Br Ir Orthopt J 2005; **2:** 19–25

Attentional visual field analysis using Fastpac

I. CUNNINGHAM[1] BSc (Hons), P. C. KNOX[1] PhD CBiol MIBiol, F. J. ROWE[1] PhD DBO AND A. C. FISHER[2] PhD

[1]*Division of Orthoptics, School of Health Science, University of Liverpool, Liverpool*

[2]*Department of Clinical Engineering, University of Liverpool, Liverpool*

Abstract

***Aim:* To investigate the effect of dividing attention using conventional automated perimetry in normal, healthy young and elderly subjects.**
***Method:* A Humphrey Visual Field Analyzer was modified by the addition of external lasers, which introduced a task additional to the standard threshold field test by presenting red targets at fixation. Young and elderly subjects inexperienced in perimetry were recruited. Two standard 30-2 Fastpac visual fields were examined. Three attentional visual fields were completed which varied in difficulty. The number of targets at fixation decreased from 72 (high) to 48 (medium) and then 24 (low) in each attentional visual field. The effects on visual sensitivity were compared by dividing the central 30° into four regions dependent on eccentricity. Accuracy, durations and manual response times in the different conditions were also compared.**
***Results:* In high-distraction conditions elderly subjects showed reduced visual sensitivity whereas young subjects had similar sensitivity compared with the sensitivity for standard visual fields. As the numbers of distractors was reduced visual sensitivity was shown to improve for both groups. The duration time to complete the attentional visual field increased for both groups compared with the standard fields but measures of accuracy were broadly similar in both standard and attentional visual field tests for both groups. The manual response times increased for both groups in attentional conditions.**
***Conclusion:* The loss in sensitivity in high-distraction attentional visual fields for elderly subjects, longer durations and increase in response time suggest that motivational or cognitive status may have an impact on the interpretation of visual field results.**

Key words: Ageing, Attentional visual fields, Fastpac

Introduction

Automated perimeters are regularly found within ophthalmology clinics and used to test visual fields by orthoptists, optometrists, nurse practitioners or ophthalmic technicians. The Humphrey Field Analyzer (HFA, Carl Zeiss Meditec, Dublin, California) has become a worldwide leader in perimetry. Program choice has developed from an accurate but laborious Full Threshold algorithm to the shorter Fastpac program. The SITA (Swedish Interactive Thresholding Algorithms) family of programs now provide the shortest durations with relatively little loss in accuracy[1,2] compared with the gold standard Full Threshold.

Visual field results are known to be affected by pupil diameter,[3–7] incorrect refraction[8] and lens rim artefacts.[9,10] Studies now exist that investigate the cognitive and motivational effects during visual field tests. The effect of instructions has been shown to alter apparent visual field sensitivity[11] and the addition of a secondary auditory task also reduces the detection of visual field stimuli using various programs available on the HFA.[12,13] Wall *et al.* found visual field sensitivity reduced and test duration increased when subjects were distracted by a mental arithmetic task in addition to the Full Threshold program.[12] However, the Full Threshold program in standard use has long durations for healthy eyes and an increase in duration might add to subject fatigue. Generally it is the locations that are more peripherally located that are examined in the later stages of visual field analysis and if the subject is fatigued there is more chance of those targets going undetected. This might account for reduced sensitivity in this type of divided-attention test.[14] Performance has also been shown to be reduced using suprathreshold programs. Barkana *et al.*[13] required subjects to participate in a hands-free mobile 'phone conversation while concurrently performing a monocular Estermann test. Surprisingly the majority of missed targets, otherwise detected without distraction, were within the 30° region and not in the periphery.

Given these previous studies investigating attention and visual fields, we measured visual field performance in divided-attention conditions by adding a central visual task and assessing performance amongst normal healthy individuals. We wished to compare young and elderly subjects as effects were predicted to be larger with increasing age.[15,16] Modern HFA machines are capable of running four threshold programs that have variable durations.[17,18] All visual fields were completed on a HFA series VI machine and to minimise long durations, the 30-2 Fastpac program was used.

Correspondence and offprint requests to: Ian Cunningham, Orthoptic Department, Claremont Wing, Royal Victoria Infirmary, Newcastle upon Tyne NE1 4LP. Tel: 01912 275206. e-mail: Ian.Cunningham@nuth.nhs.uk

Methods

Subjects

With local ethics approval and informed consent, 15 young adult subjects (mean age 19.2 ± 1.4 years, range 18–23 years) and 16 elderly adults (71.9 ± 5 years, range 65–80 years) were recruited via local advertising. All procedures followed the tenets of the Declaration of Helsinki. All individuals were free from disease with no family history of glaucoma or diabetes. Subjects experienced in perimetry or with a visual acuity less than 0.1 LogMAR or refraction greater than 6.00DS/3.00DCyl were excluded.

