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Influence of visual feedback sampling on obstacle crossing behavior in people with Parkinson's disease

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ABSTRACT

The purpose of the current study was to investigate the role of visual information on gait control in people with Parkinson's disease as they crossed over obstacles. Twelve healthy individuals, and 12 patients with mild to moderate Parkinson's disease, walked at their preferred speeds along a walkway and stepped over obstacles of varying heights (ankle height or half-knee height), under three visual sampling conditions: dynamic (normal lighting), static (static visual samples, similar to stroboscopic lighting), and voluntary visual sampling. Subjects wore liquid crystal glasses for visual manipulation. In the static visual sampling condition only, the patients with Parkinson's disease made contact with the obstacle more often than did the control subjects. In the successful trials, the patients increased their crossing step width in the static visual sampling condition as compared to the dynamic and voluntary visual sampling conditions; the control group maintained the same step width for all visual sampling conditions. The patients showed lower horizontal mean velocity values during obstacle crossing than did the controls. The patients with Parkinson's disease were more dependent on optic flow information for successful task and postural stability than were the control subjects. Bradykinesia influenced obstacle crossing in the patients with Parkinson's disease.

1. Introduction

Walking on level ground has been well described in the literature for people with Parkinson's disease (PD) [1,2], but this kind of task has an important ecological limitation; these individuals do not walk on even terrain all of the time. They must adapt their locomotor movements to the different surface characteristics they encounter in everyday activities. When they are unable to adequately avoid an obstacle and they trip, this can lead to a fall. Tripping over obstacles has been identified as one of the major causes of falls in people with PD [3].

Several previous studies have reported foot clearance difficulties during obstacle crossing by people with PD [4–7], but none has investigated the role of visual information on their control of step adjustments while crossing obstacles. Optic flow, in particular, experienced during the act of self-propulsion, is used to control walking speed and the estimation of time to contact [8,9]. Also, it has been observed that optic flow helped to improve the gait parameters of people with PD, crossing over a striped floor [10]. Since individuals use visual information, relative to obstacle position and size, to plan and control their adaptive gait [11,12], it is important for investigators to understand the influence that visual feedback and optic flow information have on the locomotor behavior of people with PD as they cross obstacles.

Individuals' dependence on visual input to guide them through successful obstacle avoidance can be described via the concept, *voluntary visual sampling* [13]. In our previous study, which employed this paradigm of vision manipulation [14], PD patients and healthy subjects required the same amount of visual information (i.e., total duration of visual samples) while they walked on even terrain. Because the required amount of visual information is directly influenced by environmental complexity [13], and because people with PD are more dependent on visual information due to proprioceptive deficits [15,16], the voluntary visual sampling paradigm can help us understand how people with PD use visual information for space-time adjustments during obstacle avoidance. To our knowledge, this is the first study to explore this paradigm during obstacle crossing by PD.

The aim of the current study, therefore, was to investigate the role of visual information on control, in people with Parkinson's disease, as they crossed over obstacles of different heights. We hypothesized that people with PD would be more dependent on

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optic flow during the crossing of obstacles than would their healthy counterparts.

2. Methods

2.1. Participants

This study adhered to the guidelines of the Declaration of Helsinki, and was approved by the Local Ethics Committee (Process #2688/2007). Twenty-four subjects volunteered to participate in the study, including 12 people with idiopathic PD, and 12 neurologically healthy individuals (CG). The CG individuals were pair-matched with people with PD by age, body height, body mass, and gender. All had participated in a previous study by our group (that is, the data were collected at the same time and separated into different studies) [14].

A clinical assessment was performed by a neuropsychiatrist in order to test patients on the Hoehn and Yahr Rating Scale (H&Y) [17], the Unified Parkinson's Disease Rating Scale [18], and the Mini-Exam of Mental Status (MEMS). All assessments were carried out in the morning, in the "on medication" state, 1 h after participants' first dose of medication. Inclusion criteria were: independent walker and no cognitive impairment, as judged by the MEMS (according to Brucki et al.'s [19] suggestions for utilization of the MEMS in Brazil). Individuals in the control group had no neurological, musculoskeletal, or cardiorespiratory impairments. Those in the group with PD had been classified into Stages 1–2.5 of the H&Y, did not have other neurological, musculoskeletal, or cardiorespiratory diseases, and were taking regular PD medication.

