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Attentional visual field analysis amongst stroke survivors

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Abstract

Aim: **To investigate the effect of a modified attentional visual field test in subjects who had returned to independent living after surviving a cerebrovascular accident (CVA) and compare these stroke survivors with a group of age-matched control subjects.**
Methods: **A Humphrey Visual Field Analyzer was modified by the addition of external lasers which introduced a task additional to a standard threshold field task by presenting central red targets at fixation. Standard and modified visual fields were assessed in 4 stroke survivors and 4 age-matched control subjects. Visual field sensitivity, manual response times to central laser targets and duration were compared.**
Results: **Stroke survivors had depressed visual field sensitivity compared with controls. Sensitivity was further reduced when the stroke survivors were exposed to the modified field test. Manual response times to central targets increased for both groups when combined with the field test; stroke survivors had longer response times.**
Conclusion: **Subjects considered to have recovered from a CVA and who have returned to independent living may still have visual problems which are manifest only when they have to divide their attention. These problems may therefore not be detected using standard clinical tests.**

Key words: Attentional visual fields, Cerebrovascular accidents, Independent living

Introduction

Effects of a cerebrovascualar accident (CVA, or 'stroke') are determined largely by the extent and locus of damage. The mean time of recovery has been shown to be influenced by neuropsychological, physical and life habits.[1,2] Recovery of basic functions such as mobility, bathing, eating, sphincter control and sleep vary from 5.5 days to 57.6 days from rehabilitation admission.[1] Recovery time for post-stroke abilities including communication, behaviour, cognition, perceptual, visual and motor status has been shown to range from 18.7 to 32.4 days from rehabilitation admission.[2] Survivors who have suffered from cortical defects are expected to show some sign of recovery after 3 months.[3] Visual signs and symptoms include visual field defects, reduced vision, cortical blindness, visual hallucinations, agnosia, ocular motility disorders and visual inattention.[4] It has been suggested visual disorders affect 34–42% of all people who have had a stroke.[5] Visual field loss has been reported to be present in 20% of acute strokes,[6] with 8% of all persons reporting a stroke presenting with homonymous field defects.[7]

CVA resulting in visual inattentional deficits disturbs visual information at a higher processing level, causing visual problems that are cognitive rather than sensory in nature. This lack of attention to one side of space, or neglect, is thought to result from right-sided lesions, but has also been reported in left-sided or bilateral lesions although the effects are thought to be less severe.[8] Many screening tests exist to test for unilateral neglect, and commonly involve line bisection, copying, drawing or cancellation,[9,10] yet diagnosis remains complicated due to similar traits in patients with homonymous hemianopia.[4]

It has been stated that visual impairment is a threat to the personal and social existence of the individual[11] yet little interest is shown in the functional consequences of primary sensory deficits.[12] It has been reported that many stroke rehabilitation units do not have specialised ophthalmological input and a significant proportion of patients with vision problems receive no advice and go unrecognised.[13,14]

Stroke survivors returning to independent living may have residual visual problems that are undetected and undiagnosed. Activities relating to full independence include return to driving; approximately 30–70% of stroke survivors return to driving.[15] Current UK DVLA licensing laws limit drivers with visual field constriction and reduced visual acuity,[16] yet these tests require responses to single targets or high-contrast letters. The element of multi-tasking, so much a feature of visually guided behaviour in the real world, is largely missing from many standard clinical tests of vision. This may be why standard tests can underestimate visual deficits, particularly in the elderly.[17]

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More recently tests have been developed which seek to address some of these issues, notably the 'useful field of view' test (UFOV) in which two tasks are run concurrently, usually a localization task for targets presented in the periphery and a discrimination or identification task run at central fixation.[18,19] Recent work has demonstrated that UFOV performance correlates well with crash statistics in older drivers.[15,20–22] However, compared with other standard clinical tests of visual acuity and visual fields, UFOV is not widely used in UK ophthalmology or optometry clinics.

We have modified a standard test of visual function so that the results might better reflect vision as it operates in real-world behavioural situations. Visual fields, assessed using automated perimetry, often using the Humphrey Field Analyzer (HFA; Humphrey Systems, Dublin, CA, USA), are a standard approach for assessing vision. Normally a subject fixates a central spot and responds to targets of varying contrast presented in the periphery with a button-press (the 'field' task). We have modified this by adding a visual detection task at fixation (the 'fixation' task), run concurrently and asynchronously with the field task with response via a second hand-held button. While the visual fields of young subjects are not modified when the two tasks are run together we have found in pilot studies that in older subjects there is a measurable impact, particularly on the peripheral field.[23,24] We have now investigated the performance of a group of stroke survivors and age-matched control subjects on both the standard and modified field tasks. Our primary aim was to investigate whether running the second task at fixation modified the visual field in either group.

