Normal Threshold Values for Red Targets in the Central 10 Degree Visual Field

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Abstract

Automated perimetry is widely used in ophthalmic practices to monitor changes in a patient's visual threshold across the visual field. White stimuli are usually used and sophisticated statistical analysis is obtained comparing the patient's data to normal age matched results. Red stimuli can be used to monitor early effects of drugs in the visual field yet no comparative data is available.

The central visual field was examined with a 10–2 visual programme on the Humphrey Visual Field Analyser using red and white targets to establish normal perimetic data for red fields.

Red and white fields for 53 subjects (70 eyes) were obtained, age range 15–57 years. The fields were analysed using quadrant totals of decibel (db) threshold values. Then totals for superior and inferior fields, as well as nasal and temporal fields and then the whole fields were calculated. The decibel values were significantly reduced when the red thresholds were compared with white thresholds irrespective of the area of field tested. The means and standard deviations of each test location were calculated for the red fields. It was found that the visual threshold for red fields with the 10–2 program ranged from 21.1 dB with standard deviation + 1.73dB peripherally, to 26.6 dB with standard deviation + 1.83dB centrally. Three of the seventy eyes examined showed significant field defects (both clinically and statisically) when tested with the red target compared to a normal field with the white target.

Key Words:
visual threshold, computerised perimetry, central visual field, colour perimetry.

Introduction

Prior to the advent of automated static perimetry, coloured targets were used as an adjunct to kinetic perimetry [1,2]. Most commonly a red target was employed in these tests as the luminance contrast between the background and the target was significantly altered [3]. Some authors believe that red visual fields should only be performed in cases of optic nerve disease, supra– and infra chiasmal lesions, minute foveal legions, cone degeneration, diabetes, glaucoma, or toxic amblyopia, as these pathologies selectively affect colour vision mechanisms (cone photoreceptors and subsequent pathways) often before any ophthalmoscopic or visual acuity changes [4,5].

The exact explanation for why coloured targets may be useful is controversial. Perhaps retinal ganglion cells receive and convey information from different portions of the spectrum and thus coloured targets will reveal defects before other testing techniques. Others postulate that red targets only function as dull white targets and therefore defects found with coloured targets will always be demonstrated with white targets of reduced illumination[4]. A number of criticisms have been raised concerning the use of colour thresholds in perimetry [4,6]. The most serious criticism of colour perimetry is the lack of quantative evidence that colour provides any additional information compared to achromatic perimetry [7].

With the advent of automated perimetry the use of coloured targets has decreased due to the fact that much duller achromatic stimuli can be produced with this form of static perimetry. Consequently, colour perimetry is now used primarily to detect defects caused by drug toxicity. Medications that have been reported to affect colour vision mechanisms include Chloroquine, Plaquenil and Ethambutol [8].

In a study performed by Easterbrook and co–workers [9], patients with the risk of retinopathy from chloroquine therapy were examined on the Humphrey 10–2 program using both white and red targets and the Amsler Grid. They found that red targets revealed abnormalities that were not present with the white targets. Overall when the effectiveness of red and white targets was assessed by comparing their results with Amsler testing, they found that red targets yielded 91% sensitivity and 58% specificity and white targets 78% sensitivity and 84% specificity. The low specificity for red targets may have been due to the fact that the Humphrey visual field test is not as specific as the Amsler or perhaps more likely, the Humphrey visual field test using red targets was able to detect field defects not normally detected with Amsler testing.

The quantitative nature of the data from automated perimetry and the opportunity for computer analysis have stimulated interest in the development of statistical methods to describe the probability that a given set of measurements represent normality or abnormality, or that sequentially obtained field represent stability or change [10].

At present the clinician attempts to answer these important questions by simply inspecting the visual field display and looking for irregularities in the contour of the hill of vision. When a patient is tested for the first time three comparisons are commonly made:

The patients results are compared with expected normal values, the fields of the patient's two eyes are compared for symmetry, and possibly abnormal areas of the field of one eye are compared with other unaffected areas in the same field.

