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Technical note

Accuracy and re-test reliability of mobile eye-tracking in Parkinson's disease and older adults

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ABSTRACT

Mobile eye-tracking is important for understanding the role of vision during real-world tasks in older adults (OA) and people with Parkinson's disease (PD). However, accuracy and reliability of such devices have not been established in these populations. We used a novel protocol to quantify accuracy and reliability of a mobile eye-tracker in OA and PD.

A mobile eye-tracker (Dikablis) measured the saccade amplitudes of 20 OA and 14 PD on two occasions. Participants made saccades between targets placed 5°, 10° and 15° apart. Impact of visual correction (glasses) on saccadic amplitude measurement was also investigated in 10 OA.

Saccade amplitude accuracy (median bias) was −1.21° but a wide range of bias (−7.73° to 5.81°) was seen in OA and PD, with large vertical saccades (15°) being least accurate. Reliability assessment showed a median difference between sessions of <1° for both groups, with poor to good relative agreement (Spearman *rho*: 0.14 to 0.85). Greater accuracy and reliability was observed in people without visual correction.

Saccade amplitude can be measured with variable accuracy and reliability using a mobile eye-tracker in OA and PD. Human, technological and study-specific protocol factors may introduce error and are discussed along with methodological recommendations.

1. Introduction

Eye-tracking provides data regarding the acquisition of visual information, which is crucial for the safe and effective performance of many real-world activities. Eye-tracking devices have become increasingly popular for investigating visual deficits in people with Parkinson's disease (PD) and older adults (OA) [1,2]. Previous eye-tracking studies have typically measured visual activity in static laboratory settings [3]. More recently, mobile eye-tracking devices have allowed researchers to investigate the influence of both PD and ageing on visual exploration during real-world activities such as walking and obstacle crossing [1,2]. Both mechanistic and clinical research requires accurate and reliable devices. However, a recent review [1] highlighted that previous studies do not report the accuracy or reliability of their eye-tracking devices. This is likely due to a lack of 'gold-standard' device or protocol for comparison. As such, there is sparse information regarding the psychometric properties of mobile eye-tracking devices in people with PD and OA.

Previous studies [4–7] have evaluated reliability of static eye-tracking devices in various populations, measuring saccades for specific phenomena using highly specialised protocols. For example, Farzin et al. [7] reported that their static eye-tracker (Tobii, T120, 300 Hz) was reliable in reporting number and duration of fixations, and pupillary response during a seated picture-viewing protocol in Fragile-X syndrome patients and controls. Similarly, other studies have assessed reliability of eye-movement characteristics measured with static devices but focus on specific assessments such as anti- or pro-saccade tests [4,5,8], and attribute reliability differences to disease-related influences rather than the device [4]. Results of these highly specialised protocols are not easily generalised, highlighting the need for a standardised protocol.

A previous study reported the accuracy of a desk-mounted Tobii eye-tracker (TX300, 300 Hz) was 0.5° [9] when participants walked on a treadmill and look at targets on a screen at various locations. The static device had a high sampling-frequency (300 Hz) and accounted for head movement as long as participants stayed within 200 cm of the screen. As such, the results may not apply to head-mounted mobile eye-tracking devices which capture at lower frequencies (i.e. 50–60 Hz) but do not require movement to be restricted [10].

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Our previous work [11] has shown that mobile eye-trackers can accurately detect saccades, however little is known about the accuracy or reliability of specific saccade characteristics (e.g. amplitude) recorded via mobile eye-trackers during static or dynamic tasks [1]. This is important as such characteristics can inform disease-related impairment. This study aimed to evaluate accuracy and reliability of a mobile eye-tracker in measurement of saccade amplitude in people with PD and OA when sitting, standing and walking. We developed a simple protocol using visual targets placed at set distances, which could be used to evaluate other devices across different populations.

2. Materials and methods

2.1. Participants

Fourteen people with PD were recruited through local Movement Disorders clinics along with 20 age-matched OA through local advertisements.

Inclusion criteria for all participants were: ≥50 years, normal or corrected-to-normal vision (<18/6 on the Snellen visual acuity), non-demented cognitive status (≥21 on the Montreal cognitive assessment (MoCA) [12]), independently mobile indoors without a walking aid, absence of any neurological problem (other than PD for that group) or severe co-morbidity affecting gait.