2.2. Obstacle crossing task

The obstacle crossing task required participants to walk along a pathway (8 m long by 1.4 m wide) and step over an obstacle, under three visual sampling conditions. The obstacle for each condition was positioned in the middle of a pathway, which was covered with a black rubber carpet, 3 mm thick (Fig. 1). Two obstacle heights were selected: low obstacle (ankle height; 5–10 cm), and high obstacle (half-knee height; 20–25 cm). Participants were instructed to walk to the obstacle at their preferred speed, to step over it, and to keep walking until they reached the end of the pathway. Three visual conditions were tested: dynamic (normal lighting), static (static visual samples) and voluntary visual sampling. Three trials in each condition per participant (obstacle $\times$ vision = 18 trials) were performed in blocks, according to visual conditions. The presentation order of the conditions was randomized. Trials according to obstacle height also were randomized in each block of visual condition. Subjects wore liquid crystal glasses (Translucent Technologies Plato System, Toronto, Canada) for visual manipulation. These glasses are opaque and eliminate any form of motion information. When an electric current passes through the glasses, they become transparent almost immediately (response time <5 ms), providing subjects with a normal view of the surroundings. Under the static condition, the glasses were controlled by an electronic circuit that provided static visual samples at 3 Hz (sample duration <0.016 s). Under the voluntary visual sampling condition, subjects were allowed to choose when and where to take a visual sample of the environment. They pressed a hand-held switch to make the glasses transparent when they needed to sample the environment.

Participants were instructed to initiate the walking task immediately after the following command: "Ready? Go!". Visual information related to the environment was not available before the initial command in any experimental condition. Participants were allowed to familiarize themselves with each condition (and the equipment) over three to five unrecorded trials.

2.3. Data analysis

For the kinematic analysis, four passive markers (15 mm diameter reflective, adhesive Styrofoam) were attached to the following anatomic landmarks: (a) 5th right and 1st left metatarsal joints, and (b) lateral face of the right calcaneous and medial face of the left calcaneous. Also, one passive marker was fixed at the obstacle base. Images of the obstacle avoidance task at the center of the pathway were recorded at a frequency of 60 Hz by two digital camcorders (JVC, GR-DVL 9800) [20]. Further details about data processing can be found in earlier studies by our research group

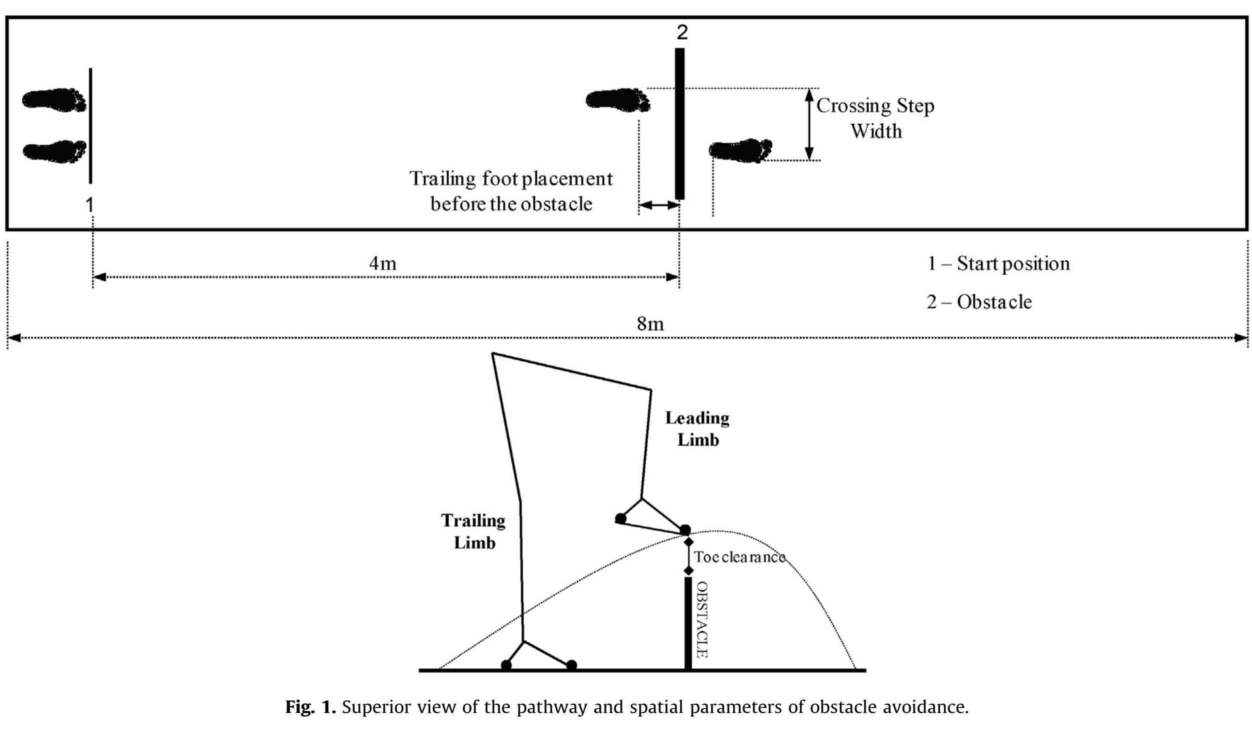

Fig. 1. Superior view of the pathway and spatial parameters of obstacle avoidance.