Research report

Obstacle circumvention and eye coordination during walking to least and most affected side in people with Parkinson’s disease

Fabio Augusto Barbieri\textsuperscript{a,b,}\textsuperscript{*}, Paula Favaro Polastri\textsuperscript{b}, Lilian Teresa Bucken Gobbi\textsuperscript{b}, Lucas Simieli\textsuperscript{a}, Vinicius Ignácio Alota Pereira\textsuperscript{a}, André Macari Baptista\textsuperscript{a}, Gabriel Felipe Moretto\textsuperscript{a}, Carolina Menezes Fiorelli\textsuperscript{a,b,c}, Luís Felipe Itikawa Imaiuzumi\textsuperscript{a}, Sérgio Tosi Rodrigues\textsuperscript{a}

\textsuperscript{a} São Paulo State University (Unesp) – Campinas, School of Science, Human Movement Research Laboratory (MOVI-LAB) and Laboratory of Information, Vision and Action (LIVIA), Department of Physical Education, Bauru, SP, Brazil
\textsuperscript{b} São Paulo State University (Unesp), Campus Rio Claro, Posture and Gait Studies Laboratory (LEPLO), Department of Physical Education, Rio Claro, SP, Brazil
\textsuperscript{c} Universidade Sagrado Coração, Bauru, SP, Brazil

\textsuperscript{*} Corresponding author at: Universidade Estadual Paulista - UNESP - FC - Bauru, Human Movement Research Laboratory (MOVI-LAB), Av. Eng. Luiz Edmund Carrij Coube, 14-01, CEP: 17033-360 Bauru, SP, Brazil.

E-mail address: barbieri@fc.unesp.br (F.A. Barbieri).

https://doi.org/10.1016/j.bbr.2017.11.032
Received 22 May 2017; Received in revised form 23 November 2017; Accepted 23 November 2017
Available online 24 November 2017
0166-4328/ © 2017 Elsevier B.V. All rights reserved.

ABSTRACT

Background: The mechanisms that contribute to gait asymmetry in people with Parkinson’s disease (PD) are unclear, mainly during gait with greater environmental demand, such as when an obstacle is circumvented while walking.

Objective: The aim of this study was to investigate the effects of obstacle circumvention of the least and most affected side on motor and gaze behavior in people with PD under/without the effects of dopaminergic medication.

Methods: Fifteen people with PD and 15 matched-control individuals were instructed to walk along a pathway, at a self-selected velocity, and to circumvent an obstacle, avoiding contact with it. Each participant performed five trials for each side. Kinematic parameters, mediolateral and horizontal body clearance to the obstacle, strategy to circumvent the obstacle, and gaze behavior were calculated. Parameters were grouped according to the side that the obstacle was circumvented and compared by three-way ANOVAs.

Results: Both people with PD and the control group presented asymmetry to circumvent an obstacle during walking, however this was exacerbated in people with PD. Individuals with PD presented safe strategies (largest mediolateral and horizontal body clearance to the obstacle, “lead-out” strategy, and higher number and time of fixations on the obstacle) during obstacle circumvention for the least affected side compared to the most affected side. In addition, positive effects of dopaminergic medication on body clearance, spatial-temporal parameters, and gaze behavior were evidenced only when the obstacle was circumvented to the least affected side.

Conclusions: The obstacle circumvention to the most affected side is risky for people with PD.

ARTICLE INFO

Keywords:
Gait
Vision
Basal ganglia
Asymmetry
Obstacle circumvention
Dopaminergic medication

1. Introduction

Obstacle circumvention is a more complex task than unobstructed walking. The former task requires that the individual detects the obstacle’s position and edges, performs precise motor actions, and adjusts their movement around it, allowing ample personal space (body clearance) at the point of moving past the obstacle to ensure safe navigation [1]. During obstacle circumvention, both people with Parkinson’s disease (PD) and neurologically healthy individuals decrease step length and step velocity compared to unobstructed walking [2]. In addition, people with PD increase gait variability and duration of gaze fixations on the obstacle and ground when walking with obstacle circumvention, and reduce body clearance without effects from dopaminergic medication [2].

The planning and adjustments to circumvent an obstacle are according to the side of obstacle circumvention [3]. Previous studies have indicated that younger adults when performing circumvention of an obstacle during walking on the non-dominant side increase their personal space [3]. Preservation of body clearance to the obstacle is used as a control criterion by the locomotor system to plan motor adaptations, which is adjusted according to time required to acquire visual information and plan for upcoming hazards [3,4]. Circumvention of an obstacle to the non-dominant side seems to present slower information processing [5] that causes impairments (i.e. asymmetry) in the
acquisition and use of visual information [6] to make motor adjustments during the task. These impairments may be exacerbated in people with PD [7] who present symptoms manifestation more severely on one side [10–12] of the body from early stage of the disease [13–18]. Asymmetrical degeneration of dopaminergic neurons in the substantia nigra [19], enlarged lateral ventricle contralateral to the more symptomatic side [20], and cognitive disruption often consistent with the symptomatic hemisphere [21] may explain the higher effects in most affected side in people with PD. In addition, dopaminergic treatment has been established to improve gait motor patterns for both side of the body [13,22], although levodopa has a greater effect on the most affected side [23,24]. However, no previous studies have investigated the effects of side to obstacle circumvention on body clearance to the obstacle, gait parameters and gaze behavior in people with PD.

The aim of this study was to investigate the effects on motor and visual behavior of obstacle circumvention during walking to the least and most affected side in people with PD, under and without the effects of dopaminergic medication. We analyzed the body clearance to the obstacle, circumvention strategy, spatial-temporal parameters, and gaze behavior during obstacle circumvention to both sides in people with PD and neurologically healthy individuals (control group). The hypotheses of this study were: i) people with PD would present safe strategies (increase body clearance, stride length and velocity and number of fixations on the obstacle) during obstacle circumvention to the side least affected by the disease compared to other side (most affected side) due to higher impairments presented in most affected side [13–18]; ii) dopaminergic medication would have a positive effect on body clearance, spatial-temporal adjustments and gaze behaviors (increase these parameters) for both sides during obstacle circumvention in people with PD, as indicated previously in a study with obstacle avoidance [22].

2. Materials and methods

2.1. Participants

Fifteen people with idiopathic PD and 15 matched-neurologically healthy individuals (control group) were selected to participate in the study. The participants with PD were referred to the current study by local neurologists. The diagnosis of the disease was performed by an expert neurologist according to the UK Brain Bank Criteria [27,28]. The groups were matched by age, gender, body weight, and height (Table 1).

