Effect of Myopia and Glare on Mesopic Contrast Sensitivity

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SUMMARY

Aim: The aim of the study is to evaluate the simultaneous effect of mild myopia and glare on contrast sensitivity under mesopic conditions corresponding to the conditions of night driving.

Material and Methods: The study included 22 volunteers (11 women and 11 men) aged between 20 and 42 years (mean age 26.5 years, standard deviation 5.2 years) with normal or corrected to normal binocular and monocular vision acuity and normal healthy eyes. The study was designed as a prospective study. After adaptation to mesopic conditions, three series of contrast sensitivity measurements (with fully corrected refractive error, with induced myopia -0.50 D and -1.0 D) were performed in random order using the Mesotest II device. In each series, measurements were performed with and without glare. All measurements were performed twice, and their average was considered as the result. The effect of induced myopia and glare was assessed using the analysis of variance method for repeated measures.

Results: Significant effects of myopia ($p < 0.001$) and glare ($p < 0.001$) on mesopic contrast sensitivity were proven, with contrast sensitivity decreasing with increasing myopia or in the presence of glare. A significant interaction of these factors ($p < 0.001$) was also found, which was manifested by an increased effect of glare in the presence of refractive error. The impact of glare increased with the size of the refractive error. In the absence of myopia, the effect of glare was minimal if any.

Conclusion: Mesopic contrast sensitivity is significantly affected by both the level of uncorrected myopia and the presence of glare. The significant effect of glare is observed especially in the presence of myopia, which enhances its impact. Therefore, emphasis should be placed on well-defined refractive correction in individuals who need quality vision under mesopic conditions (typically drivers). To prevent the undesirable effect of glare, it is also appropriate to consider correction of possible night myopia in these subjects.

Key words: contrast, contrast sensitivity, mesopic lighting conditions, glare, uncorrected myopia, Mesotest II

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INTRODUCTION

Under worsened light conditions a significant decrease of visual acuity (VA) occurs [1–4], together with a loss of the capacity to distinguish colors [5]. For orientation within space and detection or identification of objects, differences in brightness of the observed scene then become of more fundamental importance than individual details or color differences. An essential role in these situations is therefore played especially by contrast sensitivity. A typical example is driving in twilight or during the night [5], when differences in brightness for example enable the driver to determine the edge of the roadway or help detect the presence of a pedestrian without reflective clothing. The impact of contrast sensitivity on driving under these conditions has already been demonstrated [6,7].

In the case of reduced brightness, the eye adapts and its sensitivity to light increases [5]. Sudden changes of brightness in the visual field, in which the adaptive brightness of the eye is markedly exceeded may then cause unpleasant feelings or even impair vision. This condition, in which light entering the eye worsens or negatively influences visual comfort, is referred to as glare [8–10]. High values of glare may fundamentally reduce contrast sensitivity [11] and thus significantly impair vision during twilight. A typical example of the adverse impact of glare is again the situation of driving a vehicle in twilight or darkness [7].

Conditions of reduced brightness may result in a greater manifestation of the influence of an uncorrected or incompletely corrected refractive error, especially myopia, which the eye is incapable of compensating for by itself and which itself impairs not only visual acuity [8] but also contrast sensitivity [12]. Moreover, in twilight or darkness the error may be further accentuated by "night myopia" [13,14]. For example, under mesopic conditions corresponding to adaptive brightness of 0.17 cd/m^2 the results of our study [14] state an average value of night myopia of 0.50 D ±0.30 D. The joint impact of both these undesirable phenomena, i.e. myopia and glare, on contrast sensitivity, has not yet been sufficiently described under mesopic conditions. Research into the influence of these factors is important not only in the area of visual perception, but also within the broader context of the measurement and standardization of these quantities [15,16].

The aim of our study is to assess the effect of mild myopia up to a value of -1.0 D and glare on contrast sensitivity under mesopic conditions (i.e. twilight) in normal, healthy eyes. For the purposes of this study the device Mesotest II (Oculus, Wetzlar, Germany) was selected as an instrument to ensure the evaluation of contrast sensitivity under standardized mesopic conditions, both with and without glare. In this tool dazzling light is designed in order to simulate the glare from the lights of oncoming vehicles under the conditions of night driving [17].

