THE INFLUENCE OF COGNITIVE LOADING ON UNPLANNED TURNING AMONG PEOPLE WITH PARKINSON'S DISEASE

by

Caitlin Ann Bryson
A Dissertation
Submitted to the
Graduate Faculty
of
George Mason University
in Partial Fulfillment of
The Requirements for the Degree
of
Doctor of Philosophy
Rehabilitation Science

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DEDICATION

This is dedicated to my parents, for being the best parents and encouragers from day one. Thank you for believing in me and teaching me to reach for the stars. All that I am is because of you.

This is dedicated to Forbes, for being my rock and support through all of life's adventures. Thank you for your patience, love, endless laughs, and encouragement. This dissertation would not be possible without you.

This is dedicated to my sisters, and to Maria, for your never-failing encouragement and love. You have the incredible ability to make every situation beautiful. I am so lucky to have grown up with you by my side.

ACKNOWLEDGEMENTS

To my committee members, Dr. Clint Wutzke, Dr. Andrew Guccione, and Dr. Jaimie Roper. Dr. Wutzke, an endless thank you for all of the time and effort that you have put towards my growth and success. Your belief in me means more than words. Dr. Guccione, my deepest gratitude for guiding me through the transition from clinician to scientist. Thank you for encouraging me to be part of this adventure and supporting me through each step. Dr. Roper, thank you for reviewing this dissertation, your advice and support. I am forever grateful for each of your contributions towards my successes.

To my assistants, Anna and Katie, who played a critical role in the collection of this data. Thank you for being there for me and for the participants during every step of this process.

To my George Mason colleagues, we have shared countless moments of both anxieties and celebrations. Thank you for the endless discussions, treats, and support which have helped to enhance my work and career.

To my colleagues from the clinic, thank you for encouraging me to pursue this dream. Without your support I would not be here.

To the participants of this study and former studies, without your willingness and desire to promote the advancement of research in the rehabilitation science field, this work would not be done. It is because of you that I have been able to learn and grow into the scientist and physical therapist I am today and the one I am becoming. Thank you for helping to advance our field and change the lives of current and future patients.

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LIST OF ABBREVIATIONS

Parkinson's disease ..... PD
Freezing of gait ..... FoG
Freezing of gait questionnaire ..... FoGQ
Trail Making Test ..... TMT
Trail Making Test – Part B ..... TMT-B
Montreal Cognitive Assessment ..... MOCA
Hoehn and Yahr scale ..... H&Y

ABSTRACT

THE INFLUENCE OF COGNITIVE LOADING ON UNPLANNED TURNING AMONG PEOPLE WITH PARKINSON'S DISEASE

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George Mason University, 2020

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Purpose: People with Parkinson's disease (PD) demonstrate impairments within both the motor and cognitive domains. Within the motor domain, people with PD present with poor motor control strategies during unplanned turns. Turning, which requires a greater need for attentional resources than forward walking, makes up almost half of all steps taken during the day. Many of these turns are unplanned due to the need to avoid obstacles within an active environment. Unplanned turning, which results in decreased turn distance and increased turn duration among people with PD, can be made even more complex when attention must be shared between two tasks, such as when a person is walking and talking. The effects of cognitive loading on unplanned turning, however, has not yet been investigated. Additionally, within the cognitive domain, people with PD demonstrate poor cognitive flexibility, an important aspect of executive function which allows individuals to flexibly switch between tasks. Recent evidence suggests that cognitive flexibility is important to succeed in challenging walking conditions. However, cognitive flexibility has not yet been studied in relation to unplanned turning. The importance of studying motor control strategies and their relationship to cognitive flexibility among people with PD during complex environmental conditions is crucial for the rehabilitation field in order to further characterize the implications that complex environments have on people with PD. Thus, the purpose of this study was to determine the influence of cognitive demands on unplanned turning among people with PD. Two hypotheses were used: (1) Individuals with Parkinson's disease will demonstrate decreased turn distance or increased turn time during unplanned turning with cognitive loading in comparison to unloaded walking trials; and (2) cognitive flexibility would be positively associated with turn distance and negatively associated with turn duration during dual-task trials. **Methods**: Twenty individuals with PD consented and completed the examination (age: 70.15±6.81; gender: 15M/5F). Participants completed a total of sixty trials of walking consisting of a randomized combination of both unplanned turns and forward walking. The sixty trials were broken into two blocks of thirty trials. Within each block, sixteen walking trials consisted of unplanned turns while the remaining fourteen consisted of forward walks. Participants were not informed of the order of unplanned trials. The second block additionally consisted of cognitive loading in which individuals performed a secondary task (serial subtraction by 3's). Participants also completed the trail-making test (TMT). Within the TMT, TMT: part B (TMT-B) was used to assess cognitive flexibility. **Results**: Participants demonstrated decreased turn distance and increased turn time during dual-task trials compared to single-task ($p=0.0016$, $p=0.0292$, respectively). There was no association found between dual-task

distance nor duration with TMT-B results among the majority of individuals. 3 individuals performed excessively slower on the test, suggesting poorer cognitive flexibility. This subgroup of individuals presented with a strong, nonsignificant, negative correlation between TMT-B and dual-task duration (r=-0.9752; p=0.1421), while a strong negative correlation was found to be significantly related to dual-task distance (r=-0.9993; p=0.0233). **Conclusion:** People with PD demonstrated different motor control strategies when completing unplanned turns while cognitively loaded. Differences in strategies may be employed to compensate for motor control and attentional impairments. Additionally, cognitive flexibility may only be associated with turn distance and turn duration among individuals with poorer flexibility. Further research is necessary to identify strategies and associations during complex walking conditions.

THE INFLUENCE OF COGNITIVE LOADING ON UNPLANNED TURNING AMONG PEOPLE WITH PARKINSON'S DISEASE

Introduction

Parkinson's disease (PD) is a neurodegenerative disease that affects more than 10 million people worldwide with an estimated 60,000 new cases per year in the United States alone (Parkinson's Foundation, 2017). The loss of dopamine producing neurons in the substantia nigra commonly results in both motor and cognitive impairments (Laurie Lundy-Ekman, 2007). Primary motor symptoms of PD include bradykinesia, postural instability, and rigidity (Laurie Lundy-Ekman, 2007). Additionally, 56% of individuals with PD report symptoms of difficulty turning or changing directions (E. L. Stack et al., 2006).

