Assessment of Visual Impairment in Stroke Survivors

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***Abstract*— A novel, tablet-based application (app) has been developed to act as a screening tool for visual impairment in stroke survivors; The Stroke Vision app. The app includes assessments for visual acuity, visual fields and visuospatial neglect, as well as novel tools for the education of patients, carers and staff. The app has been devised by experts in the field to address two important deficiencies; firstly a set of visual assessment tools to support and improve evaluation and rehabilitation of visual impairments in stroke survivors, and secondly to provide education for staff and information to carers about their relatives visual disabilities.**

I. Introduction

In the United Kingdom, stroke is the leading cause of adult disability [1] and consequently has a significant financial and social burden. Complications in stroke survivors are wide-rangeing and include communication problems (aphasia, apraxia), motor deficits (upper limb impairment, weakness), cognitive impairments, anxiety, confusion, and depression. A similarly broad variety of interventions are therefore required to aid rehabilitation. Up to 66% of survivors will experience visual problems [2], however, in many cases, their vision is not adequately assessed [3]. Visual impairments commonly associated with stroke include visual field defects (hemianopias, quadrantanopias), visuospatial neglect and eye-movement disorders [4]. An unrecognised visual defect is a common barrier to rehabilitation progress, and their effective detection and management is therefore an important factor in optimising a patient's outcome.

This has been recognised by the National Advisory Commitee for Stroke (NACS) in Scotland, the body responsible for implementing a national strategy on stroke [3]. NACS have produced guidance for the screening and assessment of patients in the acute phase: The Best Practice Statement (BPS) for Vision Problems after Stroke [5]. This white paper was written in collaboration with experts (medical practitioners and academics), voluntary organisations, and patient representatives, and is a comprehensive review of the current limitations in the acute assessment of visual stroke.

In this paper we describe a novel, tablet-based application designed to implement a subset of the recommendations laid out by the BPS. The Stroke Vision app is intended as a screening tool targeting visual impairments commonly associated with stroke, with the aim of improving visual assessment and, as a result, improving rehabilitation outcomes. It exploits the recent rapid advancements in mobile hardware and software to provide tools for assessment and education in stroke and has been developed by a multidisciplinary team of healthcare professionals working in stroke and ophthalmology, scientists and engineers, and draws on the valuable input of patient and carer groups.

II. Aims

In developing the Stroke Vision app, the authors aim to directly address the recommendations of the BPS, creating a screening tool which (a) provides a rapid and acurate assessment of gross visual deficits in stroke survivors, (b) can be used at the bedside by non-specialist staff at the acute stage, (c), provides a means of integrating the results into the patient's electronic record, (d) provides clear information to patients and carers about the identified visual defects and their implications and (e) harnesses the features of touchscreen computer technology to aid testing in stroke patients with concurrent morbidities, such as poor vision, decreased fine motor control and comprehension difficulties.

III. Methods: The Stroke Vision App

During the design phase of development, a subset of high value assessments were identified for inclusion which target a selection of the most common visual problems associated with stroke. The majority of stroke survivors are over the age of 65 [6] and may have pre-existing visual conditions [5]; a visual acuity assessment is therefore essential to ensure that the subject's central vision is sufficient to undergo further testing (Section III-A). In order to detect the field deficits characteristic of stroke (hemianopias, quadrantanopias), a visual field test is also included (Section III-B). Finally, two custom tests of spatial awareness have been developed specifically for this app. These are included to aid in the diagnosis of visuospatial neglect, a perceptual disorder (Section III-C). Education modules are included to provide information to patients and carers as well as a novel tool for demonstrating visual deficits; StrokeSim (Section III-D). Since it is intended that the app be deployed widely and used by staff who may not have specialist ophthalmic knowledge, education modules targeting staff are also included. On completion of the screening examination, the results can be used to populate a simple report, which can be e-mailed to a secure server, ready for inclusion in the patient's electronic record.

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The app has been developed for a 10.1" tablet running the Google Android Operating System version 4.0 and above, and includes support for encryption and Personal Identification Number (PIN) protection to ensure security of the Structured Query Language (SQL) patient results database.

A. Acuity Testing

There are a number of established techniques for assessing acuity. For the Stroke Vision app, the Tumbling E test has been implemented, in which the subject is shown an 'E' optotype in one of 4 orientations (Figure 1) and asked to indicate the direction of the bars. This is a technique which works well with children, those unfamiliar with the latin alphabet, and crucially for our application, with patients who suffer from expressive and/or receptive aphasia, where patients have difficulty with expressing or comprehending words.

Fig. 1. Example of the tumbling E optotype used in the Stroke Vision app.

A version of the Tumbling E test for the Android OS has previously been developed and refined by our collaborators in the Portable Eye Examination Kit (PEEK) Consortium [7], and we have incorporated their version of the assessment into the Stroke Vison app. The assessment returns a logMAR near acuity, which is reported to the user along with an indication of whether or not the test should continue. If the subject's central vision is sufficient, the measured acuity is used to inform the visual target size used in the subsequent field and neglect assessments.