Materials and methods

Subjects

With local ethics approval and informed consent, 4 stroke survivors (mean age 66.25 ± 9 years; range 57–78 years) were recruited via a consultant physician in elderly medicine. Four normal subjects were recruited via local advertising (mean age 66.5 ± 10.2 years; range 55–80 years). The groups were thus well matched for age. All procedures followed the tenets of the Declaration of Helsinki. All stroke survivors were at least 6 months post-CVA with no previous ocular history and had returned to independent community-dwelling; one patient was diabetic. Two subjects had returned to driving. All normal subjects were free from ocular disease with no previous ocular history other than spectacle correction.

Procedure

Each subject completed preliminary tests of distance visual acuity, ocular motility, binocular vision and refraction.

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 (Humphrey Field Analyzer, HFA, model 640, program 30–2) was used with a white Goldmann size III stimulus on a white background calibrated to 31.5 apostilb.

A self-contained microprocessor-based module controlled presentation rates of two externally mounted lasers attached to the side of the hemispherical bowl. The lasers projected one 2 mm red target for 100 ms randomly to the left or right of the standard fixation target within the Humphrey Field Analyzer. Subjects responded via a second hand-held button and manual response times were recorded on a PC using a graphical user interface communicating with the laser control module across a standard serial connection.

Each subject completed normal and modified field tests in the same order. The first field, under focused attention (FA), was a normal threshold field. Before the divided-attention (DA) field test commenced, subjects were shown the central targets at fixation and given the second hand-held button in their non-dominant hand. In the DA test, the field task was combined with up to 72 central targets at fixation. To obtain a measure of manual response time in response to central targets alone, subjects were required to continue responding to targets at fixation after completion of the threshold program.

Threshold results for FA and DA conditions were combined and averaged across the 30° excluding the blindspot to give an overall threshold field sensitivity. The visual field was divided into regions from the central macular region to a more peripheral 30° region. The macular region consisted of the central 4 locations, the surrounding 12 points formed the 10° region, the next 15 locations (excluding the blindspot) consisted of the 20° region, with the peripheral 44 locations forming the 30° region. Response times to targets at fixation during modified visual field analysis were processed using Microsoft Excel. Threshold results, durations and response times for focused and divided attention were analysed with ANOVA using Prism statistical software; throughout the text mean ± standard error of the mean (SEM) are quoted.

Results

There was no statistically significant difference in static visual acuity between the two groups. The average visual threshold was compared for FA and DA conditions for stroke and non-stroke subjects. In the non-stroke subjects we found that there was very little difference between FA and DA fields (FA: 26.76 ± 0.24 dB vs DA: 26.82 ± 1.44 dB; mean ± SEM; Fig. 1). Analysis of stroke subjects revealed that the FA threshold (FA: 24.1 ± 0.9 dB) was reduced compared with non-stroke subjects. In DA conditions there was a further reduction in threshold sensitivity, unseen in non-stroke subjects (DA: 22.22 ± 1.91 dB; Fig. 1). Analysing these data with ANOVA, with field type (×2) and subject group (×2) as factors, we found that overall there was a statistically significant effect of subject group ($F_{1,12} = 10.26$; $p < 0.01$), field type failed to reach statistical significance ($F_{1,12} = 0.64$; $p = 0.47$) and there was no statistically significant interaction between the factors.

Visual field regional analysis showed a decrease in

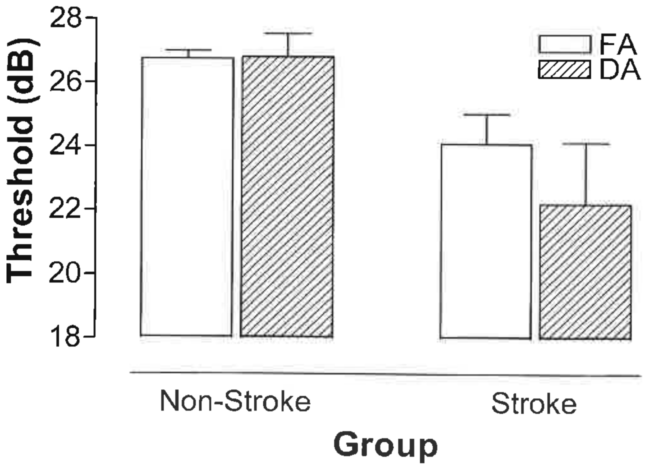

Fig. 1. Mean (± SEM) visual field sensitivity for stroke and non-stroke subjects for both FA and DA conditions. FA, focused attention; DA, divided attention.