Unplanned turning has been investigated in this population to simulate navigation in the natural environment. Recent findings suggest that people with PD present with increased turn duration, decreased turn distance, as well as poorer mediolateral stability when performing an unplanned turn (Conradsson D et al., 2018; Conradsson et al., 2017; Knobl et al., 2012). A decrease in turn distance may be suggestive of smaller steps due to a decrease in dynamic stability. Although these findings provide insight regarding our understanding of an individual with PD's ability to navigate challenging environments, the addition of cognitive overload is more representative of ambulating in the community.

It is well documented that people with PD demonstrate impairments when performing more than one task simultaneously. However, it is not understood how cognitive loading affects unplanned turning performance. Additionally, the association between cognitive flexibility (the ability to efficiently switch between tasks) (Armbruster et al., 2012; Scott, W. A., 1962) and unplanned, cognitively loaded turning remains unknown. Interestingly, cognitive flexibility has been associated with dual-tasking during walking while simultaneously avoiding obstacles among young, healthy adults (Chopra et al., 2018). Interestingly, while people with PD present with poorer cognitive flexibility than healthy older adults (Olchik, M.R. et al., 2017), they also utilize cognitive flexibility more during walking transitions, such as turns, compared with their healthy counterparts (Van Uem et al., 2016).

To maintain mobility within the community, individuals with PD must be able to safely and effectively negotiate unplanned changes in their environment while simultaneously performing cognitive tasks. Investigation of the relationship between motor organization and motor-cognitive tasks within a complex environment serves to improve our understanding of the consequences of a dual-task on movement in people with Parkinson's disease. Therefore, the purpose of this study was to determine the influence of cognitive demands on unplanned turning among people with PD. It was hypothesized that individuals with PD would demonstrate (a) decreased turn distance or (b) increased turn duration during unplanned turning while cognitively loaded. It was also hypothesized that cognitive flexibility would be positively associated with turn distance and negatively associated with turn duration during dual-task trials.

Methods

Subjects

This study was approved by the George Mason University Institutional Review Board (#1363684). Twenty participants completed this study after being recruited from a database of individuals as well as local Parkinson's community groups in the metro Washington, DC area. Prior to data collection, participants provided verbal and written consent.

Inclusion criteria for this study included a diagnosis of PD in individuals at least 60 years of age as well as being capable of ambulating at least 10 meters with or without the use of a cane. To be included in this study, individuals also had to be between 1 to 4 on the Hoehn and Yahr (H&Y) scale (Hoehn & Yahr, Melvin D, 1967) and with a Mini-Mental State score of at least 24 (Lezak MD, Howison DB, & Loring DW, 2004). Participants were excluded if they had a diagnosis of a neurological disease or disorder other than PD, an uncontrolled cardiovascular condition, or a recent surgery or medical condition that could influence walking performance. Additional exclusion criteria included inability to read or understand English, legal blindness, the use of an assistive device which provided greater support than a cane, and/or being rated greater than 4 on the Hoehn and Yahr scale to exclude those who are confined to a bed or are primarily wheelchair users (Hoehn & Yahr, Melvin D, 1967).

Procedures and Setup

Data collection was completed in a single testing session with participants on medication. After health history and demographic information were collected (blood pressure, heart rate, height, and mass), participants stood two meters from a 6-meter long pressure-sensitive Zeno™ Walkway (Protokinetics, Havertown, PA) and were instructed to ambulate forward across the walkway, stopping at a marked location two meters beyond the edge of the walkway (a total of 10 meters). A green light located 12 meters from the starting position was randomly activated manually to indicate when a turn was to be initiated. If the light was illuminated following gait initiation, participants were instructed to turn around immediately and walk back to the start position. A total of 30 walking trials were completed in this fashion. Of these, 16 trials consisted of light activation. Of the 16 trials, the light was illuminated within a 3.5-5 meter zone from the start position in 8 trials, while the light was activated within a zone 5.0-7.5 meters from the start position in the remaining 8 trials. The light was not activated in the remaining 14 forward walking trials. To remain consistent between individuals, activation of the light occurred during left push off within the designated location which was observed visually by the investigator. Trials were randomized for each participant. Participants then completed an additional 30 walking trials of the previously described trials with the addition of cognitive loading, for a total of 60 trials overall. During cognitively loaded trials, participants were asked to perform serial subtraction by 3's with 1 of 4 randomized numbers during each trial. The order between single and dual-task trials were randomized for each participant.

Participants also completed cognitive and clinical assessments. Specifically, cognitive flexibility was assessed via the trail-making test: part B (TMT-B) (Army Individual Test Battery, 1944). TMT-B is a commonly used and recommended test for cognitive flexibility in people with PD and has been found to be sufficiently sensitive to mild cognitive impairments within the population (Biundo et al., 2013; Faria et al., 2015; Goldman et al., 2015; Lezak MD et al., 2004). The TMT-B is a written, timed test in which an individual is instructed to draw lines from a letter to number, alternating in consecutive order between 13 letters and 12 numbers (i.e. 1-A-2-B, etc.) (Army Individual Test Battery, 1944). The score is the time (s) utilized to complete the test (Army Individual Test Battery, 1944). The Montreal Cognitive Assessment (MOCA) was given to assess global cognition. The MOCA is a broader instrument than the TMT-B, investigating an individual within multiple domains: executive function, naming, memory, attention, abstraction and orientation (Nasreddine et al., 2005). The test has been validated numerous times as a means to investigate mild cognitive impairment among people with PD, and, because of its global nature, is highly recommended by the Movement Disorders Society Task Force as a tool for an abbreviated diagnosis of mild cognitive impairment within the population (Litvan et al., 2012). The Freezing of Gait Questionnaire (FOGQ), a six item questionnaire designed for people with PD, was used among the participants to determine which individuals experienced freezing (N. Giladi et al., 2000). Specifically, question 3 on the FOGQ, which asks "Do you feel that your feet get glued to the floor while walking, making a turn or when trying to initiate walking (freezing)?" with options ranging from "Never" to "Always," is suggested to be effective in identifying individuals with PD who experience freezing of gait (N. Giladi et al., 2000; Nir Giladi et al., 2009). Freezing has been suggested as influencing both turning and dual-tasking among people with PD (Spildooren et al., 2010). Finally, balance confidence was assessed via the Activities-specific Balance Confidence (ABC) scale, a 16-item questionnaire which consists of questions about balance confidence during a variety of simple to complex activities (Powell & Myers, 1995). The ABC scale is commonly used as a perceived balance confidence scale among people with PD having been found to be a valid, sensitive and reliable screening for falls risk in the population (Mak & Pang, 2009).

