REPORT COMPARING DIGITAL AND NON DIGITAL CLINICAL INSTRUMENTATION TO EVALUATE OCULAR MOTILITY- THOMSON BVA ANALYSER

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NNTC LTD/ THOMSON SOFTWARE

Contents

Introduction

Assessing the eye movements of patients in the clinical environment is often done by observation. Clinicians will often scale the degree of eye movement deficit using a scale between -4 and +4 on a diagrammatic representation (Vivian and Morris, 1993). One of the challenges with this methodology is examiner variation and also detecting small changes in ocular movements. Finding methods to record ocular movements have to date relied on instruments developed more than 50 years ago. Some of these technologies are now no longer replaceable and as such new modern methods of recording eye movement deficits are welcome.

Recording eye movements is considered essential practice in patients with incomitant strabismus or mechanical deviations, especially those with a presenting complaint of diplopia.

The Hess Chart was developed originally in 1908 by Walter Rudolf Hess and has been subsequently modified to become what it is today (Roper-Hall, 2017), consisting of a grey screen with a grid of 25 lights placed 5 degrees apart and requires dissociation of either eye using red-green goggles to perform. An examiner is in patient is instructed to point at a light using the fixing eye (red filter) and a plot is recorded of where the light is perceived by the non fixing eye (green filter) in comparison to the fixing eye. The filters are then swapped and a plot of the other eye is carried out. This test will take approximately 10 to 15 minutes to record the eye movements of the patient. At the end of the test a pictorial representation of the eye movements is available. The examiner determines where to record the point indicated by the patient. This does introduce some examiner bias in undertaking the test.

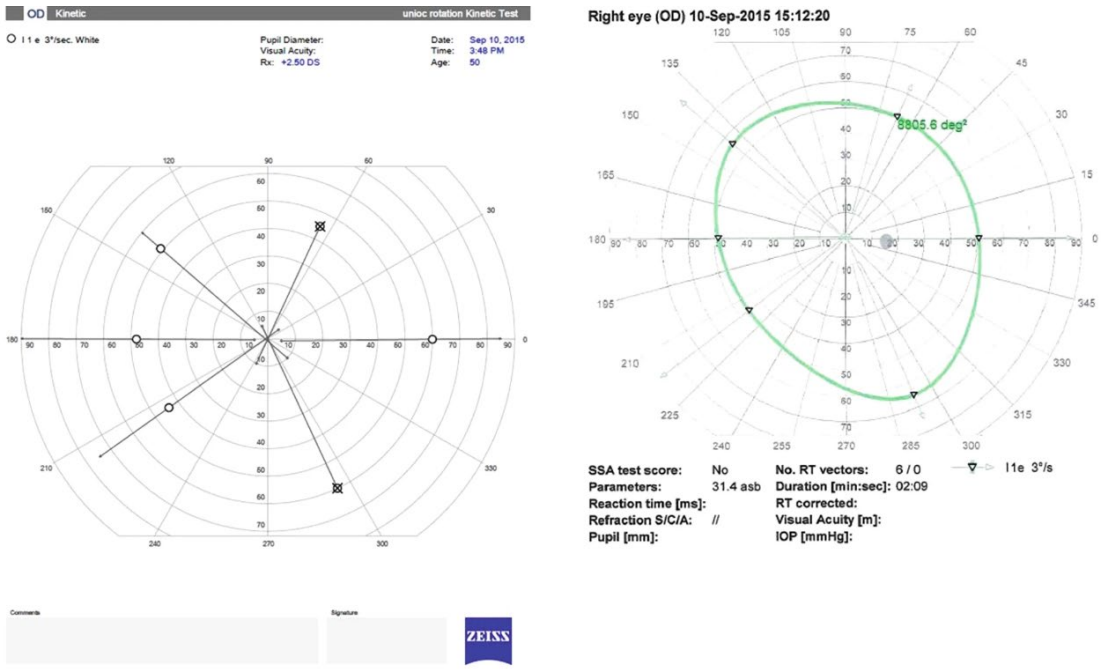
The Lees Screen is a modification of the Hess Chart used in departments for the same purpose, developed in the 1940s by Ophthalmologist V.T Lees in Manchester Royal Eye Hospital (Timms, 2017). Dissociation of the eyes in the Lees Screen differs from the Hess Chart by utilising two adjacent screens split by a mirror at a 45˚ angle with the theory that two targets are projected on the fovea and perceived as a single image. The screens consist of a similar 25 point grid. No lenses are required for this test however the fixing eye will view the screen directly in front of the patient and the non fixing eye will see a projection of the screen through the mirror. If the fixing eye has an anomaly then this will be demonstrated as misplaced proprioceptive pointing by the non fixing eye due to Hering's law of equal and simultaneous innervation.

Although the principles of the Lees Screen and Hess Chart are similar and produce interchangeable results, it has been found that the Lees Screen is preferred by patients and has been described as

being an easier test to carry out, even with younger patients (Raghuvanshi et al, 2022). This is thought to be because there is greater dissociation achieved with a physical barrier, compared to red-green goggles which can often allow targets to be perceived with both eyes if the test is not conducted well and the patient looks round the lenses. That being said often patients must move their head to see peripheral spots on the Lees and hair can provide a barrier to seeing the whole field.

Another notable advantage of the Lees Screen is that it can be modified to measure torsion with the addition of a linear pointer and protractor developed by Dulley and Harden in the 1970s (Dulley and Harden, 1974). Although both the Hess Chart and Lees Screen recordings display elements of torsion in their findings, there can be no numerical evaluation without this adaptation and is particularly useful in those with superior oblique weakness which is commonly associated with excyclotorsion.

Both tests have been a staple of extraocular movement examination influencing clinical decision making and allowing consistent monitoring of ocular motility. Alternative methods using automated perimeters have been used however there is very little evaluations of how these methods compare to older technology with only one study comparing the Octopus and Humphries visual field machine (Rowe et al 2018) that evaluated static versus kinetic measures of ocular rotation and one study that evaluated the Octopus with Goldmann perimetry for motility (Rowe&Hanif 2011). Figure 1 below shows a plot of uniocular field and fields of BSV on the Octopus.



Uniocular rotations. **a** Humphrey 850 (**b**) Octopus 900. Uniocular rotation results are displayed for the right eye from the Humphrey 850 (**a**) and Octopus 900 (**b**)

Figure 1: Plots of normal gaze on Octopus.

Access to perimeters may be problematic due to demands on the instrument for visual field analysis in hospital practice where demand is high in glaucoma clinics. The range of field that may be assessed in perimetry is similar to digital methods with the Octopus evaluating out to 60° degrees and the Thomson BVA analyser assessing out to 55° degrees.

Digital versions of the Hess chart has been available for some time, and were noted to provide consistent and easy measurements of motility that were comparable to the older instruments (Thomson et 1990) providing a potential tool for replacing the large cumbersome older instruments. A further two different computerised Hess chart systems have been described in the literature. The Assaf Ocular Motility Assessment (OMA) computerised test was compared to the Lees screen in a paper by Watts et al (2009) who concluded that the computerised Lees screen and the OMA were comparable with patients preferring the computerised system. The Thomson Digital Hess Chart was described in a paper by Akina et al (2020) as a good tool to use to monitor eye movements after an orbital fracture and it's impact on ocular motility. The digital KM screen has also been tested in a study by Thorisdottir et al (2018) where they found that this instrument that uses similar methods to the Thomson Software chart was comparable at assessing motility in all positions of gaze.

Thomson software solutions have now developed the BVA analyser that provides a digital Hess screen along with the ability to assess the field of Binocular Single Vision (FBSV) , traditionally done on the Aimark Perimeter and the Uniocular Field Of Fixation Test (UFOF) , usually conducted on the Aimark perimeter or Goldmann's visual field test or Octopus fields machine. These tests are essential to assessing the effect of motility abnormality on visual function and the ability to see singly and provide valuable data on mechanical motility disorders and bilateral disorders that are not so well tested on the Hess or Lees Screen due to the fact that these methods rely on the laws of eye movement and the development of sequelae in uniocular conditions. This does not occur in the same manner in bilateral or mechanical deviations.

This instrument is now in place across the UK , Holland and ???. This report will document a study to compare the outcomes of the BVA analyser testing normal motility using the digital Hess and the UFOF element of the software. At the current time we do not have sufficient number

Method

Participants were recruited from eye clinics and students in university following the granting of ethics by GCU university ethics committee. All had a full assessment of ocular alignment and BSV. Visual acuity had to b better than 0.2 LogMAR either eye. The testing was conducted in one session

by two examiners who were blind to the others results. One examiner conducted examinations on the old technology whilst the other carried out assessment using the BVA analyser. The inclusion criteria for the study required participants to have a minimum visual acuity of 0.2 LogMAR, corrected for those who require a prescription, in both eyes, using the LogMAR chart at 6m, confirmed stable heterophoria or orthophoria through cover test, full range of ocular movements as evidenced by ocular motility assessment . Prior to the examination, the participants' ocular movements were evaluated in free space, and the results were recorded in nine positions of gaze, which followed the standard clinical protocol outlined by Vivian and Morris (1993).

The exclusion criteria included individuals with strabismus, neurological and extra-ocular motility defects. The study participants did not receive any practice tests before the actual data collection. To prevent the impact of fatigue on results, an option of a rest period was provided to the patients before the commencement of the next test although order of testing was randomised.

Aimark Perimeter

A chinrest is provided to allow the patient to rest their chin to ensure accurate alignment and results. When performing the tests on this machine, it was recommended that they remove glasses, expect for individuals with a high prescription, due to the possibility of the frame obstructing the view of the target and limiting the eye's range of movement. The test distance between the patient and the light stimulus, measured from the edge of the arc arm, is set at 30cms. The Aimark perimeter used a suprathreshold light stimulus that was visible to all participants, rather than a foveal threshold where the smallest light was calculated.

The Aimark perimeter was used to measure UFOF, the 6 specific angles were used to measure individual muscle actions, starting at 0 and progressing in a clockwise or counterclockwise direction. The uniocular cardinal axes were evaluated using the following: (right eye) lateral rectus 0°, superior rectus 60°, inferior oblique 135°, medial rectus 180°, superior oblique 210°, and inferior rectus 285°. During UFOF assessment, as the test was only conducted on the right eye, the left eye was occluded. The examiner instructed the patient to place their chin on the left-hand side. The patient was directed to track the target in each axis, commencing from central fixation and continuing until they were no longer fixing centrally on the target. The patient was instructed to notify the examiner when they were no longer able to follow the light and look directly at it, therefore no longer fixing on the light with the fovea.

A field of BSV was nor recorded on this instrument so is unavailable for analysis.

Lees Screen

Figure 2. Wall mounted Lees screen used to record Hess chart. Subject's eyes dissociated with mirror..

Lees Screen

The Lees screen was typically aligned at eye level, with the central line of the grid also aligned at eye level. This ensures that the patient's eye is in the centre of the grid when viewing the screen. The participant was asked to rest their chin comfortably on the chin rest connected to the 45° bisecting mirror. The working distance between the patient and the screen in the Lees screen setup is 0.5m. The testing method was explained to the participant by the examiner, who provided a pointing stick. The eye movements were recorded of both the right and left eyes fixing. Right eye fixing was caried out first.

The participant was then instructed to point at the target on the screen in front of them when the researcher pointed towards the target on the left screen. To plot each point, the examiner used a foot pedal flash the participant's right-handed screen on and off intermittently during measurements. The right eye was examined in nine different gaze positions and recorded. The focus was on both the primary position and outer field, and recorded the right eye's direct elevation, direct depression, dextroversion, dextroelevation, dextro depression, laevo version, laevoelevation and laevodepression. Wearing glasses was not suitable for this test as they can block the target and thus restrict the eye's movement range. The Lees screen records measurements in degrees.

Binocular Vision Analyser (BVA)

Figure 2. the picture shows the BVA analyser used to digitally record eye movement functions..

The monitored used was 49 inches Samsung TV. The screen dimensions were 110cms width and 64cms height, with a working distance of 33cms from the central point, when the patient is in a seated position with their chin on the chin rest. The size of the field that can be measured is restricted to the angular size of the screen which is +/- 55 degrees vertically and +/- 60 degrees horizontally. The testing is performed in the darkness to eliminate background cues and enhance eye dissociation. Incomplete darkness in the room may cause the patient to see the screen surround, potentially affecting results due to binocular lock.

Hess Plot

The participant used the red/blue goggles, red filter over the right eye and blue filter over the left eye after colour calibration was carried out to ensure total dissociation of images using colour. The participant sat with their chin on the chin rest. They were asked to put the red blue circle on the red dot using the mouse and all directions of gaze were tested .

UFOF

Participants did not wear glasses but sat with their chin on the chest rest to record 6 cardinal points of motility for the right eye only.

. The spot target was automatically moved along 6 radial lines from the centre of the field and the participant reported the disappearance of the target by pressing the space bar indicating the eccentricity. The speed of the stimulus was adjusted to 6, to confirm accurate tracking of the axes path. The target was at visual acuity threshold and the speed was set at 9. Participants were informed to press the space bar when the spot was no longer clear indicating it had moved off the fovea.