The following exclusion criteria were established: disease stage above 3 on the Hoehn & Yahr scale [29,30], signs of dementia, a history of orthopedic or vision problems that would make it impossible to perform the experimental protocol. In addition, the inclusion criterion was the people with PD had to be taking PD medication. The study was approved by the local Ethics Committee (CAAE: 45435615.7.1001.5398). All participants gave their signed and written consent to all experimental procedures.

2.2. Experimental protocol

The individuals with PD performed the tasks in the OFF-medication state (after a minimum of 12 h withdrawal from PD medication), and then again 1 h after the participants had taken their dopaminergic medication (ON-medication state); if the individuals were taking dopaminergic agonist medication, they were evaluated after a minimum of 24 h withdrawal from medication. The control group performed the protocol only once.

2.3. Clinical evaluation

Participants with PD were evaluated by an expert researcher through anamneses (historical clinical, cognitive, and medication), the motor portion of the Unified Parkinson’s Disease Rating Scale – UPDRS [31], and the H&Y (stage of disease). In addition, cognitive aspects were analyzed using the Mini Mental State Exam [32,33] in all participants.

In addition, for people with PD, motor UPDRS items 20, 21, 22, 23, 25, and 26 were used to assess appendicular asymmetry [14]. The most severely affected limb was determined by finding the difference between the scores for the right and left limbs in the aforementioned UPDRS items. Then, the values of this item-analysis were summed. When this calculation resulted in a positive value, the right limb was the most severely affected limb, but when negative values were obtained, this indicated that the left limb was more severely affected. For the control group, footedness was assessed by asking the participant to kick a ball at a target [21,23]. The limb used to kick the ball was considered as the dominant limb.

2.4. Obstacle circumvention during gait

The participants were instructed to walk along a pathway (approximately 8.5 m long by 3.5 m wide), at a self-selected velocity, and to circumvent an obstacle, avoiding contact with it. In addition, participants were instructed to return to the starting line. The obstacle was cylindrical (0.35 m diameter) and 1.30 m high [2]. The obstacle was positioned in the middle of the pathway, allowing a similar space on both sides (~1.60 m) and 4 m from the starting point. In all trials, the participant was positioned lined up with the obstacle.

Each participant performed 5 circumventions for each side (10 trials in total). The participants were not instructed as to which side they needed to circumvent the obstacle. They chose the side until they had performed 5 trials for one side (e.g., right). Then, the researcher obstructed this side, necessitating that the participants circumvent the obstacle on the other side (e.g., left).

2.5. Data analysis

The kinematic parameters were recorded by an 8 cameras Vicon Motion System ™ (Bonita System Cameras) with a sample rate of 100 samples/s. Passive reflective markers were placed on the participants’ skin at predefined landmarks according to the Plug-in-Gait Full Body model (Vicon) (left and right front and back head, 7th cervical vertebrae, 10th thoracic vertebrae, clavicle, sternum, middle of the right scapula, left and right shoulder, left and right upper arm, left and right elbow, left and right forearm, left and right wrist bar thumb and pinkie side, left and right fingers, left and right anterior and posterior superior iliac spine, mid-way between the posterior superior iliac spines, lateral epicondyle of the left and right knee, left and right lower lateral 1/3 surface of the thigh, left and right lateral malleolus, left and right lower lateral 1/3 of the shank, left and right second metatarsal head and left and right calcaneous) and four markers were placed on the obstacle. Data were filtered using a 5th order low-pass digital Butterworth filter (zero-lag) with a cutoff frequency of 6 Hz.

The data were recorded in two phases of obstacle circumvention: the approach phase – final stride before circumvention of the obstacle; and circumvention phase – stride during the obstacle circumvention (Fig. 1). Nexus software (Vicon) calculated the tridimensional center of mass (CoM) coordinates based on the tridimensional coordinates of the 39 markers, which defined a 15-segment model [34]. Following CoM coordinates, we calculated the mediolateral body clearance (largest mediolateral distance of the CoM to the obstacle during obstacle circumvention) [35,36] (solid arrow in Fig. 2C) and the horizontal body clearance (distance at which participants started to circumvent the obstacle. To calculated this parameter, first it was drawn an imaginary line between the CoM position where participant began the trial and the marker positioned centrally in the top of the obstacle. So, the begin of deviation was defined as five standard deviations of this line) (dashed arrow in Fig. 2C). In addition, the following spatial-temporal parameters of gait for each phase were calculated: stride length, stride
width, stride duration, stride speed, and double support time (percentage of stride duration). The strategy chosen by the participants to circumvent the obstacle, “lead-out” (lead limb away from the obstacle during the crossing step) or “lead-in” (lead limb close to the obstacle during the crossing step) strategies, was also determined [35].

Gaze behavior was recorded by a mobile eye tracker (Mobile Eye-5 glasses, ASL, Bedford, MA, USA). The frequency of data acquisition was 60 Hz. The eye tracker system was calibrated using the nine-point calibration method. Participants fixated their gaze on nine points displayed in a 3 × 3 grid. Calibration was also checked periodically between trials. Gaze fixation was considered when the two times point of gaze standard deviation (95% confidence interval) was less than one.

---

**Table 1**
Characteristics and clinical parameters of each participant in the control group and PD group. The last line of the table for the control group and PD group represents the means and standard deviations of each group in each parameter. FP — foot preference.

