Effects of dual task demanding manual dexterity and sit-to-stand in Parkinson disease individuals

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HIGHLIGHTS
• Parkinson’s disease causes loss of automaticity and impairment in dual task (DT) performance.
• Individuals with PD could have a pattern of prioritization of tasks according to their level of complexity.
• Postural control, upper extremity, and verbal fluency showed worse performance in the dual task condition.

ABBREVIATIONS
DT Dual task
DTC Dual task cost
DTI Dual-task interference
GDS Geriatric Depression Scale
H&Y Hoehn and Yard scale
MMSE Mini Mental Status Examination
PD Parkinson’s disease
PMC Premotor cortex

BACKGROUND: Parkinson’s disease (PD) causes loss of automaticity and impairments in dual task (DT) performance. AIM: To investigate the performance and pattern of prioritization of individuals with PD in motor and cognitive DT. METHOD: An observational, transversal, comparative study assessed 20 individuals with PD between stages 1.5 to 3 of the modified Hoehn and Yard scale. Performance was assessed during the execution of manual dexterity and sit-to-stand tasks, in a single task or in association with a verbal fluency task. RESULTS: There was a loss of performance in both dual task conditions. The cost of verbal fluency was higher than the cost of manual dexterity function. CONCLUSION: Individuals with PD showed worse DT performance and prioritized the manual dexterity task. There was no prioritization between sit-to-stand and verbal fluency. These findings suggest that the nature of tasks can influence the prioritization of dual tasks.

KEYWORDS: Parkinson’s disease | Attention | Upper extremity | Postural control

INTRODUCTION

Parkinson’s disease (PD) is caused by the degeneration of dopaminergic neurons of substantia nigra and cholinergic neurons of the pedunculopontine nucleus, among other areas of the brain.1 The cardinal symptoms of the disease include resting tremor, bradykinesia, rigidity, and postural instability.2 Due to lesions on the basal ganglia, individuals with PD have less automatic postural control, gait disturbances, and poorer execution of manual tasks.3 A lack of automaticity results in delayed muscle contraction,4,5 deficits in dynamic postural control6–8, for example, turning6 and obstacle avoidance7, as well as at upper extremity coordination tasks9 such as writing10.

Individuals with PD often require a heightened attentional focus to compensate for reduced automation to successfully perform common balance tasks.11 Thus, individuals use
cortical mechanisms to control posture and manual tasks that require the use of attentional resources and result in the division of attention between competing task demands.\textsuperscript{12}

The division of attention that occurs during simultaneous task performance has been studied using a dual task (DT) paradigm.\textsuperscript{13} In the DT paradigm two or more tasks are performed at the same time typically identifying the main task as the “primary task” with an associated “secondary task”.\textsuperscript{13} Individuals with PD have demonstrated worse performance in DT conditions as compared to a single-task condition. Possible mechanisms contributing to this decrement in task performance are: (1) loss of automaticity; (2) decreased attention resources and (3) the reduced ability to share attention among two or more tasks.\textsuperscript{11,12,14}

Previous studies have shown that individuals with PD experience extensive problems during DT (e.g., decrease in walking speed\textsuperscript{16} and higher gait variability\textsuperscript{13,15} But most studies that have investigated dual-task interference (DTI) in individuals with PD have focused on gait\textsuperscript{13,17,18} and postural control\textsuperscript{16–20}, while only a small number of studies have investigated the effects of DTI on upper limb tasks. Yet interestingly, studies of the upper limbs have shown impairments of hand dexterity in dual task conditions for individuals with PD.\textsuperscript{21,22} DTI accounted for 44\% of the variance in dexterity-related activities of daily living performance of the dominant hand.\textsuperscript{22} Individuals with PD also demonstrate to reduce performance in a simultaneously performed goal-directed upper-limb motor task when paired with a cognitive task compared to performance in age-matched controlled subjects.\textsuperscript{23} Additionally, there are writing deficits in the dual task writing condition compared to age-matched controls, more specifically during small-amplitude movements.\textsuperscript{24}

Based on the different attention mechanisms between postural control tasks and upper extremity functional tasks, we speculate that the task which requires the most attentional demand, may be more impacted by dual task performance, and worsen the performance of the primary task. Thus, this study aimed to compare the effect of DT during the performance of postural control task (i.e., 30-s chair stand) and an upper-extremity functional task (i.e., Box and Blocks test) of individuals with PD. We assessed prioritization patterns during the dual tasks involving sit-to-stand and manual dexterity performed in concert with a cognitive task.

