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The impact of light source on discrimination ability in subjects with age-related macular degeneration

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ABSTRACT.

Purpose: **To examine the influence of light source on letter contrast sensitivity in subjects with age-related macular degeneration (AMD).**

Methods: **Halogen incandescent bulbs and low-energy fluorescent tubes were tested with 70 subjects with AMD. The subjects' contrast sensitivity was determined in a randomized single-blind crossover study for each light source using photopically illuminated Pelli Robson contrast sensitivity charts. The test subjects' subjective light source preference was also determined.**

Results: **The mean contrast sensitivity for the incandescent light source was 1.28 ± 0.29 (mean ± SD), and for the fluorescent light source 1.17 ± 0.29, $p < 0.001$. The illuminance was 338 lux (± 9) for the incandescent light, and 339 lux (± 11) for the fluorescent light. Forty-nine subjects preferred the incandescent light source, while none preferred the fluorescent light source for maximum detail and clarity. Nineteen had no preference. This finding is statistically significant. Fifteen of the 19 subjects without a preference had no difference in contrast sensitivity, which supports their lack of preference. There was no significant difference with regard to sex or order of exposure to light source. Subjects with AMD had significantly reduced contrast sensitivity compared with expected normal values. We found no relationship between visual acuity and contrast sensitivity.**

Conclusion: **We are only able to recommend photopic full spectral radiance incandescent light sources to visually impaired subjects for their domestic surroundings. Furthermore, we recommend the use of full spectral radiance light sources for the illumination of Pelli-Robson contrast sensitivity charts. Given equal illuminance, as in our study, the findings show that contrast sensitivity was better by illumination with incandescent light with full spectral radiance compared with fluorescent light with interrupted spectral radiance.**

Key words: age-related macular degeneration – contrast sensitivity – fluorescent light – halogen incandescent light – photopic spectral analysis

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Introduction

Quality of life is reduced for elderly people with impaired vision (Swamy et al. 2009) including age-related macular degeneration (AMD) (Mangione et al. 1998). The subjects experience loss of vision and see shadowy, fuzzy or distorted areas in the central vision – 'like seeing through a haze' – with loss of clear and correct colour perception and potentially with glare. The ability to read and perform delicate tasks that rely on clear vision is impaired, and mobility may also be affected (Kuyk et al. 1996; Kuyk & Elliott 1999). Contrast sensitivity tests have proved superior to common acuity tests such as the Snellen charts to indicate functional or 'real world' vision (Kleiner et al. 1988; Pelli et al. 1988). Reduced contrast sensitivity means that the patient will often have difficulty travelling safely, because many visual tasks require good contrast conditions and well-defined contours for good visibility. Studies also show that postural control is impaired with reduced contrast sensitivity and visual acuity (Elliott et al. 1995; Anand et al. 2003), among other things and that elderly people with reduced contrast sensitivity are less capable of predicting and thus avoiding falls than elderly people with reduced visual acuity and good contrast sensitivity (Lord et al. 1991;

Cumnings et al. 1995). Many elderly people with impaired vision have difficulty seeing stairs and thresholds because of poor contrast conditions, which might explain why there is a greater prevalence of fall accidents among elderly people with reduced contrast sensitivity (American Academy of Ophthalmology 1994, 2007; de Boer et al. 2005; Lord 2006).

There is no correlation between visual acuity and contrast vision in AMD patients (Frennesson & Nilsson 1993), and thus, it is not surprizing that patients with relatively good visual acuity have considerable vision and mobility problems because of poor contrast vision.