Measurements

Quantification of turning performance was determined post data collection via analysis of steps which exceeded 2 standard deviations of foot angle from the cumulative steps prior to the illumination of the light and the forward walking trials from the pressure-sensitive walkway and/or visual inspection (*ProtoKinetics Movement Analysis*, 2013). Turn distance was calculated by determining the cumulative mediolateral and anterior-posterior distance of the heel contacts within the turn based on data from ProtoKinetics Zeno^{TM} Walkway (*ProtoKinetics Movement Analysis*, 2013). Turn duration was quantified as the time of initial contact of turn initiation to the time of last contact of the final turning step based on data from ProtoKinetics Zeno^{TM} Walkway (*ProtoKinetics Movement Analysis*, 2013).

Data Analysis

Data analysis was performed using Stata 14.1 with alpha set to 0.05 (StataCorps, College Station, Texas). Individual means and standard deviations of the turn from each trial type (turn, turn + cognitive loading) were averaged. A paired t-test was utilized to assess differences between cognitively loaded and unloaded conditions. Pearson's correlation coefficients were calculated to determine associations between results of the TMT-B with dual-task trial distance and duration. Additionally, multiple regression equations were calculated to investigate the influence of cognitive flexibility and determine other clinical variables associated with the difference between dual and single task turn distance and duration.

Results

Baseline Characteristics

Twenty individuals completed the study, fifteen males and five females with a mean age of 70.15±6.81 (Table 1). 75% of individuals were rated as a 1 on the Hoehn and Yahr scale, 20% of individuals were rated as a Hoehn and Yahr 2, and 5% of individuals were rated a 3, suggesting that the majority of participants in this study had moderate symptoms. 45% of individuals reported a history of freezing per their response on question 3 of the FOGQ. Additionally, 6 participants were given a score of below 26 on the MOCA, suggesting mild cognitive impairments (Dalrymple-Alford JC, Nakas CT, et al., 2010).

Table 1: Participant Demographic Information

Characteristic	**Value**
Gender, males/females	15 / 5
Age (y)	70.15 (60-87)
Height (cm)	172.36 (157.5-184)
Mass (kg)	77.79 (57.6-107)
Mini-Mental State Exam	29.65 (28-30)
Hoehn and Yahr	1.3 (1-3)
Disease duration (m)	66.15 (4-211)
History of falls – past year, yes/no	7 / 13
Concern about falling, yes/no	11 / 9
Mild cognitive impairment (per MOCA), yes/no	6 / 14
Activities-Balance Confidence Scale (%)	82.05 (51.25-100)
Freezing of gait (per Question 3, FOGQ), yes/no	9 / 11

Values are mean (range) for all variables except for gender, history of falls, a concern about falling, mild cognitive impairment, and freezing of gait that are presented as a proportion.

Unplanned Turning With and Without Cognitive Loading

Individuals completed turns with reduced turn distance during dual-task trials (126.73±23.07cm) compared with single-task trials (139.58±26.96cm, p=0.0016; Figure 1). Turn duration was longer for individuals while walking and completing the cognitive task compared to single-task trials (1.68±0.54s and 1.58±0.48s respectively, p=0.0292; Figure 2). For individual means and standard deviations please view figures in the appendix.

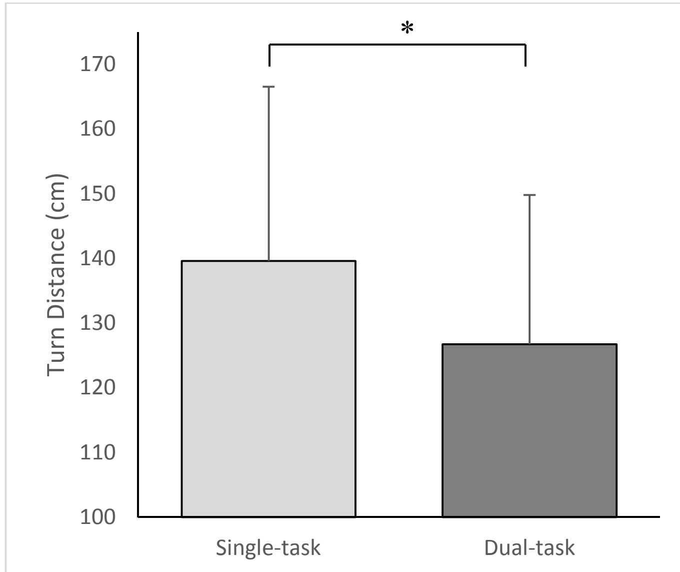


Figure 1: Mean (SD) of turn distance during single-task walking (left column) and walking with cognitive loading (right column). *Significant difference ($p<0.05$)

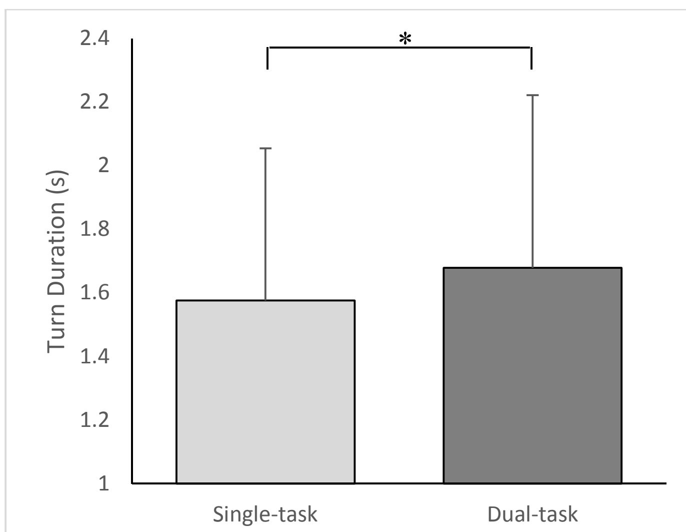


Figure 2: Mean (SD) turn duration during single-task walking (left column) and walking with cognitive loading (right column). *Significant difference ($p<0.05$)

Relationship between Dual-Task Unplanned Turning and Cognitive Flexibility

Prior to analysis of the relationship between cognitively loaded unplanned turning and cognitive flexibility, three outliers were removed due to exceptional slowness on the TMT-B exam. The three outliers who were removed had an average performance on the TMT-B of 658.64±309.94s whereas the remaining 17 participants had an average of 75.82±19.92s. Each of these outliers were considered to have mild cognitive impairment based on their MOCA score. Following removal of the outliers, no significant correlation was found for the relationship between cognitive flexibility and both turn duration ($r=0.0038$, $p=0.9883$) and turn distance ($r=-0.3282$; $p=0.1983$) (Table 2).

