Sensitivity and Specificity of the Humphrey Matrix to Detect Homonymous Hemianopias

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Purpose. To compare the sensitivity and specificity of the Humphrey Matrix frequency-doubling perimeter (Carl Zeiss Meditec, Inc., Dublin, CA) to that of standard automated perimetry (SAP) in detecting homonymous hemianopic visual field defects.

Methods. Thirty-three patients with homonymous hemianopias and 50 normal subjects were tested with SAP with the Humphrey Visual Field Analyzer (SITA standard program 24-2) and Humphrey Matrix frequency-doubling perimetry, program 24-2 (Matrix) on the same day. Patients with hemianopias had lesions of the retrochiasmal visual system that were documented by magnetic resonance imaging or by computed tomography. To be classified as a hemianopic visual field defect, the abnormal test location had to be homonymous, respect the vertical meridian, and have no additional scattered abnormal points that obscured the hemianopic pattern. The sensitivity and specificity of SAP and Matrix in detecting hemianopic defects were calculated. The χ^2 test was used to test for differences between groups.

Results. The sensitivity for hemianopic defects by total deviation probability plots was 75% for SAP and 59% for Matrix (not statistically significant, $P = 0.29$). The sensitivity of hemianopic defects by pattern deviation probability plots was 88% for SAP and 69% for Matrix (not statistically significant, $P = 0.13$). The specificity of total deviation probability plots was 84% for SAP and 86% for Matrix. The specificity of the pattern deviation probability plots was 68% for SAP and 74% for Matrix.

Conclusions. Although there was no statistically significant difference between the Matrix and SAP in the detection of hemianopias, the sensitivity of SAP was higher, probably because of the obscuration of defects by scattered abnormal test locations with the Matrix. (*Invest Ophthalmol Vis Sci.* 2008;49:924–928) DOI:10.1167/iovs.07-0248

Frequency-doubling technology (FDT) perimetry is based on the frequency-doubling effect, which occurs when a low-spatial-frequency sinusoidal grating (<2 cyc/deg) is counterphase flickered at a high temporal frequency (>15 Hz) to give the appearance of a grating whose spatial frequency is twice that of the actual spatial frequency.[1,2] FDT is designed to predominantly stimulate magnocellular mechanisms. A review of FDT studies may be found in Anderson and Johnson.[3]

The frequency-doubling effect has been reported to be produced by a nonlinear response to contrast.[4] Although most P cells and M cells exhibit a linear response to contrast, a small subset (~25%) of M cells, called M_y cells, have been reported to exhibit nonlinear responses to contrast.[2,5] One theory behind FDT is that it preferentially stimulates the M_y cells,[4] although the existence of M_y cells in humans has been questioned recently by other investigators.[6] Since M and M_y cells are sparse, they would have little redundancy if tested, possibly allowing for the early detection of visual field defects.[1,4,7]

FDT perimetry (version 1 or FDT 1) has been shown to have sensitivity similar to that of standard automated perimetry (SAP) in the detection of glaucoma.[7] FDT 1 and SAP have also been shown to have specificities and sensitivities similar to those of screening tests in patients with nonglaucomatous optic neuropathies.[1] However, in a previous study of 25 patients with homonymous hemianopias, FDT 1 was shown to have low sensitivity in clearly identifying hemianopic defects due to detection of the stimulus by the uninvolved hemifield (in 3/25 patients) and the presence of scattered abnormal test locations (in 15/25 patients).[1] To address these and other problems and improve visual field defect resolution, FDT version 2, also called the Humphrey Matrix, was developed. It has 55 stimuli compared to 17 in version 1 and smaller 5° stimuli (compared to 10° stimulus) test locations; the Matrix also has a 2° stimulus offset from the vertical midline, and a grayscale printout.

The purpose of this study was to evaluate the performance of the Humphrey Matrix, used with the 24-2 grid, to detect hemianopic visual field defects and to compare sensitivity with that of SAP.

