Influence of uncorrected ametropia on computer-based perimetry in patients with visual field defects and normal subjects

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Background: During perimetric testing it is well known to wear spectacles. But less is known about to what extent refractive errors affect the response time performing computer-based visual tasks.

Methods: Patients with visual field defects (VFD) (n = 6) and normal control subjects (n = 6) performed computer-based high resolution perimetry (HRP) with and without the use of spectacles. We recorded stimulus detection, response times, false hits, and fixation controls as well as contrast sensitivity with and without spectacles.

Results: Performance without spectacles resulted in decreased contrast sensitivity of control subjects (41.5%, $p < 0.05$) and patients with VFD (36.4%, $p < 0.05$) and slowed reaction times from 436.2 ms to 463.7 ms in patients ($p < 0.05$) and from 371.3 ms to 402.3 ms in normal subjects (nonsignificant). In patients also reduced stimulus detection from 64.0% to 58.6% (nonsignificant) and increased number of false hits from 1.7 to 2.8% (nonsignificant) occurred. However, the normal subjects showed more false hits with glasses (2.3%) than without (1.0%, nonsignificant). The number of fixation control responses was unaffected. The majority of the subjects felt subjectively better wearing eyeglasses.

Conclusion: Both in normal subjects and patients with VFD computer-based diagnostic tests should always be performed with eyeglasses to optimize visual performance.

Keywords: ametropia, computer-based perimetry, eyeglasses, response times, visual field defects

Introduction

Uncorrected ametropia results in blurred images on the retina, making the image bigger by virtue and stimulating more receptive fields while lowering contrast. The consequences of an uncorrected ametropia for perimetry performance can result in decreased sensitivity in several perimetric methods (Martin-Boglind 1991; Herse et al 1992; Donahue et al 1999; Aung et al 2001; Artes et al 2003) Gaffney (1993) found that an error of as little as 1 D can significantly influence the visual field of normal subjects. In the peripheral visual field, refractive errors have a minor influence on the decrease (Sloan 1960; Atchison 1987) but contrast sensitivity in the periphery decreases with an increasing ametropia (Wang et al 1998; Koller et al 2001).

Given these observations, it is not surprising that perimetry manufacturer's instructions (such as that of the Tübinger Automatic Perimeter [Oculus, Wetzlar, Germany], see Manufacturers' Instructions) suggest correction in every patient older than 35 years by using spectacles. Pianta and Kalloniatis (1998) showed increasing reaction times with decreased stimulus intensity in observers with normal and abnormal binocular vision by using a simple reaction time paradigm. However, in other studies it was found that an uncorrected ametropia has no influence on the visual field (Ito et al 2001).

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While several studies have considered the role of refractive error on perimetry in terms of threshold performance and the advantage of refraction correction to detect stimuli seems evident little is known about how the response times are influenced. Furthermore, there are no systematic studies with computer-based tasks. While many psychological tests are done with the use of a computer we were interested in how the test quality is influenced by refractive errors using the high resolution perimetry (HRP) (Kasten et al 1998). In contrast to standard perimetry, which typically uses low-contrast and near-threshold perimetry, these diagnostic programs present high-contrast and super-threshold stimuli which seem less prone to refractive errors. With this perimetry we could measure the stimulus detection, the fixation performance, the response times and the false hits at the same time.

Patients with visual field defects (VFD) display not only blind areas or intact regions, but they often have areas of partial injury as well ("relative defects" or "areas of residual vision"). In these regions, stimuli which would normally be perceive as high-threshold and high contrast stimuli are, in fact, perceived as near-threshold or low-contrast which reduced detection probability considerably (Kasten et al 1998) While the correction of the refractory error may not have much influence on the apparent size of the totally blind regions or the intact field, it is expected to be a relevant factor in the analysis and interpretation of areas of residual vision. It is these regions where most restoration of vision can be achieved (Kasten et al 1999).

The present study was therefore carried out to study the influence of wearing spectacles on performance in super-threshold perimetry in patients with VFD and in normal subjects. Especially the influence of refractive correction on the response times in patients with VFD has not been studied yet.

Methods

Subjects

Twelve subjects who regularly use spectacles when working with a computer participated in this study. Of these six were patients with VFD and six normal subjects without VFD (see Table 1). The patient group consisted of three women and three men with an average age of 53.33 ± 15.47 years; the control group (two women, four men, see Table 2) has a comparable age of 55.00 ± 8.79 years, respectively. These two groups did not differ from another in visual acuity (Z = −1.546, nonsignficant), in age (Z = –0.241, nonsignficant), gender, or general intelligence (Z = −1.366, nonsignficant).