Table 2: Pearson correlation and statistical significance of TMT-B results with dual-task duration and distance. Significance set to $p<0.05$

	Dual-task Duration (s)	Dual-task Distance (cm)
TMT-B (s)	r=0.0038; p=0.9883	r=-0.3282; p=0.1983

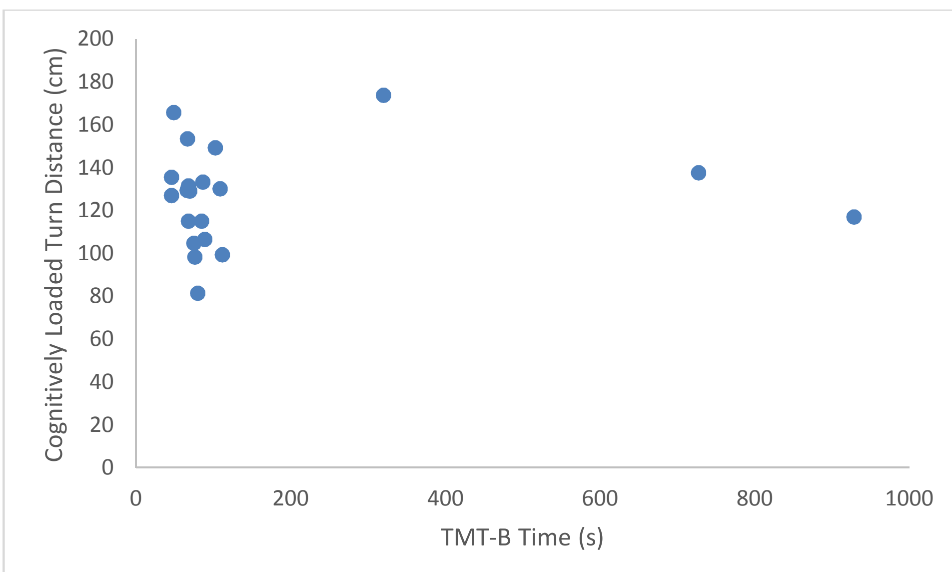


Figure 3: Individual means of cognitively loaded turn distance and TMT-B scores.

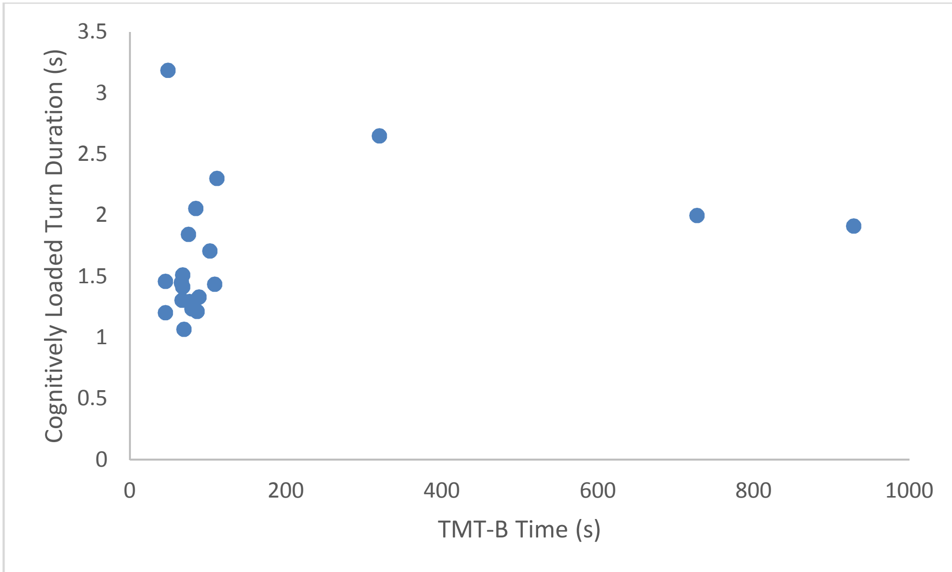


Figure 4: Individual means of cognitively loaded turn distance and TMT-B scores.

Within the subgroup of individuals presenting with exceptional slowness on the TMT-B, a strong, nonsignificant, negative correlation was observed between dual-task duration and TMT-B scores (r=-0.9752; p=0.1421), while a strong negative correlation was found to be significantly related to dual-task distance (r=-0.9993; p=0.0233) (Table 3).

Table 3: Pearson correlation and statistical significance of TMT-B results with dual-task duration and distance within the subgroup of exceptional TMT-B slowness. Significance set to p<0.05

	Dual-task Duration (s)	Dual-task Distance (cm)
TMT-B (s)	r=-0.9752; p=0.1421	r=-0.9993; p=0.0233

Associated Variables of the Difference between Single-task and Cognitively Loaded Trials

Associated variables of the difference between single-task and cognitively loaded turn distance were explored with the TMT-B outliers removed. While cognitive flexibility was not found to be associated with the difference in turn distance, the turning speed during the cognitively loaded trial (p=0.046; Figure 3) was found to be significant while controlling for cognitive flexibility (TMT-B), global cognition (MOCA), balance confidence (ABC scale), the speed during the single-task trials, disease duration, disease severity (H&Y score), and freezing of gait (Question 3; FOGQ). The regression equation utilized was "DistanceDifference = -70.1978 + 0.0409*TMTB + 1.4092*MOCA + 0.1381*ABCscale + 0.1376*FOGQ#3 + -0.0905*H&Y + 1.0765*STVelocity + -0.8016*DTVelocity".

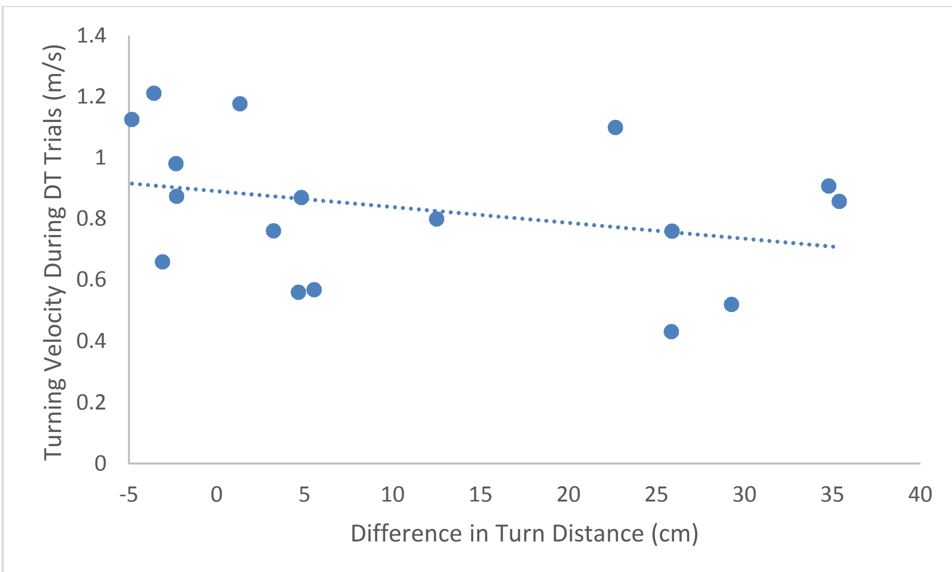


Figure 5: Relationship between turn velocity during cognitively loaded trials and the difference in turn distance during single-task and cognitively loaded turning.

