 2 weeks for as much as possible and then the second filter for a further 2 weeks; the order of use was randomised. For those who preferred the red photochromic filter there was no objective VA improvement over the fixed tint, although there was often a reported subjective improvement. A second study was conducted and the photochromic lenses were matched with surface tinted, plastic lenses that had a similar appearance to the red photochromic lenses. Fourteen disliked both, 12 preferred the red photochromic filter, 25 the surface tinted plastic and two were happy with either. It was concluded that although there was no objective improvement in VA, overall subjects preferred some sort of filter.

Barron and Waiss (1987) measured VA for 53 low vision subjects (various pathologies) and 50 age and gender-matched normal subjects, using CPF®527, a 40% transmission ND filter (transmission similar to the lightened CPF®) and a clear plano lens. Visual acuity was measured for a random order of presentation of CPF®527, ND filter, and plano lens. A correlated *t*-test indicated that there was no significant difference in the average VA obtained with CPF®527 and the clear plano lens (ANOVA, $p = 0.01$). A *t*-test also showed that the average VA with the ND filter was significantly less than with CPF®527 for both groups (ANOVA, $p < 0.01$). The results of a Pearson correlation test demonstrated that CPF®527 had no selective effect on VA for any particular ocular pathology (CPF vs VA, $r = 0.99$). It was concluded that a subjective impression of better vision with CPF®527 might not be equivalent to the conventional definition of VA as measured with a high contrast and high spatial frequency optotype chart. Furthermore, Bremer *et al.* (1987) found that VA for five subjects with cone dystrophy did not improve after 1 month of CPF®527 use. However, one subject increased RA from (Jaeger) J3 to J2 (working distance not specified). Cohen and Waiss (1991) compared the effectiveness of CPF®527 with amber NoIR® no. 511 (40% transmission) and horizontally louvered (Venetian blind style) sunglasses. Louvered glasses are claimed to work by reducing the amount of stray light entering the eye. Twenty-eight low vision subjects (various pathologies) were assessed, of which 22 had glare complaints. Four different randomised VA charts were used to prevent learning effects. For those subjects with cataracts there were no cases where the tints were more effective than the louvered glasses and for those without cataract there was only one case where a tint (amber NoIR® no. 511) was more effective. There was not a single case where CPF®527 was better than either alternative device. Subjective preferences matched the device that gave the best VA. The authors suggested that the best way to determine which glare control device will be most successful is to conduct an outdoor evaluation of several different types of device.

Gawande *et al.* (1992) measured Snellen VA of 12 RP subjects with Protective Lens Series® (PLS; Younger Optics, Los Angeles, CA, USA) 530 (orange), PLS®540 (brown), PLS®550 (red), CPF®511, CPF®527, CPF®550, NoIR® dark brown no. 107 (2% transmission), NoIR® medium green no. 102 (18% transmission); custom dyed blue filter; custom dyed ND filter, matched for photopic transmission with either PLS®530 or PLS®550. For all the filters VA remained unchanged or decreased.

Nguyen and Hoeft (1994) measured VA for 160 low vision subjects (various pathologies, divided into pre-retinal, retinal and others) using CPF®450, CPF®511, CPF®527 and CPF550®XD. Although the study did not reveal a statistically significant improvement in VA from grouped data (ANOVA, $p = 0.283$), some subjects did show an improvement in VA of one line or more. The investigators noted ‘this may be significant to them’.

Contrast sensitivity

Van den Berg (1990) noted an improvement in CS for RP subjects when using red glass lenses and Zigman (1990) noted that contrast thresholds were significantly lowered in the high frequency regions with polycarbonate filter use (absorption below 480 nm) for 21 subjects with ARMD or cataract, in other words CS improved (ANOVA, $p = 0.05$). Zigman (1992) went on to investigate the effect of the same filter on CS for 14 normal eyes and 34 subjects with low vision (various pathologies). For the normal eyes the filter improved CS significantly (ANOVA, $p = 0.03$) in the 3–12 cycles per degree region, but no significant differences were found at lower or higher frequencies. In cataractous eyes, the filter improved CS most significantly in the high frequency range. In aphakic eyes CS improved similarly to the normal eyes, but at all frequencies (ANOVA, $p < 0.025$). For ARMD subjects, CS was improved mainly in the lower frequency area while at higher frequencies less significant changes were observed. Leguire and Suh (1993) assessed CS effects of five filters on 12 low vision subjects (various pathologies) and nine normal controls. The test filters were; sunglasses with a 95% UV cut-off (16.9% transmission), ND filter (25.6% transmission), NoIR® no. 111 (35.2% transmission) (no colour details provided), CPF®527 (43.6% transmission), yellow filter (86.0% transmission). A CS function was plotted for each subject with and without a filter in the presence of a glare source. The sunglasses produced a statistically significant decrease in mean log CS (paired t–2.71, $p < 0.03$), in other words an increase in CS, for the low vision group. Other filters only slightly improved CS at higher spatial frequencies. The investigators noted that when compared with normal subjects, the study group did show a relative improvement in CS. Rosenblum *et al.* (2000) used four types of yellow lens to assess monocular CS (subjects as described above). With lenses, CS increased 32% for the cataract group, 25% for those with albinism, 27% for the aphakics and 34% for those with congenital macular dystrophy. The authors suggested that similarly to VA, CS improved by a reduction in chromatic aberration, photophobia and intraocular light scatter.

