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THE NATURE OF DUAL-TASK INTERFERENCE DURING GAIT IN INCIDENT PARKINSON'S DISEASE

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Abstract—Dual-task interference during gait is a common phenomenon in older adults and people with Parkinson's disease (PD). Dual-task performance is driven by cognitive processes involving executive function, attention and working memory which underpin resource capacity and allocation. The underlying processes that contribute to dual-task interference are poorly understood, and confounded by methodological differences. The aim of this study was to explore the nature of dual-task interference in PD with respect to age-matched controls. We examined 121 people with early PD and 189 controls and controlled for baseline task demand on both tasks allowing between-group differences to be attributed to dual-task interference rather than differences in baseline performance. We also compared a wide range of gait characteristics to evaluate the pattern of interference. Participants walked for two minutes at a preferred pace under single- and dual-task (test of working memory capacity – digit span recall) conditions. In a sub-group task demand was increased (digit span + 1) ($n = 55$ control, $n = 44$ PD) to assess the influence of resource capacity. Finally the association between dual-task interference with motor and cognitive characteristics was examined to evaluate resource capacity and allocation. PD and controls responded similarly to the dual-task for all gait characteristics except for step width and step width variability and this was the same when task demand increased (dual + 1). Control participants took wider steps ($p = 0.006$) and step width variability increased significantly for controls ($p = 0.001$) but not PD. Interference was specific to the gait characteristic rather than a global pattern of impairment. Digit span error rates were not significantly different between groups during dual-task performance. There were no significant correlations with dual-task interference and global cognition, motor deficit, and executive function for either group. Effects of dual-tasks on gait performance are twofold and specific to the gait characteristic. They reflect an age-related reduction in gait performance (especially forward progression) in PD and controls possibly due to reduced resource capacity; and secondly, show postural stability during walking in early PD is disproportionately affected highlighting a PD-specific dual-task co-ordination deficit. Further work is required to identify the cognitive, executive and motor correlates of dual-task interference from which inferences about underlying cognitive processes can be made. These findings inform an understanding of dual-task impairment in early PD and suggest that management should target postural control under dual-task conditions from the early stages.

Key words: Parkinsons, gait, dual-task, postural control, attention, step width variability.

INTRODUCTION

The ability to carry out two tasks at once is critical to effective functioning in the real-world and deficits (termed dual-task interference) have been linked to loss of independence and increased risk of falls (Beauchet et al., 2009; Beurskens and Bock, 2012), although the latter is controversial (Zijlstra et al., 2008; Beauchet et al., 2009; Smulders et al., 2012). People with Parkinson's disease (PD) describe difficulties with dual-task performance when walking (Jones et al., 2008) and studies typically highlight a slower, more variable gait when distracted by a dual-task (Hausdorff et al., 2003; Rochester et al., 2004; Yogev et al., 2005; Lord et al., 2011; Kelly et al., 2012). Some evidence suggests that people with PD are more affected by dual-tasks than healthy older adults although this is by no means a robust finding (Kelly et al., 2012). At present the extent of dual-task interference in PD over and above age-associated changes is unclear.

Dual-task gait interference in PD becomes evident when attentional control cannot fully compensate for motor impairment due to basal ganglia pathology. Dual-task gait performance is supported by cognitive processes such as executive function and attention (Yogev-Seligmann et al., 2008) and theoretical models such as the working memory system offer a framework to understand the processes underlying dual-task interference. The working memory system underpins the ability to hold and manipulate information over brief time periods and is limited by its capacity to process information (*resource capacity*) and co-ordinate multiple sources of information (*resource allocation*) (Baddeley,

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Abbreviations: ANCOVA, analysis of covariance; GDS, Geriatric Depression Scale; MMSE, Mini Mental State Exam; OTS, One Touch Stockings; PD, Parkinson's disease; PFC, prefrontal cortex; PIGD, Postural Instability and Gait Disorder; PoA, Power of Attention; SD, standard deviation; UPDRS, Unified Parkinson's Disease Rating Scale.

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1992). The working memory system draws on executive functions to co-ordinate allocation of attention between concurrent tasks and these are features associated with the function of the pre frontal cortex (McCabe et al., 2010). Both attention and executive function deficits are features of basal ganglia pathology even in early PD (Williams-Gray et al., 2009), and both are associated with dual-task interference (Amboni et al., 2013). Greater attention to walking and/or cognitive impairments (particularly executive function and attention) in PD may therefore result in disproportionately greater interference as a result of reduced resource capacity (working memory capacity), resource allocation (dual-task co-ordination deficit within working memory) or, as some authors have suggested, an inability to prioritize tasks appropriately. However at present the nature of dual-task interference in PD is unclear.

