

Measuring contrast sensitivity in normal subjects with OPTEC[®] 6500: influence of age and glare

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Abstract

Background The purpose of this study was to develop age-related curves for contrast sensitivity (CS) in normal subjects under day and night conditions with and without glare.

Methods Sixty-one healthy eyes from 61 subjects were measured with the OPTEC[®] 6500 P under day and night conditions (luminance levels: 85 cd/m² and 3.0 cd/m² with and without glare; spatial frequencies: 1.5, 3, 6, 12 and 18 cycles/degree). A reliability analysis with five repeated measurements of six persons on 4 days was performed to examine the repeatability. The influence of age on contrast sensitivity, forward and backward scatter was examined by means of linear regression.

Results Contrast sensitivity was significantly reduced under night conditions with glare, whereas glare had less influence under daylight illumination. Mean reliability

coefficients are 0.87 (day), 0.77 (day with glare), 0.69 (night) and 0.81 (night with glare), which suggests sufficient retest reliability of the device. Regression analyses showed a highly significant influence of age, but the variance of the measurement values is not explained by age alone. The coefficients of determination for the regression of area under the log contrast sensitivity function (AULCSF) on age are 0.33 (photopic), 0.34 (photopic with glare), 0.29 (mesopic) and 0.36 (mesopic with glare, $p < 0.0001$ in all cases).

Conclusion A significant relationship between age, CS and scatter was confirmed in our study. The results provide baseline values for the examination of patients with different diseases in which contrast sensitivity is impaired (such as glaucoma, cataracts and amblyopia) and might be useful in studies of roadworthiness or in investigation of the impact of intraocular lenses.

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Introduction

Contrast sensitivity (CS) describes the ability to distinguish differences in luminance. It can be reduced by a number of disorders that might not be detected by conventional visual acuity measurement. The commonly used visual acuity tests use objects with high contrast, while contrast sensitivity tests are determined by low-contrast targets presented in spatial or temporal relationship. Thus, contrast sensitivity testing can reflect visual perception in everyday life more accurately than standard acuity tests. A multitude of conditions (i.e., size, orientation and luminance) influence the ability to identify low contrast items [15, 40].

The Functional Acuity Contrast Test (FACT) [23, 45] is one of the earlier published possibilities to study contrast sensitivity in a clinical setup. Using this method visual function and early forms of eye diseases have been investigated [20]. It could be shown that refractive disorders can reduce the sensitivity for detection of grating targets [50, 52]. Moreover, uncorrected residual astigmatism caused by soft contact lenses may decrease contrast sensitivity in high spatial frequencies [20]. Glaucoma [24], advanced cataracts, diabetic retinopathy, optic neuropathies, macular degeneration and amblyopia can decrease contrast sensitivity. Lower contrast sensitivity is found with early cataracts and in middle grating sizes by pituitary adenoma and toxic chemicals. Several drugs like alcohol reduce the contrast sensitivity as well. The present FACT is a compact and easy-to-use method that allows performing CS measurements with and without glare under reproducible illumination conditions in clinical routine. However, beside advantages in convenience, this method also shows shortcomings. Pesudovs et al. [42] found low repeatability as well as strong floor and ceiling effects. Similar results have been affirmed by Bühren et al. [6] for young persons and low spatial frequencies.

Results in healthy control eyes revealed a high variability of contrast sensitivity in normal subjects due to age, gender, luminance and surrounding illumination. Mäntyjärvi et al. [34] defined normal values for the Pelli-Robson contrast sensitivity test, which operates with optotypes. The aim of this study was to deliver age-related contrast sensitivity curves for normal subjects using the FACT at two light conditions (OPTEC® 6500 P). Further on, the influence of glare on CS was investigated. Normal values for the device exist only for investigation at daylight, but not for night conditions, and also the effect of glare has not been considered for reference values before.

Materials and methods

Normal subjects

Sixty-one subjects were recruited from university staff and hospitalized patients of the Department of Ophthalmology and Eye Hospital, Friedrich Alexander University of Erlangen-Nuremberg for this study. Exclusion criteria were a visual acuity less than 0.7 and any diseases that may affect contrast perception, especially ptosis, dry eye syndrome, glaucoma, aphacia and pseudophacia, and any pathology of the retina including age-related maculopathy. Further on, neurological diseases like dementia, Alzheimer's disease and Parkinson's disease were excluded. Any physical disability that made it impossible to take part in the tests (for example, being bound to a wheelchair), mental

disability and age lower than 18 years were excluded. To ensure all the above-mentioned criteria, all included subjects received detailed ophthalmologic examination. If both eyes met all inclusion criteria, one eye was chosen randomly. Informed consent was obtained for investigations from all participating subjects. The research was conducted in accordance with the principles laid down in the Declaration of Helsinki.