<table>
<thead>
<tr>
<th>PD Group</th>
<th>Sex</th>
<th>Age (years)</th>
<th>Body mass (kg)</th>
<th>Height (m)</th>
<th>H&amp;Y OFF</th>
<th>MMSE OFF (pts)</th>
<th>MMSE ON (pts)</th>
<th>UPDRS III OFF (pts)</th>
<th>UPDRS III ON (pts)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>M</td>
<td>61</td>
<td>82.20</td>
<td>1.70</td>
<td>2</td>
<td>30</td>
<td>30</td>
<td>30</td>
<td>25</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>64</td>
<td>70.00</td>
<td>1.60</td>
<td>2</td>
<td>28</td>
<td>29</td>
<td>29</td>
<td>22</td>
</tr>
<tr>
<td>3</td>
<td>F</td>
<td>54</td>
<td>86.00</td>
<td>1.52</td>
<td>2</td>
<td>28</td>
<td>29</td>
<td>29</td>
<td>25</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>61</td>
<td>50.30</td>
<td>1.63</td>
<td>2.5</td>
<td>2.5</td>
<td>29</td>
<td>30</td>
<td>47</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>74</td>
<td>48.00</td>
<td>1.41</td>
<td>3</td>
<td>3</td>
<td>20</td>
<td>21</td>
<td>60</td>
</tr>
<tr>
<td>6</td>
<td>F</td>
<td>74</td>
<td>64.80</td>
<td>1.61</td>
<td>1.5</td>
<td>1</td>
<td>26</td>
<td>26</td>
<td>16</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>64</td>
<td>85.70</td>
<td>1.55</td>
<td>1.5</td>
<td>1.5</td>
<td>30</td>
<td>28</td>
<td>26</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>52</td>
<td>70.70</td>
<td>1.49</td>
<td>2</td>
<td>2</td>
<td>27</td>
<td>30</td>
<td>41</td>
</tr>
<tr>
<td>9</td>
<td>M</td>
<td>80</td>
<td>79.30</td>
<td>1.70</td>
<td>2</td>
<td>2</td>
<td>28</td>
<td>27</td>
<td>35</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>63</td>
<td>47.30</td>
<td>1.58</td>
<td>1</td>
<td>27</td>
<td>27</td>
<td>27</td>
<td>16</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>75</td>
<td>61.50</td>
<td>1.67</td>
<td>2.5</td>
<td>2.5</td>
<td>25</td>
<td>25</td>
<td>39</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>84</td>
<td>67.00</td>
<td>1.60</td>
<td>3</td>
<td>3</td>
<td>28</td>
<td>28</td>
<td>25</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>58</td>
<td>98.00</td>
<td>1.69</td>
<td>2</td>
<td>1.5</td>
<td>30</td>
<td>30</td>
<td>23</td>
</tr>
<tr>
<td>14</td>
<td>F</td>
<td>53</td>
<td>80.00</td>
<td>1.60</td>
<td>2</td>
<td>1</td>
<td>26</td>
<td>30</td>
<td>18</td>
</tr>
<tr>
<td>15</td>
<td>F</td>
<td>63</td>
<td>51.10</td>
<td>1.60</td>
<td>2.5</td>
<td>2.5</td>
<td>29</td>
<td>30</td>
<td>32</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>5 M/10 F</td>
<td>65.33</td>
<td>69.46</td>
<td>1.59</td>
<td>2.10</td>
<td>1.97</td>
<td>27.53</td>
<td>28.00</td>
<td>30.73</td>
</tr>
<tr>
<td></td>
<td>9.90</td>
<td>15.75</td>
<td>0.08</td>
<td>0.54</td>
<td>0.67</td>
<td>2.64</td>
<td>2.54</td>
<td>11.84</td>
<td>9.77</td>
</tr>
</tbody>
</table>

**Control Group**

<table>
<thead>
<tr>
<th>Control Group</th>
<th>Sex (M/F)</th>
<th>Age (years)</th>
<th>Body mass (kg)</th>
<th>Height (m)</th>
<th>MMSE (pts)</th>
<th>FP</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>F</td>
<td>74</td>
<td>63.50</td>
<td>1.53</td>
<td>29</td>
<td>R</td>
</tr>
<tr>
<td>2</td>
<td>F</td>
<td>56</td>
<td>57.50</td>
<td>1.57</td>
<td>26</td>
<td>R</td>
</tr>
<tr>
<td>3</td>
<td>M</td>
<td>67</td>
<td>76.50</td>
<td>1.67</td>
<td>29</td>
<td>R</td>
</tr>
<tr>
<td>4</td>
<td>M</td>
<td>74</td>
<td>74.00</td>
<td>1.68</td>
<td>27</td>
<td>R</td>
</tr>
<tr>
<td>5</td>
<td>F</td>
<td>65</td>
<td>62.90</td>
<td>1.65</td>
<td>29</td>
<td>R</td>
</tr>
<tr>
<td>6</td>
<td>M</td>
<td>67</td>
<td>64.70</td>
<td>1.69</td>
<td>27</td>
<td>R</td>
</tr>
<tr>
<td>7</td>
<td>F</td>
<td>62</td>
<td>80.30</td>
<td>1.59</td>
<td>27</td>
<td>R</td>
</tr>
<tr>
<td>8</td>
<td>F</td>
<td>71</td>
<td>67.60</td>
<td>1.57</td>
<td>27</td>
<td>R</td>
</tr>
<tr>
<td>9</td>
<td>F</td>
<td>65</td>
<td>76.50</td>
<td>1.55</td>
<td>27</td>
<td>R</td>
</tr>
<tr>
<td>10</td>
<td>F</td>
<td>65</td>
<td>75.40</td>
<td>1.54</td>
<td>24</td>
<td>R</td>
</tr>
<tr>
<td>11</td>
<td>M</td>
<td>77</td>
<td>62.30</td>
<td>1.62</td>
<td>28</td>
<td>R</td>
</tr>
<tr>
<td>12</td>
<td>F</td>
<td>77</td>
<td>77.80</td>
<td>1.57</td>
<td>27</td>
<td>R</td>
</tr>
<tr>
<td>13</td>
<td>M</td>
<td>69</td>
<td>88.00</td>
<td>1.75</td>
<td>28</td>
<td>L</td>
</tr>
<tr>
<td>14</td>
<td>F</td>
<td>73</td>
<td>51.00</td>
<td>1.52</td>
<td>29</td>
<td>R</td>
</tr>
<tr>
<td>15</td>
<td>F</td>
<td>66</td>
<td>59.00</td>
<td>1.56</td>
<td>25</td>
<td>R</td>
</tr>
<tr>
<td>Mean ± SD</td>
<td>5 M/10 F</td>
<td>68.53</td>
<td>69.13</td>
<td>0.98</td>
<td>0.54</td>
<td>0.67</td>
</tr>
</tbody>
</table>

---

Fig. 1. Bird’s eye view of the task when an individual performed obstacle circumvention to the left. The approach and circumvention phases are presented in the figures.
degree of visual angle (horizontal and vertical) over 99 ms. We analyzed the following parameters: number of fixations (total number of fixations during the trial), mean duration of the fixations, and time of fixations (percentage of the travel time) [8]. In addition, gaze fixations were classified into four different areas of interest: ground (any location on the ground before, on or to the side of the obstacle), obstacle (any location on the obstacle), wall (any area on the wall at the end of the walkway), and random (any areas not included in the other three areas). Finally, we determined the percentage of trials in which there were no fixations on the obstacle (no area of interest to the obstacle).