FBSV

Occlusion and glasses were not required. The central spot target in the test moves automatically towards the periphery, following a series of radial lines at 20-degree intervals. Participants tracked the movement of the spot with their eyes and indicated when it appeared double or disappeared by pressing the space bar, the eccentricity was documented automatically. The size of spot was decreased to threshold levels for detection.

Results

Lees Comparison with BVA Analyser Hess Plot

Comparison of size of deviation detected was carried out for 20 participants , assessing deviations in the nine positions of gaze. Results showed little difference in deviation detected with the mean deviation size found on the instruments using a T-test for each comparison Fig 3a . The standard deviation was greater on the Lees with more variation on left gaze. However there was no significant difference in deviation found in any horizontal gaze position .

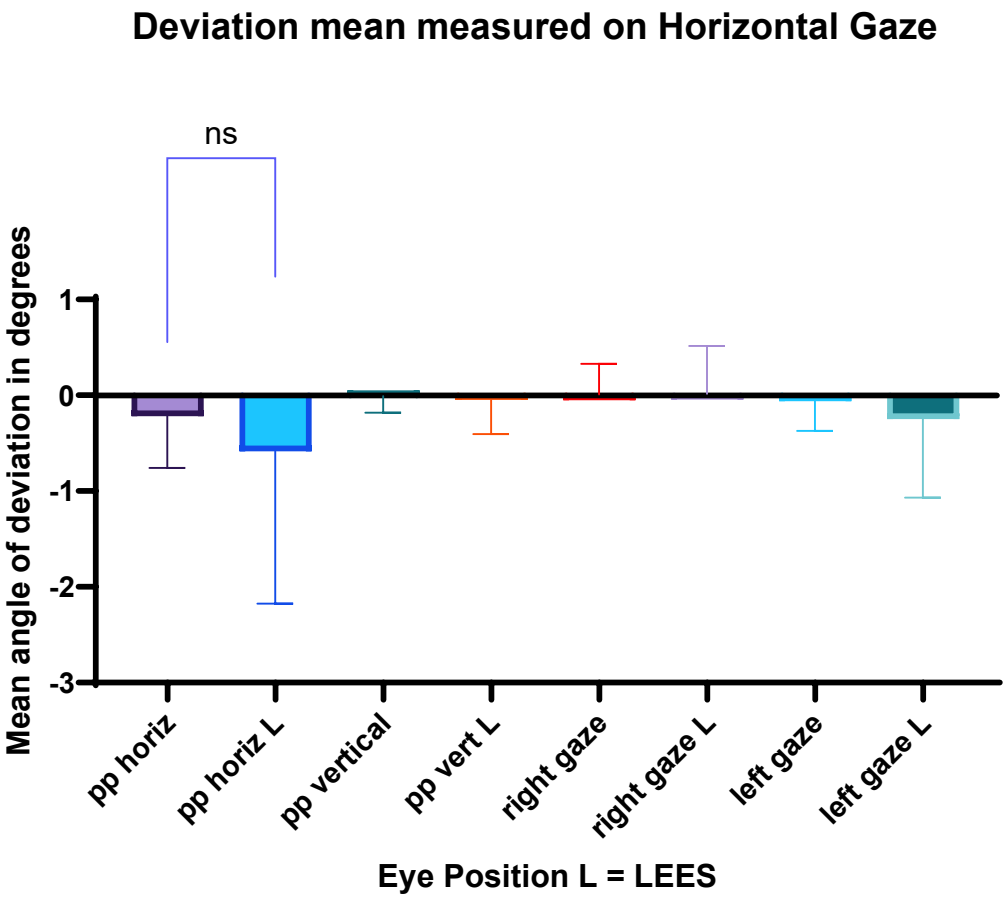


Fig 3a : Mean deviation in horizontal positions of gaze +/- SD (Paired T-test p>0.05)

A statistical difference was found for dextro and laevo elevation (Paired T-Test p=0.01 ***) between the instruments with the BVA analyser recording more deviation than the Lees. This may be due to a number of participants being unable to view the extreme right and left top element in LEES and a not seen note was recorded or a zero .

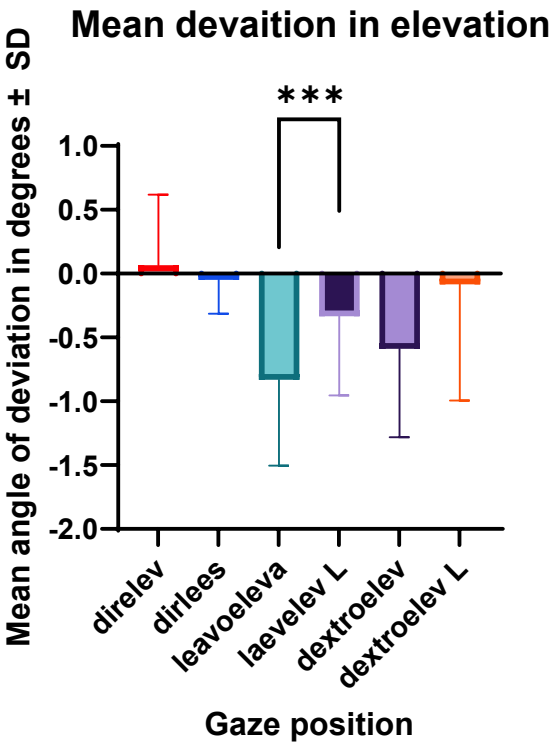


Figure 3B shows the mean deviation detected in instruments in elevated positions.

A similar analysis was conducted for elevation and the down position also revealed some difference in extreme right and left gaze (dextro depn p=0.02< *) . (Fig3C)

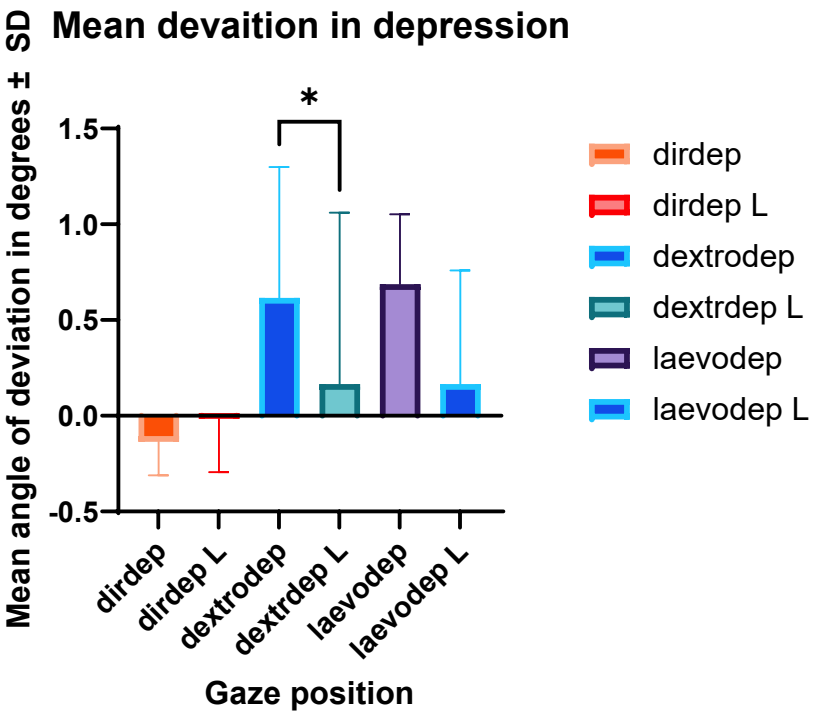
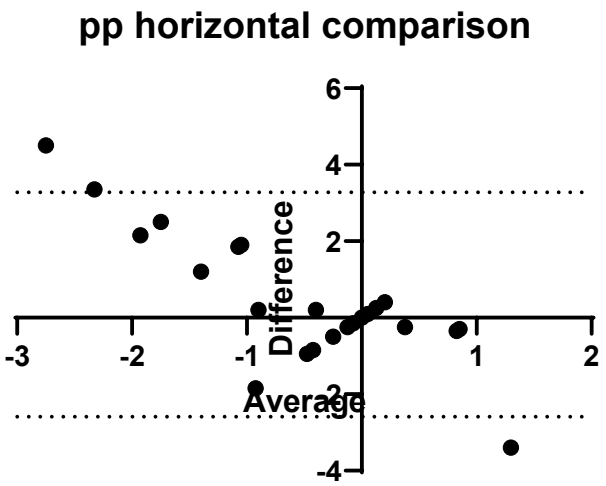


Figure 3C : Mean deviation detected in depressed position

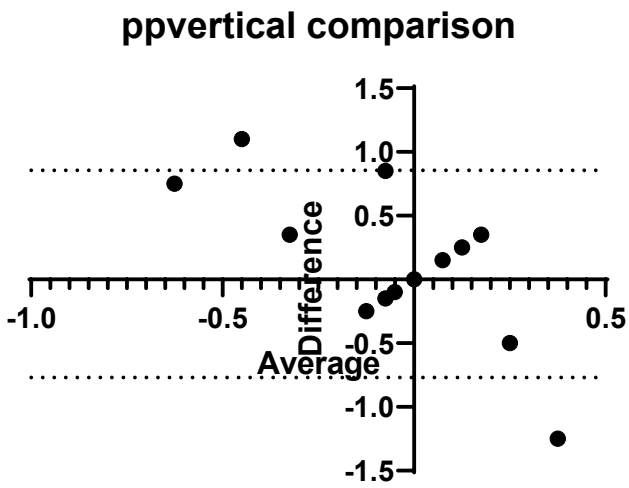
A Bland Altmann analysis was carried out to compare the horizontal deviation in the primary position (PP) . The majority of points fell within the 95% confidence interval with the LEES measuring slightly greater deviations horizontally. Small bias indicates that any differences are unlikely to have significance clinically .(Fig 4)



Bias	0.3483
SD of bias	1.497
95% Limits of Agreement	
From	-2.586
To	3.283

Figure 4 :Comparison of measures in the LEES and BVA analyser in primary position using Bland Altman Analysis

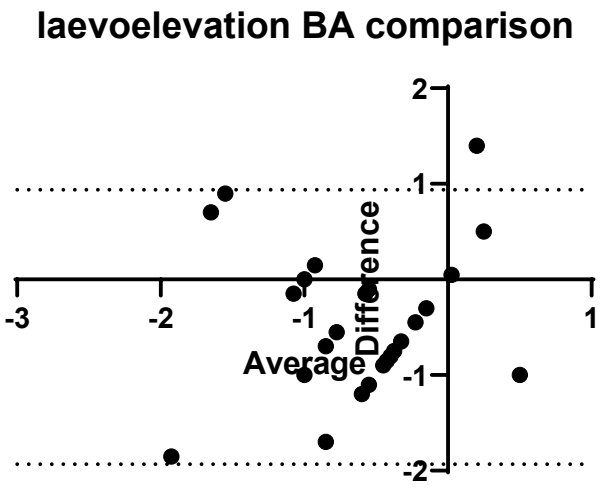
A Bland Altman analysis to compare the instruments was conducted for vertical deviation detected in the primary position (Fig 4).Figure 4 shows that the majority of points fell within the 95% confidence interval suggesting good levels of agreement. S between the tests. The BVA analyser detected small levels of vertical deviation that were not always indicated by the Lees. (Fig5)



Bias	0.04333
SD of bias	0.4141
95% Limits of Agreement	
From	-0.7684
To	0.8550

Figure 5 : Comparison of vertical deviation detected in Lees and BVA analyser where most points fell within 95% confidence interval with a small Bias suggesting good levels of agreement between the tests.

Bland Altman analysis of laevoelevation revealed that most points fell within the 95 confidence interval with only one point outside. The degree of BIAS was small and differences are unlikely to be of clinical significance . (Fig6)



Bias	-0.4967
SD of bias	0.7318
95% Limits of Agreement	
From	-1.931
To	0.9376

Fig 6 : Comparison of deviation found in laevoelevation on instruments using Bland Altman analysis .

There were a number of points that were not recorded on the LEES indicated as NS to mean not seen. This occurs due to anatomical issues and hair or spectacle rims blocking the view.

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2 Uniocular field of fixation on Aimark Perimeter and BVA Analyser

Due to time to complete all tests only the right eye was recorded on the UFOF element of the test. 11 Plots are represented below. The Aimark perimeter is plotted as the patient is looking at you so the left hand side of the chart represent right gaze. The Aimark is able to assess up to 100 degrees in temporal gaze . The BVA analyser extends to 60 degree meaning that the airmark can assess wider gaze however in practical terms patients rarely rotate the eyes to these extremes and usually turn their head at about 60-70 degrees (Fig6) The fields are comparable qualitatively however quantitively the BVA analyser assesses smaller fields of uniocular fixation than the Aimark perimeter due to the flat screen format being unable to replicate the bowl like features of the Aimark that facilitates wider gaze assessment.