Methods

Subjects

The visual testing protocol was approved by the University of Iowa and the University of California, Davis, Institutional Review Boards. The protocol adhered to the tenets of the Declaration of Helsinki. Thirty-three patients with hemianopias and 50 normal participants (mean age, 57 ± 7 years) were tested. Normal subjects were recruited by random phone calls to individuals listed in the telephone directory and by advertisements in a hospital newspaper. Normal subjects were invited to participate if they had (1) no history of eye disease except refractive error (no more optical correction than 5 D of sphere or 3 D of cylinder), (2) no history of diabetes mellitus or systemic arterial hypertension, (3) no history of ophthalmic surgery, and (4) normal findings in an ophthalmic examination including

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TABLE 1. Sensitivity and Specificity of SAP and Humphrey Matrix Perimetry in the Detection of Hemianopic Defects in Patients with Hemianopia, with 95% Confidence Interval

	SAP	Matrix
Total Deviation (%)		
Sensitivity	75.0 ± 15.0	59.4 ± 17.0
Specificity	84.0 ± 10.2	86.0 ± 9.6
Pattern Deviation (%)		
Sensitivity	87.5 ± 11.5	68.8 ± 16.1
Specificity	68.0 ± 12.9	74.0 ± 12.2

20/25 or better corrected Snellen acuity. The included subjects had either undergone a complete eye examination within 12 months before this study or were examined by an ophthalmologist on the day of testing to ensure normal ocular health. Informed consent was obtained from the subjects after explanation of the study.

All patients were seen in the University of Iowa Neuro-ophthalmology clinic or in the Neuro-ophthalmology clinic of the Department of Ophthalmology and Vision Science, University of California Davis School of Medicine, Sacramento, California, and they underwent neuro-ophthalmic examination, including intraocular pressure measurement. Patients' lesions were documented by magnetic resonance imaging or by computed tomography. All patients had perimetry tested in both eyes on the same day, and normal patients had testing in one eye with the Humphrey Visual Field Analyzer (SITA Standard program 24-2; SAP) and Humphrey Matrix perimeter (program 24-2).

Perimeters

SAP was performed with a Humphrey Visual Field Analyzer (Carl Zeiss Meditech, Inc., Dublin, CA) with a 4-mm^2 Goldmann size III stimulus (0.43° diameter) on a dim background (31.5 apostilb). The SITA Standard strategy was used for the 24-2 test presentation pattern. The visual threshold was found at each test location by asking patients to press a response button whenever they saw a stimulus. For this test, the patients' appropriate near correction was used, and rest breaks were allowed when requested.

Humphrey Matrix perimetry (Welch-Allyn, Skaneateles, NY) was performed either before or after SAP testing with at least a 5- to 10-minute rest period between to diminish the effect of fatigue. The order of testing was alternated, such that half of the patients underwent testing with the Humphrey Matrix first, and half underwent testing with SAP first. Humphrey Matrix testing was performed in a dimly lit room. Patients were asked to look through the eyepiece at a centrally located fixation point and press a response button whenever they saw a small patch of alternating light and dark gray bars at any location within the field of view. Each test lasted approximately 5 to 6 minutes per eye. For this test, the patients wore their own prescription glasses and did not use an eye patch to cover the fellow eye.[8] Rest breaks were allowed when requested.

The Humphrey Matrix perimeter used a four presentation ZEST (zippy estimation by sequential testing) procedure to determine stimulus intensity.[9,10]

Visual Field Defects

A visual field defect, to be judged present, required at least three adjacent abnormal points on the total deviation probability plot at the $P < 0.05$ level or two adjacent points with one abnormal point at the $P < 0.01$ level. The abnormal points, to qualify as a hemianopic visual field defect, had to be homonymous and respect the vertical meridian. Another requirement for a hemianopic visual field defect was that there could not be scattered abnormal points that obscured the hemianopic pattern.

