



The role of vision in Parkinson's disease locomotion control: Free walking task

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ABSTRACT

The current study addressed the role of visual information in the control of locomotion in people with Parkinson's disease. Twelve healthy individuals and 12 mild to moderate Parkinson's disease patients were examined while walking at self-selected velocities, under three visual sampling conditions: dynamic (normal lighting), static (static visual samples) and voluntary visual sampling. Subjects wore liquid crystal glasses for visual manipulation. Outcome measures included spatial-temporal parameters, braking and propulsive impulses, number of samples and total duration of voluntary visual samples. Interaction between groups and visual conditions was not observed for kinematic parameters or braking and propulsive impulses. There were no significant differences between groups for voluntary visual sampling variables. These findings suggest that the visual control of locomotion in Parkinson's disease patients was similar to that observed in controls. Furthermore, Parkinson's disease patients were not more dependent on visual information than healthy individuals for the locomotion control.

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1. Introduction

Gait in people with Parkinson's disease (PD) is characterized by shortened step and stride length, reduced velocity and increased stride variability [1–4]. While cadence rate typically does not seem to be modified, in some cases, it increases to compensate for an amplitude regulation disorder [2].

Several studies have demonstrated benefits in locomotion offered by visual cues in people with PD [5–7]. Two possible mechanisms have been suggested to explain the effect of visual cues, but it still remains unclear. In the first hypothesis, stripes placed on the walking surface may draw attention to the stepping process if people with PD are instructed to put their feet on the stripes [5,8,9]. These subjects are then able to transform the automatic movement of gait into a conscious movement, which would induce a facilitation of walking, due to the bypass of the affected neural pathways. In the second hypothesis, the stripes on the floor are used to enhance optic flow and the motion of the stripes is essential to improve gait parameters [6].

Azulay et al. [6] evaluated the type of visual cues (static or dynamic) required for locomotion control in PD. People with PD

and control subjects were asked to walk on the stripes on the floor without any instruction regarding foot positioning. Two visual conditions were employed: normal lighting and stroboscopic illumination at 3 Hz, the latter acting to suppress dynamic visual cues. Under normal lighting, the stripes induced a significant increase of stride length and gait velocity only in PD subjects. This improvement disappeared with stroboscopic light, demonstrating that the perceived motion of the stripes was essential to improve the gait parameters. Finally, a greater dependence of gait parameters on optic flow was found in PD patients than in controls—the use of stroboscopic light without stripes deteriorated gait parameters only in PD subjects. While relevant, these findings need to be confirmed by other studies.

The voluntary visual sampling paradigm, previously employed by Patla et al. [10] to identify the visual demand to guide locomotion over various terrains in young adults, may contribute to the knowledge of visual gait control in PD. The characteristics of visual sampling required for successful locomotion can better describe subjects' dependence on visual inputs to guide locomotion. Consequently, they could distinguish PD patients and healthy subjects if these groups are really different in using visual information in locomotion control. To our knowledge, it is the first study to explore this paradigm during gait in PD.

The current study addressed the role of visual information in the control of locomotion in people with PD, employing two different paradigms of vision manipulation (static and voluntary visual sampling). We expected to observe conservative locomotor

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behavior under optic flow suppression only in PD patients. Also, PD patients were expected to show greater total duration of voluntary visual sampling than controls.

2. Methods

2.1. Participants

This study adhered to the guidelines of the Declaration of Helsinki, and it was approved by the Local Ethics Committee (Process #2688/2007). All participants signed a consent form.

Twenty-four individuals, including 12 people with idiopathic PD (Table 1), and 12 neurologically healthy individuals (CG), participated in the study. The CG was pair matched with people with PD by age (respectively, 69.6 ± 6.04 and 69.8 ± 5.72 years, $t_{22} = 0.104$, $P = 0.918$), body height (162.1 ± 6.69 and 163.6 ± 7.25 cm, $t_{22} = 0.243$, $P = 0.811$), body mass (68.8 ± 8.27 and 69.8 ± 10.75 kg, $t_{22} = 0.498$, $P = 0.624$) and sex.

A neuropsychiatrist performed a clinical assessment in order to determine the stage of the disease (Hoehn and Yahr Rating Scale; H&Y) [11] and to test participants on the Unified Parkinson's Disease Rating Scale (UPDRS) [12], and the Mini-Exam of Mental Status (MEMS). Inclusion criteria were: independent walker and no cognitive impairment as judged by the MEMS. The cut-off score for the MEMS used to indicate relatively preserved cognition varies between 20 (illiterates) and 29 (more than 12 years of educational level) in Brazil [13]. Individuals without neurological, musculoskeletal or cardiorespiratory impairments were included in the control group. People with PD without other neurological, musculoskeletal or cardiorespiratory diseases and classified in Stages 1–2.5 of the H&Y were included and they were on regular PD medication. PD patients were tested in the morning, in the “on medication” state, 1 h after taking the first morning dose of Levodopa. No PD patient suffered from freezing of gait.

2.2. Walking task

The walking task required participants to walk, at a self-paced speed, on a pathway 8 m long by 1.4 m wide (Fig. 1), which was covered with a black rubber carpet, 3 mm thick. Three visual conditions were tested: dynamic (normal lighting), static (static visual samples) and voluntary visual sampling. Three trials in each condition per participant (9 trials) were performed in blocks and the presentation order of the conditions was randomized. 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, while maintaining a general nonspecific ambient light level. When an electric current passes through these 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.