The parameters were grouped considering the side that the obstacle was circumvented during the task: people with PD – most and least affected side (defined by UPDRS items); control group – dominant and non-dominant side. In addition, the variability of each parameter was calculated. First, the average and standard deviation of each parameter were calculated. Then, the variability was calculated from the coefficient of variation [37].

### 2.6. Statistical analysis

The level of significance was set at 5% for all analyses. For clinical parameters, paired sample student t-tests were employed to compare dopaminergic medication effects (OFF-medication state – without dopaminergic medication effects × ON-medication state – under effects of dopaminergic medication). Independent sample student t-tests were employed to compare cognitive status of the control group and people with PD under the effects of dopaminergic medication. The spatial-temporal parameters, mediolateral and horizontal body clearance to the obstacle, and gaze behavior, as well as the variability of these parameters, were compared by two-way ANOVAs (group: PD patients under effects of dopaminergic medication and control group X side: least affected/dominant side and most affected/non-dominant side), separately for the approach phase and the circumvention phase, with side as repeated measure. For areas of interest, the data were analyzed by three-way ANOVAs (group X side X area of interest: ground, wall, obstacle, and random), with side and area of interest as repeated measures. A separate analysis for people with PD was conducted with dopaminergic status in a within-subject design with ON and OFF medication state as the repeated-measure (dopaminergic status comparison). In addition, Tukey post hoc tests were carried out to identify the significant differences when a significant main effect was found.

### 3. Results

#### 3.1. Clinical parameters

The characteristics of both the PD and control groups and clinical features of the PD group under and without the effects of dopaminergic medication are presented in Table 1. The groups presented no significant differences in cognitive aspects (t14 = 1.36, p = 0.34). In addition, there were dopaminergic medication effects in UPDRS-motor, in which people with PD presented the lowest score (improvement in UPDRS-motor) under the effects of dopaminergic medication (t14 = 5.75, p = 0.001). There were no effects of dopaminergic medication on H&Y (t14 = 1.74, p = 0.11) or cognitive aspects (t14 = −1.20, p = 0.25).

#### 3.2. Obstacle circumvention strategy, body clearance, and spatial-temporal parameters

There was not a preferred side (most/non-dominant or least/dominate side) to circumvent the obstacle for both groups. For control group, five participants, two participants and eight participants performed the first five obstacle circumvention to, respectively, dominant side, non-dominant side and randomly (i.e. two for one side and for the other side). For people with PD, two participants performed the first five obstacle circumvention to least affected side (five participants in OFF-medication state), one participant performed the first five obstacle circumvention to most affected side (two participants in OFF-medication state) and twelve participants performed the first five trials randomly (eight participants in OFF-medication state).

Regarding obstacle circumvention strategies, people with PD used the "lead-in" strategy more when they performed obstacle circumvention to the most affected side while the control group used the "lead-out" strategy and "lead-out" strategy more when they performed obstacle circumvention to the dominant side and non-dominant side, respectively (Fig. 2). Both groups increased the horizontal body clearance to the obstacle (beginning the obstacle circumvention) when they performed obstacle circumvention to the least affected/dominant side (F1.28 = 14.89,
Means and standard deviations of spatial-temporal parameters according to side the obstacle was circumvented and group. *The first part of the table presents parameters for the approach phase and the second part presents parameters for the circumvention to the least affected/dominant side.

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Group DP OFF-medication state</th>
<th>Circumvention to least affected side</th>
<th>Group DP ON-medication state</th>
<th>Circumvention to least affected side</th>
<th>Control group</th>
<th>Circumvention to least affected side</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stride length (cm)</td>
<td>86.60 ± 15.60</td>
<td>76.87 ± 17.92</td>
<td>81.46 ± 16.31</td>
<td>74.64 ± 13.84</td>
<td>91.69 ± 18.02</td>
<td>85.23 ± 15.43</td>
</tr>
<tr>
<td>Stride width (cm)</td>
<td>3.08 ± 0.63</td>
<td>3.03 ± 0.70</td>
<td>3.05 ± 0.65</td>
<td>3.08 ± 0.63</td>
<td>3.08 ± 0.63</td>
<td>3.08 ± 0.63</td>
</tr>
<tr>
<td>Stride duration (s)</td>
<td>0.99 ± 0.13</td>
<td>0.97 ± 0.12</td>
<td>0.98 ± 0.12</td>
<td>0.99 ± 0.13</td>
<td>0.98 ± 0.12</td>
<td>0.98 ± 0.12</td>
</tr>
<tr>
<td>Double support (-)</td>
<td>0.86 ± 0.14</td>
<td>0.86 ± 0.14</td>
<td>0.86 ± 0.14</td>
<td>0.86 ± 0.14</td>
<td>0.86 ± 0.14</td>
<td>0.86 ± 0.14</td>
</tr>
<tr>
<td>Circumvention phase</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stride length (cm)</td>
<td>81.76 ± 12.17</td>
<td>76.12 ± 15.02</td>
<td>73.66 ± 12.51</td>
<td>69.36 ± 12.51</td>
<td>86.96 ± 15.76</td>
<td>78.96 ± 12.51</td>
</tr>
<tr>
<td>Stride width (cm)</td>
<td>3.06 ± 0.52</td>
<td>3.05 ± 0.52</td>
<td>3.05 ± 0.52</td>
<td>3.06 ± 0.52</td>
<td>3.06 ± 0.52</td>
<td>3.06 ± 0.52</td>
</tr>
<tr>
<td>Stride duration (s)</td>
<td>0.98 ± 0.11</td>
<td>0.97 ± 0.12</td>
<td>0.98 ± 0.12</td>
<td>0.99 ± 0.13</td>
<td>0.98 ± 0.12</td>
<td>0.98 ± 0.12</td>
</tr>
<tr>
<td>Double support (%)</td>
<td>0.84 ± 0.14</td>
<td>0.86 ± 0.14</td>
<td>0.86 ± 0.14</td>
<td>0.86 ± 0.14</td>
<td>0.86 ± 0.14</td>
<td>0.86 ± 0.14</td>
</tr>
</tbody>
</table>

*p < 0.001 (Fig. 2). In addition, people with PD presented lower variability in horizontal body clearance to the obstacle than the control group for obstacle circumvention to the least affected/dominant side (*F*₁,2₈ = 7.61, p < 0.01). With respect to mediolateral body clearance to the obstacle, people with PD increased the clearance to the obstacle (p < 0.008) when they performed obstacle circumvention to the least affected side compared to obstacle circumvention to the most affected side (group*side interaction − *F*₁,2₈ = 4.95, p < 0.004). The control group did not present significant differences between sides for mediolateral body clearance, however they increased variability of mediolateral body clearance (p < 0.04) for non-dominant obstacle circumvention compared to dominant obstacle circumvention (group*side interaction − *F*₁,2₈ = 3.42, p < 0.02).