The mean refractive error of the patients group was in the right eye +0.5 ± 3.9 D and in the left eye +0.9 ± 4.3 D. The refractive error of the normal subjects differed not from the patients (right eye +1.4 ± 3.9 D, left eye +1.6 ± 3.4 D, Z = –0.160, nonsignficant, Z = −1.043, nonsignficant).

No patient had deficiencies seeing colours which was tested with the "Ishihara-Plates".

The study has been approved by the ethics commission of the Otto-von-Guericke Universität Magdeburg and followed the tenets of the Declaration of Helsinki.

Computer-based perimetry

In this study we used a computer program for diagnosing and localizing VFD and the HRP (Kasten et al 1998). Briefly, the subjects´ head was positioned 40 cm in front of a computer monitor with the chin-rest. To be sure that the patient does not make excessive eye movements the subject was asked to fixate a fixation stimulus (diameter 5 mm) located in the middle of the monitor, which occasionally changed its color for a short time (150 ms) in irregular time intervals (light green to light yellow). The subject had to respond to each color change by pressing the space bar which is hard to recognize when the subject fixates more than 2° next to

Table 1 Demographics of the patients group

Patient code	Age/sex	Cause of lesion	VFD	SE right eye (D)	SE left eye (D)
RG	74/m	operated pituitary tumour	Complete HH to the right	+5.75	+5.75
FS	30/m	operation	Complete quadrantanopia to the left upper quadrant	–3.00	–5.00
RB	54/f	Apoplexia	diffuse	+3.25	–0.75
AL	46/f	Apoplexia	Complete quadrantanopia to the left lower quadrant	–2.75	–2.75
EB	66/f	Apoplexia	diffuse	–3.00	–5.25
LZ	50/m	Apoplexia	Complete quadrantanopia to the left upper quadrant	+2.75	+2.25

Abbreviations: HH, homonymous hemianopia; SE, spherical equivalent; VFD, visual field defect.

Table 2 Demographics of the normal subjects

Patient code	Age/sex	SE right eye (D)	SE left eye (D)
GH	56/m	+3.75	+3.75
ST	59/m	+2.50	+2.50
JK	41/m	−6.25	−5.00
WS	66/f	+4.50	+4.50
DK	49/m	+2.00	+2.00
EB	59/f	+1.75	+1.75

Abbreviations: SE, spherical equivalent.

the fixation point. The number of such color changes was recorded as a measure of fixation quality. Furthermore, the fixation was controlled by the investigator via a mirror. The subjects were asked to also respond to additional white "target" stimuli presented at random locations on a dark grey background anywhere in the visual field. A total of 220 target stimuli were presented on the computer monitor during each of the tests. These super-threshold stimuli (29.2 cd/m²) were clearly brighter than the background (17.4 cd/m²) and had a diameter of 5 mm on the monitor which represents 0.7° of visual angle (presentation time: 150 ms). It is a single intensity test registering only seen and no seen stimuli. The subjects were instructed to respond to these and to the colour changes of the fixation point as fast as possible but also as exact as possible.

The HRP program recorded both the correct detections of the target stimuli and the fixation spot colour changes as well as the response time. If subjects pressed the space bar even if there was no stimulus or outside a permissible time window of 1500 ms after stimulus onset, a false hit was registered.

The resolution of the computer monitor was 1024 × 768. Every patient used the same monitor.

The duration of one HRP-test was approximately 20 minutes, that is depending on the patients response time.

Additional measurements

We measured visual acuity at a distance of 40 cm with and without spectacles using a Near-distance-test (Oculus). Before the investigations started every patient carried out the "Mehrfach-Wahl-Wortschatz-Test" (Lehrl 1995), a simple and short general intelligence test. Contrast sensitivity was quantified using Vistech-plates (Kennedy and Dunlap 1990). After completing all tests, all subjects were asked to fill out a questionnaire to determine if they felt subjectively better wearing eyeglasses during the measurements.

Every patient did the "Ishihara-Plates" for excluding patients with deficiencies in seeing colours.

In all subjects we tested if the glasses were well correcting. A deviation of ≥0.25 D was not accepted and the subjects were excluded from the study.

Statistical analysis

Because of the small number of patients we had to apply nonparametrical tests only. To survey the mean values the Wilcoxon-Test was used.

Results

Visual acuity

All patients were refracted to be sure that they had the best refraction.

Visual acuity and all other results of this study are given in Table 3 (mean ± SD).