MATERIAL AND METHOD

Cohort of probands

The study included 22 volunteers (11 women and 11 men) aged between 20 and 42 years with a mean age of 26.5 ±5.2 years, with normal or corrected to normal binocular vision and normal monocular and binocular VA (of at least 1) naturally or with correction. The presence of ocular pathology or an undergone surgical procedure influencing VA or contrast sensitivity was a criterion for exclusion. The study was governed by the principles of the Helsinki Declaration, each proband was familiarized in detail with the course of the study before taking part and signed an informed consent form.

Measurement procedure

The study was conducted as a prospective study. At the outset monocular and binocular VA of each proband was tested on an optotype corresponding to the ETDRS standard, and the value of dioptric correction was determined.

Measurement was performed binocularly. In the case that a refractive error was determined, the proband had corresponding correction applied, worn in a testing frame. Myopia was induced by binocular superimposition of converging lenses in front of the proband's own correction. On the basis of pilot measurements, three values of converging lenses were selected (0.00 D, +0.50 D and +1.00 D), which correspond respectively to a situation without dioptric error, myopia of -0.50 D and myopia of -1.00 D. At the same time these values correspond to the usual scope of night myopia and mesopic conditions [14].

VA was determined before the actual measurement for each of the induced values of myopia. Subsequently, each participant adapted to darkness for a period of at least 10 minutes in a completely darkened room. This time is sufficient for adaptation of the eye to the mesopic conditions used during measurement and is also recommended by the manufacturer of Mesotest II [17].

After adaptation, examination of mesopic contrast sensitivity was performed using the Mesotest II, in which the result was stated in the form of relative success, see below. Contrast sensitivity was measured in three series, differing in the degree of induced myopia. In each series two partial measurements were conducted, the first without the presence of glare and the second with glare (thus a total of six partial measurements were conducted, differing in the degree of induced error and presence of glare). The order of the individual series was chosen at random. Only a brief interval was necessary for the change of superimposed diopters between the individual series.

As the pilot experiments demonstrated, measurement under mesopic conditions is more susceptible to chance random errors. As a result, after a brief interval of at least 5 minutes, all six partial measurements were performed a second time, and the average of the two corresponding partial measurements was considered as the final result. All the data in the results relate to this mean value.

Examination on Mesotest II

In the actual measurement of contrast sensitivity on Mesotest II, the participant in the study rested the chin and forehead on the rubber sleeve of the instrument, thus preventing the penetration of surrounding light, and observed the projected dark gray Landolt rings on a lighter background within the device. The optically simulated observation distance of the rings from the observer's eyes was 5 m, the brightness of the background was 0.032 cd/m^2 without glare and 0.1 cd/m^2 with glare. The Landolt rings had a constant size corresponding to VA of 0.1 and were presented in four ratios of brightness of the ring to the background (i.e. in four levels of contrast), specifically 1:23 (95.7% contrast), 1:5 (80% contrast), 1:2.7 (63% contrast), and 1:2 (50% contrast). Five rings with varying orientation were projected for each contrast, in which the number of correct responses was recorded. In each partial measurement a total of 20 rings were therefore projected for identification (five rings for each of the four contrast values). White light situated 3° to the left of the center of the visual field served as the source of glare, generating illumination of 0.35 lx on the level of the pupil. All the stated parameters represent the standard configuration of the instrument [17]. Contrast sensitivity was represented in the given partial measurement by the relative success in identification of the rings (i.e. number of all correctly determined rings divided by their total number; a higher value corresponds to higher contrast sensitivity).

Data analysis

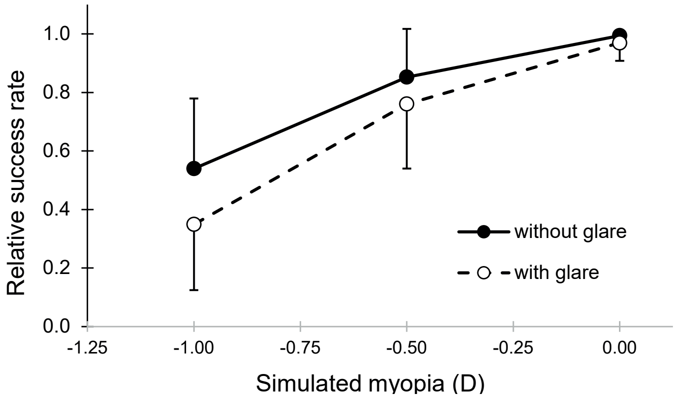
Normality of the data was evaluated using a Shapiro-Wilk test. The repeated measures analysis of variance

(ANOVA) was used for analyzing normally distributed data, the other data were either transformed to normal or analyzed using a Friedman nonparametric test. In the case of the ANOVA method a post-hoc pairwise comparison was performed by means of a Tukey HSD (honestly significant difference) test. All the statistical tests were performed in the program STATISTICA 13.4 (TIBCO Software Inc., Palo Alto, CA, USA) on a level of significance of 0.05.

