Neuroscience Letters 686 (2018) 47–52

Contents lists available at ScienceDirect

Neuroscience Letters

journal homepage: www.elsevier.com/locate/neulet

Research article

Parkinson's disease does not alter automatic visual-motor coupling in postural control

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ARTICLE INFO

Keywords:
Sensorimotor coupling
Posture
Vision
Parkinson's disease

ABSTRACT

This study examined the coupling between visual information and body sway in patients with Parkinson's disease (PD) compared with healthy controls. Postural control performance was compared between 14 patients with PD (age: 69.6 ± 8.8 years - stages 1–3 of the Hoehn and Yahr scale) and 14 healthy control participants (age: 68.6 ± 3.0 years). Participants stood upright in a moving room that remained motionless or continuously oscillated in the anterior-posterior direction. Ten trials were performed in the following conditions: no movement of the room (1 trial) and with the room moving at frequencies of 0.1, 0.17, and 0.5 Hz (3 trials each frequency). Body sway and moving room displacement were recorded. The results indicated that patients with PD displayed larger body sway magnitude in the stationary room condition. Body sway of patients with PD was induced by visual manipulation in all three visual stimulus frequencies, but body sway of patients with PD was less coherent compared to that of the control participants. However, no difference was observed in the visual-body sway coupling structure. These results indicate that patients with PD can unconsciously couple body sway to visual information in order to control postural sway in a similar manner to healthy participants with intact visual-motor coupling for posture control. However, this coupling is marked by greater variability, indicating that people with PD have a motor system with greater inherent noise leading to a more varied behavior.

1. Introduction

Parkinson's disease (PD) is characterized by disruption of many types of sensorimotor control, including postural control. Although postural instability might not be an initial symptom of the disease [1], it is associated with an increased risk of falling [2] and a decline in the ability to independently perform daily living activities. Even in the initial stages, patients with PD display larger body sway magnitude [3], reduced limits of stability [4,5], and higher incidence of falls [6], which worsen with disease progression. Poor postural control performance in patients with PD is not surprising, considering the many changes in motor [1,7,8] and sensory [9,10] systems.

The use of sensory cues for postural control may be examined by manipulating cues from a specific source, leaving the remaining cues unaltered, and observing the body sway induced by this manipulation [11]. After the pioneering studies of Lee and Lishman [12], the moving room paradigm has been extensively employed to examine and elucidate the underlying aspects of visual-motor coupling in different populations: young [13,14] and older adults [15], typical infants [16,17], infants [18] and adults with Down Syndrome [19], typical children [20], children with cerebral palsy [21], and children with dyslexia [22]. The moving room strategy has also been used to examine the impact of visual flow manipulation on the postural control of patients with PD [23], leading to the finding that patients with PD were susceptible to visual manipulation, as they displayed body sway corresponding to the discrete movement of the room. Such results are surprising at first glance, considering that patients with PD experience several visual changes such as visual acuity, color, and contrast sensitivity [24] that may lead to changes in control of stance and gait [25].

Bronstein et al. [23] also demonstrated that patients with PD

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https://doi.org/10.1016/j.neulet.2018.08.050
Received 28 March 2018; Received in revised form 25 July 2018; Accepted 31 August 2018
Available online 04 September 2018

exhibited a larger body sway magnitude response when exposed to displacements of the visual environment than other patients, suggesting that patients with PD have an abnormal reliance on visual information for postural control. Following these studies, several reports have suggested that patients with PD are more dependent on visual information, which leads to difficulties in performing certain motor tasks [26–29], most likely to compensate for poor and less informative somatosensory cues [30]. Conversely, visual cues have been used to improve motor performance, particularly gait, as a typical therapeutic approach to minimize the lack of automatic control [31].

Despite these conflicting suggestions regarding the use of visual cues for postural and motor control, overreliance on visual optical flow has been also observed in older adults with no PD. Wade et al. [15] observed that older adults were more influenced by the discrete movement of a moving room than young adults. Similar results were observed when older adults were exposed to discrete [32] and continuous periodic oscillation [33,34] of the moving room. Based on these results, the overreliance due to optical flow manipulation observed in patients with PD [23] might not be due to the disease but due to the natural aging process, which impacts the quality of sensory cues and leads to less accurate information regarding body position [33,34]. In this case, under any visual manipulation, postural control mechanisms would induce an exaggerated response and produce larger body sway in both older adults and in patients with PD of a similar age. Therefore, the aim of this study was to compare postural control performance and the use of visual information in controlling body sway in patients with PD and healthy older adults.