Participants were instructed to initiate the walking task immediately after the following command: “Ready? Go!” Visual information of the environment was not available before the initial command for any experimental condition. Participants were allowed to familiarize themselves with visual condition (and equipment) during 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 calcaneus and medial face of the left calcaneus. The images of the right sagittal plane of one right stride at center of the pathway were recorded with a frequency of 60 Hz by two digital camcorders (JVC, GR-DVL 9800). Images were captured by a video card (PINNACLE™). Markers were digitized automatically on Digital Video for Windows

software [14]. Tridimensional reconstruction of the markers trajectories was performed by means of a reference system (leveling wires with equally spaced markers, forming a cube with a 3.0 m length, a 1.70 m height, and a 1.30 m width) as a calibration of the experimental set. The procedure accuracy was 4.61 mm, precision was 3.27 mm, and the bias was 3.26 mm. Raw data were filtered using a low-pass, 2nd order digital Butterworth filter, with a cut-off frequency defined by a residual analysis for each coordinate of each marker in one trial in the Matlab 7.0 environment. The following kinematic dependent variables were calculated on the central right stride, from heel contact to the next heel contact: stride length, stride duration, stride velocity, cadence, double-support phase duration, and stance phase duration on the force plate (as it is an important component in impulse calculation, it is shown in seconds). The right step width was also calculated at the same stride.

One force plate (AccuGait, Advanced Mechanical Technologies, Boston, MA) embedded in the pathway measured vertical and anterior–posterior ground reaction forces under the right foot (on second support phase of the right member at central stride). The force plate was also covered with the same black rubber carpet and data were sampled at 200 Hz. Force plate data were normalized by body weight and used to calculate the following dependent variables: Braking and propulsive impulses in two directions (vertical and anterior–posterior). The transition between braking and propulsive impulse was defined by identifying the zero crossing point in the anterior–posterior component of the ground reaction force. Braking impulse was obtained by computing the area under the curve from heel contact (vertical component ≥ 5 N) to zero-crossing, whereas propulsive impulse was defined as the area from zero-crossing to toe-off (vertical component <5 N) [15].

Voluntary visual sampling was registered by a light-emitting diode, which was recorded by the camcorders. When the glasses became transparent, the diode was turned on. With this, the onset and duration of viewing times were recorded and used to calculate dependent variables. The following parameters related to visual sampling were obtained: number of samples and total duration of visual samples. As people with PD are shown to walk slower than controls, total duration of visual samples was normalized by the time spent during the walking task. Travel time was defined from “Go!” command to toe-off when the right foot had left the force plate.

2.4. Statistical analysis

For kinematic variables and impulses, two-way ANOVAs (group $\times$ visual condition) were carried out with repeated measures in the condition factor. Bonferroni post hoc test was used to localize the differences among visual conditions (Bonferroni adjustments to P -value ≤ 0.017). For voluntary visual sampling variables, one-way ANOVAs (group) were performed. P -value was set to 0.05. The statistical analysis employed SPSS for Windows®.

3. Results

Dependent variables for each group on dynamic, static and voluntary visual sampling conditions are shown in Table 2. Post hoc test results for conditions are outlined in Table 3. There was no trial effect for all dependent variables.

3.1. Kinematic parameters

Univariate analysis for group revealed differences for stride length [$F_{(1, 22)} = 7.580$, $P = 0.012$], and stride velocity [$F_{(1, 22)} = 4.479$, $P = 0.046$]; both were smaller for people with PD. There were no significant differences between groups for stride duration [$F_{(1, 22)} = 0.554$, $P = 0.465$], cadence [$F_{(1, 22)} = 0.567$, $P = 0.459$], double-support phase duration [$F_{(1, 22)} = 3.498$, $P = 0.075$], stance phase duration [$F_{(1, 22)} = 1.247$, $P = 0.276$], and step width [$F_{(1, 22)} = 0.003$, $P = 0.955$]. Univariate analysis for visual condition revealed differences for stride length [$F_{(2, 44)} = 29.478$, $P < 0.001$], stride duration

Table 1
Characteristics of Parkinson's disease group.

Patient	A	B	C	D	E	F	G	H	I	J	K	L	Mean	SD
Gender	M	F	M	M	F	F	M	M	M	M	M	F		
Age (years)	60	70	80	71	70	68	68	76	67	74	73	61	69.8	5.72
Body mass (kg)	75	62.6	68	56	53.4	73.5	55	72.2	79.2	80.4	85.5	76.5	69.8	10.75
Body height (cm)	173.5	157	166.3	160.2	148.8	160	172.2	162.5	163	174	162.5	162.7	163.6	7.25
UPDRS-I	3	2	5	3	2	2	5	2	4	4	2	5	3.3	1.29
UPDRS-II	15	7	15	17	7	4	14	14	5	10	12	12	11.0	4.33
UPDRS-III	27	13	46	34	10	8	27	26	9	10	18	10	19.8	12.15
H&Y	1.5	1	2.5	1.5	1	1	2	1.5	1	1.5	1.5	1	1.4	0.47
MEMS	30	25	20	30	29	29	28	29	30	27	28	30	27.9	2.91

UPDRS, Unified Parkinson's Disease Rating Scale; H&Y, Hoehn and Yahr Rating Scale; MEMS, Mini-Exam of Mental Status; SD, standard deviation.

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