Measurement of lens density

In order to control influence of possible opacity caused by mild cataracts, all included subjects were measured with the Opacity Lens Meter 701 (OLM, Interzeag, Schlieren, Switzerland), the Stray Light Meter (SLM, Observator, Amsterdam, the Netherlands) and photographed with the slit lamp. Photographs were performed after dilation of the pupil in a dark room. Four different photos were acquired: an overview photo with a slit lamp to get a general idea of the lens. Afterwards one narrow slit photo (1/10 mm), one regredient and one with lateral illumination was taken.

The Opacity Lens Meter 701

Measuring the density of the nuclear lens by the Opacity Lens Meter is based on the detection of stray light from the lens [8, 13]. A light beam (diameter 1.5 mm; wavelength 700 nm) is directed through the pupil in the middle of the lens. Depending on the density of the lens, a part of the light is reflected towards the Opacity Lens Meter. This backward scatter is detected by a sensor and converted to an electrical impulse [8]. The minimum of pupil width amounts to 4 mm without use of a medication. Table 1 presents mean values from six repeated measurements.

The Stray Light Meter

The Stray Light Meter is very sensitive in detecting early [48] and subcapsular cataracts [9]. The forward scatter is assessed by a direct-compensation method [12, 26, 47] and results from circular, yellow flickering LEDs (frequency: 8 Hz) at 10° eccentricity to the fixation light in the fixation target [39]. While varying brightness of the light-emitting diodes, the subject has to observe the flickering and report about its disappearance. The so-called "silent range" [8] was measured for three times to avoid overstraining of the eye (van den Berg TJTP Stray Light Meter, user manual). The stray light can be modulated in its depth from 100% to 2.5% in 0.2 log steps accommodated to flicker sensitivity of the patient. For all measurements a constant modulation depth of 25% and a ring with 10° diameter was chosen.

Table 1 Age distribution and scores for Opacity Lens Meter (OLM) and Stray Light Meter (SLM)

Age (years)	Frequency (%)	OLM	SLM	AULCSF day	AULCSF day with glare	AULCSF night	AULCSF night with glare
<30	13 (21.3)	10.1±1.4 10.0	0.86±0.19 0.81	1.99±0.19 2.03	2.00±0.17 2.02	1.75±0.21 1.72	1.59±0.27 1.54
≥30<40	10 (16.4)	10.6±1.7 10.2	0.83±0.16 0.83	1.93±0.24 1.95	1.99±0.19 2.03	1.78±0.24 1.85	1.64±0.22 1.70
≥40<50	11 (18.0)	14.2±3.0 13.2	0.92±0.23 0.90	1.64±0.27 1.71	1.65±0.33 1.62	1.40±0.25 1.40	1.23±0.33 1.24
≥50<60	14 (23.0)	16.4±4.0 15.7	0.99±0.17 0.97	1.78±0.23 1.80	1.71±0.23 1.73	1.54±0.19 1.55	1.26±0.27 1.33
≥60	13 (21.3)	19.9±3.4 19.0	1.24±0.24 1.24	1.53±0.29 1.48	1.49±0.36 1.50	1.34±0.37 1.35	1.01±0.38 1.24
Total	61 (100.0)	14.7±4.7 13.2	0.98±0.25 0.98	1.76±0.30 1.79	1.75±0.33 1.83	1.54±0.31 1.60	1.32±0.38 1.35

Areas under the log CS function (AULCSF)

Number of patients and corresponding percentage are given for each subgroup (age decades). Scores for Opacity Lens Meter and Stray Light Meter and areas under the contrast sensitivity function are demonstrated as mean ± standard deviation and median

OPTEC® 6500 P

The functional test system OPTEC® 6500 P (Stereo Optical Co., Inc., Chicago, IL) is based on the Functional Acuity Contrast Test (FACT) [23, 45]. This device allows measurement of visual acuity, contrast sensitivity, disability glare as well as stereo- and color vision. Eyes can be examined separately as well as in binocular view concerning near and distance vision. The tests can be performed at daylight without a computer or monitor and in constant dialogue with the subject. In this study only the contrast sensitivity in the distance is quantified.

The test is based on the standards published by the American National Standards Institute (ANSI). The stimuli imply linear sine-wave grating charts of 1.5, 3, 6, 12 and 18 cpd (cycles per degree) [20] in nine circular patches (diameter: 1.7°) arranged in two rows (five patches above, four patches below). For each spatial frequency sine-wave gratings in 0.15 log CS decrements were presented. To maintain the retinal illumination and avoid ghost images, the back is tapered into a grey field. Further on the gratings are inclined -15°, 0° or +15° to remain in the spectrum of the visual channel. The subjects had, if necessary, to attach their glasses for the distance vision, while looking at a table of nine small boxes with sine-wave grating. The orientation of the stripe pattern is reported according to left, upside or right, whereas the last correct response for each spatial frequency is written down. The three-alternative forced-choice method was stopped after first wrong reply. For each spatial frequency (increasing while testing) nine grating charts with decreasing contrast were presented, mounted as slides on a rotatable drum.