Correct indoor lighting is essential for comfortable vision for subjects with AMD, especially if the contrast sensitivity score is poor. This applies not only to reading light but also to general room lighting. It is well known that patients with AMD require higher lux values for reading than people with normal eye health. Several previous papers have shown that daylight or photopic illumination improves visual capacity for subjects with a visual impairment, including subjects with AMD (Kuyk et al. 1996; Kuyk & Elliott 1999; Fosse et al. 2001; Wood & Owens 2005). Quality of life has also shown to be improved by improving the lightning conditions on several parameters (Brunnström et al. 2004). However, the significance of the quality of lighting is poorly documented and has only been investigated in smaller studies (Höfling 1979; Sharon et al. 2006; Eperjesi et al. 2007). A small study by Eperjesi et al. showed that at a constant illuminance at 2000 lux, there was no difference in reading between four commonly used lamps [standard (clear envelope) incandescent, daylight simulation (blue tint envelope) incandescent, compact fluorescent and halogen incandescent] (Eperjesi et al. 2007).

The definition of 'quality light sources' is controversial. In particular, the discussion about the difference in quality between light bulbs and fluorescent tubes has been going on for decades. This discussion has not become any less complex after the introduction of newer types of fluorescent light tubes or bulbs with an emphasis on developing different qualities. Thus, minimum regulatory demands concerning colour reproducibility and flicker now apply to the producers of fluorescent tubes according to function and design (European Commission Regulation 2008; Wilkins 1995). Today, the low-energy fluorescent light bulb is recommended by many energy advisors as the replacement for the incandescent light bulb, which is going to be banned within the EU by 2012 because of more restrictive energy efficiency requirements (European Commission Regulation 2008). The alternative to the low-energy fluorescent light bulb is the halogen light, which fits into a standard lamp socket. The halogen light has the same physical properties as the incandescent light bulb: approximately 1200 colours corresponding to 3–5 million nuances, exactly like daylight, in contrast to fluorescent tubes where the colour balance depends on the number of powder coatings of the tubes (Ganslandt & Hofmann 1992). The low-energy fluorescent light bulb is currently the most economical light source in the market, but it is criticized for its technical properties. Flicker, radiation, slow on/off function and poor colour reproduction are just some of the criticisms raised against the low-energy light bulb. Low-energy light bulbs come in a range of different qualities. Cheap low-energy light bulbs with fluorescent light, which only have 50 Hz and thus produce flicker, are not recommended and will probably be phased out. Hence, they have been left out in this study to minimize bias. The current study used representative high-quality light sources selected with a particular emphasis on finding fluorescent low-energy light bulbs with physical properties that were as close as possible to those of the halogen light. Both types of light sources are available from retailers.

Denmark has no official recommendations concerning lighting; thus, there are no requirements concerning the physical properties of the light or, consequently, concerning the quality perceived by the eye. Many people are either unaware of the importance of proper lighting (Lindner et al. 2001), or misled by recommendations given by manufacturers or government agencies with a view to conserving energy, the possibility of exchanging light sources in traditionally designed lamps, and the prospect of future technical developments (Energy Saving Trust 2008). Nonpublished empirical data have underscored the risk of reduced contrast perception because of a general implementation of low-energy light bulbs, which highlights the fact that the illumination characteristics of the Pelli-Robson charts are provided only for illuminance levels, not for the quality of the light in terms of spectral radiance.

The purpose of the current study is to ensure optimum lighting for contrast sensitivity charts and to determine whether there is a discernible difference in visual contrast sensitivity in patients with AMD when the individual patient's contrast vision is tested with, respectively, a halogen light and a fluorescent low-energy bulb.

Material and Methods

Subjects

Seventy subjects participated, 50 women and 20 men with a median age of 79.5 years (61–92). Ten subjects had a unilateral intraocular lens, 20 had bilateral intraocular lenses. Two subjects did not answer the preference question unequivocally and were excluded from this part of the analysis.

The subjects were recruited among subjects who had previously been diagnosed as having nonexudative AMD with characteristic morphological retinal findings, and who had been consecutively referred to the Municipal Resource Centre for the Blind and Visually Impaired in the town of Vordingborg in Denmark. Additional inclusion criteria were contrast sensitivity < 1.65 log CS, as contrast sensitivity among elderly people with good eye health is 1.65 log CS (Elliott et al. 1990), and binocular visual acuities between 0.5 and 1.0 at the time of referral expressed as logMAR (equal to Snellen 6/18-6/60). The visual acuity (best eye) was 0.34 ± 0.22 (range 0.10–1.00).