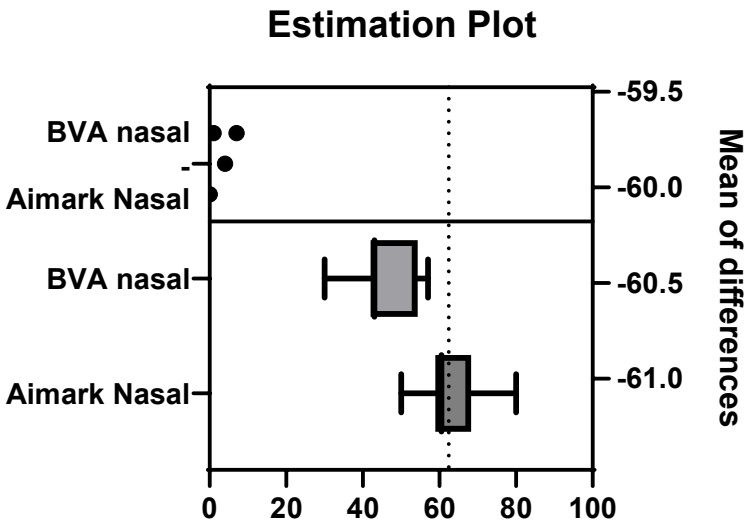
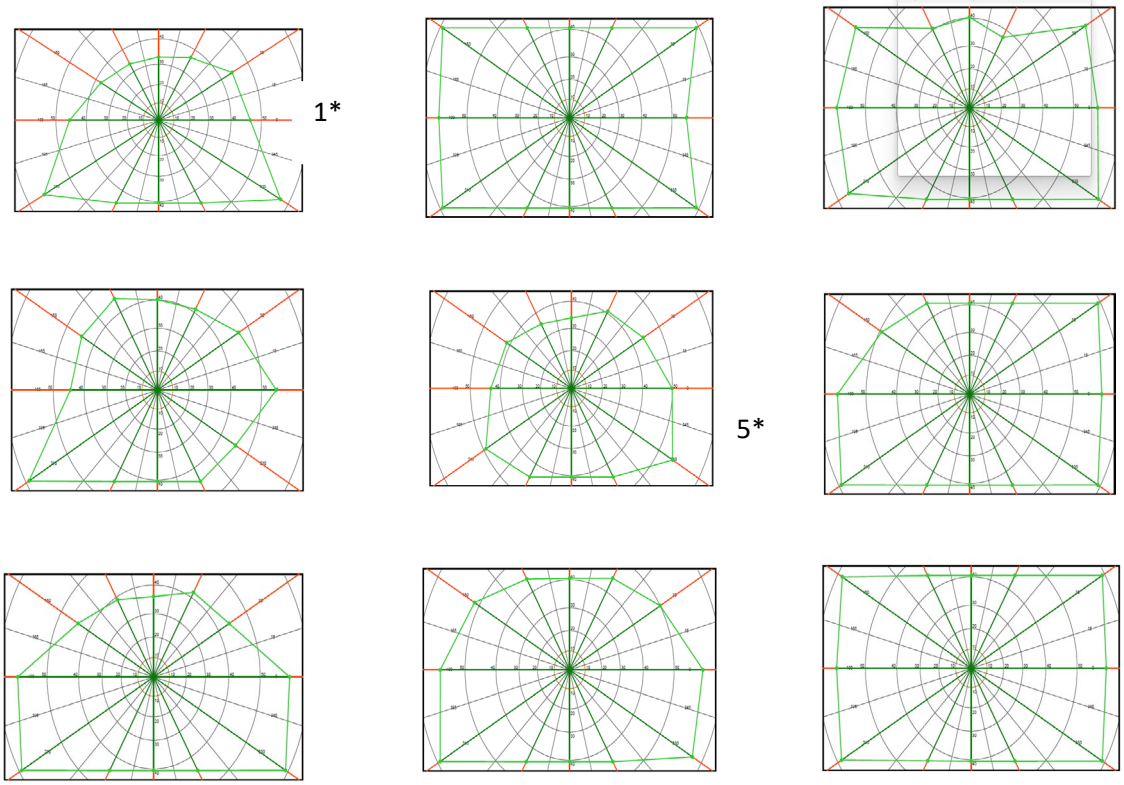


Figure 7 : Mean limits of gaze on instruments with means being statistically different in Nasal gaze ± SD (ttest p=000.1)

Comparison of the plot shapes was carried out on the BVA analyser show a high degree of consistency with a distinctive shape for the right eye being plotted. Greater variation can be seen in the Aimark perimeter which is hand drawn by the examiner. The mean plot area for the right eye can be calculated on the BVA analyser and this was found to be 5986 degrees ^{2} ± SD 43 degrees ^{2}

Field of BSV (FBSV)

We currently do not have reliable date of measurements of the field of BSV on the Airmark perimeter however a range of plots have can be found in Appendix 3 of FBSV plots taken on the BVA analyser. Based on an evaluation of 14 participants the Mean area size for normal motility is 6951.2 ± 770 degrees [2]



A full field will appear as a rectangle but even in normal motility the BVA analyser is able to find some areas of restriction . Field one is limited on elevation and Hess plot reveals a V exo tendency so this would be expected to reduce Binocular single vision on elevation (1* and 5*)

One example of abnormal motility was collected and is shown in Figure 8 below of a patient who has restricted elevation and abduction but has a normal HESS plot and it can be seen from this

patient with diplopia that the plots mirror each other in shape and show restriction in elevation and left gaze which is where the patient reports diplopia.

Figure 5: FBSV, with slight field restriction shown on Aimark and BVA Analyser below

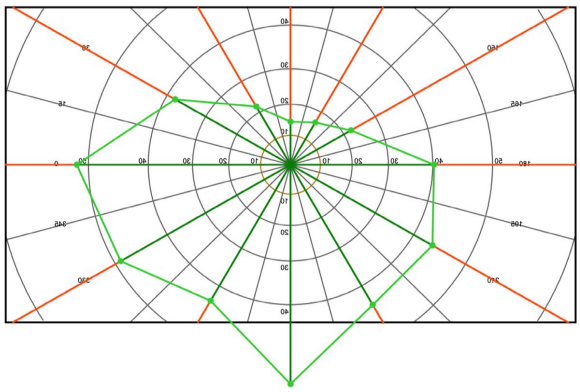


Figure 8- Restricted field of BSV in patient with ocular motility restrictions related to myopic esotropia

Discussion

Lees and BVA Analyser Hess Plot The Hess plots have been consistent between instruments. Differences in deviation size are likely to be artefacts of testing. Patients often have to move their head during testing to see the peripheral target. They struggle to see the extreme upper and lower targets and often cannot be recorded. This would explain the low averages found on the Lees

compared to the BVA analyser where patients generally did not have difficulty in seeing targets and were not required to move their head to see targets. This may explain the small variation in measurement and smaller standard deviations noted on the BVA Analyser suggesting more consistent testing. Despite some peripheral viewing issues the tests were comparable when using Bland Altman assessment . The small differences and BIAS noted are unlikely to amount to clinical significance with only 1 or2 degrees difference at maximum.

Patients generally found the BVA quicker and more easy to perform. Some issues were noted with he googles however new goggles will be available that ensure better coverage of eyes and the screen and will align with the head restraint. The colour calibration of the new filters is also optimal for the technology and will ensure total dissociation.

Without a Dulley adapter the Lees cannot record torsion . It was noted that the BVA analyser can detect torsion and this is a distinct advantage to the existing technology .

UFOF

The BVA analyser is unable to test eye movement so the same degree of extremity as the Airmark however since this instrument is soon to be obsolete and cannot be repaired new means of assessing eye excursions are needed. The greater range of motility is likely to be also due to the fact that a suprathreshold target was used on the Airmark making it difficult for patients to know when the target fell off the fovea. A threshold target was used on the BVA analyser thus ensuring that when the patient could not see the target clearly they knew they were not following it. The range of motility that can be tested on the BAV analyser is similar to the Octopus and other digital tests. The field of movement that is tested is likely to be representative of the patients experience since patients rarely move their eyes to extremes and tend to turn their head . A study carried out by Lee et al has shown that the normal range of eye movement when asking patients to move their eyes is 44.9 ± 7.2° in adduction, 44.2 ± 6.8° in abduction, 27.9 ± 7.6° in elevation, and 47.1 ± 8.0° in depression (lee et al 2019). This essentially means that the digital forms of testing cover the most important areas of gaze sufficiently.

Field of BSV

The field of BSV was easy to test on the BVA analyser. Normal BSV fields differ from the Aimark heart shape however normal fields of BSV are mostly rectangular on the BVA Analyser . It seems able to

detect weakness of BSV on elevation , something that occurs due to physiological weakness of the superior rectus giving rise to V patterns.

This paper shows a range of normal values and this can be used for comparison for users going forward.

Conclusions

The Thomson BVA analyser provides a easy, quick and consistent way to assess three elements of ocular motility that does not involve practitioner interpretation . This tool provides a compact and effective way to assess fields of ocular motility and fields of BSV that have been falling out of general practice due to the loss of equipment with age and use. The LEES requires a large space to install and although these can be replaced thy are costly and cumbersome. Whilst these are available through hospital eye departments the smaller BVA analyser may be more useful in High Street Optometry practice and may encourage more routine assessments of motility in general practice.
Enhancements such as better filters and the ability to correct points plotted in error will ensure accuracy and usability improve. Patients preferred this technology and generally it was quicker to conduct, without the requirements to move the patient between instruments or rooms. Analysis has shown that the BAV analyser is comparable both quantitively and qualitatively in recording ocular motility defects

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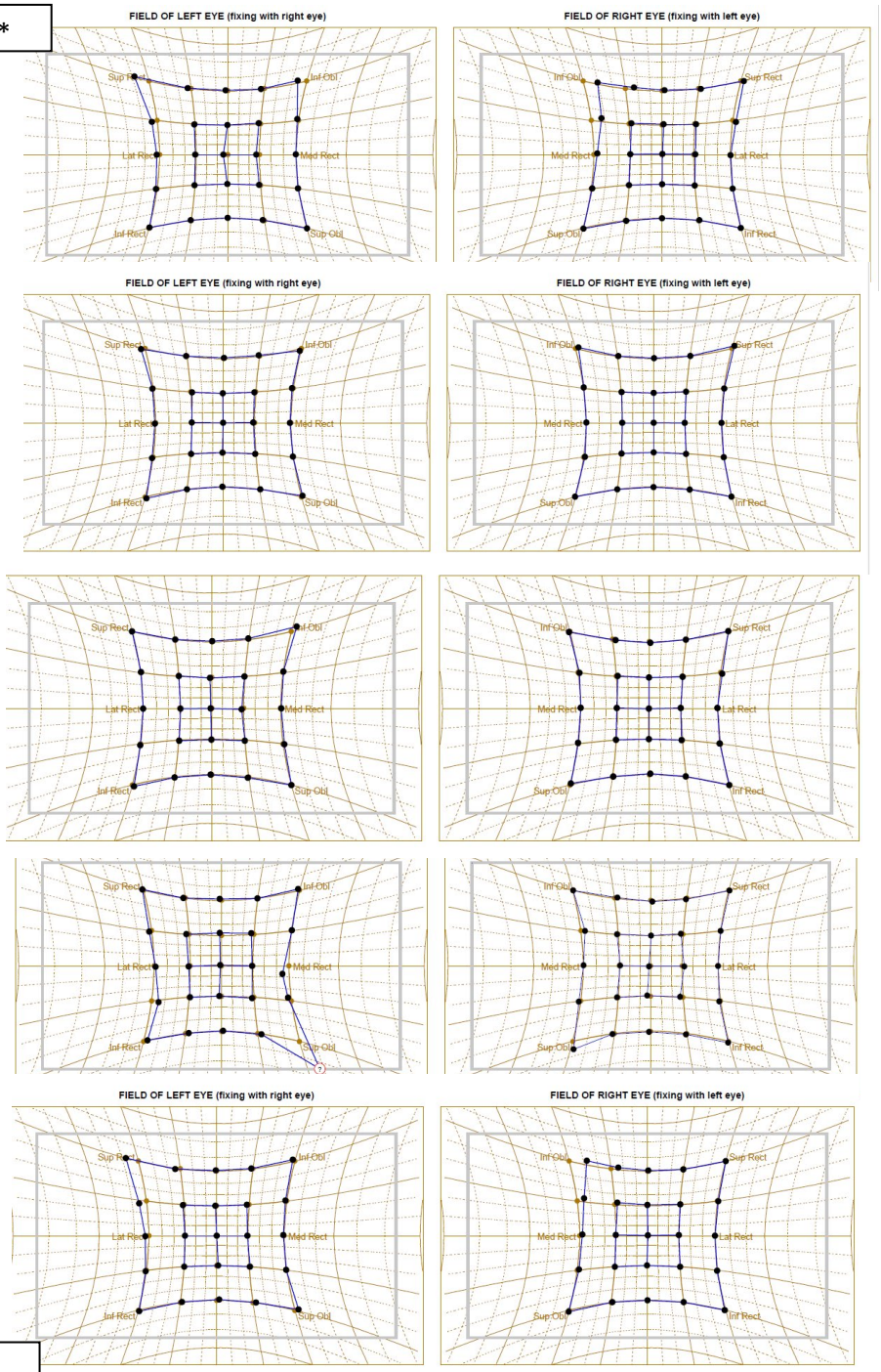
Appendix 1 Hess Charts Accompanied Automatically Plotted on the BVA

