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Research report

Do people with Parkinson's disease look at task relevant stimuli when walking? An exploration of eye movements

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ABSTRACT

Eye movements are impaired by Parkinson's disease (PD) although limited research has explored if PD affects the relevance of visual fixations when walking. Visual fixations may provide crucial contextual information for safe navigation and important insights into fall risk. This study aimed to: investigate visual fixations made while walking under a range of conditions in PD; identify their task relevance; and explore their relationship with clinical features. Thirty-eight people with mild-moderate PD and forty age-matched control participants completed a straight walk with (i) no additional stimuli and (ii) with additional stimuli (visual cues or a high contrast obstacle), whilst wearing a mobile eye-tracker. Fixations were extracted and classified by location and relevance. PD participants made proportionally fewer task-relevant fixations (floor, walls and additional stimuli ahead), caused by significantly more task-irrelevant fixations (floor, walls and ceiling away from waking path) during normal walking ($p = 0.014$). These group differences were not apparent with visual cues ($p = 0.359$). During obstacle crossing trials, PD made significantly more task-relevant fixations than controls ($p = 0.007$). Reduced bilateral visual acuity was associated with fewer fixations in PD. Our findings suggest that people with PD visually explore complex environments less efficiently likely owing to underlying PD pathology. Visual exploration improved with the addition of salient stimuli (for example visual cues or an obstacle) and thus developing and optimising visual interventions could prove critical to improving locomotor safety and reducing falls risk in home environments.

1. Introduction

Parkinson's disease (PD) is a movement disorder with increasingly recognised visual impairments [1]. Changes in visual function include: reduced visual acuity and contrast sensitivity due to retinal pathology [2], visuospatial impairments due to changes within the dorsal stream of vision [3], and abnormalities in visual sampling (decreased saccadic frequency) [4]. Impairment in the acquisition, processing and interpretation of incoming visual information has the potential to affect safe locomotion and increase falls risk.

Acquiring information about the visual scene is achieved by a combination of saccades and fixations. Saccades are fast eye movements whereby the fovea shifts between different areas of interest, and these are interspersed with fixations, in which visual information is gathered from the environment [5]. People with PD display abnormalities in saccadic control including deficits in saccade suppression and control of saccade direction [6]. A reduced saccadic frequency has also been noted in people with PD when walking, particularly under dual (cognitive) task conditions and during the early approach phase of straight walking prior to turning compared to age-matched controls [4,7]. People with PD also require more saccades to complete static computer-based trials assessing visuo-cognition [8]. Saccadic deficits in people with PD may influence fixations and as a consequence acquisition of contextual information needed for efficient navigation, however this is currently unclear. While limited evidence suggests that saccades are slower [9] and fixations are longer in people with PD [10], the relevance of the

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visual information will depend upon fixation location. Moreover, disease severity plays a role with fewer fixations observed in people with more severe PD [11]. Considering the degenerative influence of PD pathology on attentional capacity, the authors concluded that this reduced fixation count was attributed to an attentional overload when navigating complex environments [11].

Visual information is processed and interpreted in pathways radiating from the occipital lobes [12], and these are likely to be affected by PD pathology [3]. Interpreting visual information regarding the surrounding environment is, in part, dependent on the clarity of the visual information acquired (i.e. acuity and contrast sensitivity). In addition, people with PD demonstrate a reduced ability to inhibit irrelevant and prioritise important visual information from reflexive saccades which will influence the acquisition of visual information [6,13]. Visual interventions for gait impairment in PD, such as visual cues, are prescribed clinically by physiotherapists to overcome gait hypokinesia and restore appropriate spatial scaling during walking [14]. The mechanism underpinning the response to visual cues in PD is not fully understood. Visual cues appear to redirect both vision and attention to relevant environmental stimuli and act as an external visual prompt to regulate and improve gait in PD [10]. Visual cues have been reported to increase the total number of fixations during walking in people with PD [11], however this study did not include a control group so inferences are limited. Interventions to improve locomotor safety are often prescribed to people with PD to overcome pathology-associated gait impairment and reduce trips and falls which are common [15]. Improving the saliency of ground-based obstacles and other trip hazards may work similarly to visual cues by redirecting attention to areas pertinent for safe locomotion. Investigating the contextual relevance of the visual information obtained from fixations exhibited during locomotion (i.e. what participants are looking at and its relevance to the task) could provide insight into one of the mechanisms underlying gait impairment in PD and may contribute to the development of effective interventions to reduce falls risk.