B. Visual Field Testing

The BPS recommends performing visual field assessments to confrontation at the patient bedside. Confrontation assessments, whereby the practioner positions themselves with their eyes level to the subject, and moves their hand in and out of their field of vision, are sufficient to detect gross defects such as hemianopia and quadrantanopias (Figure 2). However, they require a degree of skill and specialist training. The Stroke Vision app has implemented a simple-to-use kinetic field test as an alternative. It requires a minimum of training and has the advantage of standardising to an extent the examination. In this version of the test, the subject is asked to fixate on a red target on the screen, one eye is covered, and a black target slowly moves in to their field of vision towards the fixation target. The subject is asked to tap the screen when the target becomes visible, at which point a new target is generated. The visual field is mapped out by systematically moving the target round the screen.

The extent of the visual field which can be assessed is limited by the display size (10.1"). However, by moving the fixation target to the corners of the screen and repeating the test, we are able to extend our sensitivity out to a maximum of 27° in the superior-inferior direction, and 41° in the temporal-nasal direction. While this coverage would be insufficient to detect peripheral defects, it has been established that only a small fraction (1-2%) of defects that are not glaucomatic have abnormalities in the peripheral field (30°) without an additional central defect [8].

Fig. 2. Field of view with normal vision (top). Field of view with right homonymous hemianopia (bottom).

The visual targets are automatically sized based on the result of the Tumbling E acuity test. A screenshot of the visual field targets are shown in Figure 3, while an example of the visual field map obtained from a normal subject is presented in Figure 4. The field map can be stored as a bitmap in the SQL patient results database.

C. Visual Neglect Testing

Hemianopia is a visual disorder caused by a lesion along the visual pathway resulting in a defect covering one half of the visual field. This is in contrast to visuospatial neglect, a behavioural syndrome occuring after brain injury in which the subject is unable to report or respond to stimuli, typically in the contralesional space [9]. The interventions required for these two conditions are distinct and successful rehabilitation is reliant on differentiating between the two. Tests of spatial awareness are often clinically useful for doing so, and the BPS recommends using a pair of such tests. For the Stroke Vision app, two novel assessments have been developed;

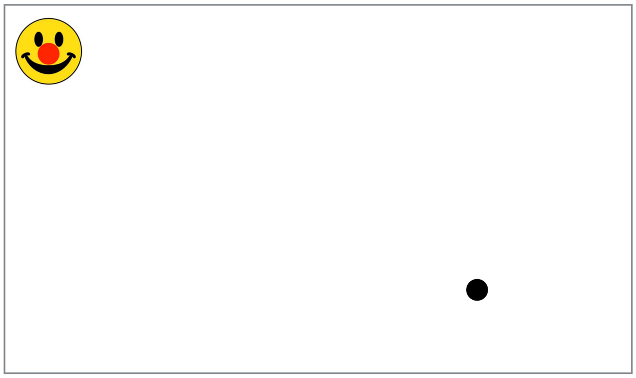

Fig. 3. Screenshot of the kinetic fields fixation image and target when used to assess the right-inferior quadrant of the visual field.

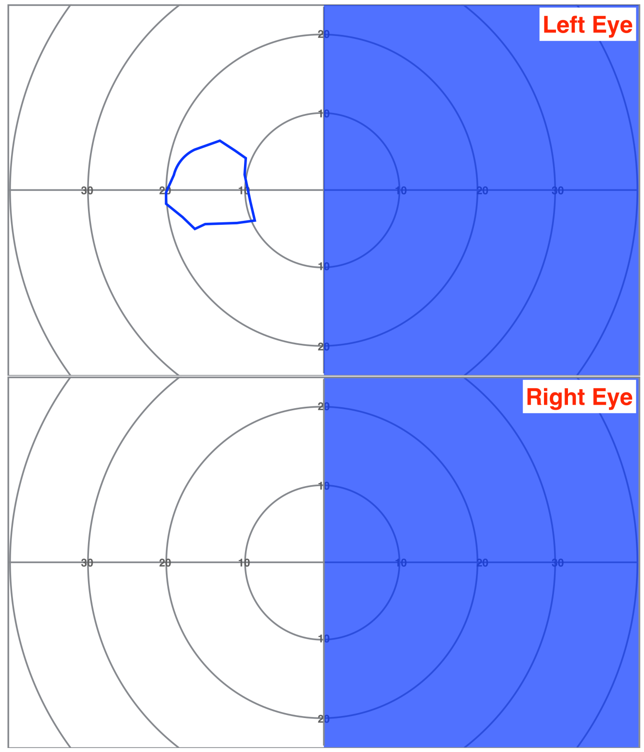

Fig. 4. An example of visual field results acquired from a subject with a right homonymous hemianopia. Blue line indicates the identified blind spot. Blue shaded area represents the identified visual field defect.