In order to determine if a patient's test is normal or abnormal, one thus needs information about the result of the same test in normal subjects. Very little has been published on expected normal values for any perimetric instrument.

One of the limitations of using coloured targets with the automated perimeter is the fact that there are no normal values for coloured targets. There is one study by Flanagan and Hovis [11] where threshold was measured on the Humphrey perimeter using white, red, green and blue targets.

The testing strategy used was firstly a macular threshold test where the central 4° was tested and secondly one meridian (5° to 195°) of the central 30°. The coloured targets showed reduced threshold values but when the luminance difference for each of the targets was compensated there was little difference in threshold values between each of these targets and white targets. Normative data for the complete central visual field has not been determined, and Easterbrook [9] stated that age – matched control data for the 10–2 program would assist in the evaluation of patients receiving chloroquine therapy.

The purpose of this study was to determine normal values for the 10–2 program using a red target on the Humphrey visual field analyser and to consider the question of whether a red target can detect defects that a white target cannot.

Method

Subjects:

A total of 53 subjects (70 eyes) recruited from the staff and students of the university and acquaintances participated in this study. All subjects had a screening eye examination prior to visual field testing consisting of relevant history questions and assessment of their visual acuity.

The criteria essential for subject participation included:

1. distance visual acuity of 6/6 Snellen's linear or better (with optical correction if required);

2. no known ocular pathology or systemic disease that might cause a visual field loss;

3. no previous ocular treatment such as surgery, laser treatment, eye medication or occlusion;

4. no use of medications such as tranquillisers that might affect their test performance or medications such as Plaquenil, that might affect their visual field;

5. pupil size greater than 2.5mm;

6. no media opacities or known retinal disease;

7. willingness to undergo the visual field test.

The age range of the subjects examined was 15 to 57 years with the average age being 20.9 years.

Forty one females and 29 males participated in this study.

Testing Procedure:

The visual field tests were done on the Humphrey field analyser using a 10–2 program where thresholds were determined at 68 locations within the central 10 degrees of field using a repeated, up and down staircase procedure to determine threshold levels [12]. Two different tests were performed, one using the standard white stimulus and another using a red stimulus (Hoya R62). Each stimulus subtends a visual angle of 0.43, equivalent to Goldmann size III [13]. Therefore each subject could have a maximum of 4 visual field tests: a white and red stimulus on each eye. All subjects were examined by one examiner (JP).

The subjects were all given standard instructions prior to commencement of the field test. All eyes were tested in randomized order and the stimulus colour to be used first was also randomized to ensure that any learning effect would not influence the results. All were tested with the iris and the ciliary muscles in their natural state. A correcting lens was worn when neccesary and the appropriate age add if needed. A demonstration of the 10–2 programme using the one minute practice test available on the field analyser was employed. The 10–2 programme was then run with either the red or white target and repeated with the colour that hadn't been examined. Subjects were given a break during the testing procedure at about five or six minutes, and between fields. The eye monitor was on so that the subject's fixation could be monitored at all times and constant encouragement was given to the subjects throughout the field test. The average pupillary diameter measured 3.5mm.

Since the aims of this study were to obtain normal values for the red test target and to observe whether the red test target detects defects before a white test target, the white field can be considered the control for each eye of each subject.

Results

From the 70 eyes examined on the Humphrey visual field analyser, 70 white fields and 70 red fields were obtained. All subjects were considered reliable according to the specifications of the Humphrey field analyser (<33% False Negatives & False Positives).

As expected when the red stimulus was used the decibel (dB) levels recorded were observed to be considerably decreased compared to the white decibel levels.