RESULTS

According to our expectations, induced myopia caused a deterioration of photopic VA, see Table 1. A significant difference in the values was statistically confirmed by a Friedman nonparametric test ($p < 0.001$).

Graph 1 illustrates the course of the values of relative success in the measurement of contrast sensitivity depending on induced myopia, both without and with glare. The data are also summarized in Tables 2 and 3. It is evident from the course of the graph that the success rate, and therefore also mesopic contrast sensitivity, decreases markedly upon the increase in the value of myopia. It is also visible that the influence of glare is clearly manifested only at non-zero values of induced myopia, in which the increase in size of the refractive error leads to a decrease in relative success more rapidly when glare is present than without glare. Since the data did not have a normal distribution, for the purposes of the statistical analysis they were transformed so that for each proband the average attained from all the values of the relative success of this proband was deducted from the values of relative success. In addition, one proband whose data deviated from the others and impaired the normality was excluded from the analysis. The data thus transformed now met the condition of normality. In accordance with the course of the graph, a two-factor ANOVA test for repeated measurements (factors of "glare" and "size of induced myopia") applied to the transformed data confirmed a significant influence of glare ($p < 0.001$) and myopia ($p < 0.001$) on the relative success rate. A significant influence of mutual interaction of both factors was also determined ($p < 0.001$). A subsequent post-hoc pairwise comparison of all six combinations of myopia and glare demonstrated that the values of success differ from each other in virtually all cases (always $p < 0.01$), the sole exception being comparison of values without simulated refractive error with and without glare, between which no significant difference was determined ($p = 0.95$). On the basis of the results of the statistical analysis and graphic interpretation of data, it is possible to state that in the given sample of probands glare without the presence of simulated myopia has a statistically insignificant impact on contrast sensitivity. However, if myopia is present the impact of glare fundamentally increases. Nevertheless, the impairing influence of glare with non-zero myopia was not manifested in all probands. With a refractive error of -0.50 D there was in fact a slight improvement of the success rate with glare in 6 people (27%) (maximally by a value of 0.15), with a refractive error of -1.00 D this occurred in 4 people (14%) (maximum improvement by 0.23). However, in contrast with this, the maximum observed deterioration reached values as high as 0.45 and 0.48.



Graph 1. Dependence of the value of relative success rate in the measurement of contrast sensitivity on the value of simulated myopia without glare (solid curve) and with glare (dashed curve). The points represent the average values across all probands, the error bars represent the corresponding standard deviation

Table 1. Photopic visual acuity in logarithms of minimum angular resolution (logMAR) for individual values of simulated myopia; SD represents standard deviation

Simulated myopia		0.00 D	-0.50 D	-1.00 D
Visual acuity (logMAR)	Average	-0.195	-0.036	0.10
	SD	0.049	0.090	0.13
	Median	-0.20	0.00	0.10

Table 2. Relative success rate in measuring mesopic contrast sensitivity at different levels of simulated myopia without glare; SD represents standard deviation

Simulated myopia		0.00 D	-0.50 D	-1.00 D
Relative success rate	Average	0.994	0.85	0.54
	SD	0.013	0.16	0.24
	Median	1.00	0.90	0.55

Table 3. Relative success rate in measuring mesopic contrast sensitivity at different levels of simulated myopia with glare; SD represents standard deviation

Simulated myopia		0.00 D	-0.50 D	-1.00 D
Relative success rate	Average	0.969	0.76	0.35
	SD	0.062	0.22	0.22
	Median	1.00	0.84	0.31