METHODS

Subjects

This cross-sectional study was approved by the Ethical Committee of the University (CEP/ICS/UNIP: 641.783). Subjects were invited to participate in the study and were asked to sign the Consent Term in which the objectives and procedures of the study were explained in detail.

Twenty individuals with PD of both sexes were enrolled in this study. The inclusion criteria were: (1) diagnosis of idiopathic PD; (2) individuals between stages 1.0 to 3 of the modified Hoehn and Yard scale (H&Y)\textsuperscript{25}; (3) on levodopa replacement therapy and (4) no signs of dementia as evaluated by the Mini-Mental Status Examination (MMSE).\textsuperscript{26} We adopted cutoff scores of MMSE based on educational level (>20 for illiterates; > 25 for patients with from 1 to 4 years of education; > 26 for patients with 5 to 8; > 28 for patients with 9 to 11 years; > 29 for individuals with more than 11 years of education).\textsuperscript{27}
Individuals with other neurological, orthopedic, cardiac, or pulmonary diseases or who were unable to perform the required tasks were excluded from the study.

Procedures

For sample characterization, we performed the Geriatric Depression Scale (GDS) and recorded the age, sex, H&Y, and MMSE of each participant.

Single task assessment

We assessed the performance in single and dual task conditions. Single- and dual-task accomplishments were assessed during the “on” PD medication period, about 40 minutes to two hours after Levodopa was administered. Primary tasks included the postural control task (the 30-s sit-to-stand) and manual dexterity task (Box and Blocks Test), respectively. A secondary, cognitive task (reciting the weekdays backward) was assessed in setting as a baseline condition and associated with each of the primary tasks to form a dual task condition. Each task was performed and recorded for 30 seconds.

Manual dexterity was assessed using the Box and Block test. Individuals seated comfortably on a chair in front of a table where there was a wood box with two compartments of equal dimensions. Inside the box, there were 150 woodblocks. The manual dexterity task consisted of transferring the greater number of blocks from one side of the box to the other side, being one block each time, as fast as possible, and using the dominant hand for 30 seconds. The number of blocks transferred from one to the other side was recorded.

Postural control was assessed using the 30-s sit-to-stand. Each participant began the task seated on a chair without arms and was asked to stand up and sit back down many times as possible and as fast as possible during 30-second intervals. The 30-s sit-to-stand was performed on a chair with a seat height of approximately 44 cm, according to the description in Duncan et al. The subject sat on the center of the chair, with the back straight, the feet parallel and separated by a distance equivalent to the shoulder width, and arms folded across the chest. The number of times the participant stood up from the chair was recorded. The 30-s sit-to-stand test was selected as a measure of postural control because it is a dynamic test which the performance of individuals with PD is related to PD motor impairments. Such as balance disorders and bradykinesia, and postural control to change from one posture to another requires a complex control of the center of mass. It is an easy-to-use and reliable test to assess the risk of falling of this population.

Dual task assessment

We paired each primary task with a simultaneous performance of the cognitive task to form a dual task condition. Verbal instructions were given to the participant to perform the two tasks as best as possible with no prioritization. We recorded the number of blocks transferred from one to the other side, the number of times the individuals stood up from the chair and the number of weekdays recited correctly. We randomized the order of task performance, including single task (30-s chair stand and manual dexterity) as well as single x dual task.
Dual task cost

The dual task cost (DTC) is a measure of the impact of performing a secondary task on the performance of a reference task.13 The DTC allows a more direct comparison of dual-task deficits across studies and provides a way to assess the relative effects of individual, tasks, and environmental factors.13

The DTC was calculated by the difference between performance on the dual task condition and performance on each single task condition, as described by McDowd33: $$DTC\,(\%) = \frac{(\text{dual task} - \text{single task})}{\text{single task}} \times 100\%.$$ 

Statistical analysis

SPSS was used to perform statistical analysis.

The homogeneity of variance was performed using the Kolmogorov-Smirnov and Levene test, respectively, and these tests showed that our data presented normality conditions. We applied a Student paired t-test to compare the performance in single and dual task conditions (i.e., manual dexterity in single task versus manual dexterity in the dual task; sit-to-stand in single task versus sit-to-stand in the dual task).

The performance of the secondary tasks in the three conditions (single task versus manual dexterity in the dual task versus sit-to-stand in the dual task) was assessed using a one-way ANOVA. To detect differences among the conditions, we conducted a Tukey post hoc test.