People with PD presented slower stride velocity (approach phase − *F*₁,2₈ = 6.08, p < 0.02; circumvention phase − *F*₁,2₈ = 8.07, p < 0.008), shorter stride length (approach phase − *F*₁,2₈ = 10.01, p < 0.004; circumvention phase − *F*₁,2₈ = 12.70, p < 0.001), and higher variability of double support time (approach phase − *F*₁,2₈ = 6.71, p < 0.01; circumvention phase − *F*₁,2₈ = 5.39, p < 0.02) in both the approach and circumvention phases than the control group (Table 2). Specifically for the approach phase, people with PD increased stride width (*F*₁,2₈ = 8.08, p < 0.008) and variability of this parameter (*F*₁,2₈ = 5.47, p < 0.02) compared to the control group. In addition, when the individuals performed the obstacle circumvention to the most affected/non-dominant side, people with PD increased variability of stride width (p < 0.03) compared to the control group in the approach phase (group*side interaction − *F*₁,2₈ = 10.33, p < 0.003). For the circumvention phase, people with PD increased variability of stride length (*F*₁,2₈ = 7.63, p < 0.01) and velocity (*F*₁,2₈ = 3.88, p < 0.05) compared to the control group. In addition, when individuals performed obstacle circumvention to the least affected/dominant side, people with PD increased variability of stride length (p < 0.001), velocity (p < 0.003), and double support time (p < 0.01) compared to the control group (group*side interaction: stride length − *F*₁,2₈ = 3.53, p < 0.05; stride velocity − *F*₁,2₈ = 7.16, p < 0.01; double support time − *F*₁,2₈ = 3.59, p < 0.05). People with PD also increased variability of stride length (p < 0.01) and velocity (p < 0.01) when they performed obstacle circumvention to the least affected side compared to the most affected side, while the control group reduced variability of stride duration (p < 0.05) when they circumvented the obstacle to the dominant side compared to non-dominant side (group*side interaction: variability of stride duration − *F*₁,2₈ = 3.67, p < 0.05). Finally, the control group was faster (increased stride velocity) in both phases (approach phase − p < 0.01; circumvention phase − p < 0.05) when they performed obstacle circumvention to the dominant side compared to the non-dominant side.

### 3.3. Gaze behavior and area of interest

People with PD presented higher variability of time of fixations (*F*₁,2₈ = 4.22, p < 0.04) compared to the control group (Table 3). In addition, when individuals performed obstacle circumvention to the least affected/dominant side, they increased variability of mean duration of fixations (*F*₁,2₈ = 5.35, p < 0.02). Post hoc analysis of group*side interaction (mean duration of fixation − *F*₁,2₈ = 4.82, p < 0.03; variability of time of fixations − *F*₁,2₈ = 10.98, p < 0.003) indicated that when the obstacle circumvention was performed to the most affected/non-dominant side, people with PD increased the mean duration of fixation (p < 0.04) and variability of time of fixations (p < 0.03) compared to the control group. In addition, the control group presented higher time of fixations (p < 0.04) when they circumvented the obstacle to the dominant side (group*side interaction − *F*₁,2₈ = 4.82, p < 0.03).

In general, for area of interest, individuals presented a higher number of fixations (*F*₁,2₈ = 36.52, p < 0.001) and time of fixations (*F*₁,2₈ = 43.56, p < 0.001) on the ground compared to other areas of
interest (obstacle, wall, and random areas) (Table 3). The number of fixations (p < 0.001) and time of fixations (p < 0.001) on the obstacle was higher than on the wall and random. In addition, the mean duration of fixations (F1,28 = 9.13, p < 0.001) on the obstacle and ground was higher than random. When individuals performed obstacle circumvention to the most affected/non-dominant side, they decreased the number of fixations (p < 0.002) and time of fixations (p < 0.004) on the obstacle, and increased the number of fixations (p < 0.002), time of fixations (p < 0.002), and mean duration of fixations (p < 0.01) on the ground compared to obstacle circumvention to the least affected/dominant side (side*area interaction – number of fixations: F1,28 = 13.56, p < 0.001; mean duration of fixations: F1,28 = 6.31, p < 0.001; time of fixations: F1,28 = 13.24, p < 0.001). Furthermore, when obstacle circumvention was performed to the most affected/non-dominant side, they performed a higher number of fixations (p < 0.001) and time of fixations (p < 0.001) on the ground than the other three areas of interest, while when obstacle circumvention was performed to the least affected/dominant side, they performed the same number of fixations (p < 0.001) and time of fixations (p < 0.001) on the obstacle and ground, but both higher than on the wall and random.

Specifically, people with PD presented a higher number of fixations (p < 0.001) and time of fixations (p < 0.002) on the obstacle than the control group (group*area interaction – number of fixations: F1,28 = 5.01, p < 0.02; time of fixations: F1,28 = 7.78, p < 0.003). In addition, people with PD increased the number of fixations (p < 0.001), mean duration of fixations (p < 0.04), and time of fixations (p < 0.001) on the obstacle when performing obstacle circumvention to the least affected limb compared to the control group when circumventing the obstacle to the dominant side (group*side*area interaction – number of fixations: F1,28 = 17.20, p < 0.001; mean duration of fixations: F1,28 = 4.29, p < 0.01; time of fixations: F1,28 = 24.56, p < 0.001). For the other side (most affected and non-dominant side), people with PD increased the mean duration of fixations (p < 0.002) on the ground compared to the control group. Furthermore, when people with PD circumvented the obstacle to the most affected side, they decreased the number of fixations (p < 0.001) and time of fixations (p < 0.001) on the obstacle and increased the number of fixations (p < 0.001), mean duration of fixations (p < 0.001), and time of fixations (p < 0.001) on the ground; they did not fixate the obstacle in 62.66% of trials when circumventing the obstacle to the most affected side (for least affected side only 9.33% of trials). In contrast, the control group presented similarity in this variable for both sides of obstacle circumvention (dominant side – 62.66% of trials; non-dominant side – 48% of trials).