Apparatus

All tests were run on a HFA model 640. Two small lasers were mounted on the left side of the HFA, such that when turned on they projected high-intensity, suprathreshold, 1 mm spots of red light, one 1 mm to the left and one 1 mm to the right of the HFA fixation target (Fig. 1). A self-contained microprocessor-based module provided control of presentation rates and illumination intensities and also collected manual response times to the central targets. The test paradigm was implemented on a PC using a graphical user interface communicating with the laser control module across a standard serial connection. The user interface provided the operator with information on the next central target in the sequence and displayed each manual reaction time as it was collected.

Procedures

All subjects received the same instructions, defined as neutral in the Humphrey manual. The dominant eye was tested in all subjects and wide-aperture trial lenses were used if required. The Fastpac algorithm (program 30-2) was used with a white Goldmann size III stimulus on a white background calibrated to 31.5 apostilb. Two standard and three attentional monocular visual field tests were completed over two sessions separated by 1 week. Each subject completed them in the same order.

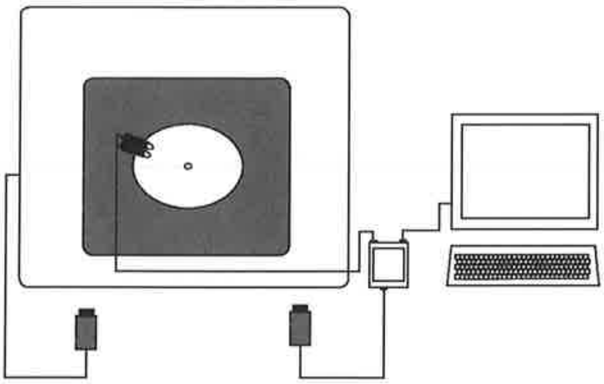

Fig. 1. Diagrammatic representation for attentional visual field equipment. Two lasers were attached to an HFA 6 series model 630 which projected a red target 1 mm in diameter 1 mm either side of the central fixation target. An offline computer via a modulation control box controlled the presentation and inter-presentation time of each laser. The response times to the laser targets were recorded by the modulation box via the additional hand-held button.

The first field was a standard focused-attention (FA) threshold field (FA1). Before the first attentional field test commenced, subjects were shown the central targets at fixation and given the second response button to hold in their non-dominant hand. In the first divided-attention (DA) field test (DA1), the field task was combined with up to 72 central targets at fixation. To obtain a measure of manual reaction time in response to central targets alone, subjects were required to continue responding to targets at fixation after completion of the threshold program. Subjects then completed a second attentional visual field test in which the number of central targets presented during the threshold field test was reduced to 48 (DA2). In the second session subjects completed an attentional visual field examination with up to 24 central targets (DA3) and then completed a final standard visual field examination (FA2).

Analysis

Threshold results for FA and DA conditions were compared by grouping test locations into concentric regions (Fig. 2). Four central test locations were grouped to form the central macular region; the other regions were approximately 10° across. The 8 locations surrounding the macula points formed the 10° region, the surrounding 18 locations (the location directly above and below the blindspot were excluded) formed the 20° region and the outer 44 test locations formed the 30° region (Fig. 2). Field data, manual reaction times, false positives, false negatives and fixation losses for focused-attention and divided-attention conditions were collated using MS Excel. Data were analysed statistically using repeated measures analysis of variance (ANOVA) or the Kruskal-Wallis test where appropriate.

Results

Threshold

We investigated whether between the first standard field (FA1) and the final standard field (FA2) there was any evidence of a significant learning effect. Fig. 3 illustrates the threshold results, grouped into four field regions, with data from the elderly and young groups plotted together for convenience. Sensitivity was higher across all regions in FA2 for both groups. Fig. 3 also illustrates that as eccentricity increased, visual field sensitivity decreased (i.e. threshold increased), and that sensitivity was markedly lower in the elderly group across all regions for both FA1 and FA2. We subjected this complete data set to a repeated measures ANOVA with group (elderly vs. young), condition (FA1 vs. FA2) and field region (macula, 10°, 20° and 30° regions) as factors. Overall there was a statistically significant alteration in threshold ($F_{6,241} = 101.8$, $p < 0.0001$). This result was driven by the group ($F_{1,246} = 221.4$, $p < 0.0001$) and field region factors ($F_{3,244} = 128.4$, $p < 0.0001$); condition failed to reach statistical significance ($F_{1,246} = 3.8$, $p > 0.05$). Given the large difference between the elderly and young groups, we further examined the data in separate ANOVAs removing group as a factor but keeping condition and field region. While for both groups (now separately) field