Associated variables of the difference in turn duration were also explored with the TMT-B outliers removed. Cognitive flexibility was not a significant explanatory variable for the difference in turn duration. However, turn velocity during the DT trials (p=0.054; Figure 4) trended towards significant while controlling for cognitive flexibility (TMT-B), global cognition (MOCA), balance confidence (ABC scale), the speed during the single-task trials, disease duration, disease severity (H&Y score), and individuals who reported freezing of gait (Question 3; FOGQ).

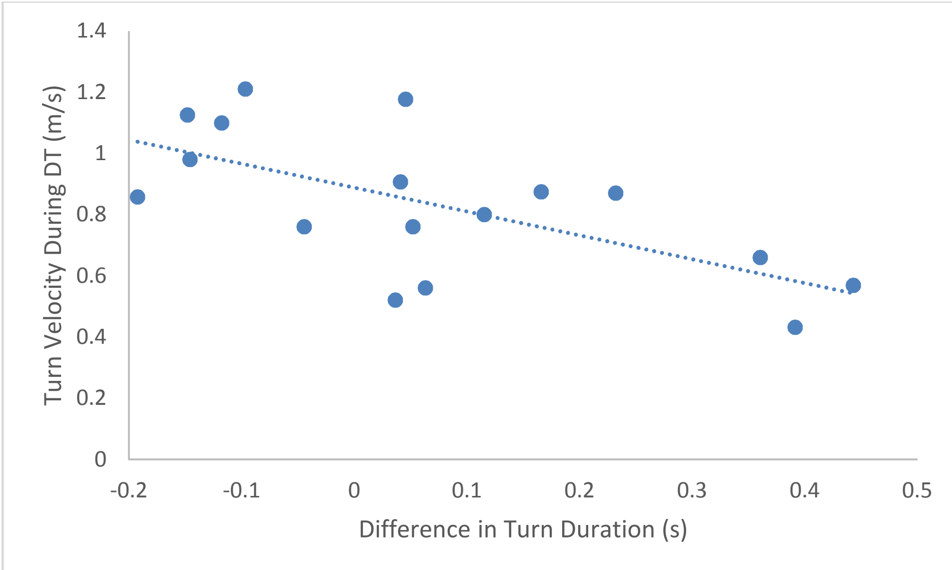


Figure 6: Relationship between turn velocity during the DT trials and the difference in turn duration between during single-task and cognitively loaded turning.

Explanatory variables were not assessed within the subgroup of individuals who presented with exceptionally longer time needed to perform the TMT-B secondary to the low sample size (3).

Discussion

The purpose of this study was to determine the influence of cognitive demands on unplanned turning among people with PD. The results of this study supported the hypothesis that individuals with PD demonstrate decreased turn distance and increased turn duration during unplanned turning with cognitive loaded walking compared to walking when not cognitively loaded. However, the hypothesis of a relationship between cognitive flexibility, as measured by TMT-B, and dual-task duration and distance was only supported among those who took exceptionally long on the TMT-B.

When completing a walking trial in combination with a cognitive task, individuals with PD negotiated unplanned turns using less distance and greater time. The decrease in turn distance was similar to the results by Conradsson et al (2017) who investigated the effects of dopaminergic medication on unplanned turn distance. The research team found that when people with PD turned unexpectedly while 'on' anti-Parkinsonian medication they increased turn distance compared to when participants were in the 'off' condition (Conradsson et al., 2017). Interestingly, although participants were on anti-Parkinsonian medication in the present study, our results suggest participants performed similarly to when in an 'off' anti-Parkinsonian medications condition (Conradsson et al., 2017) during cognitively loaded walking trials. This may be due to the complex nature of the dual-task condition, in which dopaminergic medications have been suggested as not influencing gait parameters during dual-tasking (Elshehabi et al., 2016).

In the current study, differences in turn distance between single-tasking and cognitively loaded turning were not associated with cognitive flexibility, but instead were associated with the turning velocity while cognitively loaded within the group of individuals who performed the TMT-B in a reasonable time. Those who greatly adjusted their distance traveled between single-task unplanned turns and cognitively loaded unplanned turns tended to ambulate slower during the cognitively loaded trials. This finding, while not surprising given the relationship between distance and velocity, suggests that individuals with PD who present with normal cognitive flexibility tend to strategize their spatial parameters when cognitively loaded by adjusting their speed.

Participants in this study increased their turn duration when cognitively loaded. Increased ambulation time while dual-tasking has been found during pre-planned turns (de Souza Fortaleza et al., 2017; Spildooren et al., 2010; Stuart, Galna, Delicato, Lord, & Rochester, 2017). In the present study, differences in turn duration between single and dual-tasking did not have a significant association between any of the factors within the model, including cognitive flexibility. Turn velocity during the cognitively loaded trials was close to significance, similar to the results of the difference in distance.

Relationship between cognitive flexibility and dual-task turn distance and duration

Cognitive flexibility, as measured by TMT-B, was found to be weakly correlated to both distance and duration during dual-tasking among those with greater flexibility. Among the subgroup of individuals who presented with poorer cognitive flexibility, however, a strong relationship was identified during dual-tasking, where those with poorer cognitive flexibility (higher score of TMT-B) negotiated the turn using less distance. A decreased distance may suggest that individuals negotiated the turn with smaller steps, decreasing one's dynamic balance. The association between cognitive flexibility and cognitively loaded turning is similar to previous findings of the relationship between gait parameters and cognitive flexibility during forward walking in older adults (Ble et al., 2005; Hirota et al., 2010; Hobert et al., 2017; Killane et al., 2014) and turn duration during the Timed Up and Go test among people with PD (Van Uem et al., 2016).

This study was designed to mimic the environmental constraints placed on individuals while negotiating through an active environment, similar to environments people with PD interact with outside of the laboratory. While additional research is necessary to further understand strategies used during unexpected turns while cognitively loaded, this investigation suggests that individuals with PD may adjust their turn distance and duration when cognitively loaded and turning unexpectedly in order to safely negotiate a complex environment. However, navigation within complex environmental conditions may be a greater challenge within subgroups of individuals presenting with poorer cognitively flexibility.