3.4. ON-medication state vs OFF-medication state

People with PD increased the use of a “lead-in” strategy when performing obstacle circumvention to the most affected side, independent of the effects (both under and without) of dopaminergic medication (Fig. 2). However, they used a similar number of “lead-in” and “lead-out” strategies when performing obstacle circumvention to the least affected side, independent of the effects of dopaminergic medication. In addition, the lack of dopaminergic medication increased the variability of mediolateral body clearance (F1,28 = 5.78, p < 0.02), especially when circumventing the obstacle to the least affected side (dopaminergic status*side interaction – F1,28 = 5.74, p < 0.02) (Fig. 2). Furthermore, under the effects of dopaminergic medication, people with PD began (p < 0.04) the obstacle circumvention earlier (horizontal body clearance) than when they performed obstacle circumvention to the least affected side compared to the most affected side (medication*side interaction – F1,28 = 3.84, p < 0.05).

There were no effects of dopaminergic medication, side or interaction between factors for spatial-temporal parameters of obstacle circumvention during the approach phase (Table 2). During the obstacle circumvention phase, the lack of dopaminergic medication decreased stride length (p < 0.02) and velocity (p < 0.04) when circumventing the obstacle to the least affected side — compared to the ON-dopaminergic medication state (medication*side interaction – stride length: F1,28 = 3.97, p < 0.05; stride velocity: F1,28 = 4.47, p < 0.04). Furthermore, when the people with PD, without the effects of dopaminergic medication, performed obstacle circumvention to the most affected side, they increased stride length (p < 0.006) and velocity (p < 0.02) compared to the least affected side. However, dopaminergic medication increased the variability of stride length (p < 0.05) and velocity (p < 0.03) when people with PD circumvented the obstacle to the least affected side compared to the most affected side (medication*side interaction – stride length: F1,28 = 4.77, p < 0.03; stride velocity: F1,28 = 5.20, p < 0.03). There were no effects of dopaminergic medication, side or interaction between factors for gaze behavior (Table 3). However, for areas of interest, the lack of dopaminergic medication decreased the number of fixations (p < 0.006) and time of fixations (p < 0.009) on the obstacle and increased the mean duration of fixations (p < 0.02) on the ground (medication*area interaction – number of fixations: F1,28 = 4.62, p < 0.03; time of fixations: F1,28 = 5.82, p < 0.01; mean duration of fixations: F1,28 = 5.79, p < 0.02). In addition, the lack of dopaminergic medication increased the number of fixations (p < 0.002), mean duration of fixations (p < 0.003), and time of fixations (p < 0.001) on the obstacle when the obstacle was circumvented to the least affected side — compared to under the effects of dopaminergic medication (medication*side*area interaction – number of fixations: F1,28 = 18.50, p < 0.001; mean duration of fixations: F1,28 = 3.27, p < 0.02; time of fixations: F1,28 = 24.26, p < 0.001). In addition, the mean duration of fixations on the obstacle decreased (p < 0.04) when they performed obstacle circumvention to the most affected side compared to the least affected side without the effects of dopaminergic medication. Dopaminergic medication increased the number of fixations (p < 0.001), mean duration of fixations (p < 0.001), and time of fixations (p < 0.001) on the ground and reduced the number of fixations (p < 0.001) and time of fixations (p < 0.001) on the obstacle when people with PD performed obstacle circumvention to the most affected limb compared to obstacle circumvention to the least affected limb. Finally, people with PD without the effects of dopaminergic medication did not fixate the obstacle in 41.33% and 48% of trials when circumventing the obstacle to the least and most affected sides, respectively. The percentage was greater for the least affected side and lower for the most affected side compared to under the effects of dopaminergic medication (see end of Section 3.3).

4. Discussion

The aim of this study was to investigate the effects on body clearance, spatial-temporal adjustments, and gaze behavior of obstacle circumvention to the least and most affected side in people with PD, under and without the effects of dopaminergic medication, and compare these effects with neurologically healthy individuals. People with PD and the control group presented similar strategies to circumvent an obstacle (both used “lead-in” and “lead-out” strategies, began obstacle circumvention at a similar horizontal body clearance to the obstacle, and had similar mediolateral body clearance from the obstacle), which corroborated with our previous study [2]. However, the groups performed different spatial-temporal and gaze adjustments to circumvent the obstacle. People with PD reduced gait velocity and stride length during the approach and circumvention phases, which may be due to hypometric movements and bradykinesia caused by PD [7,9]. This strategy suggests an increased time to acquire information on the environment [38], mainly the obstacle. People with PD were more gaze obstacle-dependent (they increased the number and time of fixations on the obstacle). Vitório and collaborators [39] demonstrated that environmental constraints, such as postural threat, increase the dependence of people with PD on dynamic visual information during
locomotion. Sensory and perceptual deficits caused by PD [40–42] are the main explanation for this gaze behavior during obstacle circum- 
vention. Basal ganglia damage may be associated with sensory and perceptual deficits [43,44] as well as right hemisphere damage, which is 
responsible for visuospatial processing [45]. On the other hand, re-
duced gait velocity and stride length increases instability during walking [46–48]. To deal with this unstable gait, people with PD in-
creased the basis of support (stride width) during the approach phase. In 
addition, the greater variability in stride width and double support 
time could be an attempt by the system to seek stability. Despite this, 
a large variability (besides stride width and double support time, people 
with PD increased variability of stride length and velocity during the 
approach phase), may suggest impairment in both mechanisms that 
regulate gait rhythm and the central pattern generator and those that 
 regulate balance [49] and sequential and rhythmic movements caused 
by lesions in the posterior part of the putamen [42,50]. The greater 
variability in people with PD could be interpreted, from a pathoph-
ysiology aspect, as a deficit in the basal ganglia internal rhythmicity 
[51,52].

4.1. Strategies of people with PD to deal with asymmetry when circumventing the obstacle

Our most important finding was that people with PD presented 
asymmetry when circumventing the obstacle, which confirmed our first 
 hypothesis. People with PD presented safe strategies (greater medio-
 lateraland horizontal body clearance to the obstacle, “lead-out” 
strategy, and higher number and time of fixations on the obstacle) 
don Covidamerican in circumventing to the least affected side compared to the 
most affected side, which seems to indicate asymmetric motor and gaze 
behavior to circumvent an obstacle. However, neurologically healthy 
individuals also presented asymmetric behavior, although lower than 
people with PD, in the obstacle circumvention strategy, body clearance, 
spatial-temporal, and gaze strategies, which seems to indicate that 
asymmetric behavior during obstacle circumvention begins in neuro-
logically healthy individuals and is exacerbated in people with PD. A 
previous study [3] related asymmetric behavior during obstacle cir-
mvention in younger and older adults. The explanation for this 
asymmetric behavior is that visual-spatial information is processed 
 faster when obstacle circumvention is performed to the dominant side 
due to the greater cortical representation and salience of this side [53].