The total deviation and pattern deviation probability plots were compared by inspection of the probability plots with respect to the extent of hemianopic defect by two unmasked visual field readers (PT, MW); when differences in grading occurred, they were adjudicated together. At least 25% more abnormal test locations needed to be present for one test result to be classified as showing a defect of greater extent. The similarity of the defect was also compared; the similarity of the defect was judged to be good if the defects were the same, fair if the defects differed but overlapped, and poor if the defects differed and did not overlap. The congruity of the hemianopic defect was also evaluated (except in complete homonymous hemianopias) and judged to be high, fair, or poor. A visual field defect was highly congruous if the appearance of the defect was identical, fairly congruous if the appearance of the defect was similar but not identical and was poorly congruous if the appearance of the defect was obviously different in each eye.

The sensitivity and specificity of SAP and Humphrey Matrix in detecting hemianopic defects was also calculated. The sensitivity was the percentage of patients with hemianopias who had obvious hemianopic visual fields, and the specificity was the percentage of normal subjects with normal visual fields. Because it would be rare for a normal subject to have a hemianopia by chance, as we did with our analysis of FDT 1, we used the presence of any visual field defect in a normal subject. We defined the presence of a visual field defect in the normal eyes as a cluster of three abnormal test locations at a $P < 0.05$ level in a clinically suspicious area or the presence of two such abnormal test locations with at least one abnormal location at a $P < 0.01$ level. The gold standard for hemianopia was the presence of obvious homonymous hemianopia on an initial visual field examination (usually Goldmann perimetry) and the presence of an appropriate lesion on neuroimaging to explain the homonymous hemianopia. The Fisher exact test was used to test for differences between groups.

RESULTS

The sensitivity and specificity results are presented in Table 1. Of the 32 patients with hemianopias, 24 (75%) showed hemianopic defects by total deviation probability plot results for SAP, and 19 (59%) showed hemianopic defects for the Hum-

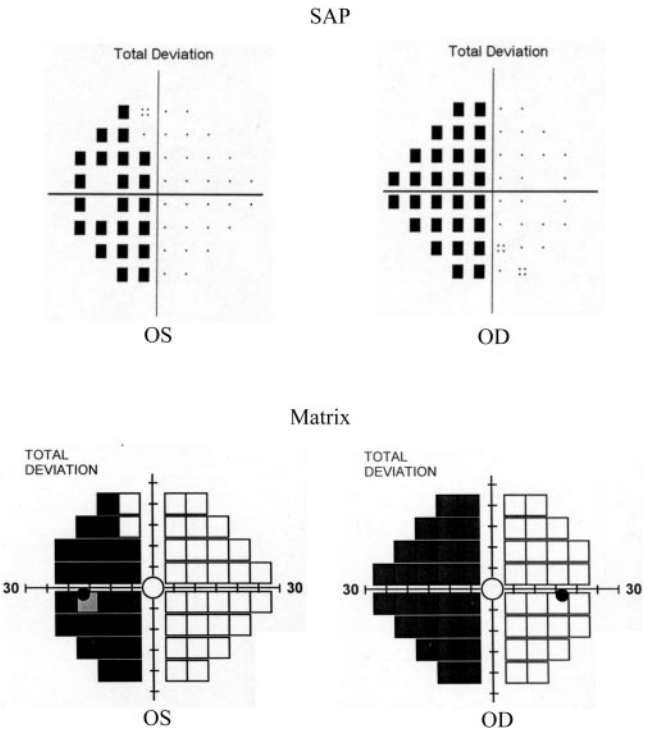

FIGURE 1. A 63-year-old woman with a right optic tract lesion had a left homonymous hemianopia present both by SAP and by Humphrey Matrix perimetry.

phrey Matrix (not statistically significant, $P = 0.29$). The pattern deviation probability plots showed 28 (88%) hemianopic defects for SAP and 22 (69%) for the Humphrey Matrix (not statistically significant, $P = 0.13$). In Figure 1, a 63-year-old woman who had a right optic tract lesion after a motor vehicle accident had a left homonymous hemianopia present both by SAP and by Humphrey Matrix perimetry. The most common reason for a hemianopic defect to be missed by the Humphrey Matrix was the presence of scattered abnormal test locations that obscured the defect. For example, a 46-year-old man had a congruous left homonymous hemianopia present on SAP testing; Humphrey Matrix perimetry showed a defect in the same area, but the hemianopia was obscured by scattered abnormal test locations (Fig. 2). There were also four instances of stimulus detection by the uninvolved hemifield along the vertical meridian by Humphrey Matrix perimetry. A 71-year-old man with a right superior quadrantanopia by SAP testing showed stimulus detection by the uninvolved hemifield along the vertical meridian by Humphrey Matrix perimetry (Fig. 3).