Testing was performed under four different conditions: day (photopic: 85 cd/m²), night (mesopic: 3.0 cd/m²) and each with and without additional glare light (1 Lux for night, 10 Lux for day glare testing). Tests started always using the lowest spatial frequency. Glare light was achieved by 12 white LEDs arranged in an oval around the field with the gratings (approximately distance to the center: 6°

horizontal; 4.5° vertical). Each subject was tested with nine contrast levels and five spatial frequencies. If subjects could not see the lowest CS, half of the lowest CS value was assumed to avoid overestimating the CS, which would have occurred if the person had been excluded [28].

Reliability analysis

Retest reliability of the OPTEC® 6500 P was tested by repeated measurements in normal subjects. Six persons were tested on 4 different days with five repeated measurements per examination. The procedure was performed in conditions of day and night each with and without glare as mentioned above.

Statistical analysis

The statistical analysis was performed using SPSS for Windows (version 13.0) and the statistical programming environment R (version 2.2.1). To examine retest reliability, reliability coefficients ρ were calculated using the repeated measurements data: the biologic variance of test persons was divided by the total variance, which leads to a theoretical range of ρ from 0 to 1. All further analyses were based on a study consisting of 61 participants. These data were subdivided into five groups according to their age. We examined the data for potential floor and ceiling effects by computation of the percentage with lowest and

Table 2 Reliability coefficients ρ for five repeated measurements at 4 days for six subjects

Spatial frequency (cpd)	Day	Day with glare	Night	Night with glare
1.5	0.80	0.54	0.17	0.68
3	0.80	0.60	0.82	0.75
6	0.91	0.88	0.71	0.70
12	0.96	0.90	0.81	0.96
18	0.89	0.93	0.93	0.94

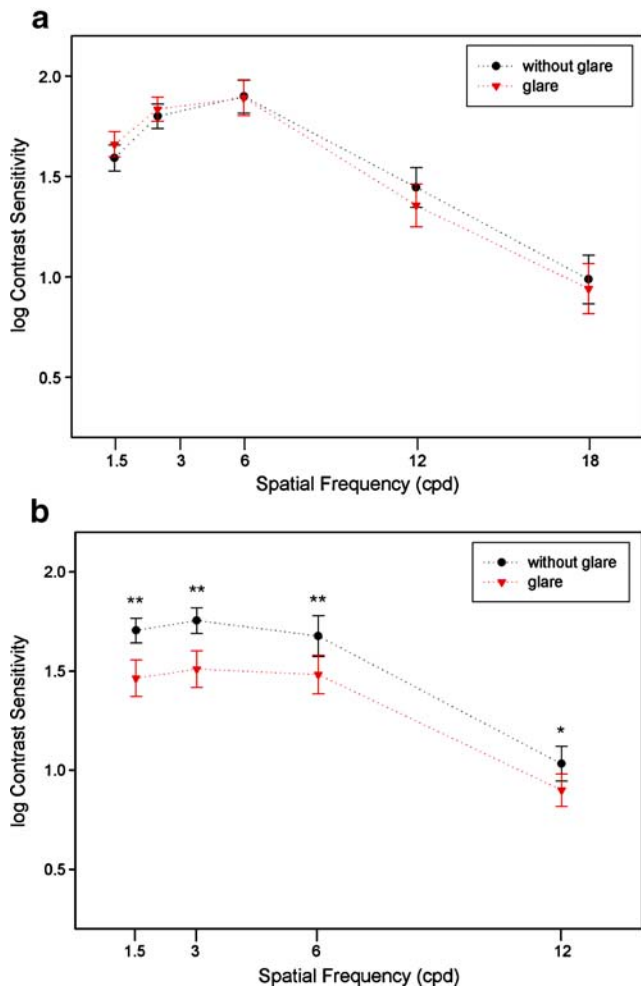


Fig. 1 Contrast sensitivity with (red) and without (black) glare as a function of spatial frequency. At day no influence on contrast sensitivity of glare was detected (a), whereas contrast sensitivity was significantly decreased at night with glare for all spatial frequencies (b). Asterisks indicate results of paired tests (Wilcoxon test) between tests with and without glare: * $p < 0.05$; ** $p < 0.01$

highest responses per age group. Box plot diagrams were drawn to illustrate the distributions of the different subgroups. For analysis of CS we calculated the area under the log CS function (AULCSF) as described earlier [6, 35, 51]. Age dependency of AULCSF was confirmed by a linear regression model. Additional linear regression models were used with forward and backward scatter, respectively, as dependents and age as independent variable to test whether a decrease of CS with age could be partially due to scatter. As scatter measurements of eight persons were missing, the regression models were based on 53 participants. The relationship between backward and forward scatter was examined by correlation analysis. To take into account the problem of multiple testing, a Bonferroni correction was performed (uncorrected level of significance $\alpha = 0.05$). Non-parametric tests (Wilcoxon Test, U test) were used to compare CS in age subgroups as well as for

Table 3 Age-dependent reduction of contrast sensitivity under glare condition at night, described as percentage of contrast sensitivity at night without glare

Age (years)/spatial frequency (cpd)	$x < 30$	$30 \leq x > 40$	$40 \leq x > 50$	$50 \leq x > 60$	$60 \leq x$
1.5	9%	6%	4%	16%	17%
3	5%	7%	10%	14%	13%
6	10%	3%	11%	11%	7%
12	7%	6%	1%	2%	13%

correlation analyses (Spearman rho test). Figures present log contrast sensitivity (mean and 95% confidence interval) for five (photopic) and four (mesopic) spatial frequencies.