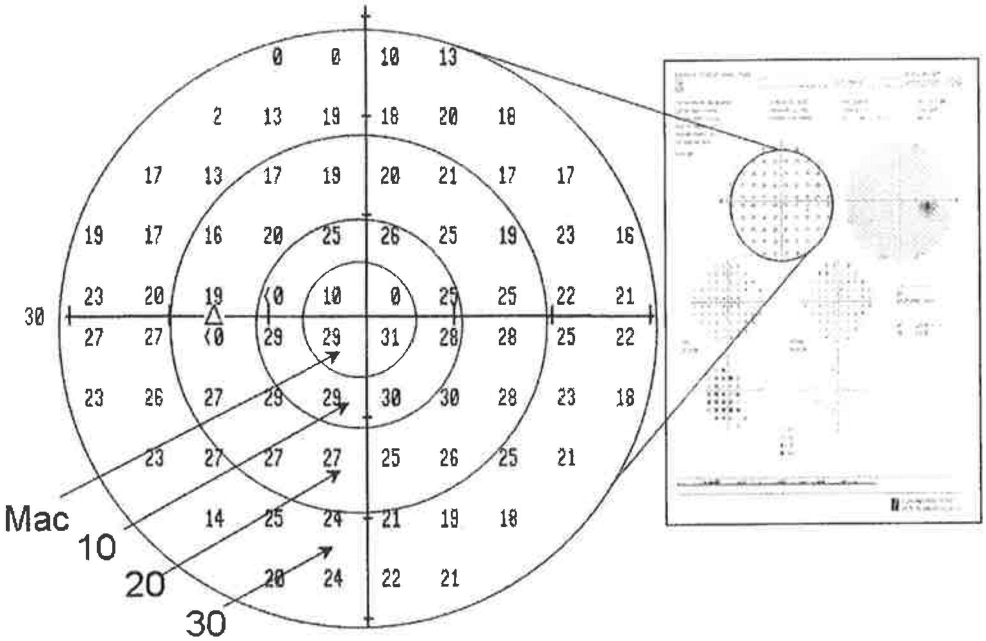

Fig. 2. Numerical threshold data were grouped and averaged. Four central test locations were grouped to form the central macular region (Mac); the other regions were approximately 10° across. The 8 locations surrounding the macular points formed the 10° region, the surrounding 18 locations formed the 20° region (the location directly above and below the blindspot were excluded) and the outer 44 test locations formed the 30° region.

region was highly statistically significant (elderly: $F_{3,124} = 98.0$, $p < 0.0001$; young: $F_{3,116} = 39.9$, $p < 0.0001$), there were still no statistically significant differences for condition (elderly: $F_{1,126} = 2.6$, $p > 0.05$; young: $F_{1,118} = 1.4$, $p > 0.05$).

We next compared the results of the first standard field (FA1) with the first divided-attention field test for the two groups (DA1; Fig. 4). While there was no detectable difference between the two fields in the young groups, sensitivity was decreased in the elderly group for the three more eccentric field regions; there appeared to be little effect for the macular region. When analysed using ANOVA with group (elderly vs. young), condition (DA vs. FA) and field region (macula, 10°, 20° and 30° regions) as factors, we found a statistically significant overall alteration in threshold ($F_{6,239} = 115.6$, $p < 0.001$) driven by the group ($F_{1,244} = 258.0$, $p < 0.0001$) and field region ($F_{3,242} = 143.4$, $p < 0.0001$) factors. The condition factor failed to reach statistical significance ($F_{1,244} = 2.9$, $p > 0.05$). We then ran analysis on the two groups separately, removing age group as a factor, retaining condition and field region. Field region remained highly statistically significant for both groups (elderly: $F_{3,124} = 92.2$, $p < 0.0001$; young: $F_{3,116} = 58.5$, $p < 0.0001$). However, condition was now statistically significant for the elderly ($F_{1,126} = 4.0$. $p < 0.05$) but not the young group ($F_{1,118} = 0.0$, $p > 0.05$).

Fig. 5 shows data from each of the attentional visual field tests (DA1, DA2 and DA3) for young and elderly subjects. The difference between these three tasks was the number of central targets presented in parallel with the field task and therefore the difficulty. Most central targets were presented in DA1, fewest in DA3. For both groups sensitivity was lowest in DA1. Within the elderly group there was a trend across the field tests with sensitivity higher in DA2 and highest in DA3 compared with DA1. This pattern was less clear in the younger group where there was no difference between DA2 and DA3, although sensitivity in both was slightly higher than in DA1. When the whole data set was subjected to ANOVA with group, field region and condition (DA1, DA2 and DA3) as factors, in addition to the expected overall statistically significant result ($F_{8,362} = 165.7$, $p < 0.0001$), all three factors were also statistically significant (group: $F_{1,369} = 565.0$; field region: $F_{3,367} = 258.8$; condition: $F_{2,368} = 10.4$; all $p < 0.0001$).

Accuracy

Information on fixation loss, false positive and false negative responses was recorded by the HFA along with mean deviation, short-term fluctuation and test duration; these values were tabulated and the data for young subjects are shown in Table 1, while the data for elderly subjects are shown in Table 2. The mean values for fixation loss, false positive and false negative in standard and attentional visual fields was below the 30% error rate for fixation loss and 20% error rate for false positive/negative benchmark required to accept that responses during the visual field test were given accurately.