The comparison of the hemianopic defects between SAP and Humphrey Matrix with respect to extent and similarity is listed in Table 2. Both the extent and the similarity of the hemianopic defects were very comparable between SAP and Humphrey Matrix perimetry. For instance, a 26-year-old woman with a congruous left homonymous hemianopia had the same extent and good similarity of the visual field defect by SAP testing and Humphrey Matrix perimetry (Fig. 4).

The congruity of the hemianopic defects was also similar between SAP testing and Humphrey Matrix perimetry, with no significant difference indicated by χ^2 testing ($\chi^2 = 4.39$ for total deviation, $\chi^2 = 4.43$ for pattern deviation, $P = 0.11$ for both total deviation and pattern deviation). There was a trend for SAP to show more congruity (Table 3).

Finally, because defects that are occasionally obscured on the probability plots can appear homonymous on the grayscale printouts, a comparison of the grayscale printouts of patients with hemianopia was made and showed that the hemianopic defect was present in 87.9% by SAP testing and 81.8% by Humphrey Matrix perimetry.

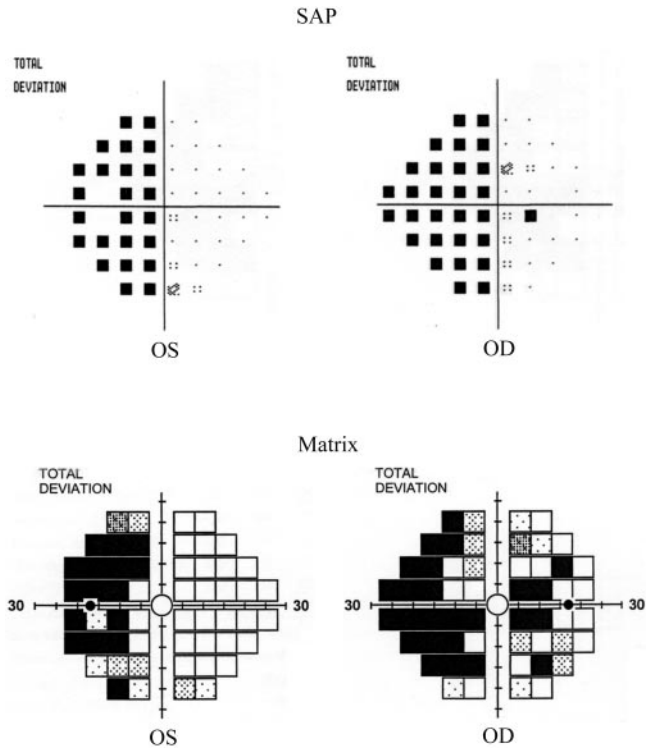

FIGURE 2. A 46-year-old man had a congruous left homonymous hemianopia present on SAP testing, but the hemianopia was obscured by scattered abnormal test locations on the Humphrey Matrix.

