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Saccadic eye movements and face recognition performance in patients with central glaucomatous visual field defects

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ABSTRACT

Patients with more advanced glaucoma are likely to experience problems with everyday visual tasks such as face recognition. However, some patients still perform well at face recognition despite their visual field (VF) defects. This study investigated whether certain eye movement patterns are associated with better performance in the Cambridge Face Memory Test. For patients with bilateral VF defects in their central 10° of VF, making larger saccades appeared to be associated with better face recognition performance (rho = 0.60, $p = 0.001$). Associations were less apparent for the patients without significant 10° defects. There were no significant associations between saccade amplitude and task performance in people with healthy vision (rho = −0.24; $p = 0.13$). These findings suggest that some patients with likely symptomatic glaucomatous damage manifest eye movements to adapt to VF loss during certain visual activities.

1. Introduction

Patient-reported measures have repeatedly suggested that glaucoma leads to problems with performing everyday activities and a poorer perceived quality of life (Glen, Crabb, & Garway-Heath, 2011; Ramulu, 2009). However, the subjective nature of these studies mean that results are susceptible to bias, and as such, studies involving more objective 'performance-based measures' of visual disability have begun to complement these research findings. Such studies involve the direct assessment of a person's ability to perform activities such as reading, mobility tasks, driving, searching for objects and face recognition, using standardised conditions and predetermined criteria (Glen et al., 2012; Haymes et al., 2008; Kotecha et al., 2009; Ramulu et al., 2009; Smith, Crabb, & Garway-Heath, 2011; Turano, Rubin, & Quigley, 1999). These findings suggest that the performance of patients with glaucoma is significantly reduced on average, compared with people with healthier vision. However, a common feature in data reported in these studies is the high between-patient variability in task performance; simply put, some patients continue to perform well at visual tasks despite the severity of their visual field (VF) loss. For example, patients with significant damage to the central 10° of VF performed worse, on average, at a face recognition task compared to people with normal vision of a similar age, but some patients still performed well at the task (Glen et al., 2012). We hypothesise that eye movements, an element of visual function not typically considered in glaucoma, may explain some of this variability in visual task performance.

Eye movements are a vital tool for processing visual information; since acuity naturally attenuates with increasing eccentricity from the point of regard, an individual must move their eyes to bring new information onto the fovea in order to analyse details of a visual scene. Prior studies have suggested that some patients with glaucoma may be forced to sample information differently during everyday tasks, and that these changes may therefore underlie any apparent functional deficits. For example, when patients were shown dynamic movies of road traffic scenes, they were found to produce more fixations and saccades than controls with healthy vision (Crabb et al., 2010). Other research suggests that VF loss may lead to restrictions in eye movements in less dynamic tasks, with patients shown to produce fewer saccades and to view different locations of static naturalistic scenes than visually healthy people (Smith et al., 2012). Evidence in people with normal vision suggests that the type and difficulty of task influences the manner in which people move their eyes (for a review see Rayner, 2009), suggesting the importance of considering eye movements in different contexts. There is some compelling evidence that 'training' in eye movement control can improve task performance in subjects with age-related macular degeneration (AMD) (Seiple, Grant, & Szlyk, 2011; Seiple et al., 2005) and hemianopia (Pambakian et al., 2004). It has also been suggested that eye movements play a functional role in normal face recognition; for example, scanning behaviour may underlie some of the face recognition deficits seen in older adults, with the way faces are sampled at first

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viewing influencing subsequent recognition accuracy (Chan et al., 2011; Firestone, Turk-Browne, & Ryan, 2007).

This report aims to examine data from a ‘performance-based’ task in order to see if there is a link between eye movement behaviour and performance in glaucoma. Specifically we test the hypothesis that better performance at a face recognition task is associated with aspects of saccadic eye movements in patients with bilateral glaucomatous VF loss in the central 10° and that this association is not apparent in people with normal vision.

2. Methods

Patients with repeatable VF defects in both eyes as a result of Primary Open Angle Glaucoma (and no other ocular disease) were recruited from Moorfields Eye Hospital NHS Trust. People with healthy vision (controls) were selected from the Fight for Sight clinic at City University London. Prior to participation in the study, visual acuity (VA), measured in logMAR, of all participants was recorded using an Early Treatment Diabetic Retinopathy Study (ETDRS) chart. A requirement of the study was a binocular VA of at least 0.18 (Snellen 6/9). The contrast sensitivity (CS) of all patients was also recorded using a Pelli-Robson chart. Participants were verified as ‘within normal limits’ on the Oculus C-Quant (Oculus CmbH, Wetzlar, Germany), a measure of straylight indicating levels of lens opacity. In addition, visual fields (SITA Standard 24-2 and 10-2) in both eyes were recorded on a Humphrey Field Analyzer (HFA, Carl Zeiss Meditec, CA, USA) in all patients. The Glaucoma Hemifield Test (GHT), an algorithm which detects signs of glaucomatous damage, was flagged as “outside normal limits” in all recorded VFs, though patients were purposely recruited to have a range of VF defect severities. The HFA output also shows the mean deviation (MD); a standard summary measure of the overall severity of VF loss that takes the participant’s age into account. Following on from previously published research suggesting the presence of central glaucomatous defects may impact face recognition performance (Glen et al., 2012), patients were subsequently classified according to whether or not they had ‘significant’ defects in the 10-2 VF in both eyes using the MD values. As previously reported, a ‘significant’ defect was defined as one where the MD on the HFA output was flagged as being worse than the 1% normative value [MD $p < 1\%$]). To determine the impact of binocular vision in the central 10° on task functioning, greyscales for integrated visual fields (IVF) were also constructed for each patient using their 10-2 VFs (as the central 10° was the primary focus of this investigation). This method involves combining monocular VFs by taking the best total deviation (TD) sensitivity value at each VF location to represent the state of the individual’s binocular vision (Crabb & Viswanathan, 2005). None of the control subjects (who completed SITA-FAST 24-2 VFs in both eyes to screen for VF defects) failed the GHT. All participants passed the Middlesex Elderly Assessment of Mental Status (MEAMS) test (Kutlay et al., 2007), indicating they were of sufficient cognitive health and did not show any signs of dementia or any other isolated cognitive deficit.