Results

Reliability

The mean reliability coefficients are 0.87 (day), 0.77 (day with glare), 0.69 (night) and 0.81 (night with glare). With the exception of one outlier (0.17: 1.5 cpd, night), the coefficients range from 0.54 to 0.96. Reliability coefficients of the OPTEC 6500P are listed in Table 2.

Disability glare

Under daylight illumination maximal contrast sensitivity was observed at 6 cpd and was significant higher if compared to 1.5, 12 and 18 cpd ($p < 0.01$, Mann-Whitney-U test). While no significant decline was determined at daylight due to glare light (Fig. 1), a significant reduction in

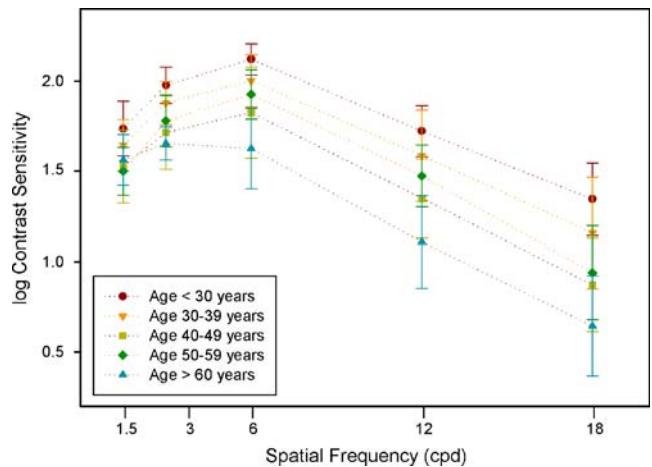


Fig. 2 Contrast sensitivity as a function of spatial frequency divided into five age groups. Maximum was observed at 6 cpd in most subjects, with a decline towards minor and major spatial frequencies. The reduction was larger for the latter

Table 4 Coefficients β , coefficients of determination R^2 and p-values for linear regression of AULCSF (day/day with glare/night/night with glare), OLM and SLM (lower/upper) on age

	AULCSF day	AULCSF day with glare	AULCSF night	AULCSF night with glare	OLM	SLM lower	SLM upper
β	-0.01	-0.01	-0.01	-0.01	0.23	0.01	0.01
R^2	0.33	0.34	0.29	0.36	0.66	0.28	0.43
p	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**	<0.0001**

**Highly significant after Bonferroni correction

contrast sensitivity was found under condition of night with glare for all spatial frequencies. Depending on spatial frequency the glare light-induced reduction of contrast sensitivity varies between 5%–10% for young participants and 7 %–17% for the oldest people (Table 3). In addition, areas under the CS functions were calculated. A summary (Table 1) shows that the AULCSF decreases when a glare source is added and that it is higher under photopic than under mesopic conditions. Additionally, a decrease of AULCSF can be observed with increasing age. If disability glare was correlated with measurements of lens opacity, correlation coefficients were significant under day and night conditions ($p < 0.01$ after Bonferroni correction).

Correlation between CS and age

Contrast sensitivity measurements using OPTEC® 6500 P demonstrates the well-known dependence on spatial frequency for all subgroups. If analyses were performed under