sensitivity from the central region to the periphery for non-stroke subjects under FA conditions (Mac: 30.66 ± 0.53 dB vs 30°: 25.58 ± 0.48 dB; Fig. 2a). When we compared thresholds for the different regions under FA and DA conditions, we observed slight decreases in sensitivity in DA conditions, most marked for the 30° region (Mac: 30.1 ± 0.62 dB vs 30°: 24.44 ± 1.02 dB; Fig. 2a). A two-way ANOVA with field region (×4) and field type (×2) as factors demonstrated that field region was statistically significant ($F_{3,24} = 39.42$, $p < 0.001$) but test type failed to reach significance ($F_{1,24} = 3.1$, $p = 0.09$), with no interaction between the factors. We observed the same pattern of results in the stroke subjects. Visual field sensitivity decreased towards the periphery in FA attention conditions, but this was more marked than for the control subjects (Mac: 29 ± 1.55 dB vs 30°: 22.04 ± 1.02 dB; Fig. 2b). When attention was divided for stroke subjects, the visual field sensitivity decreased by more than in the control subjects, particularly for the 20° and 30° regions (Mac: 29.35 ± 1.19 dB; 20°: 22.26 ± 1.88 dB; 30°: 20.17 ± 2.19 dB; Fig. 2b). Two-way ANOVA with field region (×4) and test type (×2) showed field region to be extremely significant ($F_{3,24} = 14.64$, $p < 0.0001$) but test type again failed to reach significance ($F_{1,24} = 1.70$, $p = 0.2$). There was no interaction between the factors.

We compared the time to complete the threshold field across the two groups, in both FA and DA conditions (Fig. 3). The stroke survivors on average took longer to complete a normal threshold field than non-stroke subjects (491 ± 14.84 seconds vs 574 ± 37.56 seconds). For the non-stroke subjects the time increased slightly to 526 ± 32.24 seconds in DA conditions. However, for stroke survivors there was a marked increase in completion time to 665 ± 33.62 seconds. An ANOVA, with field type (×2) and subject group (×2) as factors, demonstrated a statistically significant difference for duration between subject groups ($F_{1,12} = 13$, $p = 0.003$). The field type factor did not reach statistical significance ($F_{1,12} = 4.18$, $p = 0.06$). There was no interaction between factors.