PD specific inclusion criteria were; a diagnosis of idiopathic PD (by a consultant neurologist) and mild-moderately severe symptoms (Hoehn & Yahr (H&Y) stage I-III). PD participants were excluded if they presented with severe dyskinesia or experienced prolonged off periods. PD participants were tested on the peak dose of their medication.

2.2. Equipment

2.2.1. Mobile eye-tracker

A Dikablis (Ergoneers GmbH, Germany) mobile (head-mounted) infra-red eye-tracker measured saccade amplitude (distance between two fixations), which has an adequate sampling frequency (50 Hz) to detect saccades [11,13]. The Dikablis consisted of a lightweight head-unit and transmitter (weight: 69 g). The head-unit was double-sided taped to each participant's forehead to prevent slippage. The dual-camera system consisted of a monocular infra-red eye-camera to track pupil blackness and a fish-eye field-camera to record the environment in front of the participant. The system was calibrated using the manufacturer's four-point procedure (Fig. 1) for each participant. Calibration created a shared coordinate system relating the position of the pupil captured by the eye-camera with the gaze direction displayed on the field-of-view camera [11].

2.2.2. Head movement

Head and eye-movements are interdependent [14]. Head movement can impact saccade amplitude measurement when the head is unconstrained [15]. Therefore, head movement was recorded using a tri-axial accelerometer (Axivity AX3, York, 100 Hz) fixed to the Dikablis head-unit to examine whether head movement affected our findings.

2.3. Protocol

The study consisted of two sessions, one week apart. Accuracy was assessed using data from session 1 and re-test reliability was assessed using data from both sessions. Prior to testing, participants underwent demographic, clinical and cognitive assessments (MoCA and Mini Mental State Examination (MMSE)).

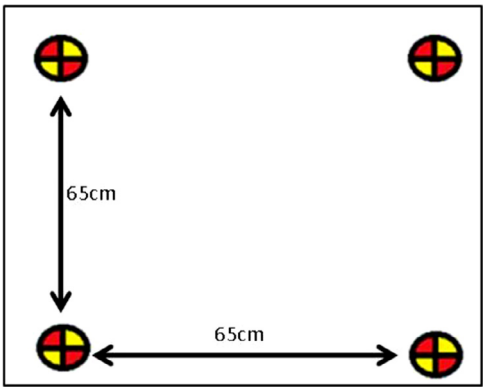

Fig. 1. Calibration board and procedure. Participants were seated and had a chin rest in place, and were then asked to move only their eyes to look at the targets on the board (65 cm square) starting at the bottom left target and continuing in a clockwise direction.

2.3.1. Accuracy (session 1)

Accuracy of saccade amplitude was examined by tracking eye-movements as participants looked between two targets placed at set distances (5°, 10° and 15°, Fig. 2) in time with a metronome (1 Hz) for 20 seconds (s). A maximal target distance of 15° was chosen as most naturally occurring saccades occur within this range [16]. Beyond 15°, co-ordinated eye-head movement is required [17]. Brief (30 s) rests were permitted after each trial to avoid fatigue, as previous studies have reported that fatigue occurs after a sequence of 36 s of eye-movements [18].

Eye-movement procedure:

Two highly salient targets (coloured red and yellow to attract visual attention) were placed on a white board 200 cm from the participant, with the central target at eye-level (Fig. 2). Participants were instructed to move their fixation from central to peripheral target (Fig. 2). Order was as follows:

(1) Horizontally: 5°,10°,15°
(2) Vertically: 5°,10°,15°

Tasks:

The eye-movement procedure was repeated during:

(1) Sitting (with chin rest; restricted head movement).
(2) Standing (asked not move their head; self-restricted head movement).
(3) Walking on a treadmill (Force Link, Netherlands) (head movement permitted). Treadmill speed was set to 80% of that achieved during a 10 m walk test carried out at the start of each session. Researchers provided verbal feedback to ensure participants stayed 2 m from the testing board.

2.3.2. Reliability

To assess re-test reliability, the same protocol described in Section 2.3.1 was repeated one week later (Mean: 7, SD: 2 days). All testing conditions were kept as consistent as possible, with trials conducted by the same researchers (SS, LA) using the same procedure, instructions and testing sequences.

2.3.3. Older adult without visual correction

To assess potential influence of visual correction (glasses or contact lenses) on accuracy and reliability, data from OA participants who did not require visual correction (n = 10) was re-analysed (Table 3).