Mean Values for Red and White Targets:

The usual method of statistically analysing the decibel levels of each field (known as Statpac) could not be employed in this study as it relies on making comparisons between the field recorded and normal age matched populations. There are no normal values for red stimuli using this testing strategy. In order to compare the red fields in this study with the white fields for each subject another printout was used known as a 3 in 1 format. This provides a grey scale, defect depth, and decibel levels printout with quadrant totals for each quadrant of the field. With this in mind the following comparisons were made:

a) Mean values and standard deviations were tabulated for each quadrant in the white field. (White superior nasal – WSN; White superior temporal – WST; White inferior nasal – WIN; White inferior temporal –WIT.) The same values were recorded for the red field. (Red superior nasal – RSN; Red superior temporal – RST; Red inferior nasal– RIN; Red inferior temporal, – RIT.)

b) Secondly a comparison between the superior half of the fields and inferior half was made for both white and red stimuli. (White superior –WS, Red superior RS, White inferior WI, Red inferior RI).

c) Thirdly a comparison between the nasal and temporal fields was recorded for red and white stimuli. (W–field, R–field).

These comparisons were made to see if the field was reduced in any of these quadrants or half fields more so than others.

d) Lastly, an overall mean value and standard deviation was recorded for each field.

As each quadrant tests 17 threshold points the mean quadrant totals calculated were divided by the number of points in each sector examined so that the values presented relate to dB values that appear on the printout in common practice. From these values MANOVA– Multivariate analysis of variance (repeated measures analysis) was calculated showing that the difference in dB levels for white and red targets was statistically significant. Table 1 and Figure 1 depict these results. From Table 1 we can see that red scores were significantly lower than white scores. A similar difference was evident in all quadrants tested. It is also evident that the statistical level of significance did not alter depending on whether quadrants were tested, half fields analysed, or whole field analysed. The quadrant totals for each quadrant are listed in Table 2 so that clinicians can compare quadrant totals to the calculated normal range from this population.

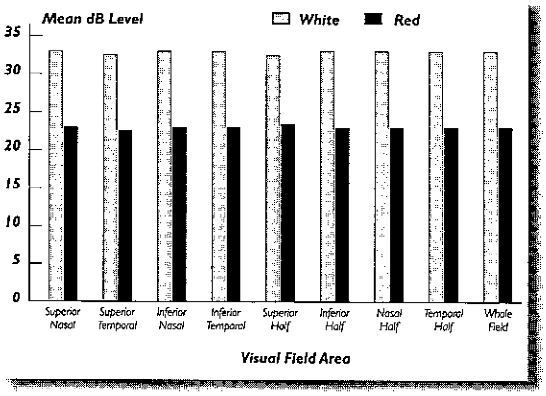

Figure 1

Histogram comparing mean dB levels for red and white stimuli for each area of field analysed.

Correlation between corresponding red and white fields:

Given that there were large mean differences between the red and white decibel threshold levels obtained, correlations were calculated (including all 70 subjects) to see if subjects who had performed best with white targets also performed best with red targets. Table 3 does show moderate positive correlations however it cannot be concluded that subjects who perform best on the red field will always perform best on the white field and vice–versa.

Normal Values for Red 10/2 Test:

The normal threshold values (mean and standard deviation) for each test location on the red field 10–2 test have been calculated and depicted in Figure 2. It was found that the visual threshold for red fields ranged from 21.1 dB with standard deviation ±1.73 more peripherally to 26.2 dB with standard deviation ± 1.83 at central fixation. In this study age appeared to make no difference to the threshold level recorded. That this, sensitivity was not decreased significantly in the older subjects when compared to the younger subjects, however there were only 3 subjects in the older age group (aged 48, 55 and 57).

Abnormal fields with red target not detected by white target:

In order to identify any abnormal field results from this series of subjects any fields that had a quadrant total more than one standard deviation outside the range of values indicated above were considered abnormal. Of the 70 subjects examined 3 subjects showed a field defect when examined with the red stimulus, but no defect when examined with the white stimulus. Removing these from the results of Tables 1&2 produced very similar means which have not been included in this report. In addition removing the 3 abnormal fields produced similar correlations to those shown in Table 3.