For fixation losses and false positives and negatives there was a clear floor effect (i.e. subjects in both groups recording 0). Therefore we tested these data with a Kruskal-Wallis test in order to determine whether there was a significant difference between young and elderly groups. For fixation losses and false positives the difference between groups, across conditions, was not statistically significant ($p > 0.05$ for both). The difference between groups did reach statistical significance for false negatives (Kruskal-Wallis H 5.2, $p < 0.05$).

Mean deviation (MD) values given by the HFA compare the generalised visual field sensitivity against a normal age-matched database. We found that when MD was tested using repeated measures ANOVA with condition (FA1 and 2, DA1-3) and age group (elderly vs. young) as factors there was no overall statistically significant difference in MD ($F_{9,145} = 1.6$, $p > 0.05$) and no difference for group ($F_{1,154} = 0.9$, $p > 0.05$). However, for condition the differences did reach statistical significance ($F_{4,150} = 2.9$, $p < 0.05$), a result which is consistent with the threshold results detailed above.

Measures of concentration calculated by the HFA and recorded as short-term fluctuations (SF) are not expected to vary by more than 3 dB in a visual field test. Tables 1 and 2 show SF was within the accepted limits for standard and attentional fields for both groups. Statistically, there were differences in SF between groups and between conditions. Thus when tested with condition (FA1 and FA2, DA1–3) and group as factors, the result overall was statistically significant ($F_{9,145} = 3.5$, $p < 0.001$), and both factors were statistically significant (group: $F_{1,153} = 14.9, p < 0.0001$; condition: $F_{4,150} = 2.8$, $p < 0.05$).

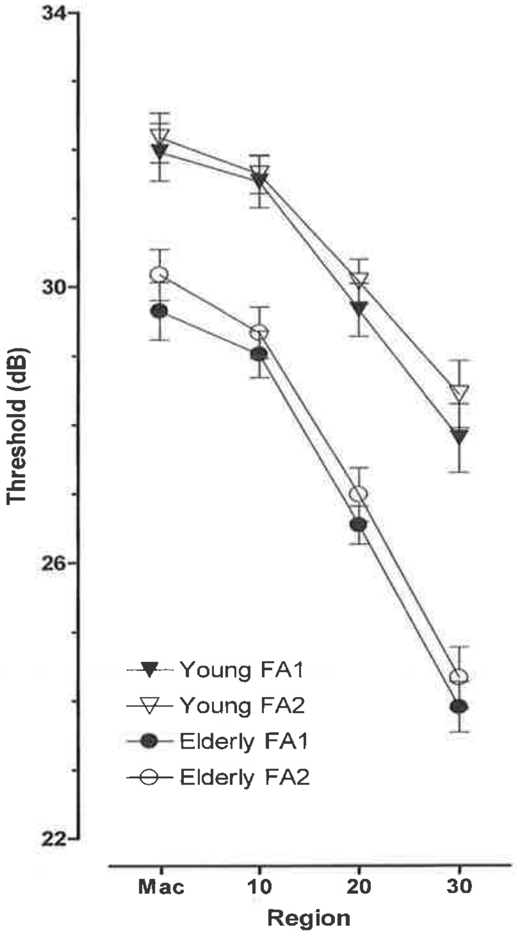

Fig. 3. Standard visual field sensitivity for young and elderly subjects at the beginning (FA1) and end (FA2) of the experiment (mean ± SEM). Sensitivity was dependent on eccentricity and age. Slightly elevated levels were found in the second standard test (filled symbols, FA1; open symbols, FA2).

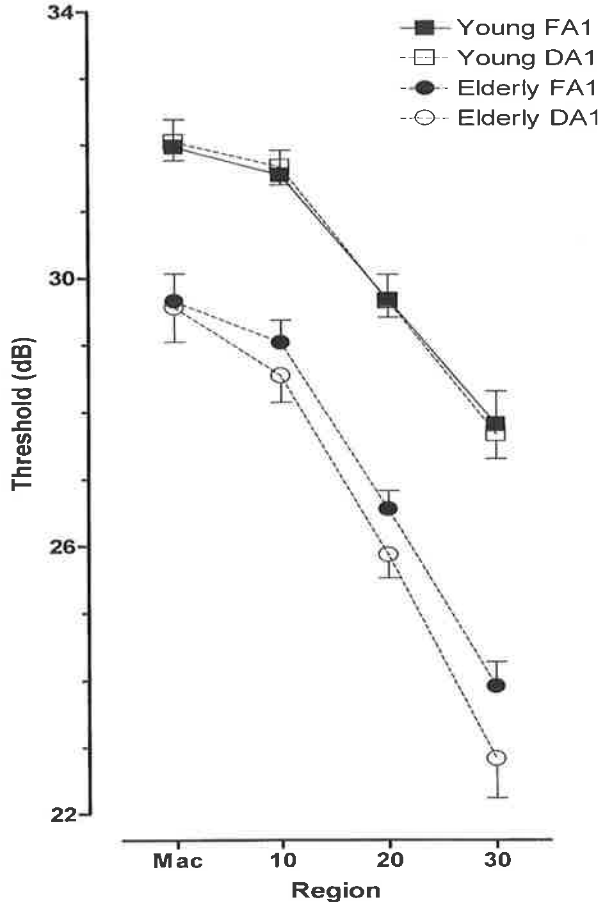

Fig. 4. Regional visual field sensitivity for young and elderly subjects in standard (FA1) and high-distraction (DA1) conditions (mean ± SEM). Filled symbols, standard conditions; open symbols, attentional conditions; squares, young subjects; circles, elderly subjects.