DISCUSSION

Uncorrected or poorly corrected myopia and glare are two phenomena that may significantly impact upon contrast sensitivity in an otherwise healthy eye. The impact of these phenomena is evident especially under worsened light conditions, when due to low brightness the pupil dilates and a larger amount of dazzling light may therefore enter the eye. When the pupil dilates the influence of refractive error, especially myopia, is also manifested to a greater extent [8]. This may then be added to by night myopia [13,14], which worsens the situation further. Deterioration of visual performance when driving may have fatal consequences. It has been demonstrated that worsened mesopic contrast sensitivity and increased sensitivity to glare is associated with avoidance of night driving [6], especially in the older population. Our study determined that in our studied sample of young person's glare alone (without refractive error) has only a small, insignificant impact on contrast sensitivity at the observed intensities and in the corresponding situations during regular driving in darkness or twilight. However, in the presence of myopia glare begins to significantly impair contrast sensitivity, its impact increasing with the size of the refractive error.

As has been demonstrated previously, the presence of myopia alone has a demonstrable impact on contrast sensitivity. Jansonius and Kooijman [12] state a manifest deterioration of contrast sensitivity from values as low as -0.50 D, while -1.00 D worsens sensitivity by half. These results correlate fully with our finding, see Graph 1. However, our study was conducted under mesopic conditions, whereas Jansonius and Kooijman [12] evaluated vision under photopic (daylight) conditions. From this we may deduce that myopia influences contrast sensitivity in a similar way in both cases – blurring of the image probably causes a change of brightness, especially of the peripheral parts of the test symbol, and thereby induces a decrease of contrast against the background.

Upon measurement with glare we determined a further pronounced decrease of mesopic contrast sensitivity, though only in combination with refractive error. In the case of a corrected or emmetropic eye, the difference in our studied sample of young persons was minimal. The influence of glare on mesopic contrast was also the focus of the study conducted by Maniglia et al. [11], though without the influence of refractive error. The authors determined that mesopic glare has an impact on contrast sensitivity only at high values, whereas low values which correspond to the glare in our study had no influence on contrast sensitivity. A certain influence of glare on mesopic contrast sensitivity was also suggested by a study conducted by the authors Puell et al. [6]. Based on our results it is therefore possible to assert that the presence of glare on average amplifies the impact of myopia on contrast sensitivity and vice versa, thus uncorrected myopia fundamentally worsens the impact of glare. An interesting finding was the slight improvement of contrast sensitivity in approximately 27% of people upon an induced error of -0.5 D and 14% upon an error of -1.0 D. It is possible that in this case the dazzling light caused greater pupil contraction, thereby limiting the influence of myopia on vision (the image became sharpened due to the influence of the contraction of the dispersion ring on the retina). However, this effect was recorded in a minority of cases. In practice it is therefore rather necessary to reckon with a significant deterioration of vision upon a combination of both phenomena.

A limitation of this study is its focus only on a relatively young population and on myopia. It is possible to assume that in older people deteriorated quality of optic media may be manifested more pronouncedly in the eye, especially the lens, as indicated for example by the study conducted by Puell et al. [6]. Our study focused only on myopia, while the influence of other dioptric errors was not observed. In the case of hypermetropia, which the eye can correct to a certain degree through accommodation, it is possible to expect different results, which will depend on the size of the facultative component as against the absolute error. By contrast, in the case of astigmatism, which always causes a certain degree of blurring of the retinal image without corresponding correction, we may expect a similar effect as with myopia. Higher order aberrations, induced e.g. during refractive surgery or orthokeratology, may also have a fundamental impact. Deterioration of contrast sensitivity under mesopic conditions in these cases has been described e.g. by the studies conducted by Montés-Micó et al. and Hirahoka T et al. [18,19]. However, the authors of these publications have not dealt in detail with the influence of glare. Conversely, in our study we did not focus on aberrant states of the eye.

CONCLUSION

It is evident from the results we measured that even mild myopia has a substantial influence on contrast sensitivity under mesopic conditions, in which this effect markedly amplifies the presence of glare. This is significant because it is contrast sensitivity that has the dominant impact on quality of vision under worsened light conditions. In practice these undesirable effects may be manifested e.g. while driving a vehicle in twilight or during the night, when glare from an oncoming vehicle in combination with insufficient correction may have fatal consequences. As a result, for individuals who require quality vision under mesopic conditions (typically drivers), emphasis should be placed on well configured correction of their refractive error. In order to avert the adverse effects of glare, for these individuals it is also appropriate to consider correction of night myopia, which otherwise may worsen the situation further.

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