2. Materials and methods

2.1. Participants

Fourteen patients with idiopathic PD (age: 69.6 ± 8.8 years, 4 females and 10 males), who obtained a severity score of 1–3 on the Hoehn and Yahr scale [35] and received dopamine replacement medication, and 14 healthy older people (control group, age: 68.6 ± 3.0 years, 5 females and 9 males) participated in this study. Participants with PD were recruited from the Brazilian Parkinson Association and were tested in their "on levodopa" state. Inclusion criteria involved: (1) idiopathic PD diagnosed by an experienced specialist, following the UK Brain Bank criteria; (2) absence of neurological diseases, except for PD, and detectable sensory and/or motor disturbances in the hands and arms; (3) a minimum score of 24 on the Mini-Mental State Examination; (4) normal or corrected visual acuity; and (5) lack of auditory losses. All these criteria were based upon previous evaluations performed in the Brazilian Parkinson Association. Participants of the control group were recruited using personal contacts. All participants provided informed written consent, according to procedures approved by Institutional Review Ethics Committee.

2.2. Procedures

In a single visit to the laboratory, participants were asked to stand inside a moving room. The room consisted of three walls (2 m length, 2 m width, 2 m height) and a ceiling mounted on wheels, allowing for movement in the anterior-posterior (AP) direction while the floor remained motionless. The walls were covered with a pattern of white (33 cm wide) and black (22 cm wide) stripes. The movement of the room was produced by a servomotor mechanism consisting of a linear guide (Ottime, model PL6-90C-LD-MT-RC), stepper motor (Ottime, model SM3452808), and motor drive (Ottime, model MBD-8080DC) controlled by Motion Planner software. Two fluorescent lights (20 W) were placed on the room ceiling to maintain constant illumination.

Participants were asked to stand upright as stable as possible, with their feet placed comfortably at hip width apart, and to look at a target attached to the front wall of the room. An experimenter remained aside and close to the participant to assure that the task requirements were accomplished and in case participants would need any assistance. Participants of both groups performed a total of ten trials of 60 s each. In the first trial, the room remained motionless. The other nine trials were grouped in three blocks of three trials, in which the room oscillated at frequencies of 0.1, 0.17, and 0.5 Hz (one trial at each frequency, in randomized order). The peak-to-peak velocity of 0.6 cm/s was maintained for all three frequencies as amplitude was varied. These frequencies were selected based on the postural sway characteristics during upright stance, aiming to drive the postural control system close to the natural frequency (0.17 Hz) and to frequencies below (0.1 Hz) and above (0.5 Hz) the natural frequency.

All participants were unaware of the movement of the room. In addition, a random sound (white noise) was provided to mask possible auditory cues that emanated from the room. At the end of experimental procedures, participants were asked if they had noted any unusual condition and none of them reported anything related to the movement of the room and, therefore, it was assumed that body sway induced by the visual manipulation occurred unconsciously by the participants.

One infrared emitting diode (IRED) was placed centrally on the participant's back at the scapula level (~8th thoracic vertebra), and another IRED was placed on the front wall of the room to record body and room position, respectively. One OPTOTRAK™ camera block (Northern Digital Inc., Waterloo, Canada) was positioned behind the participants to track the IREDs at a sampling rate of 100 Hz.

2.3. Data analysis

In the stationary room condition, the mean sway amplitude for both AP and medial-lateral (ML) directions was obtained. The mean sway amplitude was calculated by subtracting a first-order polynomial and the average of the time series from each data point and obtaining the standard deviation of the time series, indicating sway variability.

Because the room oscillated in the AP direction, mean sway amplitude in the room oscillation conditions was obtained only for the AP direction. Similarly, the relationship between room movement and postural sway was also obtained only for the AP direction, using coherence, gain, and phase. *Coherence* indicated the strength of the relationship between room movement and body sway, at the respective frequency of the driving signal in each condition (0.1, 0.17, and 0.5 Hz). Coherence values close to one/zero indicated strong/weak dependency between these two signals, respectively. *Gain and phase* indicated the magnitude and the temporal influence of room movement on body oscillation. Altogether, these two variables indicated the coupling structure between body sway and visual information. These variables were calculated by obtaining a transfer function (frequency response function), which was computed by dividing the Fourier transforms of body sway by the Fourier transforms of the respective driving signal (moving room). *Gain* corresponded to the absolute value of the frequency response function, indicating 1 when body sway matched the moving room amplitude, and lower/higher values indicated that the response amplitude was lower/higher than the stimulus driving amplitude. *Phase* corresponded to the argument of the frequency response function, thereby indicating the temporal relationship between body sway and the moving room position. Phase values of zero indicated that body sway was occurring in-phase with the room movement, and positive/negative phase values indicated that body sway led/lagged behind the room movement, respectively.

All of the above-described procedures were performed using specific custom software written in Matlab (Math Works, Inc.).

2.4. Statistical analysis

A multivariate analysis of variance (MANOVA) was performed using group as a factor and the mean sway amplitude, for both AP and ML directions in the no visual manipulation condition, as dependent