Limitations

There are several limitations to this study. The majority of participants in this study were high functioning males, therefore this data may not be generalizable to the greater Parkinson's population. The TMT-B may have been too simple for the majority of the current sample where perhaps a different test may have shown stronger results. The secondary cognitive task used in this study consisted of serial subtraction from a randomized order of 4 different numbers. It is possible that individuals became familiar with specific numbers during the trial. The study allowed each individual walk at their preferred walking speed. By not controlling for walking speed, the duration and distance traveled during the turn may have been influenced. Lastly, the environment in which testing occurred was not completely controlled with regards to distractions, including noise and movement.

Conclusion

This study investigated differences between unplanned turning with and without cognitive loading among individuals with PD. The sample studied demonstrated a decrease in turn distance and an increase in turn duration while cognitively loaded. This suggests individuals with PD use different motor control strategies during unplanned turning while performing a secondary task compared to only a single task. The results also suggest that cognitive flexibility may not be associated with dual-tasking performance, except in those who have exceptionally poor cognitive flexibility. The significance of these findings may explain, in part, the influence complex environments have on the motor control strategies used by people with PD.

APPENDIX

Project Overview

Parkinson's disease (PD) is a neurodegenerative disease that affects over ten million of the world's population (Parkinson's Foundation, 2017). The disease process, which involves the loss of dopamine releasing cells, results in impairments within both the motor and cognitive domains (Laurie Lundy-Ekman, 2007). These impairments lead to a variety of activity limitations and participation restrictions, particularly when attempting to negotiate complex environments.

Within the motor domain, gait impairments during forward walking include decreased gait speed, step length and increased step variability among people with PD compared to unimpaired adults (Hoehn & Yahr, Melvin D, 1967; Peterson & Horak, 2016). People with PD also present with rigidity of gait both in the axial and appendicular skeletons, presenting with less natural rotation during walking (Hoehn & Yahr, Melvin D, 1967; Peterson & Horak, 2016). Poor postural control (the ability to maintain and restore balance during movements) also plays a crucial role in the gait impairments seen among people with PD (Peterson & Horak, 2016). Together, these gait deviations are an important safety concern for the rehabilitation field as they are associated with an increased falls risk in many populations including PD (Hausdorff et al., 2001; Maki B.E., 1997; Nakamura et al., 1996; Schaafsma et al., 2003).

Even more challenging than forward walking is turning. Turning is made up of multiple transitions: walking straight, slowing down, reorienting the body to a new direction, accelerating, and walking forward again. People with PD demonstrate a number of challenges with transitions, making turning an important task to study in this population (Ashburn et al., 2008; de Souza Fortaleza et al., 2017; E. Stack & Ashburn, 1999; E. L. Stack et al., 2006). Individuals with PD have been identified as having difficulty turning and demonstrate decreased step width, decreased step length, increased double support time, increased freezing episodes, en-bloc turning, and increased falls (Ashburn et al., 2008; Cheng FY et al., 2014; Hulbert et al., 2015; Huxham F et al., 2008; E. Stack & Ashburn, 1999; E. L. Stack et al., 2006). Falls during turning are even more dangerous because when individuals fall while turning, they are more likely to fall sideways with the lateral femur making contact with the ground (Cummings et al., 1994). This type of fall, as opposed to falling while walking straight, makes individuals 8X more likely to fracture their hip (Cummings et al., 1994).

An active physical environment with unexpected obstacles causes even more challenges to individuals with PD. Unplanned or reactive change of direction represent a challenge in the physical environment for people with Parkinson's disease. Previous research suggests that people with PD demonstrate changes in gait characteristics when having to negotiate an unplanned change (Conradsson, D et al., 2018; Conradsson et al., 2017; Knobl et al., 2012). Specifically, people with PD demonstrate both an increase in freezing episodes as well as increased stepping variability during unplanned turns (Knobl et al., 2012). Additionally, people with PD compared with unimpaired adults, even while on anti-Parkinson's medication, have been found to turn with less distance and poorer mediolateral stability during unplanned changes of direction (Conradsson, D et al., 2018; Conradsson et al., 2017). These findings, though limited, suggest that people with PD negotiate complex physical environments differently than unimpaired adults. The limited studies suggest that additional research is necessary to progress the rehabilitation science field's understanding of the implications a complex environment has on walking performance among people with PD.

Although people with PD demonstrate a number of differences in their motoric strategies when compared with unimpaired adults, they also present with a variety of executive function impairments (the processes that allow higher order mental function to occur), including attention and cognitive flexibility, within the cognitive domain. People with PD demonstrate decreased attentional processing abilities, often resulting in poorer performance when completing more than one task simultaneously, as evidenced by changes in gait and cognitive performance during dual-task compared with single-task (Yogev et al., 2005, 2008). People with PD also demonstrate lower scores in multiple cognitive tests, including the trail-making test (TMT) – part B (TMT-B) and trail-making test – B-A (deltaTMT), where part A is subtracted from part B, which suggest difficulties with cognitive flexibility (the ability to adjust behavior in response to environmental stimuli) (Armbruster et al., 2012; Kourtidou et al., 2015; Scott, W. A., 1962). These cognitive impairments have been associated with pre-planned gait characteristics, however the relationship between the cognitive and motor domains has not been investigated during unplanned turning. Investigation of the effects of this relationship is of great importance as it adds to our understanding of the influence a complex environment has on individual performance.

Previous research had found that people with PD demonstrate changes in their gait, such as decreased speed and increased step variability, when performing a cognitive task while walking (Yogev et al., 2005). A pre-planned environment does not fully represent an active environment where obstacles and unplanned situations commonly occur, therefore requiring the individual to switch attention between tasks. To date, there is little evidence to indicate the influence of cognitive loading on unplanned turning. Improved understanding of the effects of increased attentional demand during a dual-task situation is a crucial step to understand the influence of environmental challenges on people with PD (Figure 7).

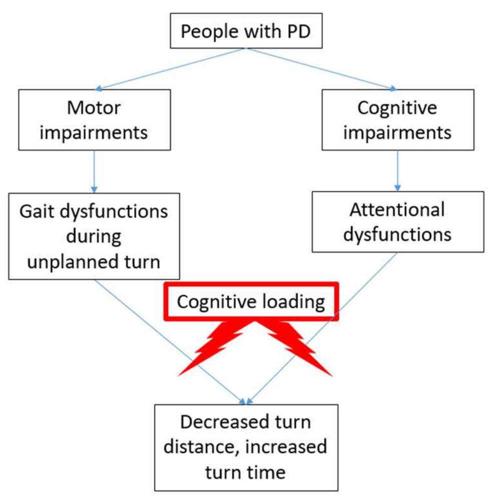


Figure 7: Conceptual framework of the influence of cognitive loading on unplanned turning, thereby taking account both the motor and cognitive impairments seen in people with PD.

