Background: Traquair described the topography of visual field sensitivity as a “hill” or “island” of vision. Achromatic automated perimetry (AAP) demonstrates this shape of the visual field in photopic conditions. Techniques claimed to target the magnocellular pathway (frequency doubling perimetry, FDP) and those using a stimulus targeting the koniocellular pathway (short wavelength (or blue on yellow) automated perimetry, SWAP), might produce one that is different. The authors compared the visual field topography from FDP with those of SWAP and AAP, to investigate whether there were significant differences in their shape.

Method: A sample of 51 patients with previously confirmed normal perimetry were recruited; either low risk glaucoma suspects or normal controls. AAP, SWAP, and FDP perimetry was performed in random order on the same day. The topography of each field was analysed to determine its average shape and to compare results in the same individuals.

Results: The topography of the visual field produced by each perimeter differed significantly. While all three had maximal sensitivity centrally, over the 24 degrees from the centre to the periphery, mean sensitivities decreased by 4.9 decibels (dB) for AAP and 7.3 dB for SWAP, while FDP sensitivities by just 1.8 dB over 20 degrees (the extent of the FDP field). FDP mean sensitivities decreased by approximately 0.3 dB with every 10 year increase in age, compared with 1 dB for AAP and 2 dB for SWAP.

Conclusion: While the topography of the SWAP (koniocellular) field is steeper than corresponding AAP fields, that of the FDP (magnocellular) visual field was considerably flatter. The difference in this shape may reflect retinotopic or cortical mechanisms, which are specific to the magnocellular pathways.

METHOD

We recruited a consecutive sample of normal subjects (n = 15) and low risk glaucoma suspects (n = 36) with normal visual fields from those patients who were regularly attending an urban glaucoma clinic. Exclusion criteria were corrected visual acuity worse than 6/9, the presence of definite glaucomatous optic neuropathy, diabetes, cataract, refractive error of more than 5 D sphere or 3 D of cylinder, pupil size less than 3 mm and/or corneal or retinal disease that could affect test results. The glaucoma suspect group had a family history of glaucoma, or suspicious optic discs with no definite structural changes and normal intraocular pressure (IOP <21 mm Hg on at least three occasions), or ocular hypertension (IOP ≥21 mm Hg on at least three occasions). They were not high risk or “pre-perimetric” suspects, having previously been found to have normal SWAP and FDP visual fields during the preceding 2 years. All patients underwent assessment with the three perimeters.

Abbreviations: AAP, achromatic automated perimetry; FDP, frequency doubling perimetry; GHT, glaucoma hemifield test; IOP, intraocular pressure; PSD, pattern standard defect; SWAP, short wavelength automated perimetry.

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Topography of the frequency doubling perimetry visual field compared with that of short wavelength and achromatic automated perimetry visual fields
patients also had at least two consecutive normal visual fields on threshold AAP testing performed within the preceding 2 years, so they were experienced at perimetry. One eye from each patient was considered. When both eyes were eligible, a random choice was made.

AAP, SWAP, and FDP were performed in random order after obtaining informed consent in accordance with the South Eastern Sydney Area Health Services clinical research ethics committee requirements. AAP was performed using the Humphrey field analyser II (HFA) (Carl Zeiss, Dublin, CA, USA) with a 24-2 SITA-Standard program. SWAP was performed using the HFA with a 24-2 SWAP full threshold program, in which the background was illuminated with a yellow light at 100 cd/m² and the target was a blue stimulus (440 nm), size V (1.72 degrees). Subjects had the same refractive correction for both tests. A normal field was defined as a field with a normal glaucoma hemifield test (GHT) and a mean defect and a pattern standard defect (PSD) of p>5%. A normal field was also one in which there were less than five points whose sensitivities were no worse than p<5%, with no clustering of such points. FDP was performed using a Humphrey-Zeiss frequency doubling technology (FDT) perimeter (Carl Zeiss, Dublin, CA, USA) using a full threshold N-30 program. A normal visual field had a mean defect and a PSD of p>5% and had no more than two target locations with sensitivities no worse than p<5%, with no clustering of locations. In all cases, fields were considered reliable if there were less than 33% false negative and false positive errors and less than 20% fixation losses.