The present study aimed to: (1) identify and classify fixations during walking according to relevance to the task (i.e. Task Relevant or Task Irrelevant), (2) examine the effect of visual cues and obstacles on the task relevance of fixations when walking, and (3) examine whether clinical outcomes (disease specific, visual and cognitive function) are associated with visual exploration in people with PD. We hypothesised that: (1) PD participants would make a lower proportion of task relevant fixations when walking (i.e. due to fewer task relevant fixations and/or more task irrelevant fixations), (2) visual cues and a salient obstacle would increase the proportion of relevant fixations made, and (3) differences in the task relevance of fixations would be associated with visual function, global cognition and PD-specific measures.

2. Materials and methods

2.1. Participants

This study included 41 PD and 41 healthy older adult (control) participants. Data were obtained and collated from two pre-existing data sets: Study 1 (VFDG 'Visual function during gait' [16]) and Study 2 (V-TIME 'Virtual-reality treadmill training to improve mobility and reduce falls in the elderly' [17,18]). The PD cohort were recruited through movement disorder clinics, and controls were identified through local community partnerships. NHS ethical approval was granted for both studies (REC Ref: V-TIME: 12/NE/0249, VFDG: 13/NE/0128), and informed written consent was obtained according to the Declaration of Helsinki [19].

2.2. Inclusion and exclusion criteria

PD participants were recruited providing that they: had a formal diagnosis of PD (UK Brain Bank Criteria) [20], were currently taking antiparkinsonian medication, and were of mild-to-moderate disease severity (Hoehn & Yahr stages I-III) [21]. PD and control participants were included in the study provided they were: > 50 years old, able to ambulate unassisted for at least five minutes, and had stable medication for the month prior to assessment. Participants were excluded if they presented with uncorrected visual or auditory deficits and any psychiatric or neurological disorder (other than PD). Severe cognitive impairment (i.e. dementia) was screened for and excluded using the Mini-Mental State Exam (MMSE) [22] (< 24/30 for both groups). PD participants were assessed while optimally medicated approximately one hour after taking their antiparkinsonian medication. 68% of the PD cohort had experienced at least one fall within the last 12 months (28 of 41) whereas none of the control group had fallen.

2.3. Outcome measures

Demographic data were collected from participants (age, sex, education) in combination with measures of global cognition (MMSE), visual function (visual acuity and contrast sensitivity) and PD disease severity (disease duration, Hoehn & Yahr stage [21], Unified Parkinson's Disease Rating Scale part III (UPDRS-III) [23]). Monocular and bilateral visual acuity (LogMAR) and contrast sensitivity (Mars CS, Mars Perceptix, NY) were measured following the manufacturers' procedures, using a different chart in each test (three in total) to avoid learning effects. Differences in left/right visual acuities may interfere with depth perception during navigation [24], so the absolute difference was calculated (left minus right). The modified Falls Efficacy Scale (FES-I) was used to assess fear of falling in the PD group only with higher scores indicating a greater fear of falling [25].

2.4. Protocol

Participants completed two walking conditions at a self-selected pace: (i) walking and (ii) walking with additional stimuli (visual cues or an obstacle) (Fig. 1A). Both study cohorts completed the straight walking trials and only data for this walking condition were combined. For the visual cueing trial (Study 1), five parallel lines of black tape were affixed directly onto the light coloured floor surface. The lines were perpendicular to the trial pathway and started from 150-cm into the walk separated by 50-cm. For the obstacle crossing trial (Study 2), a high contrast (yellow) obstacle (HxWxD 15 × 60 × 2 cm) was placed half way down the walking path. All walking trials were completed over a 10-m walkway. Trial order was counterbalanced and each trial was completed three times. The laboratory was well lit which remained consistent during all testing sessions.

2.5. Equipment and calibration

Eye movements were tracked using a Dikablis infrared mobile eye-tracker (Ergoneers GmbH, Germany) which uses synchronised video footage from two head-mounted cameras sampling at 50 Hz. A forward-facing camera captured the participant's visual scene and a monocular infrared camera recorded the movements of the left eye (Fig. 1B). The manufacturer's software (Dikablis Recorder v2.5) detected the pupil position using inbuilt algorithms relying upon the relative blackness of the pupil. This data was exported as XY co-ordinates. System calibration was completed per participant prior to data acquisition to ensure that the camera views had been overlaid correctly.

2.6. Data analysis

Eye-tracking data from the first trial of each condition were analysed as visual exploration was considered most natural when participants were naïve to the environmental condition. Raw co-ordinate data were cropped to the trial duration (start and end of walking). Frame-by-frame manual interpolation and error correction were completed in the