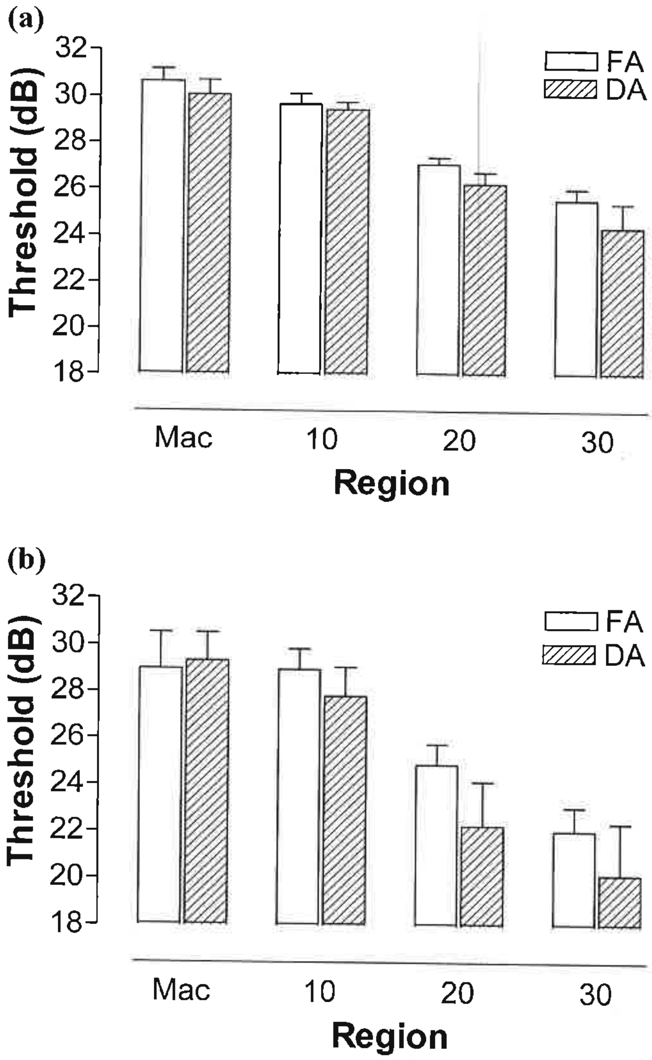

Fig. 2. (*a*) Mean (± SEM) visual field sensitivity for (*a*) non-stroke subjects and (*b*) stroke subjects from the central macular area to the more peripheral 30° region in both FA and DA conditions. A greater difference is seen between the two conditions within the 20° and 30° regions in the stroke subjects compared with non-stroke subjects. FA, focused attention; DA, divided attention; Mac, macular area.

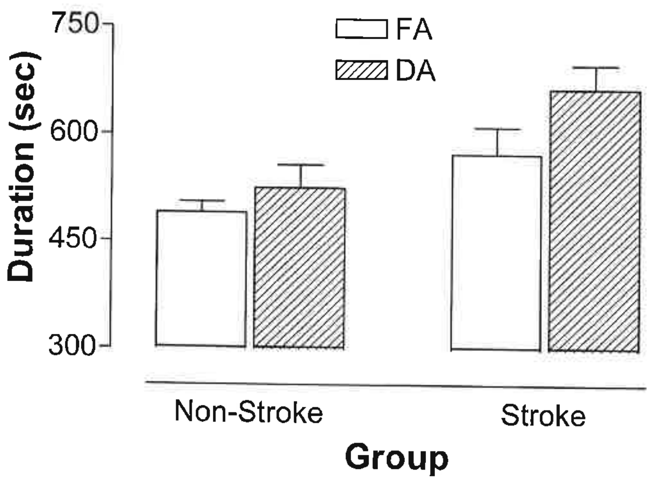

Fig. 3. Mean (± SEM) duration for stroke subjects to complete a visual field analysis in conditions of divided and focused attention. FA, focused attention; DA, divided attention.

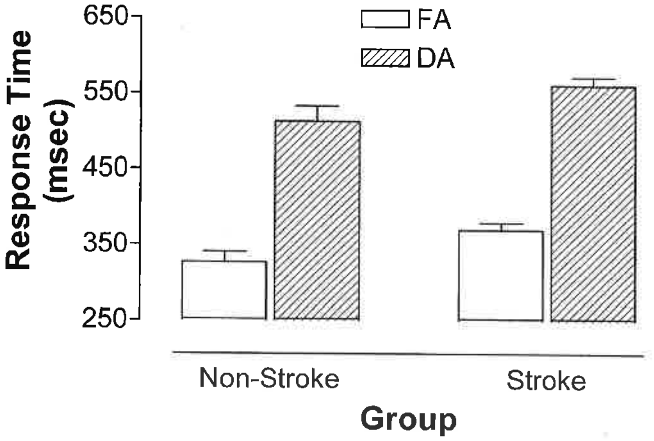

Fig. 4. Mean (± SEM) response time for stroke and non-stroke subjects in milliseconds in conditions of divided and focused attention. FA, focused attention; DA, divided attention.

In addition to visual field data, we also recorded the manual response times to the targets presented at fixation. We compared these for the two groups for FA and DA conditions (Fig. 4). When only performing the fixation task the two groups had similar manual response times to central targets (non-stroke: 327 ± 13.76 ms vs stroke: 370 ± 9.79 ms). When the fixation and field tasks were run together we observed an increase in the manual response time for both groups (non-stroke: 514 ± 20.08 ms vs stroke: 562.4 ± 10.96 ms). An ANOVA with test type (×2) and group (×2) as factors demonstrated that both effect of type and effect of group were statistically significant (type $F_{1,12} = 177.47$, $p < 0.0001$; subject group $F_{1,12} = 10.45$; $p < 0.01$) but with no interaction between them.