The central 24 degrees of the HFA and the central 20 degrees of the FDP field were considered for analysis. Each test point in a field was assigned to a particular zone, depending on its eccentricity (fig 1) and a particular quadrant depending on location. Summary statistics (mean and standard deviation (SD)) were calculated for each zone and quadrant. The rate of change in these summary statistics with increasing eccentricity was then calculated and compared between tests. Because AAP and SWAP are measured in differential light sensitivity decibels and FDP is measured in contrast decibels they are not directly comparable. For calculations and figures in which they were compared, AAP and SWAP values were converted into contrast decibels:

\[ \text{Contrast decibels} = -2 \times \log_{10}\left(10^{\text{DLSdB} / 20}\right) \]

where DLSdB = differential light sensitivity decibels.

Statistical Analysis System 6.12 (SAS Institute Inc, Cary, NC, USA) was used for statistical analysis including descriptive statistics, unpaired two tailed Student’s t test and simple linear regressions. In linear regressions age and visual field sensitivity were used as continuous variables and visual field zone was used as a categorical variable. Regression coefficients, test statistics, and p values were presented.

RESULTS

There were 51 patients in our sample; 23 males (45%) and 28 females (55%). Average age was 55 (SD 13) years: 55 (12) years for males and 55 (14) years for females (t = 0.00; p = 1.0). There were 15 normal patients (29%) and 36 glaucoma suspects (71%). There were no significant differences in mean defect between normal patients and glaucoma suspects for any of the tests (t = 0.97; p = 0.34 for AAP, t = 0.54; p = 0.59 for SWAP, and t = 0.52; p = 0.61 for FDP). When a visual field was considered as a series of concentric zones (four for HFA and three for FDP) (fig 1), the mean sensitivities across the horizontal midline (dB) for each quadrant of each zone for AAP using the Humphrey field analyser is presented.
sensitivities in each zone for all three methods showed a statistically significant decrease with increasing eccentricity: for AAP ($r^2 = 0.35$, $t = 10.41$; $p < 0.0001$), for SWAP ($r^2 = 0.32$, $t = 9.84$; $p < 0.0001$), and for FDP $r^2 = 0.04$, $t = 2.33$; $p = 0.021$). However, the slope of the decrease in mean sensitivities differed considerably, with AAP mean sensitivities decreasing by 4.9 dB compared with SWAP mean sensitivities decreasing by 7.3 dB ($t = 15.32$; $p < 0.0001$) over the 24 degrees from the centre to the periphery, compared with 1.8 dB over the 20 degrees of the FDP field ($t = 49.07$; $p < 0.0001$) (fig 2). When the fields were divided into quadrants, the mean sensitivities for each zone within the quadrant were calculated (figs 3–5). There were similar decreases in the mean sensitivities for each quadrant zone with increasing eccentricity (table 1). SWAP had the greatest rate of mean sensitivity decrease followed by AAP and then FDP (table 1).

While both AAP and SWAP mean sensitivities were associated with age, such that mean sensitivity decreased by 1 dB for every 10 year increase in age for AAP ($r^2 = 0.39$, $t = 5.21$; $p < 0.0001$) and by 2 dB for SWAP ($r^2 = 0.38$, $t = 5.52$; $p < 0.0001$), a similar association between FDP mean sensitivity and age was not found (0.3 dB decrease for every 10 year increase in age) ($r^2 = 0.01$, $t = 0.77$; $p = 0.45$). The relations between mean sensitivities and eccentricity persisted following adjustment for age (table 1). For both AAP and SWAP, peripheral field mean sensitivities decreased more rapidly with increasing age compared with central locations (fig 6). FDP fields did not show this trend with eccentricity (fig 6).

**DISCUSSION**

An improved understanding of the magnocellular pathway’s properties and functions might enhance our prediction of glaucomatous damage and thus our use of this pathway to detect the disease, or its progression. This may result from greater knowledge of its retinal distribution, which may be delineated by its sensitivity topography on functional testing.