the Shape Cancellation test and the Line Crossing test. A screenshot from the Shape Cancellation assessment is presented in Figure 5. In this case, the subject is shown a selection of target and distractor images, and asked to identify and tap on the targets. In this case, the targets are small smiling faces. A patient with hemispatial neglect will only attend to one side of the screen and may only identify targets on that side. On the other hand, a patient with a visual hemianopia may scan the screen and tap targets on both sides. During the Line Crossing test, the subject is shown a series of parallel line pairs and instructed to bisect the lines by touching the screen. Each pair of lines varies in length and separation distance. Again, a patient with neglect may bisect the lines off-centre, while a patient with a hemianopia would typically scan the line to locate the centre. The assessments are configurable and the target size and line widths are informed by the subject's measured acuity. In both assessments, a measure of the spatial bias demonstrated by the subject is caculated by recording either the left-right ratio of identified targets in the shape cancellation test, or the position of the line crossing. These numerical bias measures are included in the assessment report, however, it should be noted that they have not yet been validated against other measures of visual neglect currently in clinical use. In addition, to provide a more subjective view of the patient's spatial awareness, a bitmap representing the location of identified targets in the shape cancellation assessment and the line crossing positions in the Line Crossing assessment is stored in the patient result database.

Almost all visual neglect tests are currently carried out using pen and paper. However, these are rapidly becoming antiquated as hospital records systems migrate to paperless record keeping; an approach recognised by the electronic health records initiative in NHS Scotland [10]. The digital visual neglect assessments provided by the Stroke Vision app will lead to a reduction in filing overheads and record management issues, as well as faster test completion

D. Education

There are considerable educational resources for stroke already available and it was not the aim of this project to generate new material. Instead, we have reviewed and collated the material currently available for patients, carers and non-specialist staff and, where possible, gained permission for inclusion in the Stroke Vision app. A set of links to additional information, support groups and charitable bodies has also been included.

However, an original means of illustrating visual defects associated with stroke has been developed and implemented within the app; StrokeSim. This tool acts as a window on the world by capturing video using the rear-facing camera, applying a series of filters to mimic the subject's measured visual acuity and field defects, and displaying the post-processed video on the tablet screen in real time. It can be used to communicate effectively to carers and staff the implications of the patient's particular visual defects. An example of an image processed by a prototype version of StrokeSim is shown in Figure 2.

IV. Discussion and Conclusion

The Stroke Vision app is currently undergoing informal user testing to refine the app interface and assessments. The users in this context are health professionals (stroke physicians, ophthalmologists, orthoptists, occupational therapists), stroke survivors and carers, and feedback from all three groups has been sought. Formal validation testing of the assessment portion of the app will follow, and local ethics approval is being sought for that purpose. This will be submitted in parallel with a notification to MHRA for use of a non-CE marked medical device in a clinical trial for

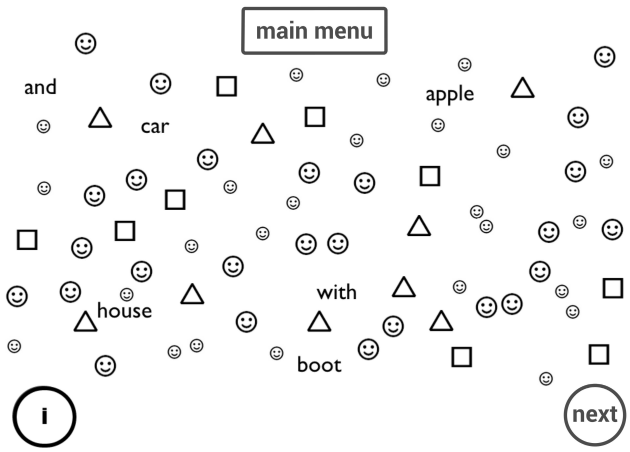

Fig. 5. Screenshot of the Stroke Vision shape cancellation assessment.

conformance testing; the first step in CE-marking the app as a Class I medical device.

The Stroke Vision app is part of a fast growing market for mobile health apps, driven by consumer demand and facilitated by the mass marketing of mobile and tablet technology. These devices are portable, flexible and low cost, and with rapid advances in both hardware and software are becoming powerful generic medical devices. While the mobile health market has expanded rapidly, it is still a relatively immature industry and the best practice for app development has yet to be established. We suggest the Stroke Vision app as an exemplar project. Ideally, the development process should begin with synthesis of thorough background evidence to identify a clinical need. In this case, the Stroke Vision app has been created as a direct response to the BPS [5]. A comprehensive search of other apps should be performed to ensure that excessive time and effort is not spent on duplicating existing resources. Diagnosis and treatment in medicine is multi-dislciplinary and it is important to seek input from all stakeholders throughout the development process. The Stroke Vision app has been developed through the collaborative activities of scientists, engineers, ophthalmologists, stroke phsycisians, occupational therapists and orthoptists specialising in stroke, while our informal user testing has provided feedback from patients, carers, health professionals, patient groups and the voluntary sector.

In conclusion, the Stroke Vision app, provides a low-cost, flexible solution to the currently limited assessment of visual stroke. It provides simple, user-friendly tools for visual acuity, visual fields and visual neglect testing, improved means of recording and reporting results, and importantly, new tools for communicating the implication of those results to patients and staff alike. Once the validation process is complete, we anticipate it will provide a powerful tool for assessing visual stroke and improve rehabilitation outcomes.

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