Contrast sensitivity

The contrast sensitivity is the mean value of all measured spatial frequencies (cycles per degree). With spectacles the

Table 3 Study results of normal subjects or patients with visual field defects with or without eyeglasses in mean ± SD. Significant differences are given as comparison between "with glasses" and "without glasses"

	Patients group			Normal subjects		
	With glasses	Without glasses	Diff.	With glasses	Without glasses	Diff.
Visual acuity	0.64 ± 0.41	0.25 ± 0.22	−0.39*	0.99 ± 0.31	0.27 ± 0.21	−0.27*
Contrast sensitivity (%)	100	63.6	−36.4*	100	58.5	−41.5*
Fixation performance (%)	96.5 ± 2.5	90.4 ± 11.9	−6.1	94.9 ± 4.5	93.5 ± 6.5	−1.4
Detection performance (%)	64.0 ± 16.3	58.6 ± 24.8	−5.4	97.1 ± 4.3	90.9 ± 13.8	−6.2
Detection performance in ARV (%)	45.4 ± 48.8	37.1 ± 39.3	−8.3	–	–	–
Response time (ms)	436.2 ± 74.3	463.7 ± 92.7	+27.5*	371.3 ± 44.3	402.3 ± 74.4	+31.0
Response time in ARV (ms)	477.9 ± 45.6	504.8 ± 66.1	+26.9*	–	–	–
False hits	3.8 ± 5.1	6.2 ± 7.6	+2.4	5.0 ± 3.4	2.2 ± 2.6	−2.8

Notes: *$p < 0.05$; **$p < 0.025$; ***$p < 0.01$.
Abbreviations: ARV, area of residual vision.

mean value in the patient group as well as in the control group was at an expected 100% (see Figure 1). Without eyeglasses the contrast sensitivity decreases significantly both in patients and in normal subjects.

Furthermore, detection ability decreases in the periphery of the visual field. The example of the normal subject JK shown in Figure 1 clearly shows this difference.

Detection performance

The patients with VFD detected on average 140.8 ± 35.8 stimuli with spectacles and only 128.8 ± 54.5 stimuli without their glasses (Z = –0.674, nonsignficant). The normal subjects detected on average 213.7 ± 4.3 stimuli with spectacles and 200.2 ± 30.3 stimuli without (Z = –0.105, nonsignficant). The variability in both patient groups was larger without spectacles.

In one of the patients and three of the normal subjects the lack of correction did not affect the performance, whereas in 3 patients and 3 normal subjects we noticed a serious impairment. However, two of the patients actually detected without their glasses a few more stimuli than with their glasses. Therefore, we could not detect any correlation between the amount of the refractive error and the detection performance or the type of visual field defect and the detection performance.

Response times

Both patients and control subjects showed extended response times without their spectacles. In the patients group this difference was 27.5 ms which was significant (Z = –1.992, p < 0.05). The normal subjects without spectacles reacted on average 31.0 ms slower than with glasses which was not significant (Z = –1.572, nonsignficant). In five of the patients and three of the normal subjects the use of correction accelerated the response times, whereas in one of the patients and one of the normal subjects the response times were unaffected. However, in two of the control subjects the response times were slowed.

Performance in areas of residual vision

VFD typically have regions with "relative defects". These regions are presumably partially damaged with some residual functions, hence also termed "areas of residual vision" (Kasten et al 1999). In HRP, these areas can be found by super-imposing the repeated computer-based perimetry charts as previously described (Kasten et al 1998) and these areas are typically located between the intact and the blind area. The difference in stimulus detection in such areas of residual vision (ARVs) were very clear. Patients perceived 45.4 ± 48.8 stimuli (20.6%) with their spectacles in these regions and only 37.1 ± 39.3 stimuli (16.9%) without their glasses. This difference was not significant (Z = –0.420, nonsignficant).

Analogue to the general response times five of the patients showed accelerated response times in the area of residual vision whereas in one patient the response times were unaffected. On average the response times in ARV slowed down from 477.9 ± 45.6 ms with glasses to 504.8 ± 66.1 without (Z = –1.992, p < 0.05).