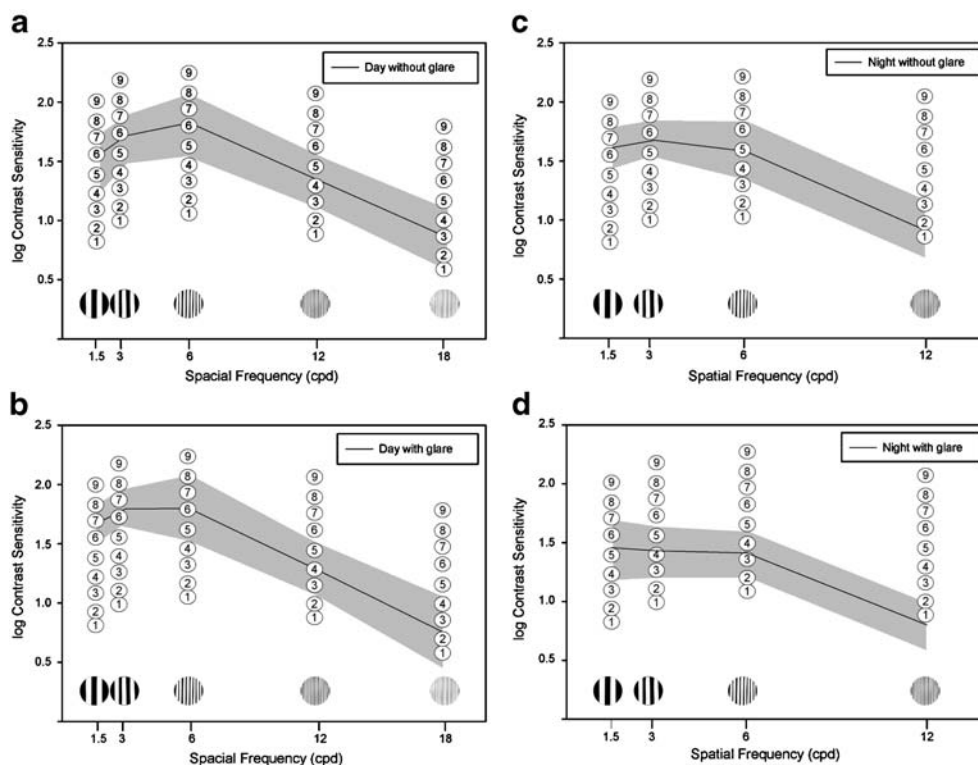
different test conditions, significant correlation between age and contrast sensitivity were observed. Figure 2 demonstrates contrast sensitivity functions under daylight illumination without glare for five age groups. A reduction of contrast sensitivity can be seen in association with increasing age.

Further analysis was conducted by linear regression for AULCSF. Summary values of all models are reported in Table 4. An analysis of age relation to AULCSF by linear regression confirms the known effect of age on CS. Under all light circumstances, the decreasing influence of age on CS is highly significant ($p < 0.0001$). The coefficients of determination range from 0.29 (night) to 0.36 (night with glare), showing that age alone can only explain a small amount of the variance of CS among the participants.

Correlation between forward/backward scatter and age

The relationship between age and scatter was examined in three other linear regression models. Each model could

Fig. 3 Contrast sensitivity as a function of spatial frequency for daylight without (a) and with (b) glare as well as for night luminance without (c) and with glare (d). The numbers 1-9 for each spatial frequency correspond to the numbers of the boxes with the stripes, presented to the patient during examination with OPTEC® 6500 P



reveal a highly significant increasing influence of age on scatter. The best model fit was obtained in the regression of OLM on age ($R^2=0.66$). Correlation analysis between forward and backward scatter shows a moderate relationship between OLM and SLM ($\rho=0.43$, $p=0.002$, for SLM (lower) and $\rho=0.60$, $p<0.0001$ for SLM (upper); both tests are significant to the Bonferroni corrected level of significance $\alpha=0.025$).

Reference values for OPTEC® 6500 P

No significant difference in contrast sensitivity was found between male and female gender for all age groups. Normal

reference values at all test conditions are presented in Fig. 3 for the age group between 40 and 49 years. These images can be used for interpretation of the examinations with OPTEC® 6500 P in other studies; the numbers 1-9 for each spatial frequency refer to the numbers of the nine boxes with stripe pattern that are presented during examination. Results for other decades will be available at: <http://www.sfb539.forschung.uni-erlangen.de/bereiche/A.1/methoden.html>.

Floor and ceiling effects

To examine the data for potential floor and ceiling effects, we calculated the percentage of participants reaching the

Fig. 4 Box plots showing the distribution of OPTEC® 6500 results among the different age groups for all spatial frequencies (a: day, b: day with glare, c: night, d: night with glare)