Duration and response time

Time taken to complete visual field tests was generally longer for the elderly compared with young subjects, and also generally longer in the attentional compared with standard fields (Tables 1, 2). When tested, as above, with ANOVA (using the same condition and group factors), the overall result was statistically significant ($F_{9,145} = 7.9$, $p < 0.001$), as were the factors (group: $F_{1,153} = 55.9$, $p < 0.0001$; condition: $F_{4,150} = 3.7$, $p < 0.01$).

The response times to the additional central red targets were recorded by the microprocessor unit. Fig. 6 shows the response time to the central targets with and without the concurrent visual field test. The 'with field' data are taken from DA1 (72 targets), DA2 (48 targets) and DA3 (24 targets). The response times to central target alone, without field test, were similar for the two age groups across all conditions. When the central targets were

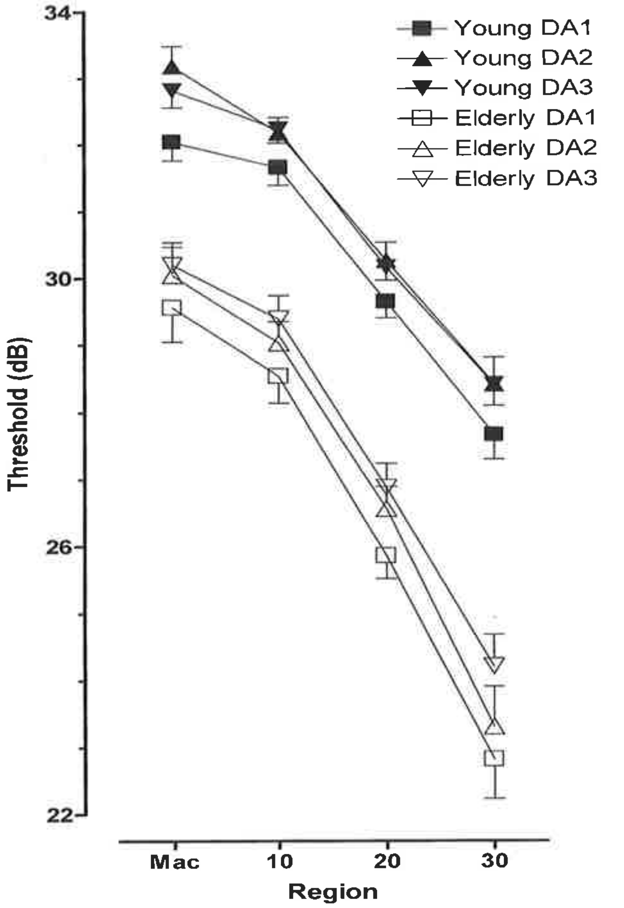

Fig. 5. Regional visual field sensitivity in high (DA1), medium (DA2) and low (DA3) attentional conditions (mean ± SEM). Filled symbols, young subjects; open symbols, elderly subjects.

combined with the visual field test, the time taken to respond to the central targets increased in both groups. However, there was a greater increase in the elderly group, such that in divided-attention conditions their manual response times were now greater than those of the young subjects. A repeated measures ANOVA on these data, with group (elderly vs. young), task (field vs. no field) and condition (DA1, DA2, DA3) as factors, was statistically significant overall ($F_{5,180} = 94.0$, $p < 0.0001$). The group and task factors were significant ($F_{1,184} = 14.2, p < 0.0001$ and $F_{1,184} = 435.4, p < 0.0001$ respectively) with a statistically significant interaction between them ($F_{1,184} = 19.0, p < 0.0001$). Condition did not reach statistical significance ($F_{2,183} = 0.7, p > 0.05$).

Discussion

The elderly subjects recruited for this study displayed typical sensitivity values for healthy eyes that were lower in sensitivity compared with the younger subjects. This confirms what has already been shown in other studies.[19–22] The reduction in sensitivity with age is thought to be due to functional or anatomical loss of photoreceptors and ganglion cells, and alterations in higher processing structures.[23,24]

The addition of a secondary task during visual field analysis showed visual field sensitivity was even lower for elderly subjects in high-distraction conditions yet was unaffected in younger subjects. Accuracy was not compromised during either standard or attentional fields, i.e. it remained within acceptable limits for each available measure but there was an increase in duration and response time in the attentional tasks.