Fixation performance

Both patients with VFD and normal subjects showed generally very good fixation performance. The patients perceived

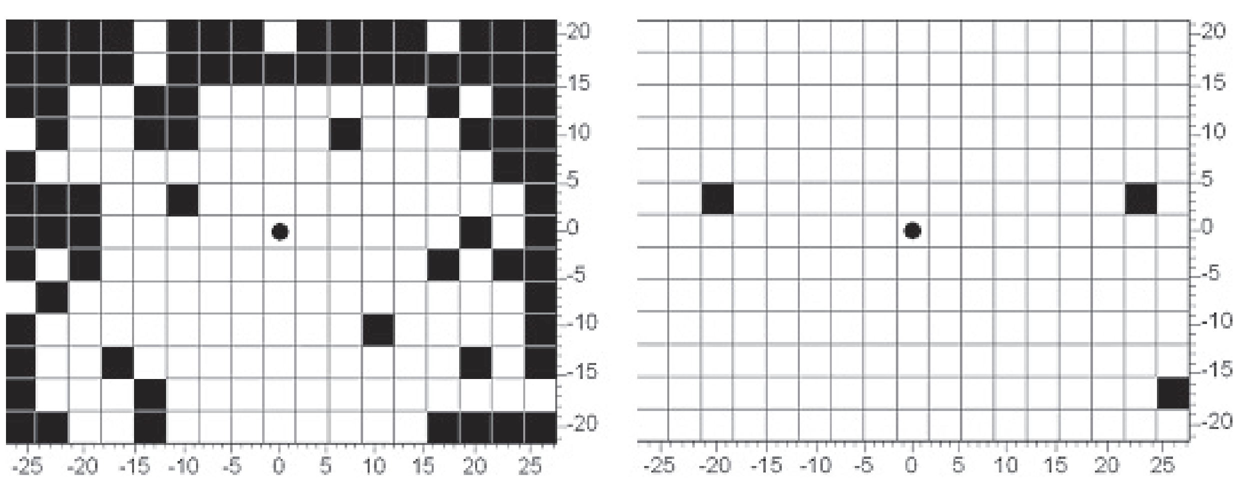

Figure 1 HRP-test of normal subject JK without visual field defect. Left panel: without eye glasses, right panel: with eye glasses. The black squares are not perceived, the white positions are seen. Note that when no eye glasses are worn, the patient displays a serious visual field loss which is not apparent when eye glasses are used.

with their glasses 96.5 ± 2.5% of the fixation controls and 90.4 ± 11.9% without. Although four of five patients recognized a little more fixation controls with their glasses this difference did not reach significance (Z = −1.483, nonsignficant).

The number of perceived color changes in the control group with and without glasses differs not significantly (Z = −0.314, nonsignficant).

False hits

One method to determine the quality of performance is to count the number of false hits. This is similar to, but not identical with, "false positive" reactions in forced choice paradigms. Rather, false hits are counted when the patient presses the space bar any time outside the post-stimulus time window of 1500 ms. It is not possible to differentiate between random responses which are independent of any target stimulus being present and hits with a response time of greater 1500 ms.

The results of the present study regarding the false hits are ambiguous. The patients with VFD showed no significant difference in the number of false hits even if they showed more false hits without their glasses (Z = −1.214, nonsignficant). In contrast, the normal subjects had more false hits with spectacles than without which was also not significant (Z = −1.461, nonsignficant).

Subjective reports

After completing all tests the subjects were asked to state if computer-based perimetry was subjectively more pleasant with or without wearing spectacles by filling out a questionnaire. Five of six patients felt better wearing their spectacles during the investigations. One patient could not detect any difference. In the normal subjects, two stated that the measurements were more pleasant without their spectacles, three felt better wearing their glasses and one person could not detect any difference.

Single case report

Patient RG was a 74 years old man with an operated pituitary tumor. The visual field loss is due to damage to the post-chiasmal optic radiations from surgery. His visual acuity was 0.32 with spectacles and 0.05 without. As Figure 2 demonstrates, he detected 37.3% of all target stimuli with spectacles (right side) and only 13.9% without spectacles (left side). Figure 3 illustrates the response times of RG. The darker the grey the longer the response time. Mean response time was 552.67 ms with spectacles and 629.33 ms without. Furthermore, RG showed no difference between the false hits with vs. without spectacles.

Conclusions

The goal of the present study was to investigate if an uncorrected ametropia can have negative consequences on performing computer-based perimetry in patients with VFD and in normal control subjects, especially on the response times. We found that contrast sensitivity without spectacles is reduced both in patient as well as in normal controls. This is in agreement with findings by Wang and colleagues (1998) and Koller and colleagues (2001) that contrast sensitivity