Discussion

The small group of stroke survivors included in our study compared well with control subjects, with little difference in static visual acuity between the two groups. Indeed all the stroke survivors had returned to everyday tasks and were unaware of any visual problems. Each individual had good communication and cognitive abilities and none presented with hemiparesis or hemianopia. Muscle tone was sufficient to maintain central fixation and respond to targets via the hand-held buttons. None of the stroke survivors complained about difficulty completing the task, even with long durations of up to 13 minutes. The applicability of our findings is therefore limited to those who have returned to independent living with no apparent visual problems on standard tests of acuity and fields. However, as treatment improves, particularly for younger stroke victims, this group will probably increase in number.

We found small but consistent differences between the stroke group and an age-matched group of control subjects. While peripheral visual sensitivity declined in both groups, this was more marked in the stroke group. Furthermore, when subjects had to engage in a competing task (i.e. the field task plus a central detection task at fixation), while sensitivity declined in both groups this was more marked in the stroke group. The alterations in performance observed when the two tasks were combined failed to reach statistical significance. However, two issues should be borne in mind. The subject groups involved were small, and the performance of the 4 stroke survivors was quite variable (as evidenced by the error bars on the plots). The trends in performance were clear nonetheless. The magnitude of reduced visual field sensitivity in the stroke group with the modified field test would not prompt a conclusion that a definite pathology was present but further investigation would probably be instigated.

A number of limitations exist in this study. A stroke specialist, with little access to visual information, recruited individuals who were considered to have recovered sufficiently from a CVA. This contributed to a small sample size, with the attendant difficulty in the interpretation of the data.[25] Motivation to participate in the study may also have biased our sample towards those patients who had recovered well. Two of our 4 patients were still not driving post-CVA whereas hospital-based studies have shown larger proportions of non-returning drivers of up to 70%.[22]

Comparing visual field sensitivity is notoriously difficult as both inter- and intra-individual variability exist between tests.[26–33] We sought to address this in various ways. We age-matched the two groups for levels of visual acuity and had them complete the two visual fields in the same order. However, the reduced visual field sensitivity when the two tasks were combined in the stroke group could be indicative of fatigue, as the FA field was always done first and the DA field second. The effects of fatigue may also be larger within the stroke survivors; the lower thresholds that were detected in this group and the test protocol used by Fastpac ensured longer durations for both tests. However, comparing mean manual response times for central targets in FA (in which only the central targets were presented) and DA conditions showed comparable increases in manual response time for the two groups. Note that the tests of responses to central targets alone occurred at the end of the second field test, i.e. at the very end of the session. Yet the increase from the FA to DA times was broadly comparable between the two groups (stroke: 192 ms vs control: 187 ms). A general fatigue effect or a marked decline in some other function, such as vigilance, in the stroke group should have manifested itself as very much longer response times in the final test and this was not observed. We sought to ensure that motivational influences over the two field tests were constant and we were careful to issue identical instructions to all subjects.[34]

The UFOV test (see Introduction) has demonstrated attentional impairment amongst stroke survivors compared with non-stroke subjects.[22] Alterations in attentional processing, established using attentional visual field tests, are known to correlate with general functional problems. Thus in a battery of visual function tests related to functional ability in older adults, a change in attentional visual field performance of 10% increased the odds of mobility problems by about 20%.[35] The tests of standard and attentional visual field were also significantly associated with self-reported mobility limitation. While our subjects did not report mobility or other functional problems we did find evidence of lower visual field sensitivity. However, unlike the UFOV test, in which a peripheral visual localisation task is combined with a central visual identification task, our modified field test combined a peripheral contrast detection task with a second detection task at fixation. Our central task is therefore much less challenging than the task used in the UFOV test. Further research is required to establish what will happen to visual field sensitivity when the central task is made more demanding.

As far as we can ascertain, the UFOV test, which is commercially available, is not available in UK clinics to assist in diagnosis of visual attention problems. Other computer-based divided-attention tasks are similarly rarely available. However many, if not all, ophthalmology departments utilise visual field analysers. Thus a simple modification of the type we have used may be of considerable use in helping to detect visual problems which patients may well experience when trying to perform real-world tasks.

Summary

We observed decreases in visual sensitivity in recovered stroke patients compared with an age-matched control group. These decreases were more marked when two tasks were run concurrently. Duration of field test and manual response times did not reach statistical significance but were greater for stroke patients, and again in stroke patients were increased more when two tasks were run together. Thus the modified field test we have used may reveal residual visual problems in recovered stroke patients which are undetected by standard tests of vision such as static visual acuity and standard threshold fields. The problems may also manifest themselves in real-world behavioural tasks where an element of multi-tasking is often present. Further experiments with a larger group of stroke patients are now required to confirm these findings.

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