In any study of ageing the results from a sample of subjects may not well represent the overall population due to the large amount of variability that exists within any age group. The elderly subjects we recruited were living independently with no long-term systemic disease and with well-preserved vision. Many were still driving and some participated in fitness regimes. None of the elderly subjects were unable to complete the tests and many did not complain about lengthy durations of up to 12 minutes per eye. It could be possible, therefore, that the relatively good results we observed do not fully represent the effect of ageing on vision within a general elderly population, as standard visual field analysis in a clinical setting still remains a complicated procedure for many elderly patients.

The normal inter-test variability that is expected in visual field analysis[1] was minimised in our experiments by allowing each subject adequate rest between tests, using the same conditions and measuring standard fields at the start and end of the experiment. The slightly raised level of sensitivity in the second standard test indicates subjects do benefit slightly from learning, but this was

Table 1. Indices given by the HFA for young subjects

	FA1	FA2	DA1	DA2	DA3
Fixation loss (%)	0.4 ± 1.6 (0–6.3)	2.1 ± 6.1 (0–23)	6.7 ± 8.2 (0–29)	9.2 ± 14 (0–50)	6.3 ± 7.9 (0–29)
False positive (%)	6.9 ± 11.0 (0–33)	4.8 ± 10.6 (0–33)	3.6 ± 7.0 (0–22)	2.3 ± 6.1 (0–22)	4.5 ± 11.2 (0–40)
False negative (%)	1.7 ± 6.5 (0–25)	2.5 ± 7.1 (0–25)	1.7 ± 4.4 (0–12.5)	1.7 ± 4.5 (0–13)	3.9 ± 8.7 (0–29)
Mean deviation (dB)	−2.2 ± 1.6 (−4.4–0.20)	−1.9 ± 1.6 (−4.9–0.3)	−1.5 ± 1.1 (−3.3–0.08)	−2.0 ± 1.24 (−4.1–−0.3)	−2.7 ± 1.23 (−5.9–−1.2)
Short-term fluctuation (dB)	1.6 ± 0.4 (0.7–2.4)	1.3 ± 0.7 (0–2.3)	1.7 ± 0.4 (0.9–2.2)	1.6 ± 0.7 (0–3.3)	1.7 ± 0.6 (0.9–2.8)
Duration (s)	474 ± 62 (370–575)	458 ± 48 (370–511)	500 ± 37 (446–556)	501 ± 48 (409–575)	482 ± 37 (409–546)

Values are mean ± SD (range).

Table 2. Indices given by the HFA for elderly subjects

	FA1	FA2	DA1	DA2	DA3
Fixation loss (%)	6.1 ± 7.2 (0–25)	9.3 ± 9.1 (0–23)	12.8 ± 17.6 (0–58)	4.0 ± 5.6 (0–18.8)	4.17 ± 6.5 (0–25)
False positive (%)	0.8 ± 3.25 (0–13)	2.6 ± 7.5 (0–27)	5.0 ± 8.2 (0–22)	5.7 ± 7.1 (0–17)	7.7 ± 16.6 (0–66.7)
False negative (%)	5.3 ± 8.6 (0–25)	5.9 ± 10.8 (0–36)	5.7 ± 9.2 (0–33)	7.0 ± 9.0 (0–27)	0.78 ± 3.13 (0–12.5)
Mean deviation (dB)	−1.6 ± 1.5 (−5.2–0.43)	−1.2 ± 1.7 (−5.0–0.76)	−2.8 ± 2.0 (−6.3–0.39)	−1.9 ± 1.8 (−5.5–0.4)	−1.66 ± 1.9 (−7.5–0.71)
Short-term fluctuation (dB)	2.1 ± 0.8 (0.91–0.43)	1.9 ± 0.7 (0.7–3.8)	2.3 ± 0.7 (1–3.8)	2.0 ± 0.8 (1.2–4.6)	2.2 ± 0.5 (1.5–3.1)
Duration (s)	545 ± 62 (433–654)	530 ± 79 (427–698)	580 ± 63 (424–663)	585 ± 93 (462–779)	544 ± 57 (444–669)

Values are mean ± SD (range).

not statistically significant. The addition of a second task, run in parallel with the Fastpac visual field test, had no effect in high-distraction conditions on the visual sensitivity for young subjects. When the numbers of distractors decreased in DA2 and DA3, sensitivity was shown to improve slightly compared with that detected in standard conditions. The results were different for the elderly group. In high-distraction conditions, sensitivity was reduced for elderly subjects in the more peripheral locations. However, when the central task was made less demanding, by presenting fewer targets, there was little effect on visual field sensitivity.

As subjects completed the tests in a systematic order in each session, we cannot discount the possibility that the difference in sensitivity between high- and low-distraction attentional fields is due to learning. Our results show that the addition of an attentional component added significantly more time to an already lengthy examination and hence the results may also be affected by fatigue. We intend to pursue attentional fields further by randomising the order of tests and using the SITA (Swedish Interactive Thresholding Algorithm) program. SITA uses likelihood values for each test location and reduces duration by 16% compared with Fastpac, yet has similar accuracy to the gold standard Full Threshold program.[25]

The small changes in accuracy indices measured by the HFA showed subjects were able to complete the attentional field task just as accurately as for standard field tests. The reduction in false negatives and short-term fluctuation for young subjects suggests there may be an additional attentional resource that is unavailable with increasing age.