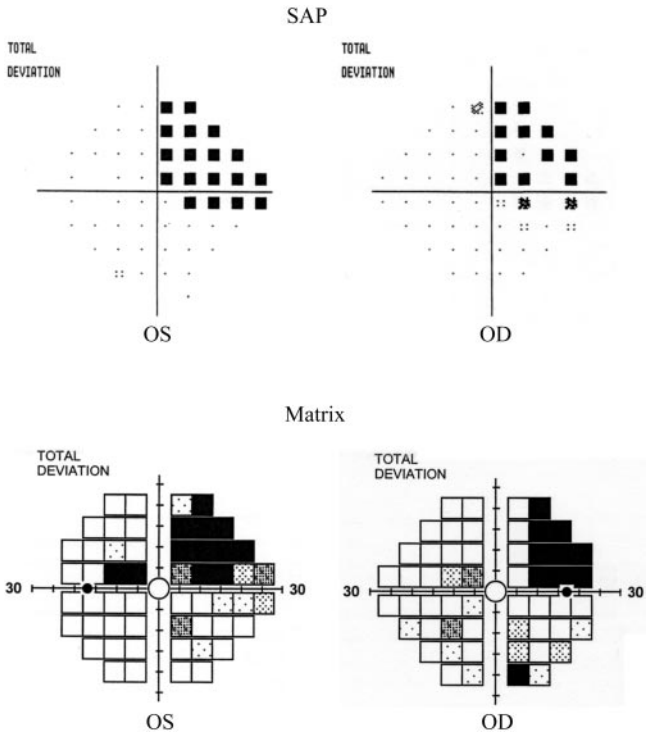

FIGURE 3. A 71-year-old man with a right superior quadrantanopia by SAP testing showed stimulus detection by the uninvolved hemifield along the vertical meridian by Humphrey Matrix perimetry.

DISCUSSION

Based on our results, the Humphrey Matrix appears to be superior to FDT 1 in the detection of homonymous hemianopias; however, it appears that the Humphrey Matrix was still less sensitive than SAP in detecting homonymous hemianopias. With the addition of more numerous and smaller stimuli, one would expect that the sensitivity and specificity of Humphrey Matrix perimetry in detecting homonymous hemianopias would be comparable to SAP. However, because obscuration of defects by scattered abnormal test locations with the Humphrey Matrix, the sensitivity of the Humphrey Matrix was less than SAP in the detection of homonymous hemianopias.

Whether or not using FDT preferentially stimulates the M_y cells, in homonymous hemianopia, damage to the posterior

TABLE 2. Comparison of SAP and Humphrey Matrix Perimetry by Extent and Similarity of Hemianopic Defects

	Total Deviation (%)	Pattern Deviation (%)
Extent		
Same	56.3	53.1
SAP greater	28.1	34.4
Matrix greater	15.6	12.5
Similarity		
Good	51.5	54.5
Fair	36.4	39.4
Poor	12.1	6.1

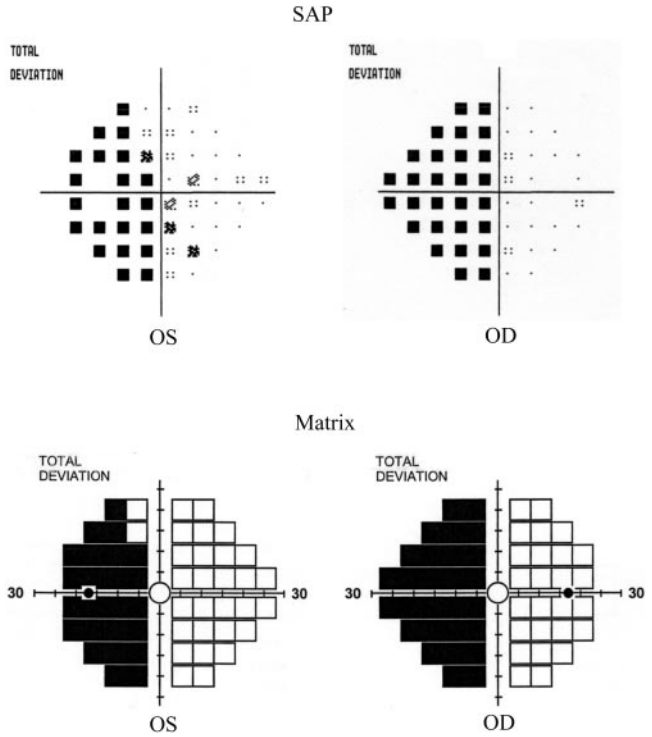

FIGURE 4. A 26-year-old woman with a congruous left homonymous hemianopia had the same extent and good similarity of the visual field defect by both SAP testing and Humphrey Matrix perimetry.