The study was approved by research governance committees of the participating institutions in addition to receiving approval from a UK National Health Service, National Research Ethics Service committee. The study conformed to the declaration of Helsinki, and all participants gave their informed written consent prior to taking part. Data was anonymised and stored in a secure database.

2.1. Procedure

Participants completed the Cambridge Face Memory Test (CFMT) (Duchaine & Nakayama, 2006) on a 22″ monitor (Iiyama Vision Master PRO 514, Iiyama Corporation, Tokyo, Japan) at resolution of 1600 × 1200 at 100 Hz. In the test, participants binocularly view six new faces at three different viewing angles for three seconds each ($n = 18$ “viewing trials”). Their recognition of these faces is subsequently tested in a series of forced-choice recognition trials ($n = 51$), whereby they are required to distinguish the previously seen face from an additional two unfamiliar faces. The CFMT is a freely available, validated test, initially designed to test for the neurological condition prosopagnosia but has also been used to investigate face recognition deficits in other clinical conditions (Hedley, Brewer, & Young, 2011; Wilson et al., 2010). It appears to have good reliability and is capable of measuring face recognition independent of IQ (Bowles et al., 2009; Wilmer et al., 2010) and has featured in a number of recent research studies (Bate et al., 2008; Degutis et al., 2007; Herzmann et al., 2008; Iaria et al., 2009). A full description of the methodology is described in the original paper by Duchaine and Nakayama in which the test validation is described (Duchaine & Nakayama, 2006). The outcome measure for the test is the percentage of correctly identified faces. Fig. 1 shows example images from the viewing and recognition stages of the task, in addition to the eye movements made by an example participant as they viewed these images during the task. Participants completed the CFMT at a viewing distance of 60 cm, and had their head mounted in a comfortable head-rest to minimise head movements. All participants wore trial frames with the correct refractive correction for the viewing distance. The images subtended a viewing angle of 7.4° horizontally and 11.1° vertically, which was calculated to be equivalent to viewing a real face at a distance of roughly 1 m in the real world.

2.2. Eyetracking

Eye movements during task performance were monitored using the Eyelink 1000 system (SR Research Ltd., Ontario, Canada). Pupil position was monitored monocularly at 1000 Hz (the chosen eye was alternated across participants). The Eyelink’s proprietary algorithm was used to calibrate and verify the subject’s point of regard in response to prompts shown at different locations of the screen. It was required that the system stated that accuracy was of a “good” level prior to beginning the task (signifying minimal

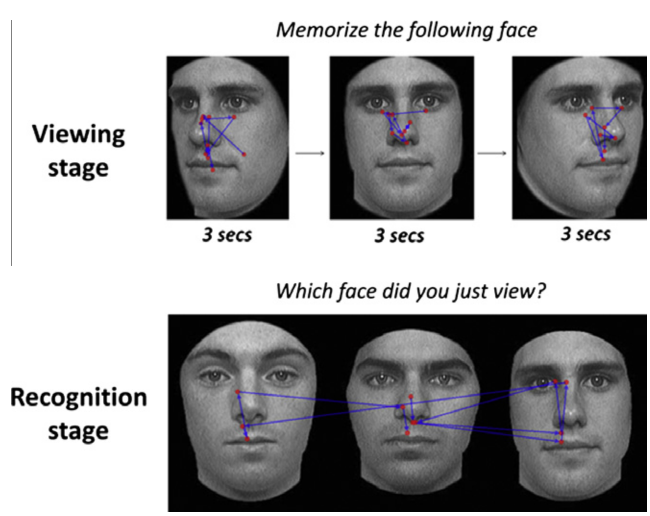

Fig. 1. Example trials from the CFMT. In the viewing stage of the study, participants are asked to memorise a face, which is shown at three different viewing angles for three seconds each. Participants are introduced to six different faces in total. In the recognition stage of the task, participants are given forced-choice trials whereby they must pick out the face they recognise from amongst the distractor faces. The scanpaths of saccades [blue] and fixations [red] made by an example participant as they carry out the task are also shown. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)