We also ran a one-way ANOVA followed by a Tukey post hoc test to compare the DTC between the different conditions. An alpha level of 0.05 was selected as statistical significance.

RESULTS

The sample consisted of twenty individuals with idiopathic PD, characteristics of the sample are highlighted in Table 1. All participants were being treated with levodopa and/or its synergists.

Table 1 – Characteristics of participants.

<table>
<thead>
<tr>
<th>Sex</th>
<th>HY (Years)</th>
<th>Age (Years)</th>
<th>Disease (Years)</th>
<th>MMSE (Score)</th>
<th>GDS-15 (Score)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean (SD)</td>
<td>13 men</td>
<td>7 women</td>
<td>25%: 1.0</td>
<td>60.1 (10.4)</td>
<td>27.0 (2.8)</td>
</tr>
<tr>
<td></td>
<td>25%: 1.5</td>
<td></td>
<td>25%: 2.0</td>
<td>7.9 (4.0)</td>
<td>3.5 (3.1)</td>
</tr>
<tr>
<td></td>
<td>20%: 2.5</td>
<td></td>
<td>5%: 3.0</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Legend: SD, Standard Deviation; HY: Hoehn and Yard modified scale; MMSE, Mini Mental Status Examination; GDS-15, Geriatric Depression Scale – 15.</td>
<td></td>
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</tbody>
</table>

All participants completed the tests. The number of times that the participants were able to sit and stand and the number of blocks that were transferred from one box to another on the single task was higher than in the dual task ($p=0.002$ and $p<0.001$, respectively). (Table 2).
Performance of verbal fluency in the single task was higher than in the dual task conditions (ANOVA, Tukey post hoc test, p<0.001) (Table 3).

The cost of verbal fluency was higher than the cost of manual dexterity (ANOVA, Tukey post hoc test: * p=0.019) (Table 4). There was no difference between the costs of manual dexterity and postural control tasks.

**DISCUSSION**

The main results of the present study were: (1) sit-to-stand, manual dexterity, and verbal fluency reduced performance in DT, and (2) the cost of verbal fluency associated with manual dexterity was higher than the costs of the other tasks. Together, these results showed that individuals with PD prioritized tasks according to the level of complexity. Hierarchically, postural control (represented by the 30-sit-to-stand task) is less dependent on superior cortical function. This is followed by manual dexterity, and then language, respectively.34 The higher the level of attention required by the task, the higher the DT cost is per condition.35–38

In the present study, individuals with PD demonstrated worse performance of upper extremity and postural control when each of these tasks was performed together with a verbal fluency task. The poorer performance associated with DT condition performance in DT may
be related to the division of attention between the tasks or with the reduced attentional resources.\textsuperscript{3}

Individuals with neurological disorders may be susceptible to DTI, as higher attentional demand is required to perform the primary task. Due to the raised attentional demand, there are fewer attentional resources available for the simultaneous performance of tasks.\textsuperscript{39} Specifically in individuals with PD, the damage to the lesion on the basal ganglia can cause loss of automaticity. Studies show that movements that were automatic before the disease become more dependent upon cortical areas, and tasks that were once automatic now require attentional resources for successful performance. Lesions of the basal ganglia can result in hyper-connectivity between the inferior parietal lobe and premotor cortex (PMC) and between the cerebellum and the PMC and primary motor.\textsuperscript{8} This hyper-connectivity can overload the system, causing an increase in DTC.\textsuperscript{8,19,40,41}

Wu & Hallé\textsuperscript{42} also demonstrated that individuals with PD had greater activity in the cerebellum, premotor area, parietal cortex, precuneus, and prefrontal cortex compared to non-PD subjects while performing automatic movements in DT condition. However, the increased activation of cortical areas during steps tasks in the DT condition was not found by Pelicioni et al.\textsuperscript{43} The authors found that the PD group demonstrated reduced cortical activity in the dorsolateral prefrontal cortex, supplementary motor area, and PMC during more complex stepping tasks that required inhibitory control.\textsuperscript{43}

Investigation of secondary task performance is extremely important in the DT paradigm because the performance of the primary task can be maintained or at least, less affected to the detriment of the secondary task.\textsuperscript{44} In the present study, our results showed that there was worsening performance in both the primary and secondary task suggesting that the secondary task was also affected.