1 *



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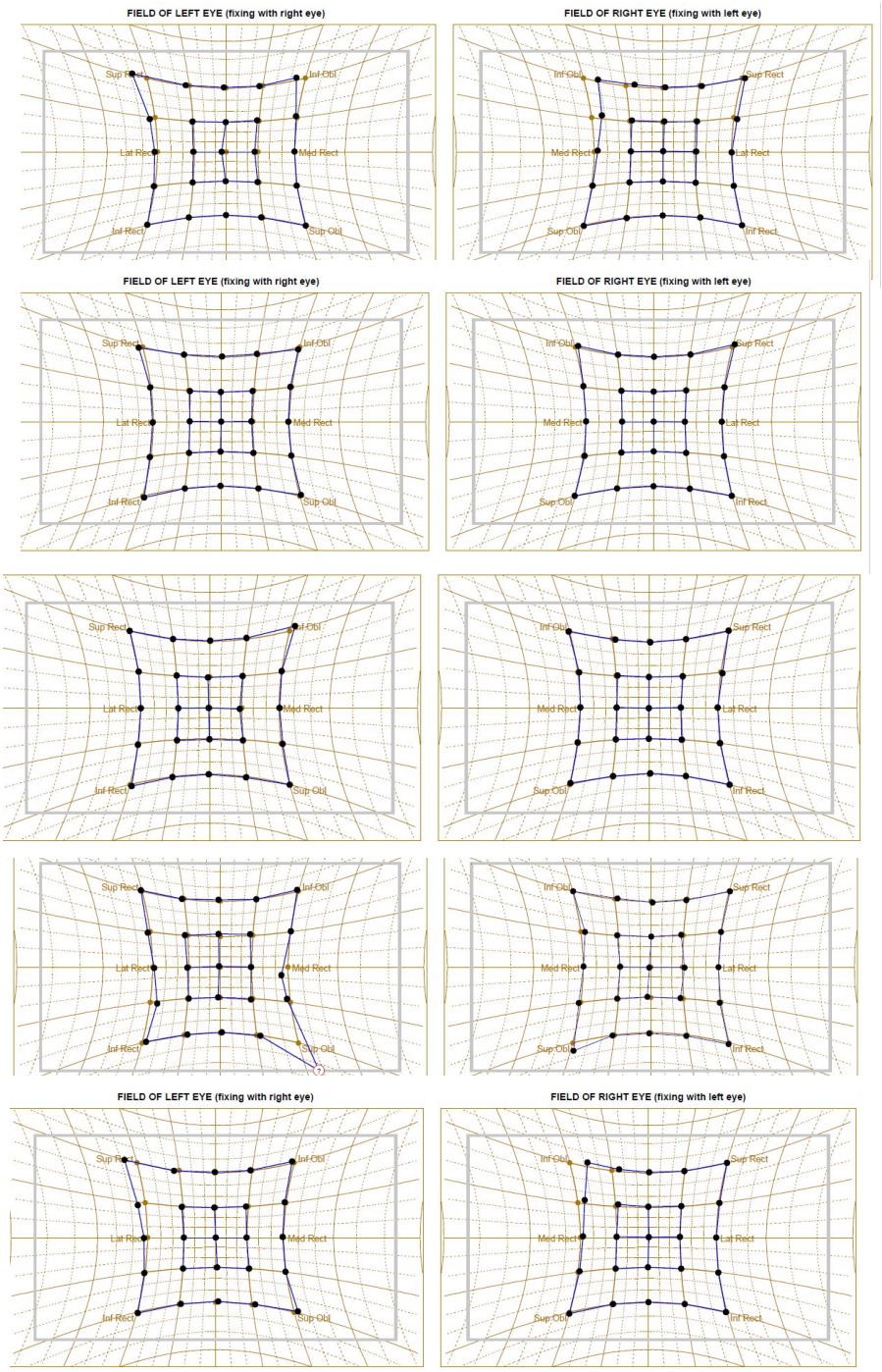
FIELD OF LEFT EYE (fixing with right eye)
FIELD OF RIGHT EYE (fixing with left eye)
Sup Rect
Inf Obl
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Med Rect
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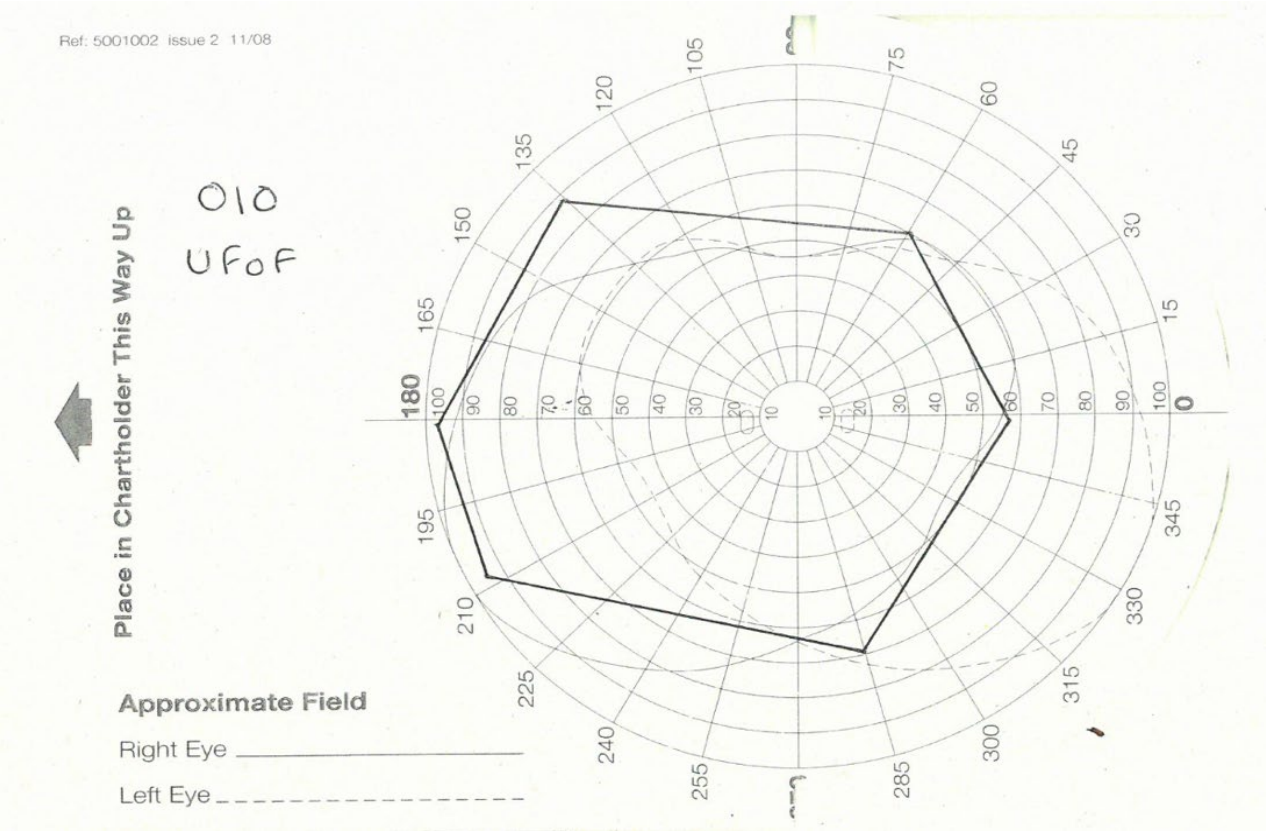
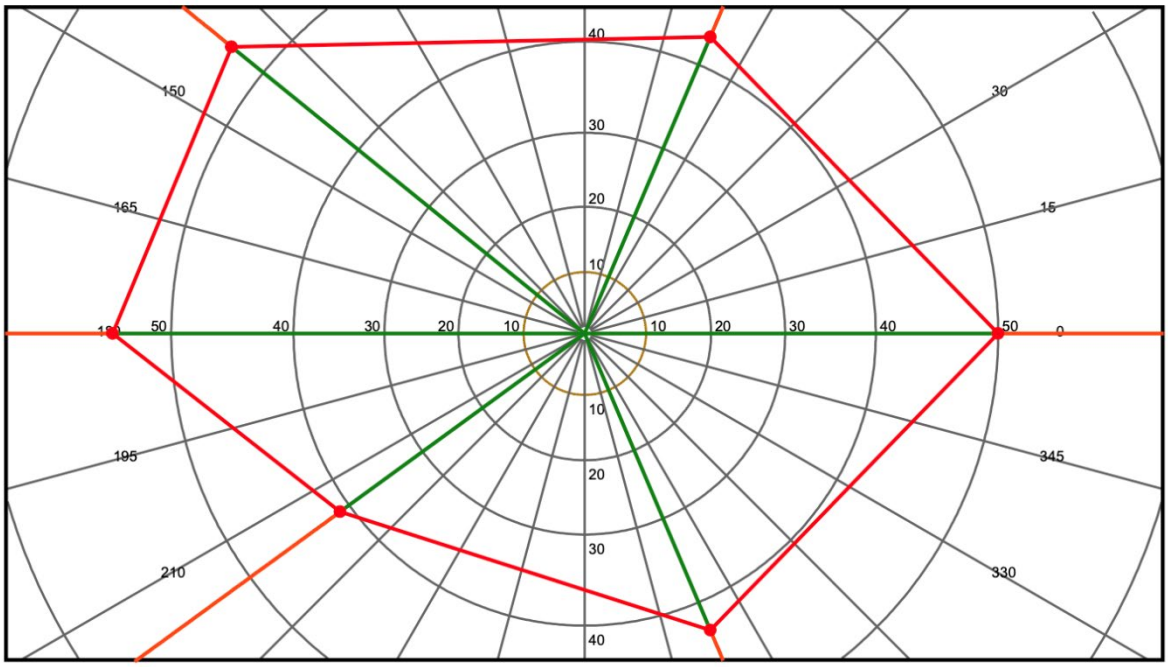
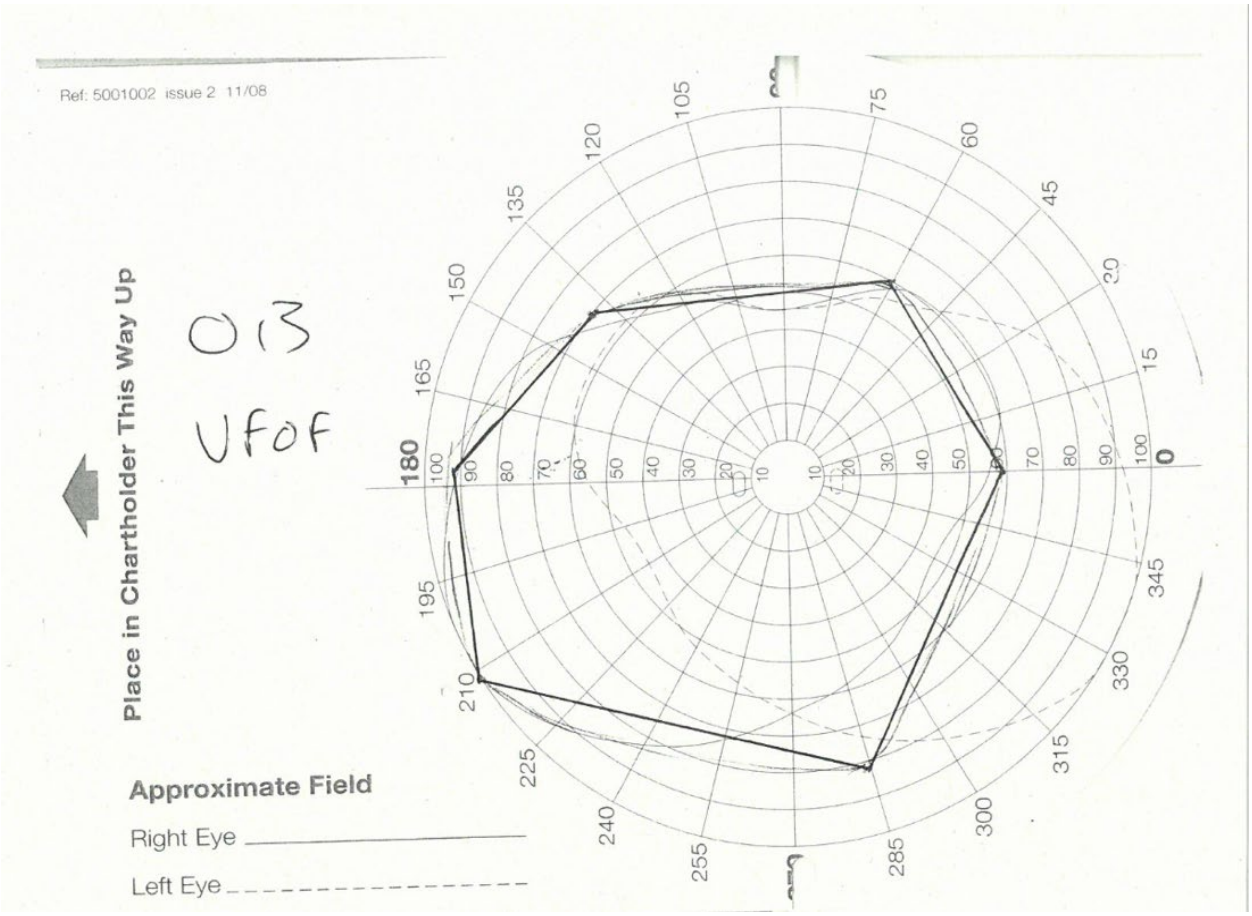
Appendix 2 – UFOF plots from Aimmark and BVA Analyser shown in Colour