This study was designed to improve our understanding of this relationship, thereby enhancing established gait protocols to create treatment programs which may improve gait function in people with PD. Thus, the purpose of this study was to determine the influence of cognitive demands on unplanned turning among people with PD. Two hypotheses: (1) Individuals with Parkinson's disease will demonstrate decreased turn distance or increased turn time during unplanned turning with cognitive loading in comparison to unloaded walking trials. (2) Cognitive flexibility will be positively associated with turn distance and negatively associated with turn duration during dual-task trials.

Review of the Literature

Parkinson's disease, the most common motor disorder associated with the basal ganglia, is prevalent in over 10 million people worldwide (Laurie Lundy-Ekman, 2007; Parkinson's Foundation, 2017). Caused by diminished dopamine production within the substantia nigra, as well as acetylcholine-producing cells in the pedunculopontine nucleus of the brainstem, the reduction results in decreased activity in the cerebral cortex as well as inhibition of both the vesibulospinal and the reticulospinal tracts (Laurie Lundy-Ekman, 2007). These central impairments cause changes both motorically and cognitively (Laurie Lundy-Ekman, 2007).

Within the motor domain, individuals with PD demonstrate changes in their gait characteristics when compared with unimpaired adults. These changes occur during both forward walking and changes of direction. Within the cognitive domain, people with PD present with impairments related to executive function (the processes that allow higher order mental function to occur in individuals) (Logue & Gould, 2014). Within the realm of executive function, people with PD demonstrate difficulty with attention (the information processing capacity of an individual) and cognitive flexibility (the ability to adjust behavior in response to environmental stimuli) (Armbruster et al., 2012; Scott, W. A., 1962; Woollacott & Shumway-Cook, 2002).

Understanding the relationship between cognitive deficiencies and gait dysfunctions caused by the disease has been of interest to multiple researchers and the field of rehabilitation science for many years. This review will examine the influence of PD on gait and cognitive loading. Additionally, studies that have examined turning during walking in people with PD will be reviewed.

Motor Aspects of Parkinson's Disease

People with PD present with multiple impairments within the motor domain including gait deviations, muscular weakness, balance and postural dysfunctions, as well as tremors (Dirnberger & Jahanshahi, 2013; Laurie Lundy-Ekman, 2007). This review will focus on gait deviations. During forward walking, individuals with PD present with a multitude of deviations including decreased step length, decreased walking speed and increased step variability (Hoehn & Yahr, Melvin D, 1967; Peterson & Horak, 2016). These deviations are important for the field of rehabilitation, in part, because of their relationship to falls. Increased variability of stepping and a decrease in walking speed have both been suggested as related to an increased falls risk (Brach et al., 2005; Montero-Odasso et al., 2005). Falls, one of the leading causes of disability, are a common occurrence in this population and often occur during movement transitions, such as turning. (Allen et al., 2013; Gill et al., 2013; Thigpen et al., 2000). Falls during a turn are even more hazardous because one is more likely to contact the ground with their hip, increasing the risk of a hip fracture (Cummings et al., 1994).

Turning in People with Parkinson's Disease

During a pre-planned turn, people with PD demonstrate decreased turn velocity, smaller steps, increased turn time, increased number of steps needed to complete the turn, as well as increased frequency of freezing (Hulbert et al., 2015; Huxham F et al., 2008). With such a multitude of impairments, 56% of people with PD have reported difficulty with turning (E. L. Stack et al., 2006). In fact, the completion of a turn is a major contributor to falls with an 8X greater likelihood to experience a hip fracture when falling compared with forward walking (Cummings et al., 1994; Feldman & Robinovitch, 2007). Therefore, it is critical to better understand aspects related to turning in people with PD. Although pre-planned turning is common, unexpected changes in the physical environment, such as an obstacle, require individuals to deviate from forward walking with little advance notice. Changes in the physical environment force individuals to quickly react by changing direction. To successfully complete a sudden change in direction, individuals must be able to flexibly modify motoric goals from forward walking to maintaining upright posture while walking in a different direction. A sudden change in a motor task requiring motor flexibility is a concept known as motor task-switching (Ravizza & Carter, 2008).

Task-switching abilities have been found to be impaired in people with PD within both the cognitive and motor domains (Almeida et al., 2003; Benecke et al., 1987; Brown & Almeida, 2011; Chong et al., 2000; A. R. Cools et al., 1984; R. Cools et al., 2001a, 2001b; Dirnberger & Jahanshahi, 2013; Downes et al., 1989; F. B. Horak et al., 1992; Owen et al., 1992; Robertson & Flowers, 1990; Sawada et al., 2012; Spildooren et al., 2010). Recently, however, researchers have attempted to investigate the ability to task-switch during turning while walking among people with PD. Knobl et al (2012) investigated the effects of motor planning in shifting during turning in people with PD who experience freezing of gait (FoG). The authors found that individuals with FoG demonstrated increased step length variability, increased double support time, and decreased step length compared to individuals with PD who do not experience freezing (NFoG) or healthy controls (Knobl et al., 2012). Additional walks were completed where a light cue was provided, indicating a change in direction. These trials resulted in an increased frequency of freezing episodes, suggesting that FoG may be influenced by difficulty in performing voluntary movement switches (Knobl et al., 2012). Although differences between NFoG and unimpaired subjects were not found, the methodology employed to elicit a shift was not a voluntary reactive response as the cue (i.e. light) was provided prior to the turn location, allowing participants time to preplan their strategies (Knobl et al., 2012).

A study completed by Conraddson et al (2017, 2018) also investigated pre-planned and unplanned turning in people with PD. While investigating the influence on dopaminergic medications on unplanned turning, they found that individuals with PD negotiated an unplanned turn with less turn distance and poorer mediolateral stability than unimpaired adults (Conradsson, D et al., 2018; Conradsson et al., 2017). Unplanned turn trials however, did not require task shifts as the cue to initiate the turn was provided *prior* to the turning location, thereby allowing participants the opportunity to preplan the change in direction (Conradsson, D et al., 2018; Conradsson et al., 2017; Knobl et al., 2012).