visual pathway is likely to affect all modalities. Since the M or M_y cells have less redundancy, one could argue on this basis that this stimulus may be more sensitive to damage. Our results do not support higher sensitivity for Humphrey Matrix testing in homonymous hemianopias. One of the reasons for decreased sensitivity of the Humphrey Matrix was the presence of abnormal test locations that obscured the hemianopic defect, which occurred in 3 of 32 patients. This is an improvement compared with FDT 1, in which this occurred in 15 of 25 patients tested.[1] The reason for the scattered abnormal test locations is likely multifactorial and could be due in part to a requirement that all normal subjects in the Matrix normative database were required to have normal Humphrey visual fields. This requirement would eliminate poor test takers and tighten the confidence limits for normality.

The extent of the hemianopic defects detected by the Humphrey Matrix and SAP was the same in more than 50% of the subjects, but in the remaining cases, SAP showed a more extensive defect more often than did the Humphrey Matrix. This discrepancy may be due to the larger stimulus size of the Humphrey Matrix relative to SAP, causing occasional stimulus detection by the uninvolved hemifield, ultimately resulting in a less extensive defect.

TABLE 3. Congruity of Hemianopic Defect

	Total Deviation (%)	Pattern Deviation (%)
Congruity (SAP)		
High	73.1	76.9
Fair	23.1	19.2
Poor	3.8	3.8
Congruity (Matrix)		
High	51.9	50.0
Fair	25.9	34.6
Poor	22.2	15.4

Although there is a smaller stimulus size and 2° stimulus offset from the midline compared with FDT 1, the stimulus size of the Humphrey Matrix is still larger relative to SAP, causing continued occasional stimulus detection along the vertical meridian. This occurred in 4 of the 32 patients tested with the Humphrey Matrix and 3 of the 25 patients tested with FDT 1.[1]

There are several advantages to testing patients with Humphrey Matrix rather than with SAP. These advantages include portability of the perimeter, shorter testing times, and the ability of the patients to wear their own prescription glasses during testing. Because the test is tolerant of refractive errors of up to 3 to 4 D, optimal correction is not necessary.[3,8]

Another improvement of the Humphrey Matrix compared with FDT 1 is the addition of a grayscale printout, which is