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Place in Chartholder This Way Up
O13
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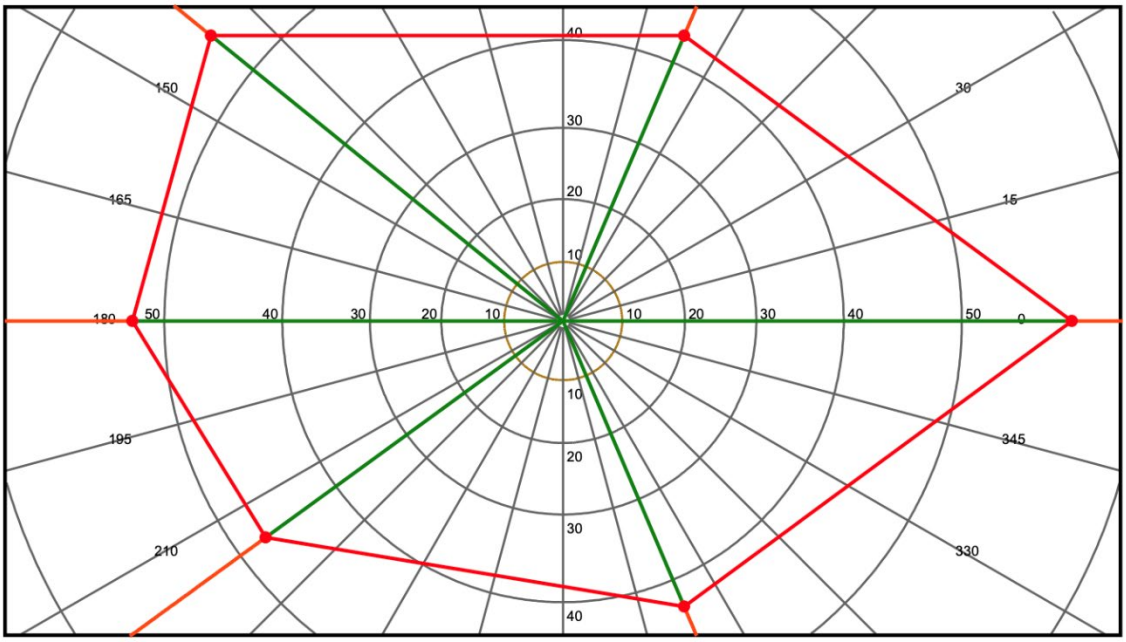
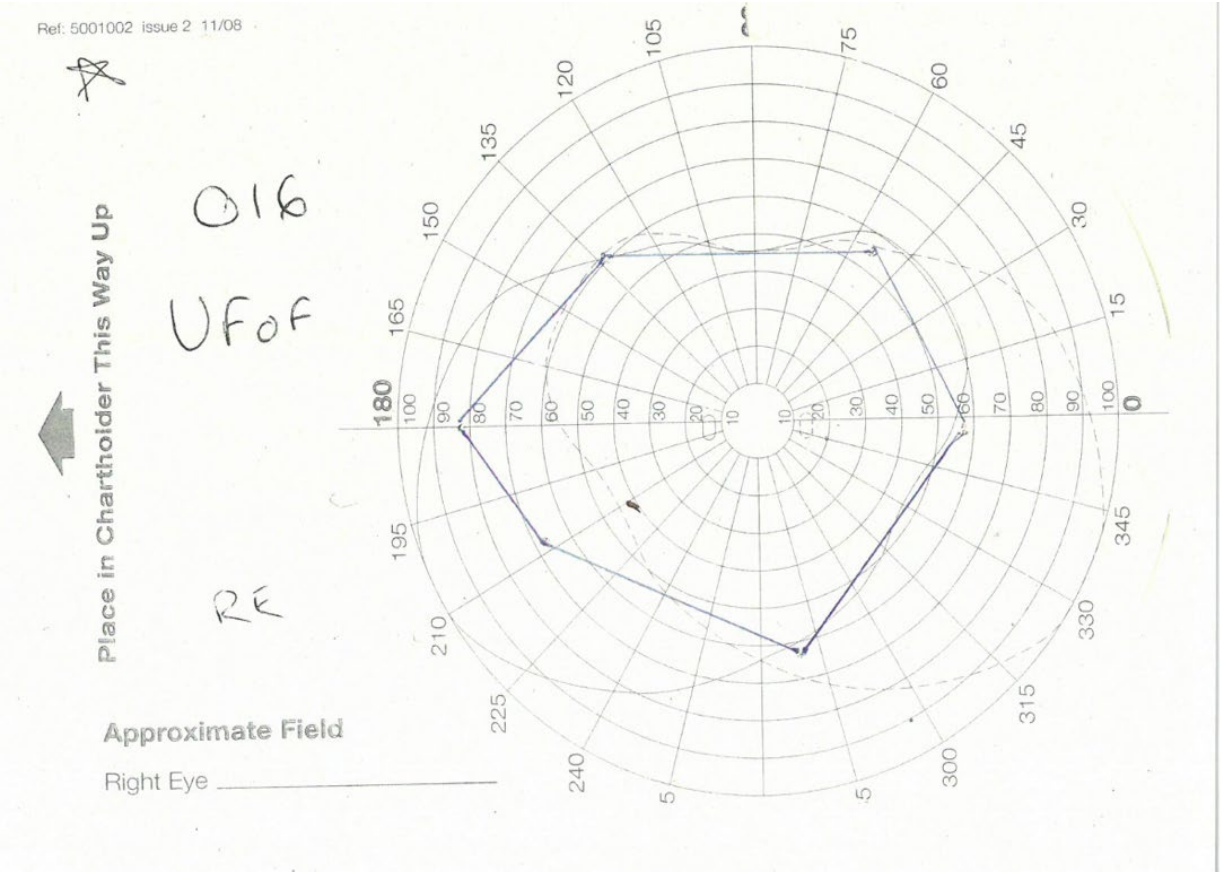
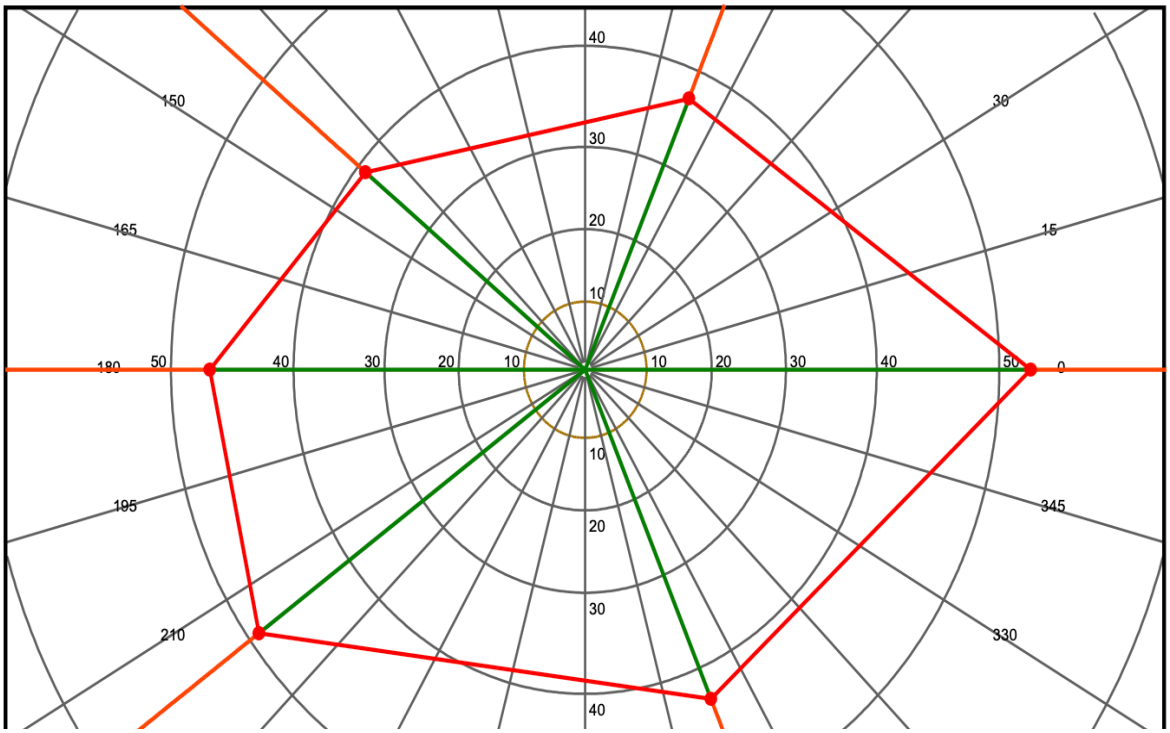
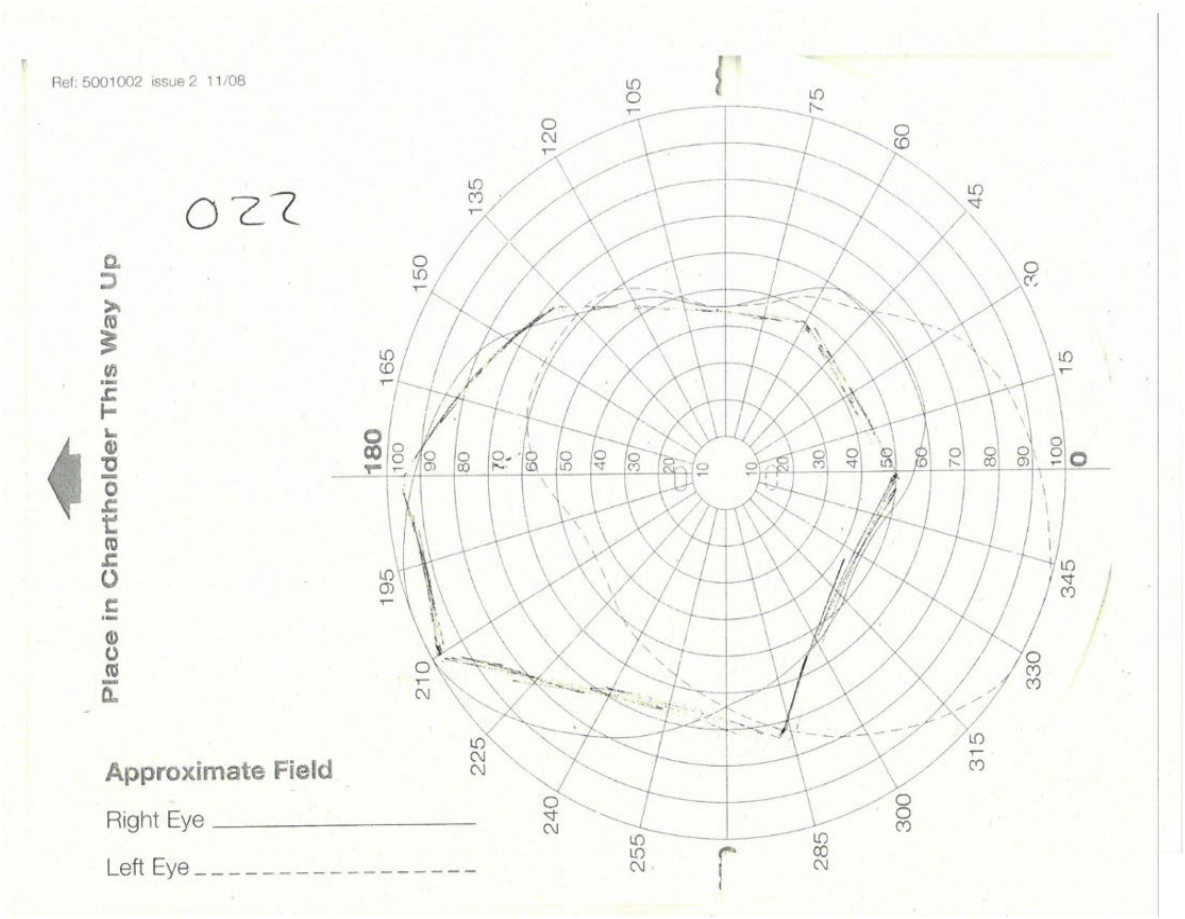
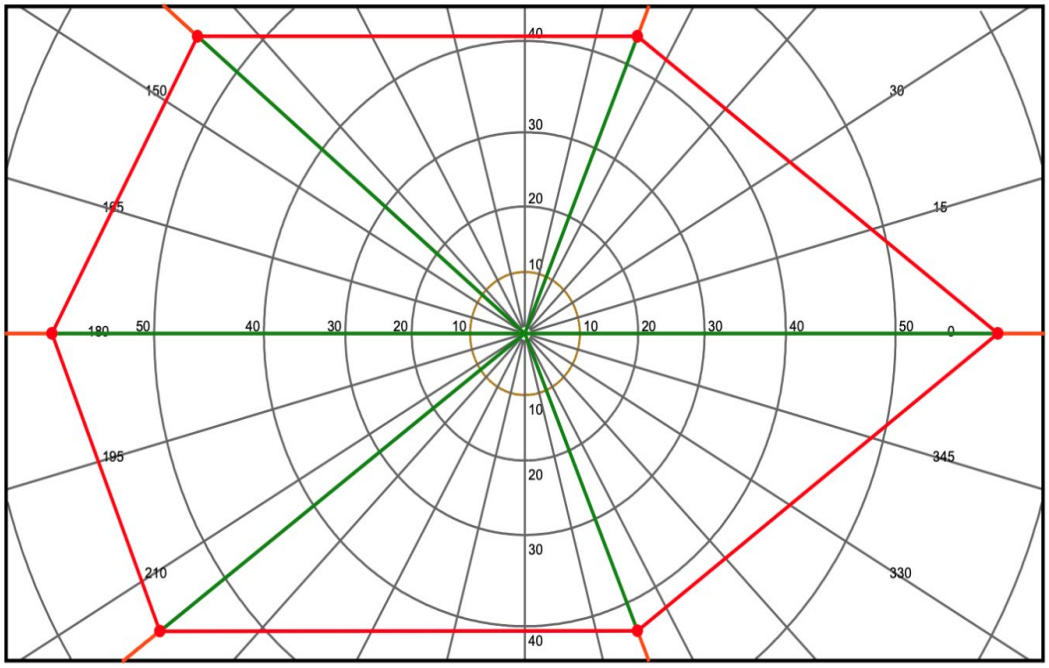
Approximate Field
Right Eye
Left Eye