Two studies noted that CS did not improve with tinted lenses or filters. Lynch and Brilliant (1984) compared a ND filter and CPF®550 with a no filter presentation and found CS unchanged. The investigators commented, however, that there were some low vision subjects (number not specified) who were able to see a higher spatial frequency with the CPF®550 than either with the ND filter or without any filter at all. Although there was little objective improvement in CS, many subjects felt that the CPF®550 did reduce glare sensitivity. Negative results were also obtained by Gawande *et al.* (1992) when CS of seven low vision subjects was tested with and without filters. Generally, lighter filters such as PLS®530 and CPF®527 had little effect on CS, while the darker PLS®550 and PLS®540 were detrimental. Interestingly, once again objective CS results did not correlate with subjective preferences.

Colour vision

Lynch and Brilliant (1984) noted colour vision loss with CPF®550. They used the City University Test (TCU) as well as a colour-naming test involving coloured blocks and found that colour normal subjects were able to pass TCU with CPF®550 and a ND filter. Subjects with acquired colour loss missed more plates with the CPF®550 (the mean was two) than without. The missed plates continued in the same direction as the original colour defect, i.e. CPF®550 did not introduce a new defect but made an existing one worse. The ND filter did not change the number of missed plates for colour deficient subjects. The CPF®550 had an even more detrimental effect on the colour-naming test with an average 50% of blocks being misnamed, compared with zero without the filter. The same subjects missed an average of less than one block with the ND filter. It was recommended that practitioners warn prospective users of the problems that CPF®550 could cause with colour recognition, especially with greens and blues. Van den Berg (1990) performed colour vision testing with and without a red glass lens. Three RP subjects made no errors without a filter, but made several errors along the tritanopic confusion line with a filter. Two other RP subjects showed very erratic behaviour overall; six made errors without a filter, but more errors with a filter, also along the tritanopic confusion line. Subjects in the Silver and Lyness (1985) study also found difficulty identifying colours with red lenses but this problem either reduced with time or was deemed unimportant by the subjects when compared with the perceived advantages. Similarly, in the cone dystrophy study by Bremer *et al.* (1987), CPF®527 interfered with 'learned colour responses for those with residual colour vision', although the subjects did not consider this to be a problem. All Corning marketing literature warns against the use of any CPF® for driving.

Adaptation

The CPF550® and a NoIR® filter (no other details provided) resulted in improved dark adaptation time when compared with the no filter assessment (Lynch and Brilliant, 1984). This was expected as both filters reduce retinal illumination. There was no significant statistical difference between the two filters. Van den Berg (1990) assessed dark adaptation with CPF®527, under four conditions both with and without filters: (1) central vision with continuous filtering; (2) extrafoveal vision with filtering during pre-adaptation in cases with complete loss of rod function; (3) extrafoveal vision with continuous filtering in the presence of 10 cdm^{-2} background illumination in cases with some rod function; (4) extrafoveal vision with filtering during pre-adaptation in cases with some rod function. For conditions (1), (2) and (3), there was no difference between the conditions with and without a red filter. However, under condition (4) the filter accelerated the dark adaptation rate. Van den Berg postulated that the mechanism for this involved the reduction of rod light adaptation when in a bright environment, as rods are insensitive to red light. When the filter was removed in the dark, the rods adapted quicker as they were less light adapted.

Visual field

Bremer *et al.* (1987) noted that three out of five subjects with cone dystrophy had improved central field sensitivity but peripheral fields remained unchanged (no other details provided). Van den Berg (1990) found that RP subjects with relatively preserved visual fields lost some sensitivity, and interestingly, those RP subjects with very restricted fields had a very slight improvement when using a filter.