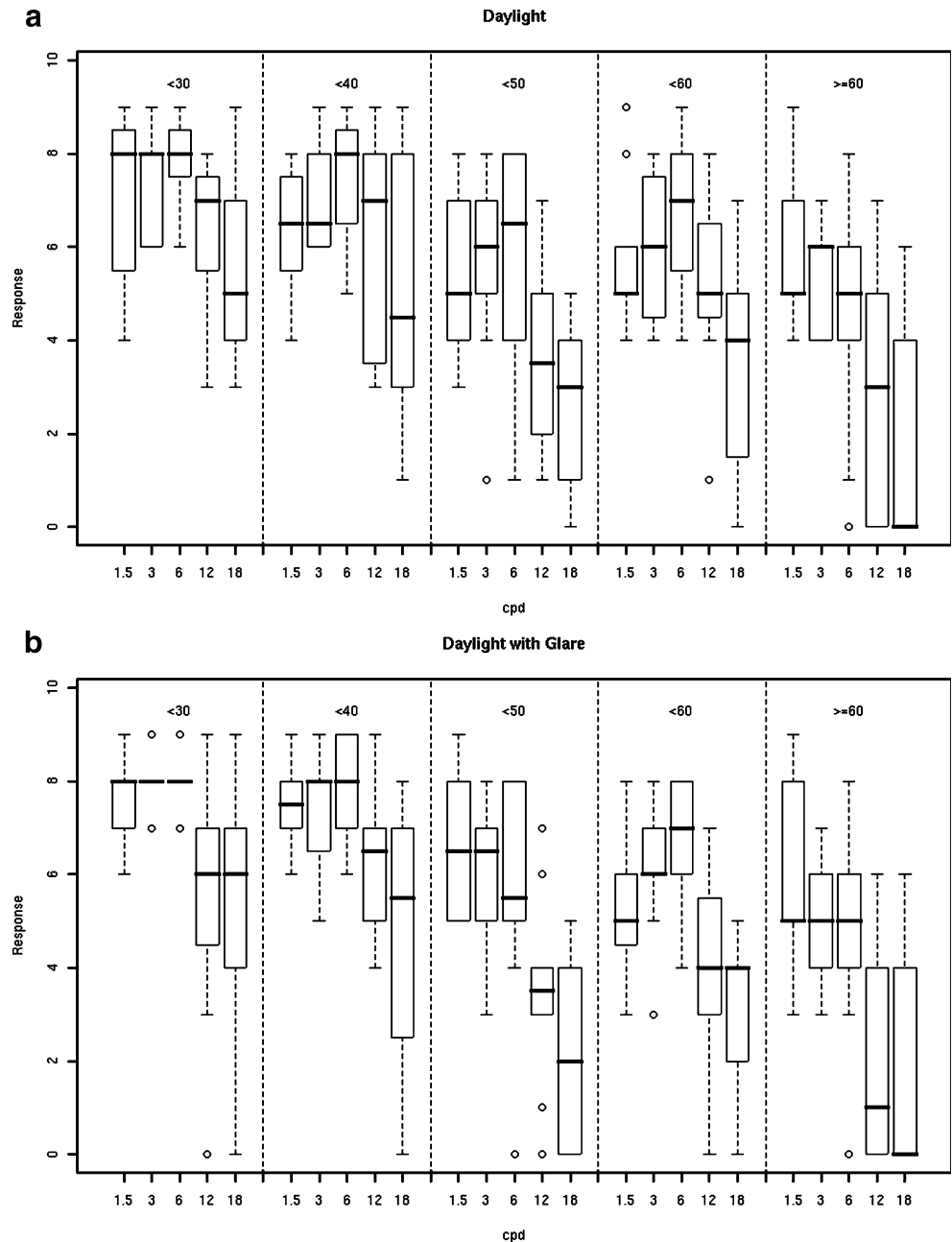
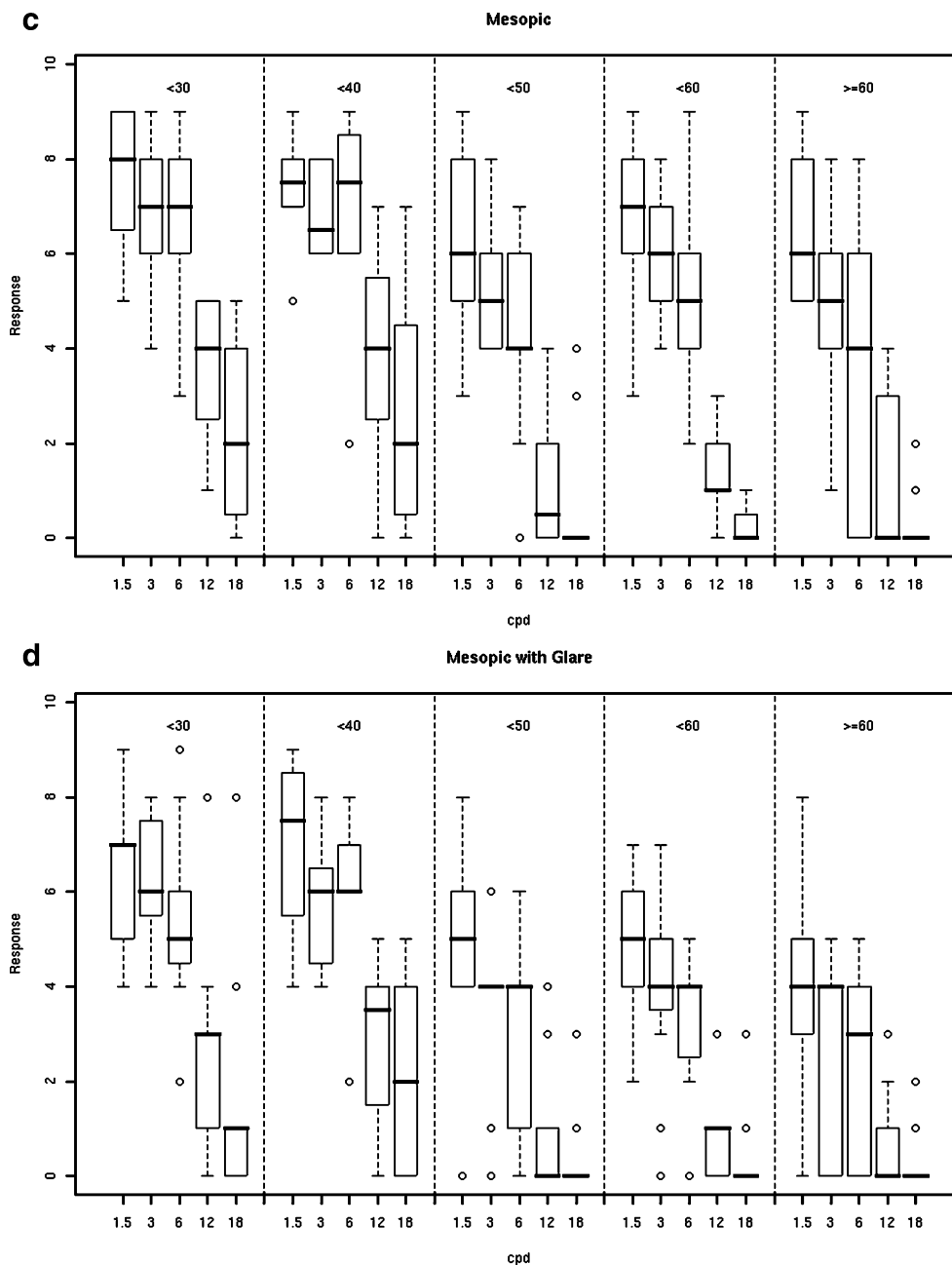