We were able to independently measure response times to the central targets with and without the concurrent field task. Comparable response times without the field task demonstrated that the general ability of the elderly subjects was excellent. However, the larger increase in response time for elderly subjects when the two tasks were combined may suggest a mechanism that relatively preserves the visual field at a cost of longer response times.

In standard visual field testing only one task is undertaken, and the aim is to have the subject devote all of their resources to performing the task. However, common factors such as a headache or anxiety might affect attention and motivation and produce abnormal results that simulate disease. In the pattern of results we observed in the elderly subjects, reduced sensitivity in high-distraction conditions could mimic nerve fibre bundle defects. This attentional problem could produce visual field abnormalities that are indistinguishable from those produced by underlying ocular disease.

The effect of dividing attention on automated perimetry results have been studied by others.[12,13] In contrast to using an additional visual task other studies

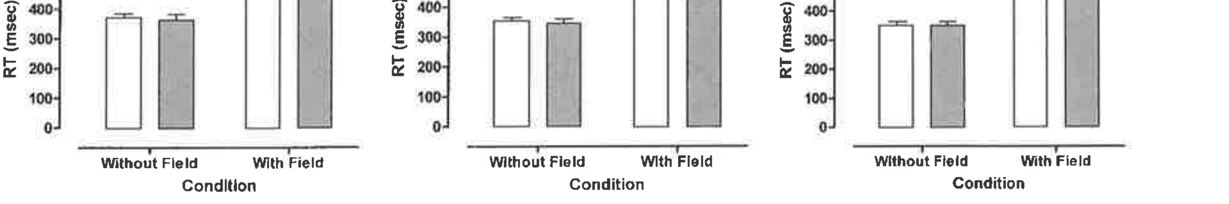

Fig. 6. Response time (RT) for young and older subjects in different attentional conditions. Simple response time (without field) was comparable for young and older subjects independent of number of targets. Response times increased in attentional ('with field') conditions for both groups but again independent of number of targets.

have combined an auditory task with a visual field program. Wall *et al.*[12] used a mental arithmetic task combined with the Full Threshold algorithm, and found that visual field sensitivity and accuracy worsened in the dual-task conditions. Reliability was also reduced in conditions employed by Barkana *et al.*[13] In their study subjects were required to respond to a mobile 'phone conversation in addition to the monocular Estermann program. Suprathreshold programs are limited as visual field sensitivity cannot be measured directly using Estermann programs, in contrast to the threshold functions which we have measured in this study.

Attentional or functional visual fields may also be measured using computer-based programs combining peripheral location and central detection tasks and are more conventionally known as the Useful Field of View (UFOV), Such a test is now commercially available (Visual Awareness, Birmingham, Alabama). UFOV tests have been shown to predict motor vehicle collisions more predictably than eye health or mental status alone in the elderly.[26] They have also been used in brain-injured patients[27,28] and results correlate with general mobility in ageing.[29] Using a similar method we combined a task at fixation with conventional automated perimetry. By using an attachment to HFA machines the acquisition of additional expensive equipment is not required and the results are given in a format familiar to clinicians.

Conclusion

Automated perimetry attempts to standardise the conditions in which the visual field is measured and the identification and monitoring of progression of eye disease has been shown to be much improved with modern automated perimeters.[30] However, standard automated perimetry is a demanding test requiring concentration for long durations, which increases the chance of obtaining unreliable results due to fatigue and inattention. We have shown that in high-distraction conditions, reduced sensitivity is found for elderly subjects that may simulate eye disease. During clinical perimetry testing it is important to monitor the patient continuously for effects of fatigue or inattention, to ensure reliable results.