People with PD performed a risky strategy when circumventing an 
 obstacle to the most affected side. They began the obstacle cir-
mvention closer to the obstacle (shorter horizontal body clearance), 
used a “lead-in” strategy and smaller mediolateral body clearance 
compared to when the obstacle was circumvented to the least affected 
side. In addition, they increased the number and time of fixations on 
the ground and decreased these parameters on the obstacle when cir-
mventing the obstacle to the most affected side. These findings re-
force the risky strategy, which can increase the chances of making 
contact with the obstacle. Obstacle circumvention to the most affected 
side seemed to increase the need to guarantee the accuracy and preci-
sion of foot placement and the path to obstacle circumvention. To deal 
with this need is the reduced gait velocity during approach and cir-
mvention phases during obstacle circumvention to the most affected 
side, which increased the time to plan the foot position and to place the 
foot precisely [48,54]. Due to the proprioceptive [43] and working 
memory [55] deficits usually observed in people with PD, they are more 
dependent on the availability of visual information in an on-line mode 
to fine tune the accuracy of foot placement [8]. Therefore, asymmetric 
control of the basal ganglia seems to be evidenced due to the fact that 
the brain side that controls the most affected limb seems to present 
worst striatal uptake in both the caudate and putamen nuclei [56,57] 
and reduced distribution throughout the cortical-basal ganglia-thalamic 
circuitry [58,59]. In addition, the deficits in circumventing the obstacle 
to the most affected side were not only in the motor system, but also in 
the sensorial system. We can speculate that degeneration in the most 
affected brain side also occurred in perceptual brain areas. Previous 
studies have also indicated that veering is side affected to PD-dependent 
[60,61]. Perceptual/sensorial asymmetry is a characteristic in the ear-
liest stages of the disease [54,59,62,63], which seems to be manifested 
depending on the basal ganglia-cortical loops activated by the visual 
and motor demands of the task [62]. Finally, obstacle circumvention to 
the most affected side decreased the variability of stride length and 
velocity. This strategy seems to indicate a greater robustness of the 
motor system that can be explained by the difficulty of people with PD 
to perform adjustments during challenging tasks due to impairments in 
the basal ganglia, decreasing motor flexibility — action reprogramming 
[37], which seems to be a worse strategy if an adaptation is necessary 
during the task [22].

4.2. No effect of dopaminergic medication during obstacle circumvention to the most affected side

The second main important finding of our study was that dopami-
nergic medication presented no effects on motor or perceptual systems 
for obstacle circumvention to the most affected side. Therefore, our 
second hypothesis was only confirmed when people with PD performed 
obstacle circumvention to the least affected side, which presented po-
positive effects from dopaminergic medication on mediodiagonal body 
clearance (reduced variability), spatial-temporal parameters (greater 
stride length during circumvention phase), and gaze behavior (higher 
number and longer fixations on the obstacle). However, our analysis did 
not reveal effects from dopaminergic medication when obstacle cir-
mvention was performed to the most affected side. These results 
suggest that effects from dopaminergic medication were dependent on 
the side that people with PD performed obstacle circumvention. No 
symmetrical action of dopaminergic medication can explain our find-
ings [23,64]. Previous studies have demonstrated that there are dif-
fences in cerebral activity between the most and least affected sides 
and that levodopa has a preferential effect on brain activations in task-
relevant brain areas [21]. The least affected side might have pre-
ferentially responded to levodopa because the nigrostrial dopami-
nergic terminals of that side were less degenerated [64]. These findings 
corroborate with our previous study that found PD medication im-
proved postural control asymmetry in people with PD in the early stage 
of disease, but not in the moderate stage, during challenging postural 
tasks [26]. Asymmetrical degeneration of dopaminergic neurons in the 
substantia nigra, such as contralateral lateral ventricle is enlarged to the 
most symtomatic side and hypoactivity in motor regions is higher in the 
most affected side, underlying symptom asymmetry in PD [18,19]. 
The advanced brain impairment due to PD presents a greater response 
with shorter duration resulting in waxing and waning between medi-
cation doses, and eventually, abrupt changes in response as if turned on 
and off by a switch [65,66] which results in delayed onset to the most 
affected side compared with the least affected side [66]. In addition, no 
effects from dopaminergic medication during obstacle circumvention to 
the most affected side occurred in the perceptual system, which seems 
to indicate that dopaminergic circuits within the basal ganglia may not 
be responsible for perceptual deficits, corroborating with previous 
studies [41,67,68]. Therefore, obstacle circumvention to the most af-
fected side is risky task, which could have a contact with the obstacle in 
people with PD without the effects of dopaminergic medication.

In conclusion, both people with PD and neurologically healthy in-
dividuals presented asymmetric behavior between sides when cir-
mventing the obstacle, however, this asymmetry was exacerbated in 
the former. People with PD performed worse motor and perceptual 
strategies during obstacle circumvention to the most affected side 
compared to the least affected side. In addition, dopaminergic medi-
cation had no effects on motor or perceptual systems for obstacle cir-
mvention to the most affected side. The effects from dopaminergic 
medication occurred only when obstacle circumvention was performed
Table 3
Means and standard deviations of gaze behavior according to side that obstacle was circumvented and group. The first part of the table presents general gaze behavior during obstacle circumvention to the least affected/dominant and most affected/non-dominant side in people with PD (under and without the effects of dopaminergic medication) and the control group. The values of variability (means and standard deviations) for each parameter are presented in brackets. The second part of the table presents gaze behavior according to areas of interest.