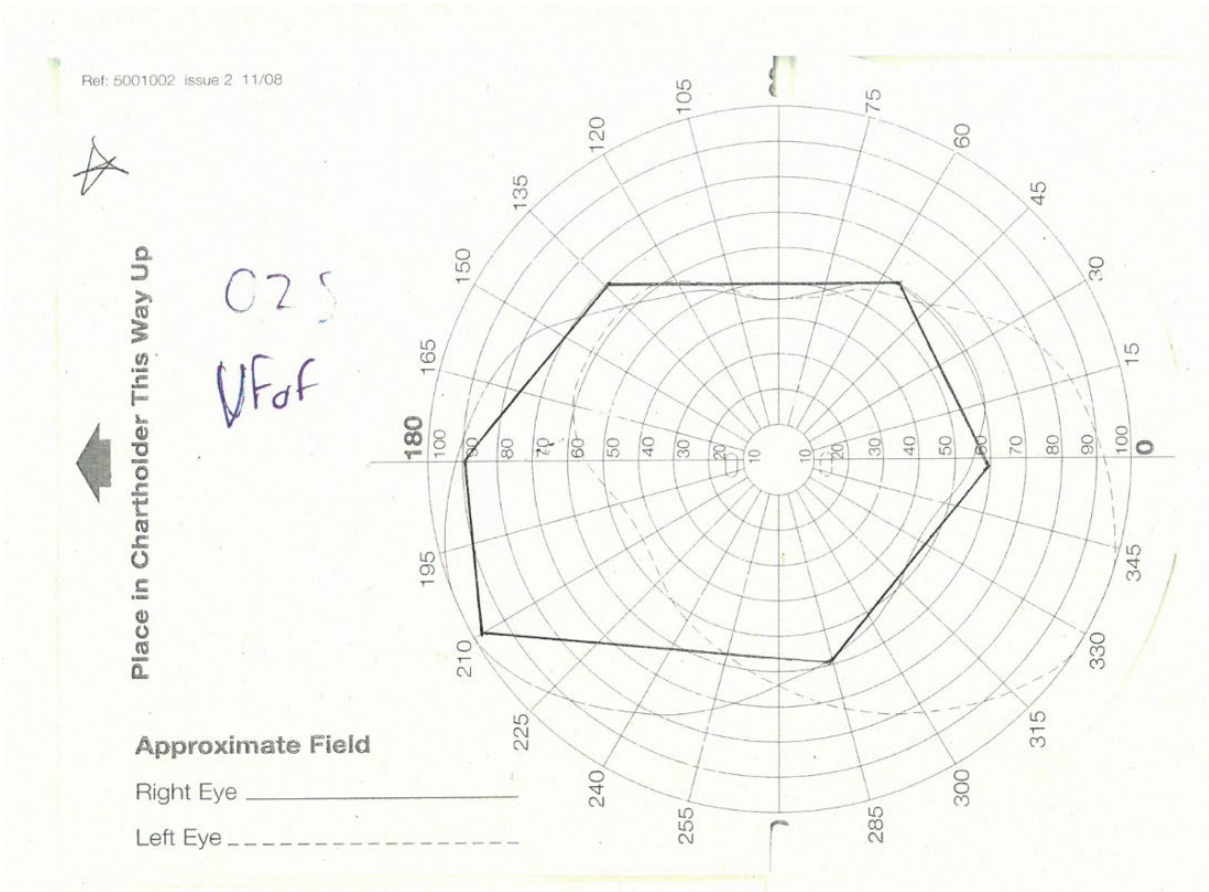



Ref: 5001002 issue 2 11/08
Place in Chartholder This Way Up
Approximate Field
Right Eye
016
UFoF
RE




Ref: 5001002 issue 2 11/08
022
Place in Chartholder This Way Up
Approximate Field
Right Eye
Left Eye




Ref: 5001002 issue 2 11/08
Place in Chartholder This Way Up
C25
VFaf
Approximate Field
Right Eye
Left Eye
180
0
105
75
120
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30
165
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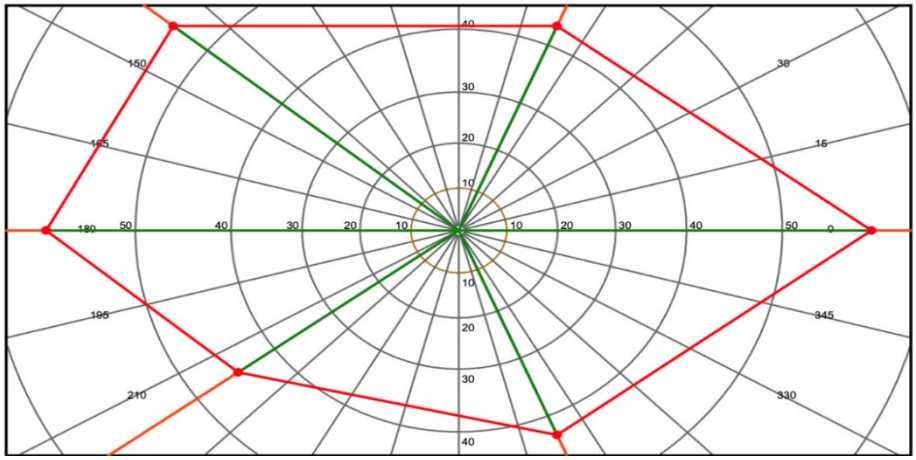
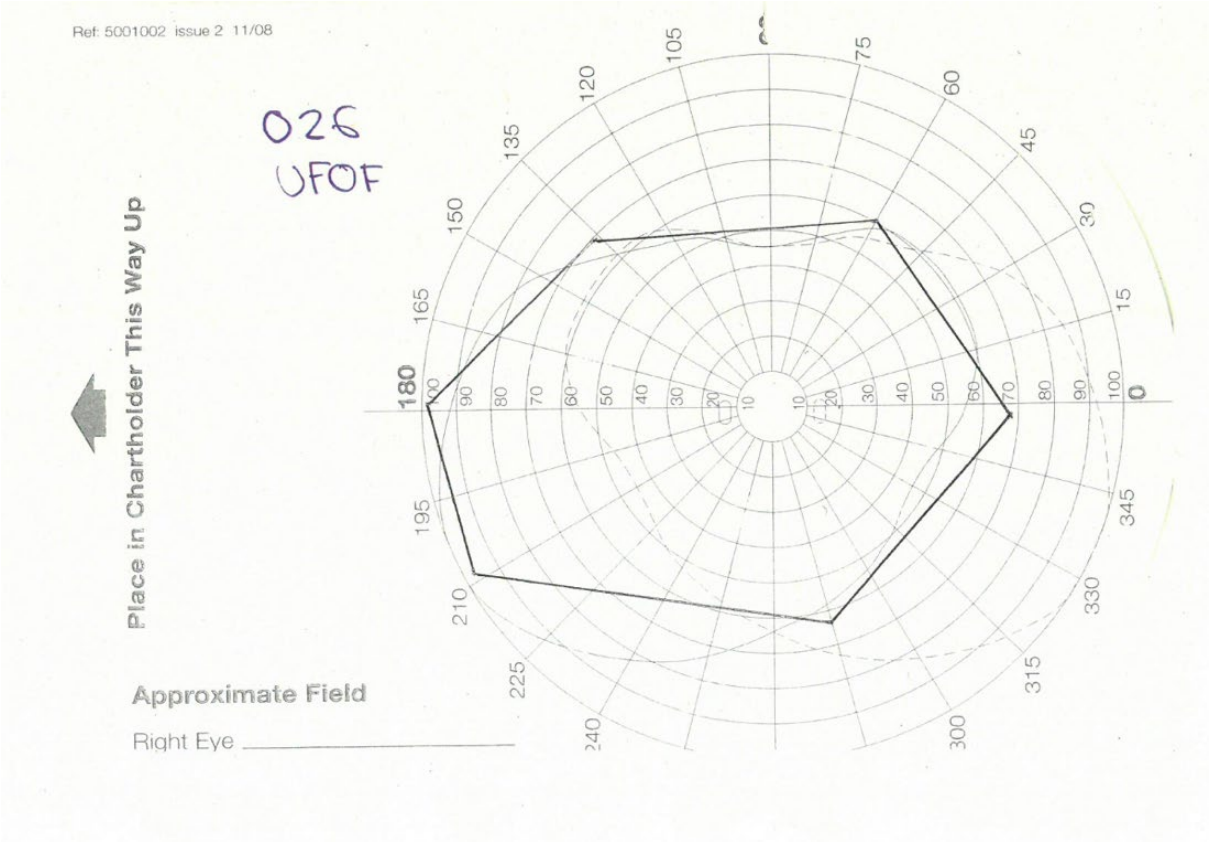
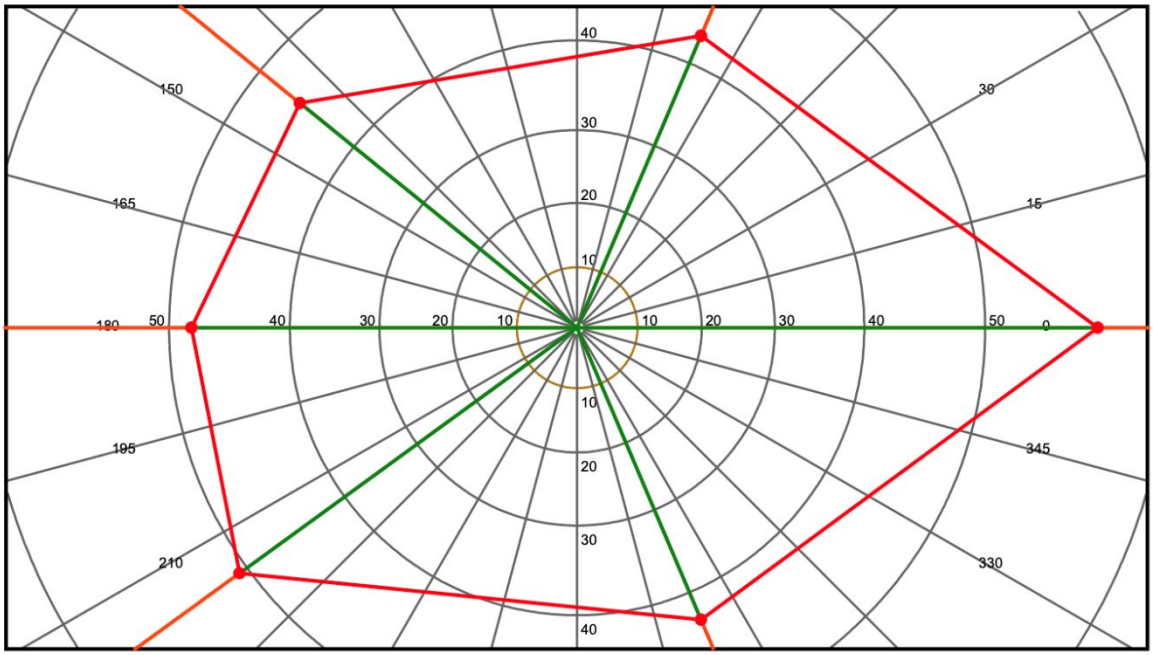
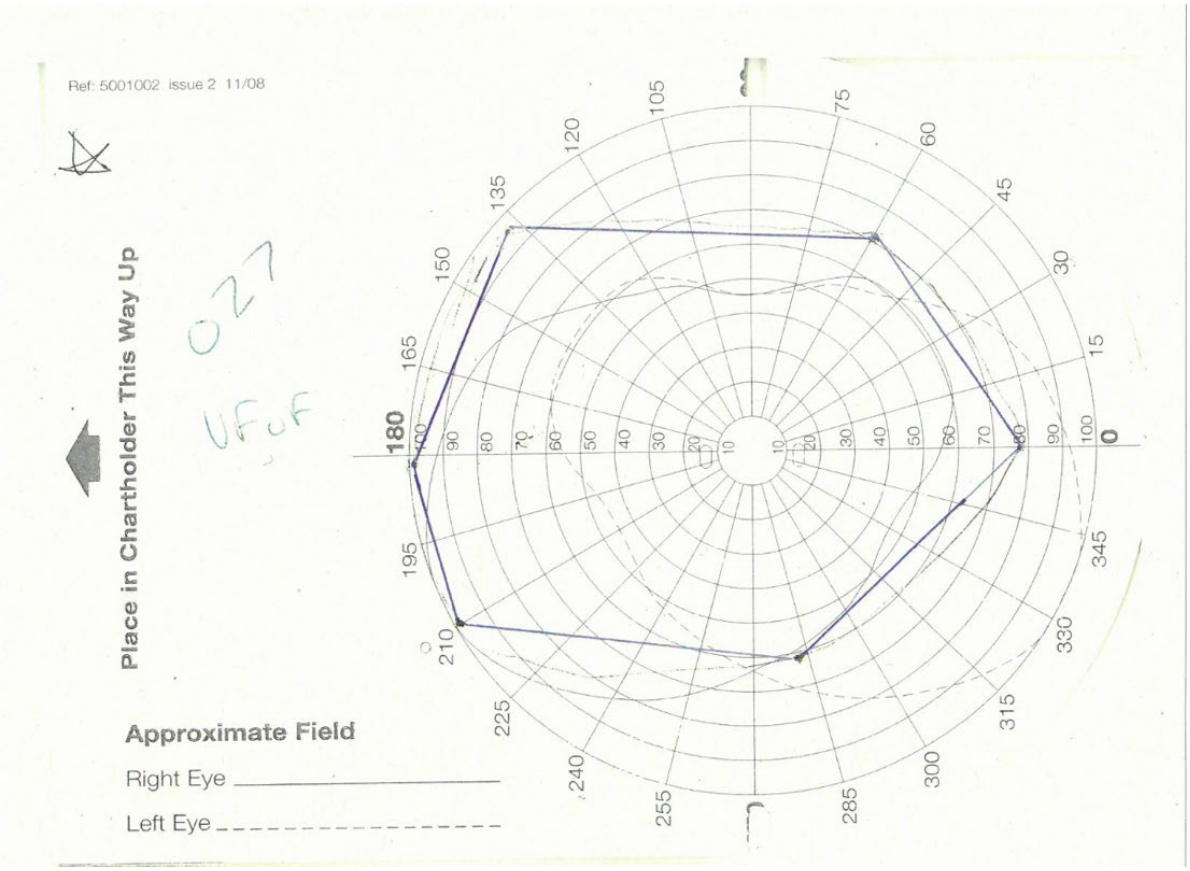
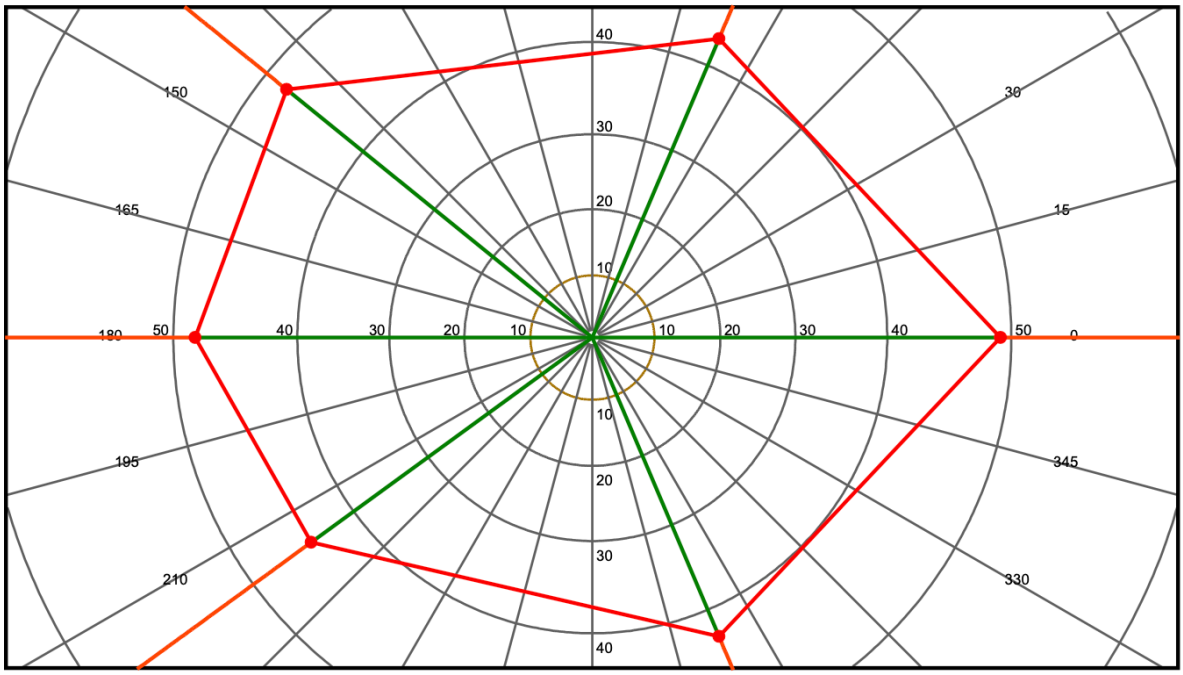
195
345
210
330
225
315
240
300
255
285