Subjects who were diagnosed with any systemic diseases or who took medication that may cause impaired contrast vision or opacity of the lens and the cornea were excluded. The remaining subjects were then exposed to an ophthalmoscope and slit lamp examination, and findings of lens or cornea opacity such as Fuchs' endothelial dystrophy or cataracts, which made it impossible to get a clear fundus view in this examination led to exclusion from the study. For optimal vision, the subjects were asked to use their own spectacles if provided; if necessary, corrections were made. Twenty-two subjects needed a correction, and they were not excluded, although the correction caused their vision to improve to more than 0.5 logMAR.

Test conditions and light sources

The study was a randomized single-blind crossover study where light source A (tungsten–halogen light, pearl; Osram, Augsburg, Germany; Osram model Halolux® ceram pearl, 100 W, type 64476IM, 2900 K, colour rendering index 99 Ra) was compared to light source B (Energy Saving Lamp. Megaman model Liliput®; Neonlite Electronic & Lighting (HK) Ltd, Kowloon, Hong Kong; plus type MU123i, 23 W, 2700 K warm white, colour rendering index 83 Ra). Both light sources were mounted in identical and exclusively forward lighting lamps (Faklen™; asger BC LYS, Kobenhaven, Denmark) on a floor stand. The light radiation characteristics and the spectral radiance curves for the two light sources are shown in Figs 1 and 2.

The tests were carried out in a dark room. The contrast sensitivity chart was illuminated in a way that avoided reflections and had an illuminance of 340 lux at the middle of the chart. With a reflectance of 85%, this corresponded to 85 cd/m^2, which was in accordance with the recommendations from the provider of the Pelli-Robson contrast sensitivity charts. The effect and distance of the light sources were adapted to obtain an even light intensity with < 5% variation. The illuminance was tested with a luxmeter (Hagner EC1, No. 5877) to verify this prior to each test. Spectral analyses of the light sources were carried out with a spectroradiometer (Konica Minolta *Spectroradiometer CS-1000A*). The distribution of light intensity for the Faklen lamp is shown in Fig. 3.