Electro-diagnostics

Electro-diagnostic testing demonstrated that CPF®527 was effective in eliminating rod saturation (Bremer *et al.*, 1987). Light reaching the retina was decreased by 50% with the filter, this prevented rod saturation and resulted in more rod contribution to the flash visual evoked response; amplitude increased by 100%. An increase in latency and a sixfold increase in amplitude of the light-adapted electro-retinogram B-wave were taken to indicate that CPF®527 allowed the rods to function in environmentally photopic conditions. The electro-diagnostic results supported the subjective improvement in visual performance and reduction in photophobia reported by the subjects.

Subjective outcome measures

Seven studies described subjective reports on the use of tinted lenses in low vision. Out of 13 RP subjects assessed by Frith (1980) with an amber NoIR® filter (7% transmission), nine reported relief from photophobia, described as dramatic in some cases. Most reported a subjective increase in VA, but only three demonstrated an objective improvement in VA (no data provided). Five subjects reported subjective increases in peripheral vision and in mobility.

Hoeft and Hughes (1981) divided 100 consecutive 'photosensitive' low vision subjects (various pathologies) according to the general location of the eye condition: pre-retinal, retinal and others. Five NoIR®

filters were tried and the 'most satisfactory' was chosen by each subject: amber no. 101 (10% transmission), grey-green no. 102 (18% transmission); dark amber no. 107 (2% transmission); dark green no. 108 (1% transmission); dark green no. 109 (2% transmission). Preferences in the order amber, grey-green, dark amber and dark green, and several trends, were noted. Diabetic and glaucoma subjects preferred grey-green (18% transmission) and amber (10% transmission). Subjects with albinism preferred amber filters (10 and 2% transmission). More than 50% of subjects with RP selected the dark amber filter (2% transmission). Subjects with retinal detachment, optic atrophy, cataract and ARMD showed no filter preference.

Three out of five subjects with cone dystrophy reported that there was a significant general improvement in subjective VA and visual-motor function with the CPF®527. However, the other two subjects felt that there was little benefit over conventional sunglasses (Bremer *et al*., 1987).

Morrissette *et al.* (1984) presented results from a retrospective, questionnaire based survey of 36 RP subjects using CPF®550. All subjects were asked to trial CPF®550 for 3 days and were then divided into two groups: those who had continued to use the filter for at least 30 days after the trial (26), and those that had rejected the lenses after the trial (10). Most users (no details) rated the CPF®550 as 'the best filter ever tried'. The results from the 10 non-users were divided, and they did not respond unanimously to any question. It was concluded that the overall findings supported the manufacturer's recommendation for a trial use of the CPF®550 for several days to allow effective user evaluation. Along similar lines, Silver and Lyness (1985) found that final filter choice did not always coincide with the initial preference and also recommended a real world trial for those who might be expected to benefit from a filter.

In another retrospective study of 318 low vision subjects (various pathologies) who complained of glare, photophobia or light sensitivity, Maino and McMahon (1986) tested five NoIR® filters: amber no. 101 (10% transmission), light grey-green no. 102 (18% transmission), dark amber no. 107 (2% transmission), dark grey-green no. 108 (2% transmission), dark green no. 109 (2% transmission). Filters were preferred in the following descending order: dark amber (2% transmission), light grey-green (18% transmission), amber (2% transmission), dark green (2% transmission), and dark grey-green (2% transmission). Fifty percent selected amber (10% transmission) and 33% light grey-green (18% transmission) filters. Those with ARMD, RP and chronic open angle glaucoma tended to prefer the amber filters. Subjective effects of filters on the 'visual abilities' of 20 low vision subjects (various pathologies) were investigated by Gawande *et al.* (1992). For outdoor, daytime conditions, yellow and orange filters were always of some value, irrespective of the type of ocular disease. Those with RP found every filter better than no filter outdoors. All RP and ARMD subjects found the lighter filters to be useful indoors, even at night. In general the darker lenses were rejected for use indoors and at night. Six RP and two ARMD subjects found ND filters, except at night, to be either just as effective or slightly better than the PLS®530 and PLS®550.

Nguyen and Hoeft (1994) asked 161 low vision subjects to make subjective and qualitative choices in deciding on the most appropriate filter. The CPF®450 was chosen by 52.80% of the group, 28.57% chose CPF®511, 11.18% CPF®527, 4.35% CPF®550 and 3.11% CPF®550XD. The majority of subjects with ARMD preferred the CPF®450 while those with diabetic retinopathy preferred the CPF®450 and CPF®511 almost equally and RP subjects preferred the CPF®511 slightly to the CPF®550. Statistical analysis was difficult because of the small number (11) of observers but subjects with poorer VA tended to choose the longer wavelength attenuating filters (ANOVA, $p = 0.000$).