The three " abnormal" fields showed no defect with a white target but definite abnormality with a red target. All the abnormal fields on red testing had excellent reliability and low short–term fluctuation. The defective areas were always in the superior field.

A calculation similar to that used by Statpac for white fields to determine the likelihood of the area of the field being defective was employed.

Each abnormal field showed a z score indicating that 95% to 99% of the population would get a better score in the defective

Table 1

Mean dB levels and standard deviation recorded for red and white stimuli for each area of visual field analysed (n=70).

Field Area Averaged	White		Red			
	mean dB	sd	mean dB	sd	F	p
Superior Nasal Quadrant	32.27	1.14	23.46	1.09	7372.82	<0.001
Superior Temporal Quadrant	31.93	1.17	23.18	1.20	5551.60	<0.001
Inferior Nasal Quadrant	32.37	0.98	23.50	0.99	7654.31	<0.001
Inferior Temporal Quadrant	32.42	0.93	23.61	0.94	8558.81	<0.001
Superior Half	32.10	1.11	23.32	1.10	7446.52	<0.001
Inferior Half	32.39	0.92	23.56	0.92	9694.65	<0.00
Nasal Half	32.32	1.02	23.48	0.97	9203.64	<0.001
Temporal Half	32.18	0.99	23.40	1.01	7877.11	<0.001
Whole Field	32.25	0.98	23.44	0.97	9385.14	<0.001

quadrant. This is similar to the statistical results provided on the Total Deviation plots of the usual Statpac analysis.

Two of the three red abnormal fields were both from the same subject. The results for this subject for the left eye with the white target and for the red target had an almost complete superior field defect with the superior temporal and superior nasal quadrants equally affected. Z–test shows that 99.92 % of the population scores better than 337 in the temporal quadrant and 99.95% of the population scores a better result than 346 for the superior nasal quadrant. Other tests performed on this subject showed normal colour vision but borderline contrast sensitivity.

Discussion

The results of this study provide standard values for the Humphrey perimeter against which the results of visual field tests in individual patients can be assessed. Most importantly, the 10° field with a red target was tested so that future fields examined by this technique can be compared with these normal values obtained.

It was found that regardless of the area of the field examined, the threshold levels measured in decibels, were considerably reduced for the red fields when compared to the white fields. These reduced decibel levels suggest that a brighter red target is needed in order to reach the same visual threshold obtained with the white target.

The threshold values for red targets obtained by Flanagan and Hovis [11] compare well with the results of this study. The subjects aged 20 to 30 years in their study achieved a 20dB level for most points in the Macular Threshold test (central 4°) compared with a level of 24 to 26dB for this study. Levels for the 5° to 195° meridian ranged from 24dB centrally to 18dB at 10°; also similar but slightly lower than those obtained from this study. Threshold values for all points tested with their standard deviations were not reported in the study by Flanagan and Hovis [11].

The reason for the difference in dB levels recorded by the Humphrey perimeter for red and white targets is due to the luminance properties of these targets. If we consider the visible solar spectrum we know that white light consists of the whole visible spectrum, whereas red light represents only part of the colour spectrum (i.e. 590nm to approx. 660nm). Hence luminance of the red test target is not the same as luminance of the white test target, therefore the red decibel level will be lower. This has been confirmed experimentally by Flanagan and Hovis[11] who calibrated for the luminance changes with coloured targets and found that dB levels obtained with red were virtually identical to those of white.

Field Area Quadrant Totals

	White		Red	
	mean dB	sd	mean dB	sd
Sup. Nasal	548.5	19.3	398.8	18.5
Sup. Temporal	542.8	19.8	394.1	20.4
Inf. Nasal	550.3	16.7	399.6	16.8
Inf. Temporal	551.1	15.7	401.4	16.0

Table 2

Mean quadrant totals and standard deviation for red and white stimuli (n=70).