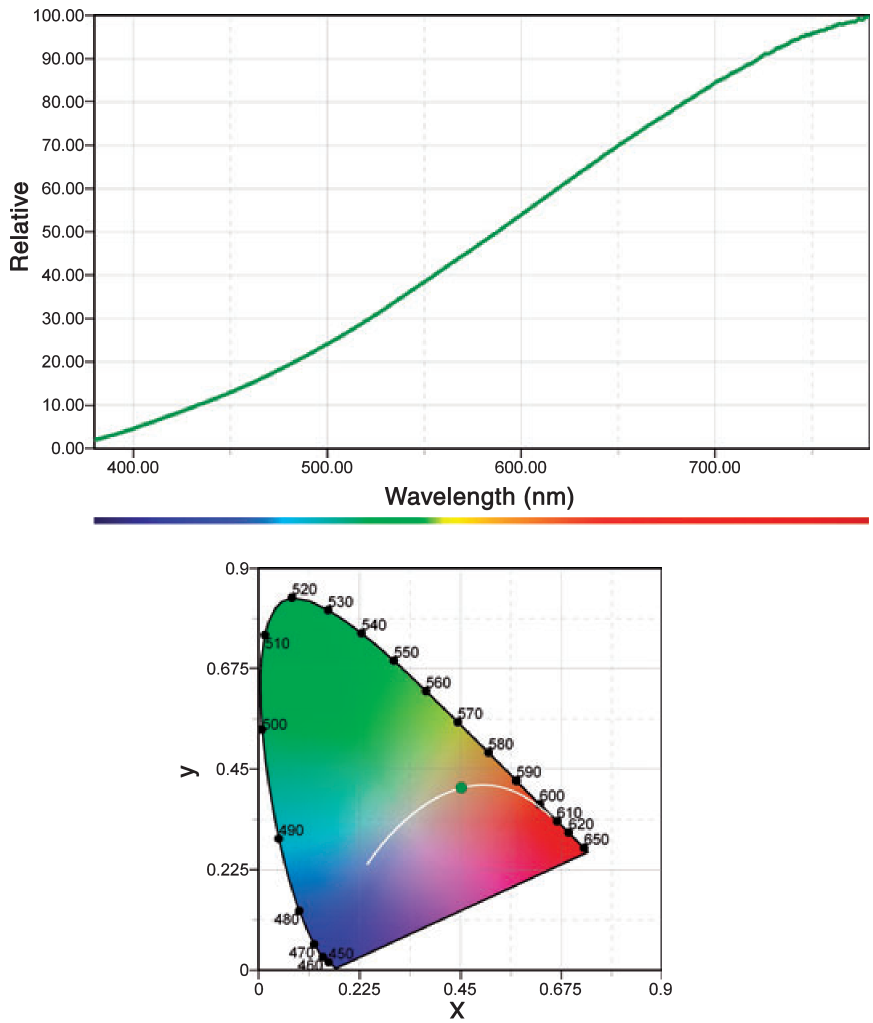


Fig. 1. Spectral radiation for light source A (halogen incandescent bulb).

Pelli-Robson contrast sensitivity chart test and visual acuity test

The subjects were tested using commercially available Pelli-Robson contrast sensitivity charts (Clement Clarke International Ltd., Harlow, UK). The binocular legibility of 4.9 cm letters on an 85 cm × 59 cm chart was examined at a distance of 1 m. The chart comprises eight lines with two triplets of three letters. The letters in each triplet had equal contrast. The contrast for each triplet decreased across and down the chart. The change in contrast was 0.15 log unit between each triplet. The chart was replaced between each light source exposure to prevent learning. The lowest legible contrast was recognized as the triplet where two out of three letters were recognized.

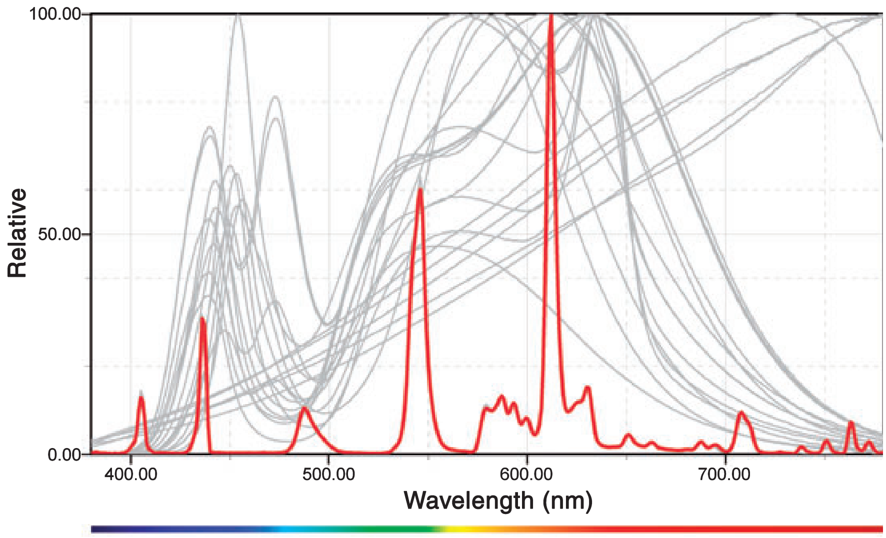
Visual acuity was assessed with the best available optical correction on a logarithmic visual acuity chart 'ETDRS' (Precision Vision, US, chart 2, CAT.NO. 2112). Test distance was 4 m (13 feet).