References

1. Bengtsson B, Heijl A. Inter-subject variability and normal limits of the SITA Standard, SITA Fast and the Humphrey Full Threshold computerized perimetry strategies, SITA STATPAC. *Acta Ophthalmol Scand* 1999; **77:** 125–129.
2. Wild JM, Pacey I, Hancock S, Cunliffe I. Between-algorithm, between-individual differences in normal perimetric sensitivity: Full Threshold, FASTPAC, and SITA (Swedish Interactive Threshold Algorithm). *Invest Ophthalmol Vis Sci* 1999; **40:** 1152–1161.
3. Lindermuth K, Skuta G, Rabbani R, Musch D. Effects of pupillary constriction on automated perimetry in normal eyes. *Ophthalmology* 1989; **96:** 1298–1301.
4. Webster A, Luff A, Canning C, Elkington A. The effect of pilocarpine on the glaucomatous visual field. *Br J Ophthalmol* 1993; **77:** 721–725.
5. Edgar D, Crabb D, Rudnicka A, Lawrenson J, Guttridge N, O'Brien C. Effects of dipivefrin and pilocarpine on pupil diameter, automated perimetry and LogMAR acuity. *Graefes Arch Clin Exp Ophthalmol* 1999; **237:** 117–124.
6. Kudrna G, Stanley M, Remington L. Pupillary dilation and its effects on automated perimetry results. *J Am Optom Assoc* 1995; **66:** 675–680.
7. Mendivil A. Influence of a dilated pupil on the visual field in glaucoma. *J Glaucoma* 1997; **6:** 217–220.
8. Henson D, Morris E. Effect of uncorrected refractive errors upon central visual field testing. *Ophthalmic Physiol Optics* 1993; **13:** 339–343.
9. Zalta A. Lens rim artefact in automated threshold perimetry. *Ophthalmology* 1989; **96:** 1302–1311.
10. Henson D, Earlam R. Correcting lens system for perimetry. *Ophthalmic Physiol Optics* 1995; **15:** 59–62.
11. Kutzko K, Brito C, Wall M. Effect of instructions on conventional automated perimetry. *Invest Ophthalmol Vis Sci* 2000; **41:** 2006–2013.
12. Wall M, Woodward KR, Brito CF. The effect of attention on conventional automated perimetry and luminance size threshold perimetry. *Invest Ophthalmol Vis Sci* 2004; **45:** 342–350.
13. Barkana Y, Zadok D, Morad Y, Avni I. Visual field attention is reduced by concomitant hands-free conversation on a cellular telephone. *Am J Ophthalmol* 2004; **138:** 347–353.
14. Wild J, Searle A, Dengler-Harles M, O'Neill E. Long-term follow-up of baseline learning and fatigue effects in the automated perimetry of glaucoma and ocular hypertensive patients. *Acta Ophthalmol* 1991; **69:** 210–216.
15. Ball KK, Beard BL, Roenker DL, Miller RL, Griggs DS. Age and visual search: expanding the useful field of view. *J Opt Soc Am A* 1988; **5:** 2210–2219.
16. Sekuler AB, Bennett PJ, Mamelak M. Effects of aging on the useful field of view. *Exp Aging Res* 2000; **26:** 103–120.
17. Schaumberger M, Schafer B, Lachenmayr B. Glaucomatous visual fields. FASTPAC versus Full Threshold strategy of the Humphrey Visual Analyzer. *Invest Ophthalmol Vis Sci* 1995; **36:** 1390–1397.
18. Flanagan J, Moss I, Wild J, Hudson C, Prokopich L, Whitaker D, O'Neill E. Evaluation of FASTPAC: a new strategy for threshold examination with the Humphrey Field Analyser. *Graefes Arch Clin Exp Ophthalmol* 1993; **231:** 465–469.
19. Drance S, Berry V. The effects of age on the central isopter of the normal visual field. *Can J Ophthalmol* 1967; **2:** 79.
20. Jaffe GJ, Alvarado J, Juster R. Age-related changes of the normal visual field. *Arch Ophthalmol* 1986; **108:** 1021–1025.
21. Iwase A, Kitazawa Y, Ohno Y. On age-related norms of the visual field. *Jpn J Ophthalmol* 1988; **32:** 429–437.
22. Katz J, Sommer A. A longitudinal study of the age-adjusted variability of automated visual fields. *Arch Ophthalmol* 1987; **105:** 1083–1086.
23. Jaffe GJ, Alvarado JA, Juster RP. Age-related changes of the normal visual field. *Arch Ophthalmol* 1986; **104:** 1021–1025.
24. Henson DB, Chaudry S, Artes PH, Faragher EB, Ansons A. Response variability in the visual field: comparison of optic neuritis, glaucoma, ocular hypertension, and normal eyes. *Invest Ophthalmol Vis Sci* 2000; **41:** 417–421.
25. Bengtsson B, Heijl A. Evaluation of a new threshold visual field strategy, SITA (Swedish Interactive Thresholding Algorithm), in normal subjects. *Acta Ophthalmol Scand* 1998; **76:** 165–169.
26. Ball K, Owsley C, Sloane ME, Roenker DL, Bruni JR. Visual attention problems as a predictor of vehicle crashes in older drivers. *Invest Ophthalmol Vis Sci* 1993; **34:** 3110–3123.
27. Mazer BL, Sofer S, Korner-Bitensky N, Gelinas I. Use of the UFOV to evaluate and retrain visual attention skills in clients with stroke: a pilot study. *Am J Occup Ther* 2001; **55:** 552–557.
28. Calvanio R, Williams R, Burke DT, Mello J, Lepak P, Al-Adawi S, Shah MK. Acquired brain injury, visual attention, and the useful field of view test: a pilot study. *Arch Phys Med Rehabil* 2004; **85:** 474–478.
29. Broman AT, West SK, Munoz B, Bandeen-Roche K, Rubin GS, Turano KA. Divided visual attention as a predictor of bumping while walking: the Salisbury eye evaluation. *Invest Ophthalmol Vis Sci* 2004; **45:** 2955–2960.
30. Heijl A, Lindgren A, Olsson J. Reliability parameters in computerized perimetry. *Doc Ophthalmol* 1988; **49:** 593–600.