Our study confirms previous work, which showed that AAP visual field mean sensitivities are highest centrally and gradually decrease towards the periphery, in an expected pattern (fig 2). SWAP fields also demonstrated a “hill” shaped topography (fig 2), as has been previously documented for perimetry targeting the koniocellular pathway and which has also been documented in other forms of perimetry that selectively target parvocellular cells.19–22 However, although similar, the “hill” appeared much steeper among SWAP fields compared with AAP, with visual field sensitivity decreasing more rapidly with increasing eccentricity (fig 2).

By contrast, FDP fields had a considerably flatter topography than HFA fields (fig 2). Thus, they were different from that of Traquair’s conventional island: a finding similar to motion perimetry, which targets the magnocellular pathway.27 This topography may be the result of the retinotopic distribution of retinal ganglion cells subserving the magnocellular pathway. While the proportion of parvocellular ganglion cells (midget cells) decreases with increasing eccentricity in a pattern similar to the shape of the conventional “hill of vision,” the proportion of magnocellular ganglion cells (parasol cells) increases with increasing eccentricity, in line with its different visual functions, one of which is the detection of movement.28 29

Cortical mechanisms may have a role in maintaining FDP sensitivities with eccentricity.29 At each visual field location, corresponding cortical cells in extrastriate areas might be arranged in a hierarchy of spatially frequency tuned channels. This hierarchy may ensure that at each point in the visual field there is a cortical channel maximally stimulated, thereby preventing any substantial reduction in visual field sensitivity with increasing eccentricity (T Maddess, personal communication). Possibly one or both of these mechanisms may determine the observed shape of the FDP visual field, as may others including the possibility that it may be determined by spatial summation of the magnocellular pathway or the larger 10 degree targets used by the FDP. Further investigation should be done using the newer FDT Matrix visual field grid, which includes a larger number of tests zones similar to standard Humphrey visual fields. Since the test zones are smaller, however, the sensitivities may not follow the same pattern as the original FDP since with smaller test points, edge recognition becomes more of a factor.

HFA visual field sensitivities in this study decreased with increasing age while maintaining the same relation with eccentricity.22 SWAP field sensitivity decreased more rapidly with increasing age.23 In part this may be associated with increasing ocular media absorption with increasing age, although, Wild et al showed that even following correction for lens media absorption, SWAP sensitivity decreased at twice the rate of AAP sensitivity.30 Furthermore, both of these types of fields showed a more rapid decrease in mean sensitivity with age in the periphery compared with central locations.20 30

The slope of the field’s “hill shape” thus increases with age. By contrast, unlike previous work, FDP mean sensitivities

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**Figure 4** Mean visual field sensitivities in decibels (SD) for each quadrant of each zone for SWAP using the Humphrey field analyser. (Eccentricity of visual field is indicated.)

**Figure 5** Mean visual field sensitivities in decibels (SD) for each quadrant of each zone for the FDP. (Eccentricity of visual field is indicated.) (Mean sensitivities in contrast decibels.)
showed substantially less reduction with increasing age; this reduction did not reach statistical significance. FDP fields also showed no trend in mean sensitivity variation with age reduction did not reach statistical significance. FDP fields have had some early visual pathway damage it is unlikely this would have influenced the overall shape of hill of vision for a particular test type, but may have caused some localised reductions in some subjects.

A limitation of our study is its relatively small sample size. However, it was large enough to detect a significant effect of eccentricity on visual field sensitivity and to detect the difference between this effect in HFA and FDP fields. Being clinic based, our sample may not represent the general population. It comprised a consecutive sample of normal patients and low risk glaucoma suspects with normal discs, AAP, SWAP and FDP. While it is possible some of them may have had some early visual pathway damage it is unlikely this would have influenced the overall shape of hill of vision for a particular test type, but may have caused some localised reductions in some subjects.

In conclusion, compared with the topography of the SWAP (konioocular) field, which is a “hill of vision” that was steeper than a corresponding AAP field, the FDP (magnocellular) field was considerably flatter than that described by the conventional “Island of Traquair.” The difference in this shape may reflect retinotopic or cortical mechanisms, which are specific to the magnocellular pathway.

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