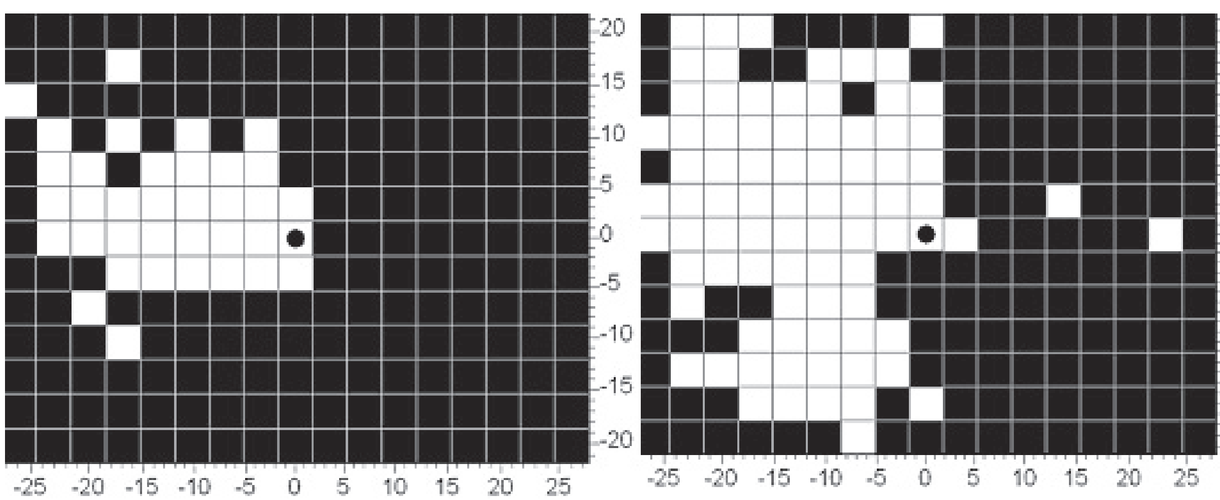

Figure 2 HRP-test of patient RG with an operated pituitary tumour without spectacles (left) or with spectacles (right). The black squares are not perceived, the white positions are seen.

of all subjects decreased in the periphery of the visual field when no correction was applied. Aung and colleagues (2001) reported that the threshold sensitivity is reduced in moderate and high myopia, regardless of the use of spectacles or contact lenses. The loss of contrast sensitivity had the expected impact on stimulus detection as well. While the patients with VFD detected on average 5% more stimuli with spectacles, the normal subjects detected on average 6% more. It should be kept in mind that the stimuli in HRP were much brighter than background. Although we have not studied it, one would expect that the loss of performance without spectacles would be greater for near-threshold stimuli.

Our study is the first to address the effects refractive correction has on response times in patients with VFD. Similar to the detection performance, both patients with VFD as well as normal subjects performed worse, ie, more slowly without eye glasses, though the statistical difference in the normal subjects was insignificant probably due to the small subject numbers. We interpret this in the following way: while the blur increases size, it also reduces perceived brightness. It may be that the subjective "halo" around the stimulus body as created by the blur is subthreshold and therefore of no benefit to subjective perception which is impaired by the brightness reduction. Nevertheless it is doubtful if this small difference in response times has a clinical relevance.

The assumption that fewer false hits should occur when using eye glasses was found to be true only for patients with VFD but not so for normal subjects. Our interpretation is that with eye glasses, patients gain confidence in their perception and thus have fewer false hits. Due to the visual field defect patients have already difficulties detecting even super-threshold stimuli and thus an uncorrected refractory error has a larger impact on perception than it does in normal observers. In contrast, for normal subjects super-threshold stimuli are very easy to detect because they are well above detection threshold. Here, some blurring under non-corrected conditions has little impact on perception and therefore the number of false hits remains unaffected.

Subjectively, patients with VFD reported that carrying out the computer-based perimetry with their eyeglasses was subjectively more comfortable. The result in the group of normal observers was more ambiguous. Though half the subjects felt better wearing their spectacles, two out of the six subjects felt better without their glasses and one person could not detect any difference. Maybe, the patients feel more confident wearing their glasses because of the sharper retinal image. This has not been investigated scientifically up to now.

We were surprised to see that in patients and normal observers the use of spectacles did not improve stimulus detection in a more significant way. Apparently, seeing a stimulus well above threshold with blur does not overall affect the ability to detect it while the speed of detection (response time) and contrast ability require correction. Despite the lack of significant differences among the groups because of too little patients and normal subjects, some individual patients clearly benefited from correction. So this study produces further evidence performing not only perimetry but also computer-based tasks with glasses. This is in agreement with older studies and the manufacturer´s instruction of the perimeter. Whenever computers are used to present small visual objects which the subject has to detected or respond to in some other way (such as in perimetric tasks or (neuro-) psychological assessments), optimal refractory correction needs to be assured first. This in agreement with Gustafsson and colleagues (2003) who stated that that optical correction is important for the vision of subjects with central visual field loss. Otherwise, a presumed "functional" deficit might mistakenly be attributed to some pathological or psychological deficit although it really is due to uncorrected refractory error.

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