<table>
<thead>
<tr>
<th>Area of Interest</th>
<th>Group DP OFF</th>
<th>Group DP ON</th>
<th>Control group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Circumventi-</td>
<td>Circumventi-</td>
<td>Circumventi-</td>
</tr>
<tr>
<td></td>
<td>on to least</td>
<td>on to most</td>
<td>on to least</td>
</tr>
<tr>
<td></td>
<td>affected side</td>
<td>affected side</td>
<td>affected side</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>side</td>
</tr>
<tr>
<td>Number of fixations</td>
<td>12.31 ± 7.8-</td>
<td>11.60 ± 7.9-</td>
<td>9.56 ± 7.11</td>
</tr>
<tr>
<td></td>
<td>5 (39.05 ± 34-</td>
<td>8 (40.39 ± 43-</td>
<td>4 (33.78 ± 15-</td>
</tr>
<tr>
<td></td>
<td>.66)</td>
<td>.23)</td>
<td>.72)</td>
</tr>
<tr>
<td></td>
<td>0.24 ± 0.13</td>
<td>0.24 ± 0.17</td>
<td>0.19 ± 0.09</td>
</tr>
<tr>
<td></td>
<td>(20.76 ± 13-</td>
<td>(22.28 ± 15-</td>
<td>(24.88 ± 13-</td>
</tr>
<tr>
<td></td>
<td>.68)</td>
<td>.77)</td>
<td>.04)</td>
</tr>
<tr>
<td></td>
<td>31.42 ± 17-</td>
<td>29.31 ± 18-</td>
<td>27.64 ± 16-</td>
</tr>
<tr>
<td></td>
<td>00 (6.96 ± 9.1-</td>
<td>05 (8.22 ± 12-</td>
<td>53 (4.97 ± 5.2-</td>
</tr>
<tr>
<td></td>
<td>1) 86)</td>
<td>8)</td>
<td>8)</td>
</tr>
<tr>
<td>Mean duration of fixations (s)</td>
<td>0.24 ± 0.13</td>
<td>0.22 ± 0.17</td>
<td>0.20 ± 0.10</td>
</tr>
<tr>
<td></td>
<td>(20.76 ± 13-</td>
<td>(22.28 ± 15-</td>
<td>(24.88 ± 13-</td>
</tr>
<tr>
<td></td>
<td>.68)</td>
<td>.77)</td>
<td>.04)</td>
</tr>
<tr>
<td>Time of fixations (%)</td>
<td>31.42 ± 17-</td>
<td>29.31 ± 18-</td>
<td>27.64 ± 16-</td>
</tr>
<tr>
<td></td>
<td>00 (6.96 ± 9.1-</td>
<td>05 (8.22 ± 12-</td>
<td>53 (4.97 ± 5.2-</td>
</tr>
<tr>
<td></td>
<td>1) 86)</td>
<td>8)</td>
<td>8)</td>
</tr>
<tr>
<td>Area of Interest</td>
<td>Ground</td>
<td>Obstacle</td>
<td>Wall</td>
</tr>
<tr>
<td></td>
<td>Number of fixations</td>
<td>42.13 ± 38-</td>
<td>8.67 ± 7.86</td>
</tr>
<tr>
<td></td>
<td>90</td>
<td>98</td>
<td>2</td>
</tr>
<tr>
<td>Mean duration of fixations (s)</td>
<td>0.16 ± 0.02</td>
<td>0.39 ± 4.67</td>
<td>0.08 ± 0.10</td>
</tr>
<tr>
<td></td>
<td>(20.76 ± 13-</td>
<td>(22.28 ± 15-</td>
<td>(5 24)</td>
</tr>
<tr>
<td></td>
<td>.68)</td>
<td>.77)</td>
<td></td>
</tr>
<tr>
<td>Time of fixations (%)</td>
<td>5.30 ± 5.88</td>
<td>18.74 ± 15-</td>
<td>18.86 ± 11-</td>
</tr>
<tr>
<td></td>
<td>55.0 ± 6.73</td>
<td>92</td>
<td>37</td>
</tr>
<tr>
<td>Wall</td>
<td>Number of fixations</td>
<td>2.93 ± 8.19</td>
<td>11.81 ± 11-</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Mean duration of fixations (s)</td>
<td>0.08 ± 0.10</td>
<td>0.15 ± 0.06</td>
<td>0.15 ± 0.06</td>
</tr>
<tr>
<td></td>
<td>(20.76 ± 13-</td>
<td>(22.28 ± 15-</td>
<td>(24.88 ± 13-</td>
</tr>
<tr>
<td></td>
<td>.68)</td>
<td>.77)</td>
<td>.04)</td>
</tr>
<tr>
<td>Time of fixations (%)</td>
<td>0.78 ± 1.30</td>
<td>7.28 ± 6.80</td>
<td>3.87 ± 5.04</td>
</tr>
<tr>
<td></td>
<td>0.40 ± 0.92</td>
<td>4.55 ± 6.49</td>
<td>3.87 ± 5.04</td>
</tr>
<tr>
<td>Random</td>
<td>Number of fixations</td>
<td>6.27 ± 10.9-</td>
<td>0.08 ± 0.08</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>Mean duration of fixations (s)</td>
<td>0.44 ± 0.89</td>
<td>0.10 ± 0.09</td>
<td>0.32 ± 0.68</td>
</tr>
<tr>
<td></td>
<td>(20.76 ± 13-</td>
<td>(22.28 ± 15-</td>
<td>(24.88 ± 13-</td>
</tr>
<tr>
<td></td>
<td>.68)</td>
<td>.77)</td>
<td>.04)</td>
</tr>
<tr>
<td>Time of fixations (%)</td>
<td>0.44 ± 0.89</td>
<td>0.10 ± 0.09</td>
<td>0.80 ± 1.00</td>
</tr>
<tr>
<td></td>
<td>1.53 ± 1.96</td>
<td>2.07 ± 3.24</td>
<td>0.84 ± 0.85</td>
</tr>
<tr>
<td></td>
<td>1.21 ± 1.15</td>
<td>1.29 ± 2.5-</td>
<td>1.39 ± 1.7-</td>
</tr>
<tr>
<td></td>
<td>2.00 ± 2.4-</td>
<td>2.00 ± 2.4-</td>
<td>2.00 ± 2.4-</td>
</tr>
<tr>
<td></td>
<td>0.09 ± 0.1-</td>
<td>0.09 ± 0.1-</td>
<td>0.09 ± 0.1-</td>
</tr>
<tr>
<td></td>
<td>0.88 ± 1.33</td>
<td>0.88 ± 1.33</td>
<td>0.88 ± 1.33</td>
</tr>
<tr>
<td></td>
<td>1.39 ± 1.7-</td>
<td>1.39 ± 1.7-</td>
<td>1.39 ± 1.7-</td>
</tr>
</tbody>
</table>
to the least affected side. Therefore, obstacle circumvention to the most affected side is risky for people with PD, mainly without the effects of dopaminergic medication. Future studies should investigate the relationship between side preference and side (most) affected by the disease to advance discussions about degeneration of the brain.

Conflict of interests
The authors have no conflict of interest to report.

Acknowledgements
This work was supported by the São Paulo Research Foundation (FAPESP) [grant numbers 2014/20549-0; 2015/15928-4; 2016/09805-0]; the Pró-Reitoria de Pesquisa da UNESP (PROPE) [grant numbers 76/2015; 07/2016].

References