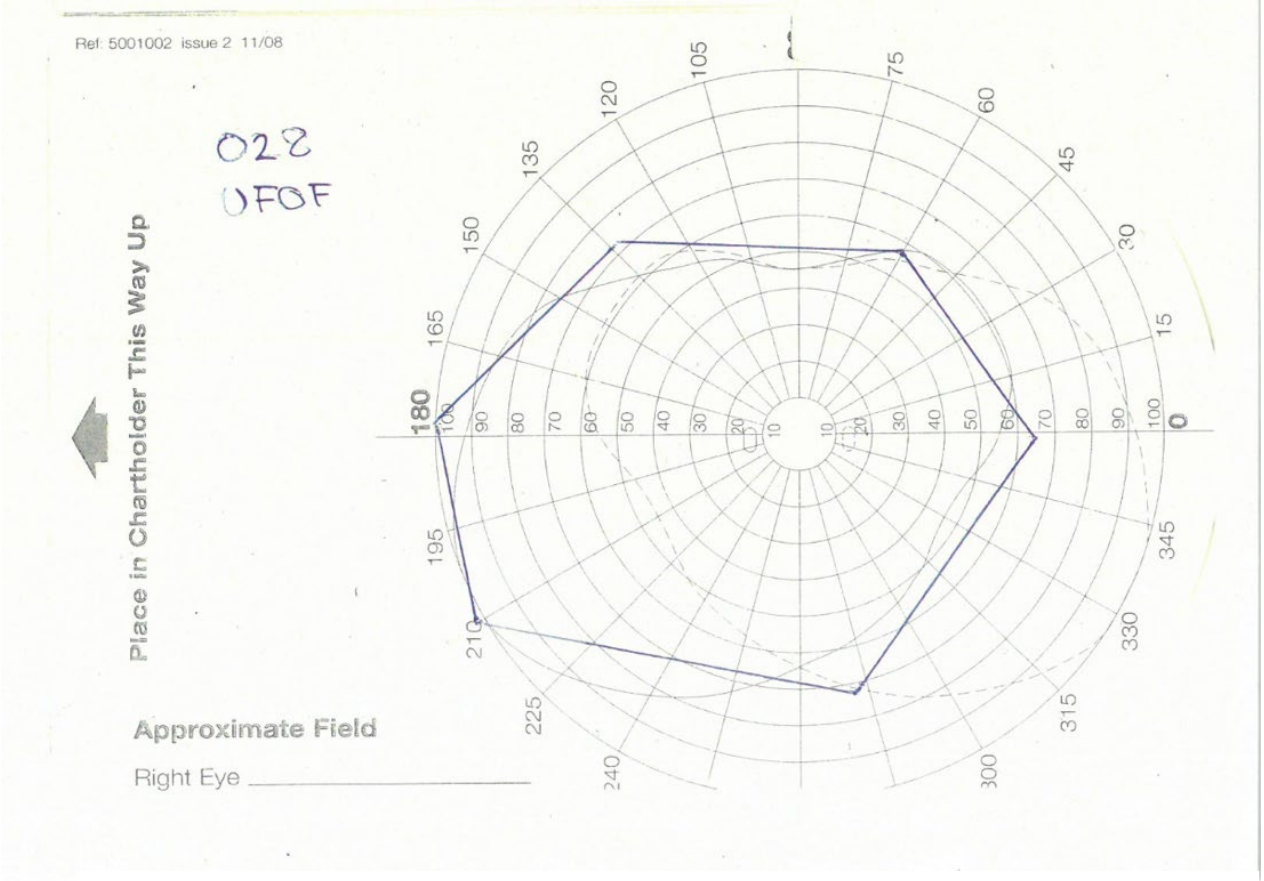

150
30
165
15
180
0
195
345
210
330

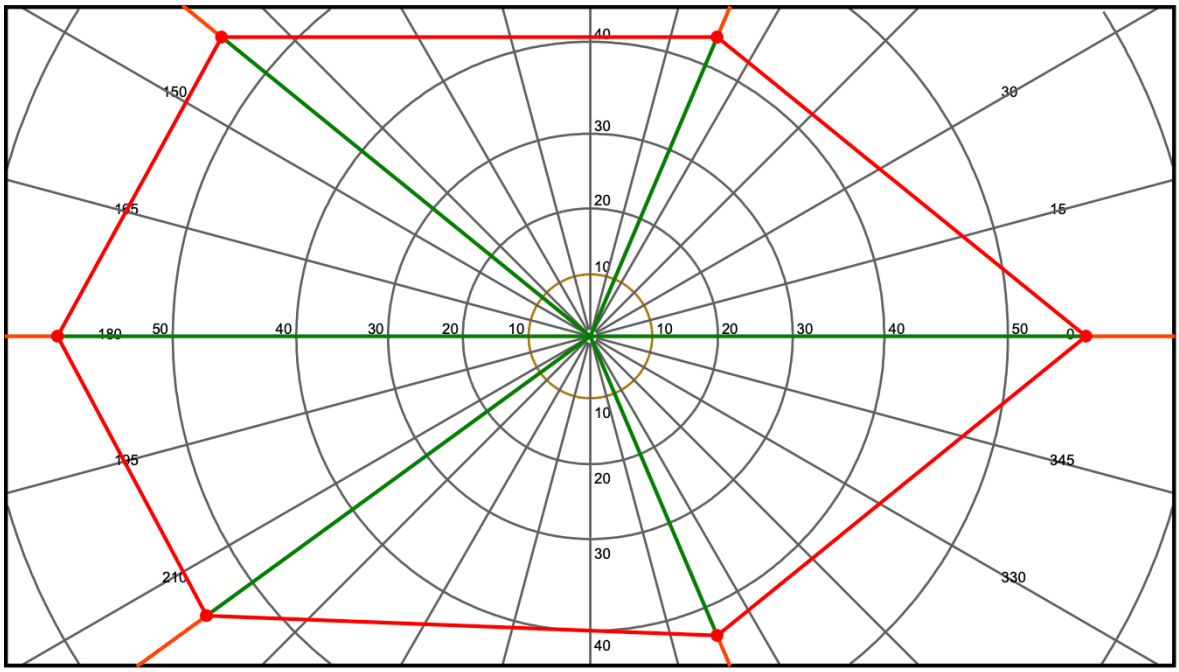

Ref: 5001002 issue 2 11/08
026
UFOF
Place in Chartholder This Way Up
Approximate Field
Right Eye