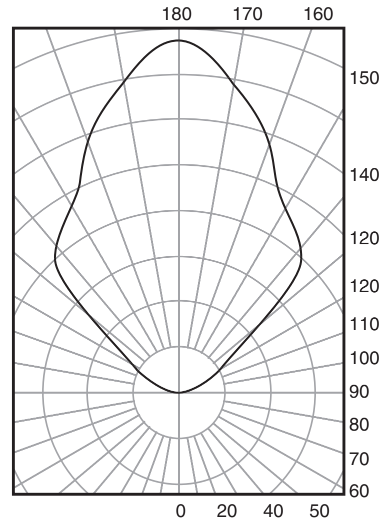
Subjective evaluation of quality of light source

The subjects were asked to state which light provided the clearest and most detailed appearance of the letters with the lowest legible contrast. The options were A, B or no difference.

Statistics

The number of subjects needed for the study were calculated prior to the study ($\alpha = 0.05$, power = 0.80, mean 1.40, MIREDIF = 0.25). Student *t* for dependent samples was used for statistical analysis of contrast sensitivity. Chi square was used for the





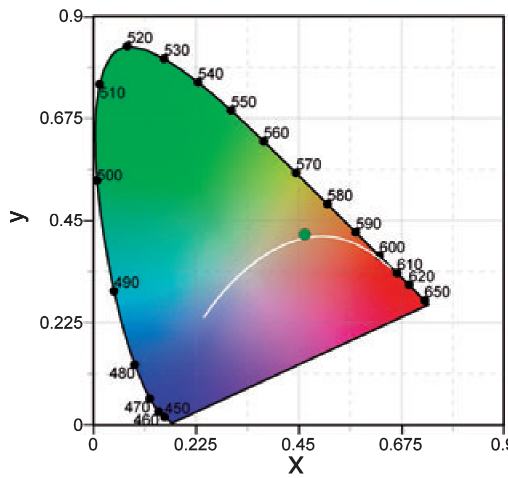


Fig. 2. Spectral radiation for light source B (compact three-powder fluorescent low-energy tube).

Fig. 3. Emission curve for the lamp Faklen™. Light distribution curve for the fixture FAKLEN. The radii depict arc degrees. The distance between the circle segments is 50 cd/1000 lm.

analysis of patient preferences. Correlation was tested by Pearson *r*. For statistical analysis, the STATISTICA software from Statsoft Inc. (Tulsa, Oklahoma, USA) was used.

Ethics

The study was made as a consequence of the proposed and most recently endorsed out-phasing of incandescent light bulbs in EU (European Commission Regulation 2008) for quality assurance of illumination of contrast sensitivity charts and therefore not obliged to ethical approval. The study was performed in accordance with the Helsinki declaration, and participation was voluntary, and informed consent was obtained.

Results

The mean contrast sensitivity for the incandescent light source was 1.28 log CS ± 0.29 (mean ± SD); for the fluorescent light source, it was 1.17 log CS ± 0.29, $p < 0.001$. The luminance for the incandescent light was 338 lux (±9), with 339 lux (±11) for the fluorescent light.

Forty-nine subjects preferred the incandescent light source, and none preferred the fluorescent light in a subjective assessment of detail and clarity. Nineteen had no preference. This finding is statically significant ($\chi^2 = 54.0$, df = 2, $p < 0.001$). Fifteen of the 19 subjects who had no preference showed no difference in contrast sensitivity ($p = 0.61$), which supports their lack of preference. There was no significant difference with regard to sex or order of exposure to the light sources.

In the study, 40 of the 70 test participants had not undergone cataract surgery. Better contrast sensitivity was observed in 65% of these 40 participants with the halogen light compared to the fluorescent light. Ten participants had monocular pseudophakia; contrast sensitivity was achieved for 50% of this group, and for 60% of the 20 participants who had binocular pseudophakia.

The study shows that subjects with AMD have significantly reduced contrast sensitivity compared with subjects without eye disease (Elliott et al. 1990; Elliott & Bullimore 1993), and that there was no relationship between visual acuity and contrast sensitivity. These findings are in accordance with findings in other studies that have found large variations in contrast sensitivity among subjects with AMD (Frennesson & Nilsson 1993).