Fig. 4 (Continued)



lowest and highest CS value, respectively. The percentages were calculated for all age groups and the total population for each spatial frequency. As expected, the proportion of subjects that reached the lowest value is highest for 18 cpd and generally increases with age. Figure 4a–d shows box plots of the results per age group and spatial frequency. These plots reveal that floor effects can be observed for high spatial frequencies under most conditions. As one example, Table 5 shows the percentage of subjects reaching lowest and highest CS scores per spatial frequency under condition of night.

Discussion

A number of psychophysical tests for measuring contrast sensitivity are commercially available. Differences between devices are type of targets presented and strategies to determine threshold of perception. Stimuli for contrast sensitivity measurement can be letters (Pelli-Robson chart, Mars Letter Contrast Sensitivity chart, Test Chart 2000 [46]), symbols (Landolt ring like FF-CATS [4, 45]) or sine-wave grating of different spatial frequency (FACT test [20]). Protocols to determine contrast sensitivity include

Table 5 Percentage of subjects reaching lowest and highest CS scores per spatial frequency under conditions of night without glare

Age	Lowest CS scores per spatial frequency					Highest CS scores per spatial frequency				
	1.5	3	6	12	18	1.5	3	6	12	18
<30	0	0	0	0.00	27.27	45.45	18.18	9.09	0	0
30–40	0	0	0	12.50	25.00	12.50	0.00	25.00	0	0
40–50	0	0	10.00	50.00	80.00	10.00	0.00	0.00	0	0
50–60	0	0	0	18.18	72.73	18.18	0.00	9.09	0	0
>60	0	0	30.77	53.85	76.92	23.08	0.00	0.00	0	0
Total	0	0	9.43	28.30	58.49	22.64	3.77	7.55	0	0

method of adjustment and increasing/decreasing contrast or forced choice paradigms. Diagnostic performance and feasibility have been studied and compared in several earlier studies. As one example the Mars Letter and the Pelli-Robson test have been compared and equal test scores as well as similar reproducibility [10, 22] have been found. On the other hand, Ginsburg [19] stated that contrast sensitivity measurements based on sine-wave grating charts are more sensitive than systems providing letters. Terzi et al. [45] presented the procedure Frankfurt-Freiburg Contrast and Acuity Test System (FF-CATS) [23, 45] with high sensitivity under photopic and mesopic conditions. In comparison to the present FACT system [45], however, the method FF-CATS shows longer time to test. A comparison of these three tests by Bühren et al. [6] showed maximal values for contrast sensitivity for photopic FF-CATS, followed by the FACT, and finally the Pelli-Robson chart. Using the latter method, Mäntyjärvi et al. [34] described significant differences among CS of distinct age groups for mono- and binocular measurements. Testing both eyes, the mean CS varied from 1.73 (40–49 years) to 1.99 (30–39 years), while at monocular tests CS varied between 1.68 (≥ 60 years) and 1.84 (20–39 years). Considering these data, the author recommended 1.65 as the lower limit of CS for the Pelli-Robson test. This method, however, studies one spatial frequency at a distinct distance only. If more spatial frequencies are tested as in the present device, age-related reference charts must be provided for the full spatial spectrum.