In order to compare the effect of dual tasks on the primary and secondary tasks we analyzed the cost of the dual task over the primary and secondary tasks. The cost of the dual task analysis allowed an investigation of task prioritizations. In other words, we intend to understand how individuals with PD share attention between the different tasks. Verbal fluency in association with upper extremity function demonstrated the greatest DTC. In this condition, verbal fluency had a cost of approximately 50%. The decreased attentional reserves may be insufficient to be shared between the two tasks (i.e., language and upper extremity function). Thus, both tasks can compete for cortical resources.\textsuperscript{3,9,12,45} Previous studies showed that lesions on dopaminergic neurons can cause deficiencies in the capacity to share attention among tasks.\textsuperscript{9,11,46}

Consistent with the results of this study, other studies showed a loss of upper extremity performance in dual task conditions with prioritization of the motor task.\textsuperscript{9,12} Nocera et al\textsuperscript{47} showed that individuals with PD had a worse performance of the cognitive task, thus suggesting prioritization of the motor task. Pradhan et al\textsuperscript{48} assessed the performance of individuals with PD in a dual task condition that incorporated a finger opposition as the primary task of this study paired with a secondary subtraction task. In the dual task condition, individuals showed worsening of performance during both tasks, but with a greater decrease of performance of the secondary task. Proud and Morris\textsuperscript{21} replicated these results using a manual accuracy task and an associated subtraction task. Results also showed that performance was worse in the dual task condition, but with prioritization of the manual task.
According to our findings, these results show that individuals with PD prioritized upper extremity function over verbal fluency task in a DT condition. Task prioritization suggests that when there is competition for attentional resources, the person must decide how to prioritize the two tasks. This self-selected strategy of task prioritization is determined by the need to reduce the danger and maximize the pleasure.\textsuperscript{39,49}

On the other hand, there was no difference between the cost of postural control and the cost of verbal fluency in the dual task condition when combining these two tasks. Dual task affects the costs of postural control and verbal fluency similarly in terms of prioritization pattern between these tasks. Kelly et al\textsuperscript{46} suggested that the severity of the disease should be a factor to consider. In the more severe stages of PD, there is a clear task prioritization pattern. In fact, this clear issue could explain our findings since most of our sample is composed of individuals with PD who showed mild motor impairments. Also, Freitas et al\textsuperscript{50} did not find prioritization between the task of sitting and standing (postural control task) and the secondary task in a dual task condition.

The lack of prioritization between postural control and verbal fluency also can be explained by the nature of the two tasks. Postural control depends mainly on the brain stem, the spinal cord, and the cerebellum, integrating information of vestibular, visual, and somatosensory systems.\textsuperscript{51} Verbal fluency is a cognitive task that is controlled by cortical areas associated with language and executive functions, the association of the cortex of the left frontal, the parietal and the temporal regions.\textsuperscript{34} Therefore, postural control and verbal fluency do not compete for the same resources of attention and cortical circuits. A review by Stuart et al\textsuperscript{52} demonstrated that the cortical activity appears to increase from baseline in postural control task in PD, and it may represent cortical compensation for subcortical dysfunction with the pathology of the PD. However, despite the absence of prioritization, both tasks showed a decreased performance in a dual task condition. Marchese et al\textsuperscript{53} stated that postural control in PD can be affected because individuals have to use more attention to compensate for the deficiencies of balance due to lesions on the basal ganglia. Therefore, we speculate that the worsening of the postural control in a dual task condition can occur due to the reduction of attention caused by the associated cognitive task.

One limitation of our study is the lack of a control group with neurologically healthy older participants and the small sample size. Thus, we were unable to determine whether or not these results are exclusively caused by the disease, or whether age could have an impact on the prioritization pattern during dual task conditions.

Individuals with PD have difficulty with DTs, which limits participation in the community. In this study, we explored the impact of carrying out DT in tasks with different demands. The relevant results here can be used to guide clinicians to develop strategies to navigate task prioritization and improve function in this population.

**CONCLUSION**

The assessment of individuals with PD in conditions associating postural control and upper-extremity function with a cognitive task of verbal fluency showed that all tasks were negatively impacted by the dual task performance. The tasks of postural control, manual dexterity, and verbal fluency performed worse in the dual task condition as compared...
to each task in a single task condition. However, the cost of verbal fluency was higher than the cost of the associated DT verbal fluency with the upper extremity function condition. There was no evidence of prioritization in the dual task condition in the postural control task.

REFERENCES


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