Discussion

In our study, the test persons subjectively found that they had better vision with the halogen light than with fluorescent low-energy bulbs, although the physical properties of the low-energy light bulb that was used in the trial were as close as possible to those of the halogen light. Forty-nine of the test persons chose the halogen light as the best light source, while 19 test persons were unable to observe any difference between the low-energy light and the halogen light. Of the 19 test persons who did not find any difference between the halogen light and the low-energy bulb, 15 had no improvement in contrast vision, which explains why they did not note any difference between the fluorescent low-energy light bulb and the halogen light. None of the test persons chose the fluorescent low-energy light bulb as the superior light source.

For the majority of the test participants, contrast sensitivity was improved by 0.15 log CS, for some it was improved by 0.30 log CS when the Pelli-Robson contrast chart was illuminated with halogen rather than fluorescent low-energy light. The negative effect of flicker was not assessed in this study but has already been demonstrated by others (Shady et al. 2004).

The study shows that subjects with AMD have significantly reduced contrast sensitivity compared with subjects without eye disease (Elliott et al. 1990; Elliott & Bullimore 1993) and that there was no relationship between visual acuity and contrast sensitivity. These findings are in accordance with findings in other studies that have found large variations in contrast sensitivity among subjects with AMD (Frennesson & Nilsson 1993).

One reason for the observed difference in contrast sensitivity may be the morphological changes in the central part of the macula with an altered proportion of cones in the residual part of the macula. The cones of the perimacular area, which are receptive to long-wave light and short-wave light, may be much more sensitive to gaps in the spectral radiance, and thus, the deprivation of stimuli may result in reduced contrast sensitivity. In relation to improving the subjects' visual capacity, we do not see any reason to place additional demands on the adaptation capacity of visually impaired subjects (Wagner & Kröger 2005) by exposing them to insufficient lighting.

Fluorescent light sources, including the low-energy bulb used in the study (Fig. 2), emit considerable amounts of light in the risky wavelength called 'Blue light Hazard' around 400–500 nm (Algvere et al. 2006). The EU regulation only states requirements concerning light sources for the area under 400 nm and above 630 nm (European Commission Regulation 2008). The possible impact of this risk has not been assessed.

The negative effect of flicker was not assessed in this study but has already been demonstrated by others (Shady et al. 2004). The flicker-free light sources used in the study were selected based on quality criteria to avoid introducing an additional problem in relation to the lighting of the contrast charts.

The lens of the eye changes size, refraction index, curvature and colour with age; but contrary to expectations, this study shows that individuals with surgically implanted intraocular lenses do not have a better chance of achieving improved contrast vision with full-spectrum light than individuals who have not undergone cataract surgery.

Eperjesi et al. (2007) did not find any differences in legibility with different light sources, which may be because of the limited size of the test group and the fact that the light level was set high, at 2000 lux. This level is considerably higher than the values measured after interventions to improve lighting that affected quality of life in previous studies, including the introduction of halogen lights above the kitchen workspace and in the reading area aimed at improving the ability to carry out detailed tasks (Brunnström et al. 2004). The improved contrast sensitivity achieved with the use of halogen lights rather than low-energy fluorescent bulbs may be the factor that improves the ability of individuals with reduced contrast sensitivity to distinguish contrasts and contours around stairs and thresholds and thus their ability to avoid falls. Thus, an implication for future interventions might be to install halogen lighting in the homes of elderly people if the homes feature steps and differences in floor level. The light installation could be made more economical with an automatic on/off function.

On the basis of our study and the referenced papers by other authors, we can only recommend photopic full spectral radiance incandescent light sources to visually impaired subjects in their home environment. It may improve reading and task performance and may even reduce the number of fall accidents and additional disability in an elderly population that is already at risk. Furthermore, we recommend the use of full spectral radiance light sources for the illumination of Pelli-Robson contrast sensitivity charts, not only photopic illumination (Puell et al. 2004). Given equal illuminance, as in the present study, the findings showed a better contrast sensitivity under incandescent lightning than fluorescent lighting. Furthermore, illumination with incandescent lightning was preferred.

Conflicts of Interest (disclaimer)

The lamps were supplied by asger bc LYS a/s owned by Asger Bay Christiansen.

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