Experimental design weaknesses

All of the studies described suffer from one or more of the following design weaknesses: no control for investigator bias or placebo, learning and fatigue effects or; several rely on subjective preferences or qualitative outcome measures; non-counterbalanced presentation techniques; no statistical analysis of results; no study used a double-masked randomised control paradigm, which is considered by many researchers to be the gold standard experimental design although many studies were masked in that several different types of tinted lens were evaluated. *Table 3* highlights experimental design weaknesses for each study.

Discussion

Do tinted lenses or filters improve visual performance in low vision? This review demonstrates that a substantial amount of research has produced equivocal results, and has failed to prove any consistent objective benefit of tinted lenses or filters (see *Table 4* for summary). There is little conclusive evidence that tinted lenses or filters improve visual function and it is unclear whether tinted lenses with particular spectral characteristics, e.g. CPF® or PLS® are any better than ND filters or conventional sunglasses. Few studies have managed to relate reported qualitative subjective visual improvements to clinically determined quantitative objective improvements. This may have been because the clinical tests that were used for assessing visual function (VA and CS in particular)

Table 3. Experimental design weaknesses

Investigators	Objective outcome measure	Subjective outcome measure	Placebo control	Counter balanced presentation technique	Filters matched for luminance transmission	Investigator bias control	Learning control	Fatigue control	Statistical analyses
Bailey *et al.* (1978)	•		•		•		•		•
Frith (1980)	•	•							
Hoeft and Hughes (1981)		•	•						
Lynch and Brilliant (1984)	•		•						•
Morissette *et al.* (1984)		•							
Silver and Lyness (1985)	•	•	•	•					
Tupper *et al.* (1985)	•		•				•		
Barron and Waiss (1987)	•	•	•		•		•		•
Bremer *et al.* (1987)	•	•							
Leat *et al.* (1990)	•								
Van den Berg (1990)	•			•	•				
Zigman (1990, 1992)	•								•
Cohen and Waiss (1991)	•	•	•				•		
Gawande *et al.* (1992)	•	•			•				
Leguire and Suh (1993)	•		•						•
Nguyen and Hoeft (1994)	•	•	•						•
Rosenblum *et al.* (2000)	•								

Table 4. Literature search overview of those studies using objective outcome measures

Investigators	Tinted lens or filter	Ocular condition	Positive outcomes	Neutral or negative outcomes
Bailey *et al.* (1978)	Various yellow filters	Cataracts	–	RA↓, RS↓
Lynch and Brilliant (1984), Tupper *et al.* (1985)	CPF®550	RP, cataracts	VA↑, DA↑	CS→, CV↓
Silver and Lyness (1985)	Red photochromic lenses	RP	–	VA→
Barron and Waiss (1987); Cohen and Waiss (1991)	CPF®527	Various	–	VA→
Bremer *et al.* (1987)	CPF®527	Cone dystrophy	VF↑, EDT↑	VA→, CV↓
Leat *et al.* (1990)	CPF®511, 527, 550	Pre-retinal disease	Grating acuity↑	–
Van den Berg (1990)	Red glass filter	RP	VA↑, CS↑, VF↑, DA↑	CV↓
Gawande *et al.* (1992)	PLS®530, 540, 550, CPF®511, 527, 550	RP	–	VA→, CS→
Zigman (1990, 1992)	Short-wavelength (480 nm)	ARMD, cataracts	VA↑, CS↑	–
Leguire and Suh (1993)	CPF®527, NoIR no. 111	Various	–	CS→
Nguyen and Hoeft (1994)	CPF®450, 511, 527, 550XD	Various	–	VA→
Rosenblum *et al.* (2000)	Yellow (490 nm)	Cataracts	VA↑, CS↑	–
	Yellow (445 nm)	Aphakia	VA↑, CS↑	–
	Amber (560 nm)	Albinism	VA↑, CS↑	–
	Orange (520 nm)	Congenital macular dystrophy	VA↑, CS↑	–

DA, dark adaptation; VF, visual fields; CV, colour vision; EDT, electro-diagnostic test; ↑, improvement; →, no change; ↓, decrease.

were too insensitive to detect subtle changes in performance. The use of a glare source during clinic based assessments and a trial in the real world may isolate more people who can benefit from tinted lenses (Silver and Lyness, 1985; Tupper *et al*., 1985; Leat *et al*., 1990; Cohen and Waiss, 1991). The only consistent objective effects reported were an improvement in dark adaptation, which would be expected intuitively, and a worsening of colour vision in those with some acquired loss. The mechanism by which subjective improvement is gained in many of these cases may be psychological. Factors such as prior knowledge about the proposed benefit of tinted lenses and the cosmetic appearance of tinted lenses may influence some user observations.