Certain features of gait have also been reported to be more vulnerable to dual-task interference in PD. For example swing time and swing time variability and bilateral co-ordination of lower limb movements are especially sensitive (Yogev et al., 2005; Plotnik et al., 2009). Whether different gait characteristics are selectively vulnerable to dual-task interference however is not clear due to inconsistent reporting and a broader understanding may help explain the association of dual-task impairment with fall risk. The question therefore remains as to the extent of dual-task interference in PD with respect to individual gait characteristics.

Methodological issues often confound interpretation, for example: controlling for baseline task demand such that dual-task performance cannot be attributed to differences in single-task performance between groups; reporting performance on both tasks to assess combined dual-task deficit to account for trade-off (task prioritization) in performance between tasks; and different methods of calculating dual-task deficits (Dalrymple-Alford et al., 1994; Cocchini et al., 2004; Logie et al., 2004; Foley et al., 2013; Fuller et al., 2013). Studies of dual-task interference in PD do not consistently address these methodological criticisms which most likely explain the inconsistent findings. Further they are typically carried out in more advanced cohorts and a better understanding of the early features of dual-task interference is important to fully understand fall risk and develop appropriate and timely therapeutic intervention.

We aimed to characterize dual-task performance during gait in people with early PD with respect to age-matched controls to: quantify the extent of dual-task interference; shed light on the nature of the underlying dual-task deficit; and compare the vulnerability of different features of gait to dual-task interference. From our work and others we used a protocol adapted for gait which was informed by a theoretical model of working memory (Baddeley, 1992; Cocchini et al., 2004; Hamilton et al., 2009) which allowed us to more fully explore the cognitive processes (resource capacity and allocation) underpinning interference. The protocol also directly addressed previous methodological concerns. Our primary hypothesis was that dual-task interference would be disproportionately greater in PD compared to age-matched controls as a consequence of resource capacity, resource allocation or task prioritization deficits. We also hypothesized that dual-task interference would be greater in gait characteristics that are more directly influenced by cognition (e.g. mean walking speed, step length and step time).

EXPERIMENTAL PROCEDURES

Participants

People with PD were recruited within 4 months of diagnosis of idiopathic PD as part of an incident cohort study of people with PD (Khoo et al., 2013). Participants were excluded if they had any neurological (other than PD), orthopedic or cardiothoracic conditions that may have markedly affected their walking or safety during the testing sessions. In addition, PD participants had to be diagnosed with idiopathic PD according to the UK Parkinson's Disease Brain Bank criteria by a movement disorders specialist (Gibb and Lees, 1988), and were excluded if they presented with significant memory impairment (Mini Mental State Exam (MMSE) $\leqslant$ 24) (Folstein et al., 1975), dementia with Lewy bodies, drug-induced parkinsonism, 'vascular' parkinsonism, progressive supranuclear palsy, multiple system atrophy, cortico-basal degeneration or poor command of English. Control participants were recruited from research-active general practices via a regional primary care research network, from local hospital trusts via advertising, and via the Public Engagement Team based at Newcastle University. Inclusion criteria were: (1) greater than 60 years of age; (2) able to walk independently without a walking aid; and (3) no significant cognitive impairment, mood or movement disorder. This study was conducted according to the declaration of Helsinki and had ethical approval from the Newcastle and North Tyneside research ethics committee. All participants signed an informed consent form prior to testing.

Demographic and clinical measures

Age, sex and body mass index (BMI) were recorded for each participant. The severity of PD motor symptoms in the PD participants was measured using the Hoehn and Yahr scale (Hoehn and Yahr, 1967) and section III of the modified Movement Disorder Society version of the Unified Parkinson's Disease Rating Scale (UPDRS III) (Goetz et al., 2007). The Postural Instability and Gait Disorder (PIGD) and Tremor subscales (nine and five items respectively from the new-UPDRS III scale) were also calculated from the New UPDRS (Goetz et al., 2007) to examine the impact of motor capacity on dual-task interference. The scales were used as continuous variables for correlational analysis. Balance self-efficacy was measured using the Activities Balance Self Confidence Scale (Powell and Myers, 1995). Depression was measured with the Geriatric Depression Scale (GDS) (Schrag et al., 2007). Levodopa equivalent dose (LEDD) scores were calculated according to established