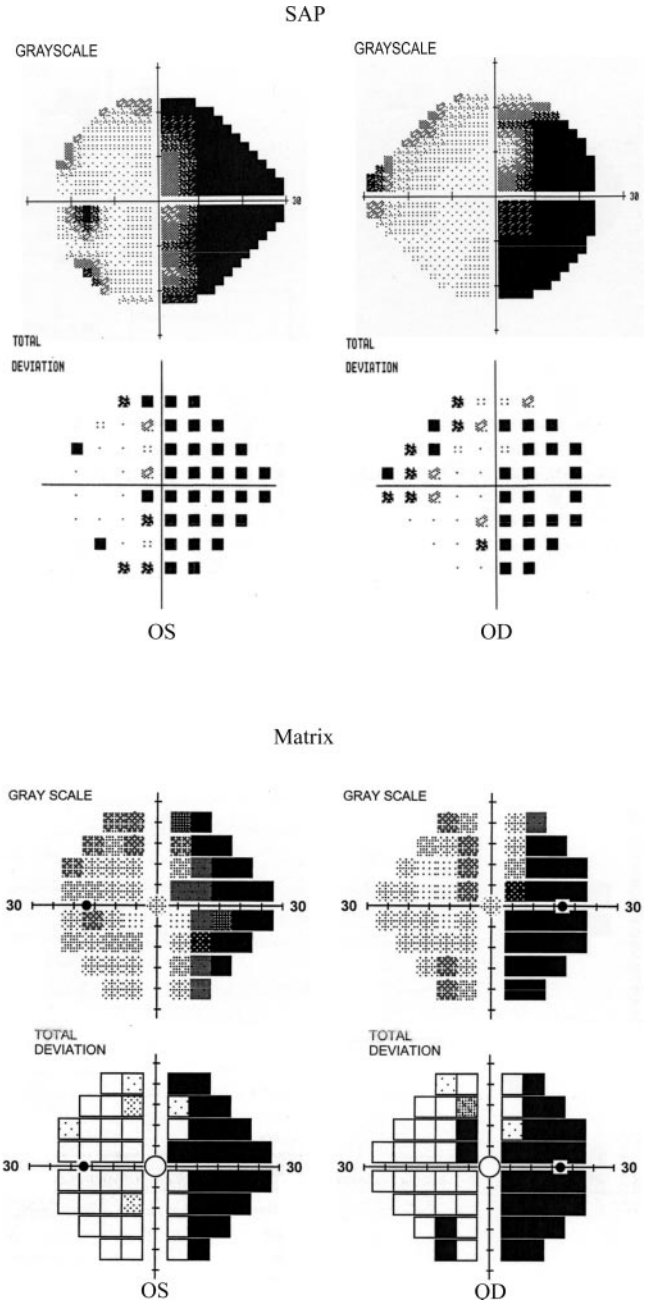

FIGURE 5. The Humphrey Matrix grayscale printout is similar to the SAP grayscale printout in terms of sensitivity of detecting a hemianopic defect. It is not uncommon for defects to be obscured on the probability plots that appear homonymous on the grayscale printouts.

similar to the SAP grayscale printout in sensitivity to a hemianopic defect. Although grayscale displays are well known to hide subtle visual field defects, it is not uncommon for defects to be obscured on the probability plots that appear homonymous on the grayscale printouts (Fig. 5).

Overall, with the more numerous and smaller stimuli, as well as the addition of a grayscale printout to the Humphrey Matrix, we found no significant difference between the Humphrey Matrix and SAP; however, the sensitivity of SAP was found to be higher, probably due to the obscuration of defects by scattered abnormal test locations and stimulus scatter into the noninvolved hemifield with the Humphrey Matrix.

References

1. Wall M, Neahring RK, Woodward KR. Sensitivity and specificity of frequency doubling perimetry in neuro-ophthalmic disorders: a comparison with conventional automated perimetry. *Invest Ophthalmol Vis Sci*. 2002;43:1277–1283.
2. Johnson CA, Samuels SJ. Screening for glaucomatous visual field loss with frequency-doubling perimetry. *Invest Ophthalmol Vis Sci*. 1997;38:413–425.
3. Anderson AJ, Johnson CA. Frequency-doubling technology perimetry. *Ophthalmol Clin North Am*. 2003;16:213–225.
4. Maddess T, Henry GH. Performance of nonlinear visual units in ocular hypertension and glaucoma. *Clin Vis Sci*. 1992;7:371–383.
5. Kelly DH. Nonlinear visual responses to flickering sinusoidal gratings. *J Opto Soc Am*. 1981;9:1051–1055.
6. White AJR, Sun H, Swanson WH, Lee BB. An examination of physiological mechanisms underlying the frequency-doubling illusion. *Invest Ophthalmol Vis Sci*. 2002;43:3590–3599.
7. Medieros F, Sample PA, Weinreb RN. Frequency doubling perimetry abnormalities as predictors of glaucomatous visual field loss. *Am J Ophthalmol*. 2004;137:863–871.
8. Anderson AJ, Johnson CA. Frequency-doubling technology perimetry and optical defocus. *Invest Ophthalmol Vis Sci*. 2003;44:4147–4152.
9. Turpin A, McKendrick AM, Johnson CA, Vingrys AJ. Development of efficient threshold strategies for frequency doubling technology perimetry using computer simulation. *Invest Ophthalmol Vis Sci*. 2002;43:322–331.
10. Vingrys AJ, Pianta MJ. Developing a clinical probability density function for automated perimetry. *Aust NZ J Ophthalmol.* 1998;26(suppl 1):S101–S103.