Based upon an extensive review of the literature, Clark (1969) concluded that VA for normal observers through yellow, brown, or orange tinted lenses was identical to VA through luminance-matched neutral tints. This conclusion was reinforced by Kinney *et al.* (1983) who showed that visual performance with dark yellow and light yellow filters was better than ND filters for targets of low contrast but were identical for targets of either higher contrast or higher spatial frequency. Zigman (1992) noted that low vision subjects improved visual function with a filter at low spatial frequencies (more like real world conditions) but not at high spatial frequencies. Most conventional VA charts have high contrast targets and this may explain why subjects often reported improved visual performance in the real world, where most objects are of low to medium contrast but this was not reproducible objectively in the lab or clinic. Real world contrast conditions are difficult to consistently replicate in the research or clinical setting. It may be more appropriate to use a test chart that provides information on functional vision such as the Pelli-Robson contrast threshold letter chart (Pelli *et al.*, 1988) or the Melbourne Edge Test (Verbaken and Johnston, 1986), in an attempt to determine whether visual benefits perceived by tinted lens users have a physiological or psychological basis.

When looking for trends within a group of people with an ocular disease, it cannot be assumed that the disease has a homogenous effect on all sufferers; in other words it is important to look for individual effects. This was emphasised by Lynch and Brilliant (1984), Van den Berg (1990) and Nguyen and Hoeft (1994). A filter effect for averaged data was not shown but visual performance did improve for some subjects on an individual basis. Most diseases do not have a homogeneous effect on all sufferers, and therefore, as well as averaging and analysing group data, individual subject results need to be studied to look for intrasubject, as well as intra- and intergroup variation.

Clinical experience in low vision assessments indicates that many people with ARMD present with difficulties in reading, TV viewing, and recognising faces of relatives and friends. The ability to read at least correspondence (spot or survival reading) may allow a person with ARMD to maintain an independent lifestyle. The CPF®450 is the filter recommended for reading by Corning for people with ARMD and was preferred by a some ARMD observers (Nguyen and Hoeft, 1994). Orientation and mobility difficulties, photophobia and photosensitivity are problems regularly encountered in RP. The ability to move comfortably and confidently in the environment may allow a person with RP to gain employment. No studies have directly addressed whether filters may be of use for these tasks. More objective data, obtained from well-controlled experiments, and rigorous analysis, is required to determine whether there is any real benefit to be gained by using filters. These experiments ideally need to use conditions and tasks that are similar to those found in the real world. Benefits can then be easily incorporated into everyday clinical practice. For the time being eye care practitioners have to continue to rely on qualitative information and subjective preferences to assist them in clinical decisions when it comes to the provision of tinted lenses and low vision.

Conclusions

With regard to the use of tinted lenses in low vision it must be re-emphasised that many studies are poorly designed and do not adequately control for investigator bias or placebo, learning and fatigue effects. Non-counterbalanced presentation techniques have been employed, subject numbers are often small and statistical analysis of data is often lacking. Some studies demonstrate a subjective improvement in visual performance with filters, but objective data is equivocal. The only definite effects are an improvement in dark adaptation and a worsening of colour vision.

It is important that eye care practitioners are able to provide accurate advice on whether filters will provide a long-term benefit, prior to their recommendation to patients. Specialised filters are expensive when compared with ND filters or conventional sunglasses and in the UK this cost is borne either by the individual or by a government funded agency. Our search of the literature has not found a scientific protocol to assist in tinted lens prescription decisions and it is not currently possible to base tinted lens recommendations on the type of task or eye condition. Unfortunately, until more definitive studies are conducted, eye care practitioners will have to continue to rely on marketing literature, subjective reports, clinic-based observations and the results of real world trials in deciding whether the supply of tinted lenses and filters to a person with low vision is appropriate. The provision of tinted lenses and filters for use in low vision therefore remains controversial.

A paper that describes a comparison of CPF450 with a ND filter and a tint prescribed after testing with the Intuitive Colorimeter® (Cerium Visual Technologies, Kent, UK) (Wilkins *et al.*, 1992) using an objective experimental protocol, a real world reading task and ARMD subjects, is in preparation.

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