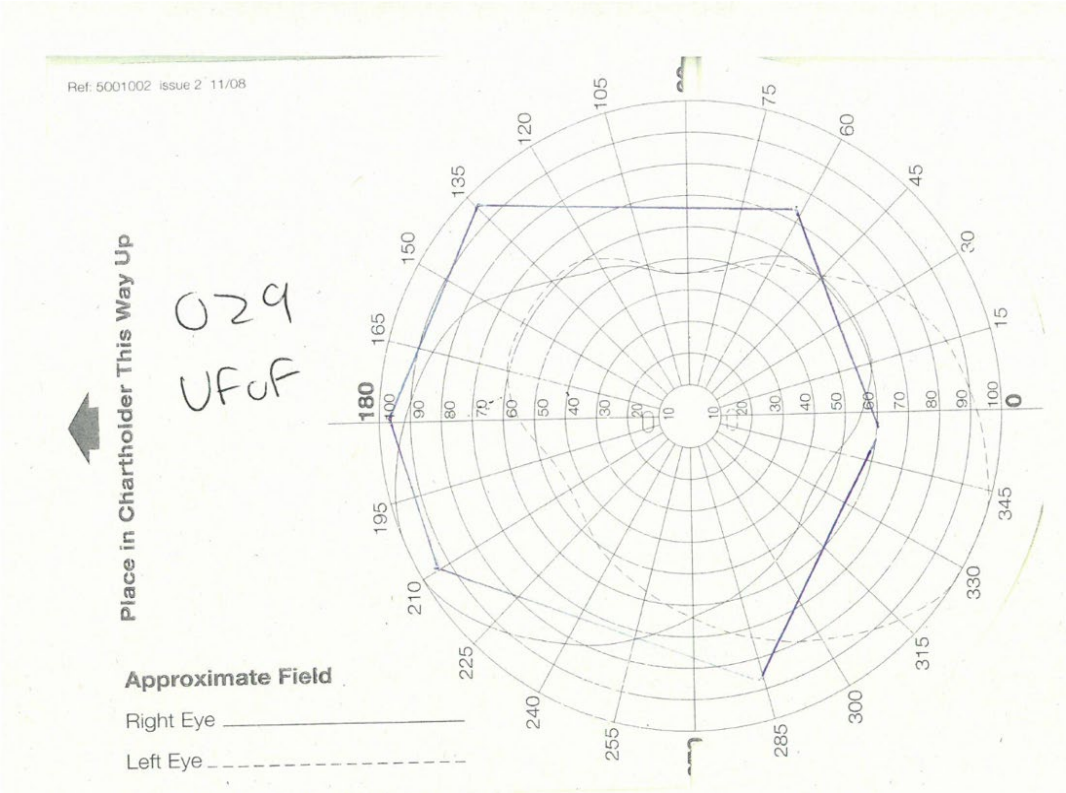


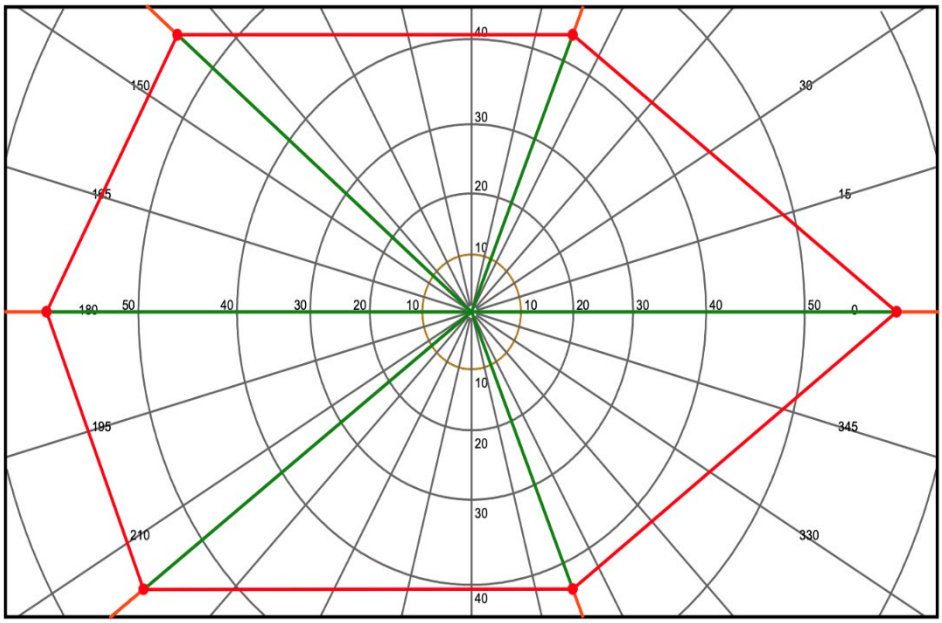

Ref: 5001002 issue 2 11/08
Place in Chartholder This Way Up
027
VFcF
Approximate Field
Right Eye
Left Eye
180
0
15
30
45
60
75
105
120
135
150
165
195
210
225
240
255
285
300
315
330
345

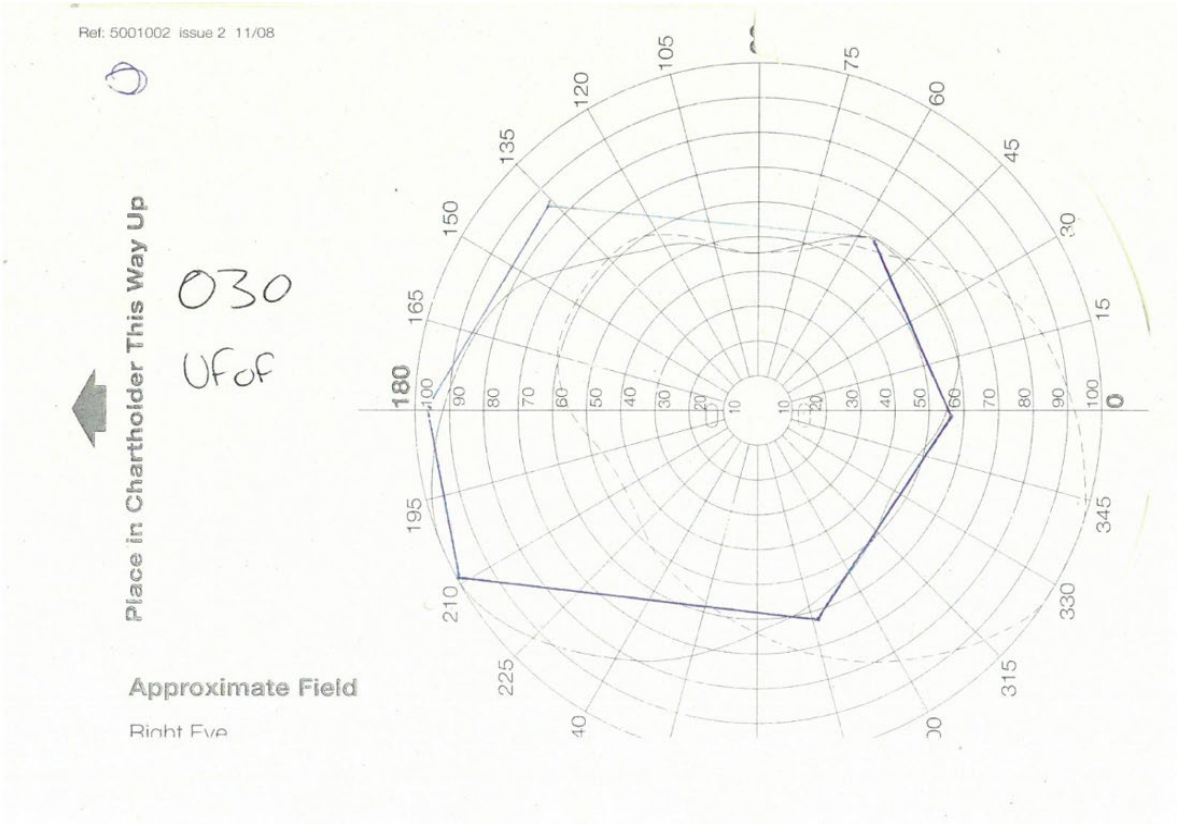

150
165
180
195
210
30
15
0
345
330
50
40
30
20
10

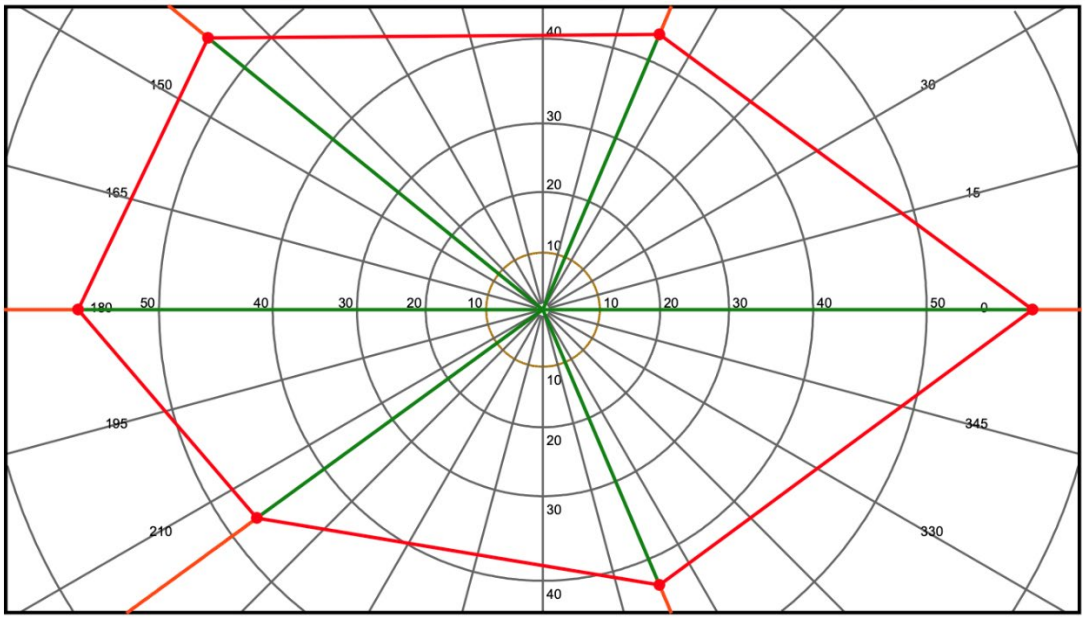

Ref: 5001002 issue 2 11/08
028
UFOF
Place in Chartholder This Way Up
Approximate Field
Right Eye

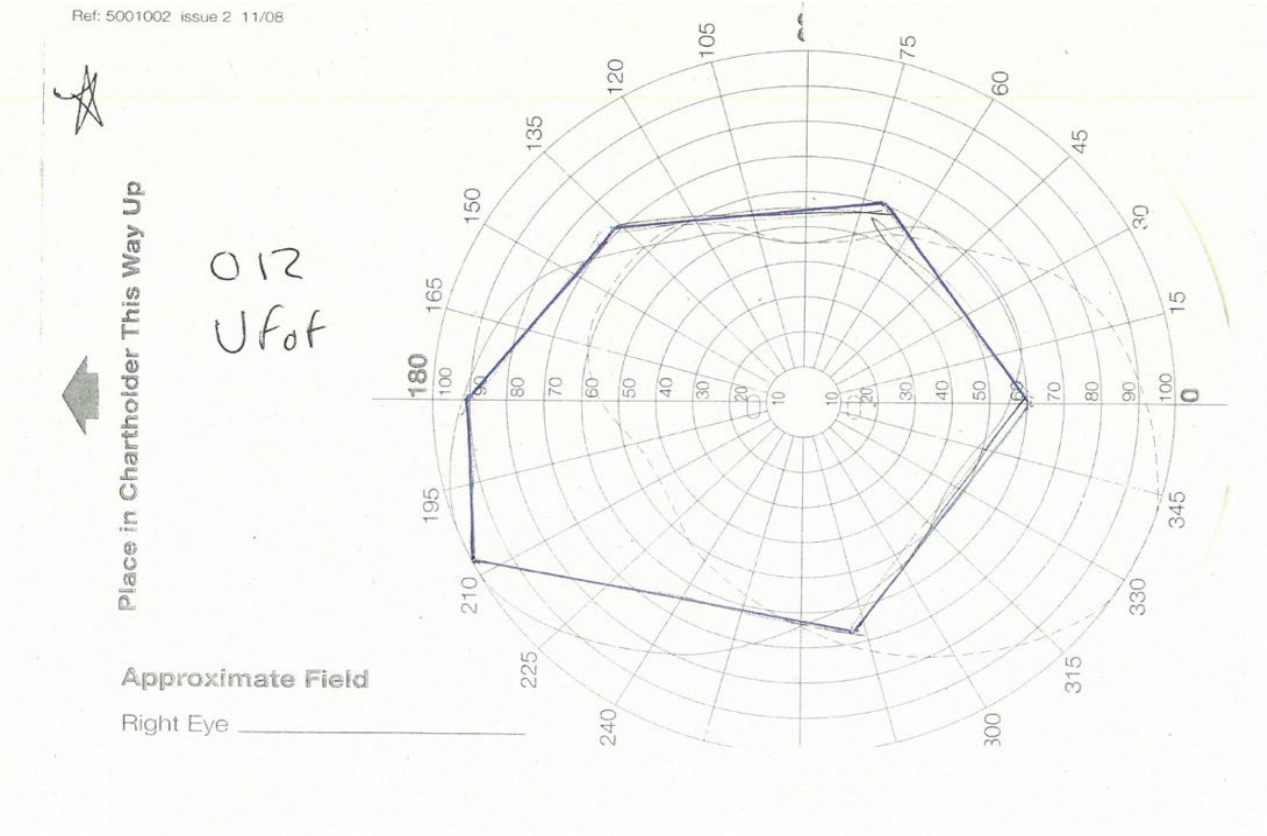



Ref: 5001002 issue 2 11/08
Place in Chartholder This Way Up
029
UFoF
Approximate Field
Right Eye
Left Eye




Ref: 5001002 issue 2 11/08
Place in Chartholder This Way Up
030
Ufof
Approximate Field
Right Eye




Ref: 5001002 issue 2 11/08
Place in Chartholder This Way Up
O12
Ufof
Approximate Field
Right Eye