A problem of FACT is the high probability of guessing (33.3%) and the 11% possibility of achieving two CS levels higher per guessing [42]. This is due to three-alternative forced-choice mode used to present the grating charts in OPTEC® 6500 P. The test arrangement should have more alternatives of response to reduce bias [37] or use an increasing method for measuring CS, which would furthermore reduce the probability of accomplishing the same threshold in different examinations compared with tests including fixed increments. Reliability analysis showed that under most circumstances, reliability coefficients of the OPTEC 6500P are high. We point out the fact that the very

high reproducibility coefficients among the older participants in mesopic conditions are mainly due to floor effects. Older persons are hardly able to detect grating charts at 18 cpd under mesopic and photopic conditions as they are not tested at their threshold. We suggest extending the lower limit of the provided grading chart at 18 cpd into lower CS values to enable older persons' examinations. As it stands, this effect leads to an overestimation of reproducibility. Considering this and the fact that outliers occur (very low reproducibility), we conclude that general reliability of the OPTEC® 6500 P is high for photopic conditions, but reduced under glare. Under mesopic conditions, reliability of the OPTEC® 6500 P decreases except for conditions where floor effects occur. The observed ceiling effect of younger subjects examined with FACT at 1.5 cpd [6, 42] was affirmed in this study by presenting grating charts above their threshold.

Pesudovs et al. [42] stated that two relevant components for testing CS are sufficient. In factor analysis including 1.5, 3, 6, 12 and 18 cpd, they found a low (1.5 and 3 cpd) and high-spatial frequency (6, 12, 18 cpd) component, whereas the middle spatial frequency is highly correlated to either the low or high spatial frequency component. As seen in the results of this study, CS values varied among different spatial frequencies. Although contrast sensitivity tests under high illumination conditions show best reproducibility, measurements of the full spectrum of the contrast sensitivity function under various light conditions might give information about the patients' visual abilities in daily life situations [29]. The instrument OPTEC® 6500 additionally includes measurements with reduced luminance and with peripheral glare. Future studies must compare outcome and feasibility of the present device and other test systems that are commercially available to study contrast and glare sensitivity with stimuli.

Older subjects performed worse than the younger during examination with CS. The present data are in accordance with several previous studies about physiological alterations advanced in years [11, 21, 38]. Elliott et al. [11] suggested that this is basically due to retinal and neural changes in senile eyes and additionally because of optical

factors at high spatial frequencies. McLellan et al. [38] confirmed decreasing visual performance with age, measured with modulation transfer function (MTF), while incremented wave front aberrations are followed by loss of CS. Artal et al. [2] affirmed these results in increasing ocular aberrations in older eyes as additional cause besides intraocular scattering.

The markedly reduced contrast sensitivity in elder subjects seems to be basically due to cortical or posterior sub-capsular lens density [41]. In the past, as in our study, it could be shown with the SLM as well as with the OLM that lens density increases rapidly in elderly subjects [8, 25]. Also, several other factors are relevant for reduced contrast sensitivity in old persons as the age-related maculopathy [5] and many psychological disorders such as depression [49]. Furthermore, pharmacological medication [18] and alcohol abuse [16] can cause reduced contrast sensitivity. Older persons who are long-term users of benzodiazepines have perceptible impairment of contrast sensitivity [14]. The moderate coefficients of determination R^2 of the regression of CS and scatter with age indicates that only a small part of the variance of CS and scatter, respectively, is described by the influence of age. The fact that R^2 for the regression model with the OLM (non-psycho-physical) is higher than with the SLM might be due to psycho-physical test strategy. The observed decreasing influence of age on CS can be assumed to be higher than in this analysis because of floor effects described above, which can lead to an overestimation of contrast sensitivity in the older age groups.

Mainly persons who are older than 50 years have a reduced visual acuity by glare conditions at night [3, 43]. It can be due to flocculated particles in the vitreous body and increased lens density [27]. Glare causes a reduction in vision because of veiling the luminance on the retina [48] and according to a decrease in image identification. This effect appears particularly at night, as documented by the results of the present study. An important question is how daily life is influenced by a subject's contrast sensitivity. Several statistics of accidents declare the reduced vision at night due to glare as the reason for a mishap [31, 32]. Decina et al. [7] confirmed the increment of older drivers' accidents due to synergistic effect of decreased CS next to visual acuity and visual field. However, up to now measurement of CS is not included in the qualifications for getting a driving license.

In view of the demographic changes, contrast sensitivity will be an issue not only now, but also increasingly in the future. Seeing all these facts, the ophthalmologic examination of driving persons might be expanded [32], especially the measurement of visual ability under standardized glare conditions [1]. Besides the criticism mentioned above, a number of points argue for OPTEC® 6500 P, such as the

microprocessor-controlled LED (light-emitting diode) allowing homogenous illumination as well as assuring repeatable tests under glare conditions. Additionally, use of transilluminated slides eliminates reflections on test targets, which can create inaccuracies of test results. Patients can easily understand the test strategy, which contributes to avoiding wrong examinations because of misunderstanding. Using the present device, visual acuity, CS, stereo- and color vision can be tested in one session.

Conclusion

The OPTEC® 6500 P can be used for fast determination of the photopic contrast sensitivity function with and without glare conditions. The present study delivers normal values for different age groups. These might be used in future studies with patients suffering from diseases that are associated with impaired contrast sensitivity. In addition, measurement of contrast sensitivity with this technique might be useful in studies of roadworthiness or to compare the quality of implanted lenses.

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