Correlation of Field Segments

White/Red Sup. Nasal	0.7036
White/Red Sup. Temporal	0.6560
White/Red Inf. Nasal	0.6308
White/Red Inf. Temporal	0.6362
White/Red Sup.	0.7050
White/Red Inf.	0.6660
White/Red Nasal	0.6995
White/Red Temporal	0.6601
White/Red Total Field	0.6958

Table 3

Correlation of Field Segments.

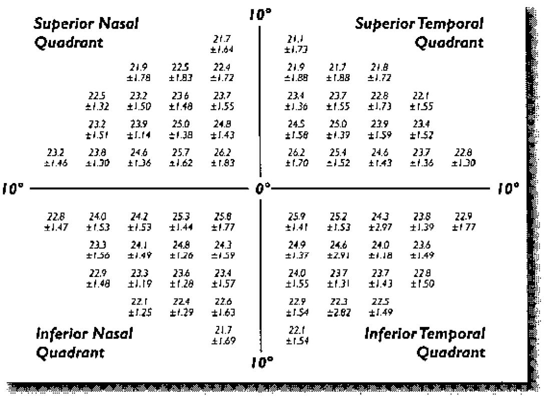

Figure 2

Normal threshold values and standard deviation for a red stimulus for each test location of the 10–2 program.

If we consider contrast between the red target and white background it was interesting to note that most subjects reported the red target easier to see than the white test target. One would expect this to hold true as a red target on a white background has greater colour contrast than a white target on a white background. Mullen [14] found there was a steeper decline in colour contrast sensitivity than luminance contrast sensitivity across the visual field of each spatial frequency, resulting in a continuous decline in colour contrast sensitivity relative to luminance contrast sensitivity. This suggests that there is a greater confinement of post–receptoral chromatic mechanisms than luminance sensitive mechanisms to the central visual field and that the central visual field has a greater degree of specialisation for colour contrast detection.

The reduction in perimetric sensitivity with age is well known. That is, as the subject's age increases the sensitivity decreases. The effect of age on threshold values has been found to be most obvious in the peripheral areas of the visual field beyond 27 degrees from fixation [15,16,17]. In this study, however, little difference in decibel levels were noticed between the younger and older subjects, although there were only 3 subjects of the 53 examined that were in the older age group.

Unexpectedly, of the 70 eyes examined, 3 were found to be "abnormal" both clinically and statistically when examined with a red target, but perfectly normal when examined with the white target. This suggests that the red target is sensitive to very subtle field changes and may not simply be acting as a dim white target as has been previously suggested [18,19].

Physiological evidence suggests that different retinal ganglion cells receive and convey information from different portions of the visual spectrum. The visual pathways, from the ganglion cells to the cortex, are composed of nerve fibres predominantly from the cone receptors. Since the majority of cones appreciate the red wavelengths, early defects in the visual pathways were thought to be more detectable with red stimuli [2,3].

Hedin and Verriest [6] suggest that colour may be selectively affected in generalised cone dysfunction; dysfunction of an isolated cone type; and when there is damage to colour opponent processes. Further studies are required in this area using both coloured and white targets on people with such abnormalities. Red fields may then play a part in early detection of disease caused by a variety of factors such as drug toxicity, defects in the visual pathway, cone dysfunction/degeneration and chiasmal lesions.

As normal data is now available for red targets, visual field testing employing a red test target can be performed with more confidence and knowledge of what the expected outcome should be. This may lead to earlier detection, hence quicker prevention of various ocular problems.

Conclusion

Normal threshold values for the 10–2 program using a red target on the Humphrey Visual Field Analsyer (Model 610) were measured from the fovea to 10° on 67 normal eyes. The data help to establish the range of normal threshold values for red size III targets on the Humphrey perimeter.

Regardless of the area of field examined, the threshold levels were considerably reduced for the red fields compared to the white fields, reinforcing the fact that red targets have lower luminance than white targets. However, three abnormal fields were found with the red target that weren't detected with the white target suggesting that the red target is sensitive to very subtle field changes and may not just act as a dim white target.

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