Cognitive Aspects of Parkinson's Disease

Cognitively, people with PD demonstrate changes in executive function, processes that allow higher order mental function to occur (Logue & Gould, 2014). Within the realm of executive function are many cognitive processes, including attention (information processing capacity of an individual) (Woollacott & Shumway-Cook, 2002) and cognitive flexibility (ability to adjust behavior in response to environmental stimuli) (Armbruster et al., 2012; Scott, W. A., 1962). Both attention and cognitive flexibility are crucial for individuals to interact and adapt to the environment (Logue & Gould, 2014). People with PD demonstrate decreased attentional capacity and slower processing abilities compared to people without PD (Dirnberger & Jahanshahi, 2013). Additionally, the automaticity used when immediate responses are required or when information is processed in parallel is impaired in people with PD (Yogev□Seligmann et al., 2012). Rather than processing information in parallel, individuals with PD utilize slow, goal directed behavior, requiring more attention for tasks, such as walking, than unimpaired adults (Yogev et al., 2005; Yogev□Seligmann et al., 2012).

The completion of a task is believed to require a certain amount of attention (Ravizza & Carter, 2008). The ability to share attentional resources among multiple tasks is crucial for maintaining an upright posture. However, when attentional capacity has been maximized, both motor and cognitive performances become impaired (McKinlay, 2013). The breakdown of performance while attention is limited has been suggested to be associated with falls risk in multiple neurological populations, including PD (Kalron et al., 2010; Plummer-D'Amato et al., 2008; Sheridan & Hausdorff, 2007; Yogev et al., 2005).

People with PD not only have difficulty dividing attentional demands, but also demonstrate challenges switching attention between tasks (McKinlay, 2013). Switching attention requires cognitive flexibility which allows an individual to efficiently end one task, develop a plan for a new goal, and implement that plan (Dajani & Uddin, 2015).

Flexibility to modify behavioral goals is especially crucial within complex, active environments, where adaptation to unanticipated occurrences is crucial.

People with PD present with decreased cognitive flexibility compared to unimpaired adults, as evidenced by slower performance on cognitive assessments such as the trail-making test (Olchik, M.R. et al., 2017). Cognitive flexibility, which is positively associated with health-related quality of life (Davis et al., 2010), has also been found to be associated with falls in people with PD (McKay et al., 2018).

<u>The Interaction of Cognitive and Motor Domains in Parkinson's Disease</u>

In addition to challenges in the physical environment, people with PD also demonstrate difficulties within the social environment. The social environment often requires individuals to communicate with others while simultaneously performing a motor task, such as walking while talking. The interaction between both environments and the strategies used by the individual with PD can lead to either disablement or enablement (Figure 8).

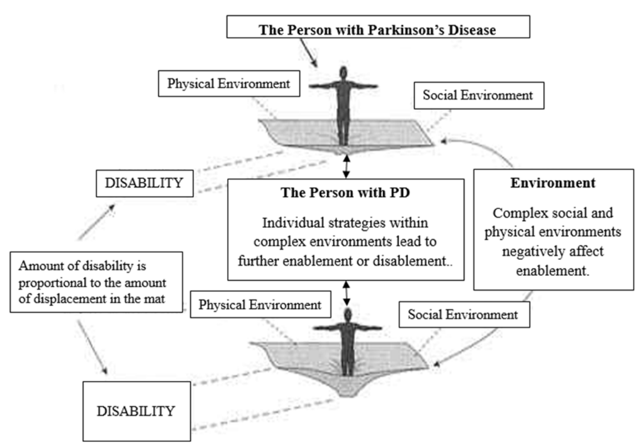


Figure 8: Modified Institute of Medicine Environmental Mat Model depicting the relationship between the environment, the person with PD, the effects on disability and enablement (Institute of Medicine et al., 1997).

When performing a cognitive task during forward walking within a complex social environment, individuals with PD must share attentional resources between the two tasks. As a result of both attentional and motor demands, people with PD demonstrate an increase in gait deviations including decreased speed and increased variability in stepping (Yogev et al., 2005). Such modifications to spatiotemporal characteristics of gait have been identified as a potential safety mechanism utilized when required to perform more than one task (Yogev et al., 2005). However, while the study of a complex social environment on forward walking is important, 35-45% of all steps taken during the day involve turning steps (Glaister BC et al., 2007). As a result of almost half of steps involving some aspect of turning, and the increased cognitive demand associated with a turn compared to forward walking, the investigation of the effects of cognitive distractions on turning performance has increased research focus (Lowry et al., 2012). Spildooren et al (2010) were among the first to study the effects of turning performance within a dual-task paradigm in people with PD when they investigated the influence of dual tasking on FoG during pre-planned turns. The findings suggest that people with PD who experience FoG demonstrate increased occurrences when completing a cognitive-motor dual-task that comprised of a 360° turn (Spildooren et al., 2010). Participants also took more steps during the turn and ambulated at a slower speed (Spildooren et al., 2010). This study, however, included only pre-planned turns and therefore cannot be generalized to an active physical environment (Spildooren et al., 2010).

De Souza Fortaleza et al (2017) also investigated the effect of cognitive loading on transitions between individuals with PD who experienced FoG and NFoG (de Souza

Fortaleza et al., 2017). Contrary to Spildooren et al's findings, de Souza Fortaleza et al found that FoG and NFoG turned similarly while turning and simultaneously completing a cognitive task (de Souza Fortaleza et al., 2017). They attributed this difference to a higher cognitive functional level in their participants compared to those in the Spildooren et al's (2010) study as well as a difference in angled turns (180° compared to 360°, respectively) (de Souza Fortaleza et al., 2017). De Souza Fortaleza et al (2017) also found that both groups decreased their peak turn velocity when completing a dual-task compared to a single-task. However, this study also did not include unplanned turn trials (de Souza Fortaleza et al., 2017). By incorporating an unplanned component within a dual-task paradigm, researchers would be able to investigate the cognitive loading effects on a change in a behavioral goal within the motor domain, manipulating both motor and cognitive flexibility within complex physical and social environments.

To date, only one paper has explored the effects of a dual-task paradigm with an unplanned motor activity among people with PD (Smulders et al., 2015). The effects of simultaneous cognitive and motor task-shifting were investigated in people with PD employing a step initiation model for the motor task-shift and a change in task rule model for the cognitive task (Smulders et al., 2015). Individuals who experienced FoG made more stepping errors during dual-task trials than unimpaired adults, suggesting that FoG may be associated with motor shifting errors and challenges (Smulders et al., 2015). However, motor task-shifting while walking was not investigated, a crucial component of safety during community participation (Smulders et al., 2015).

Summary

In summary, individuals with PD demonstrate impairments in both motor and cognitive domains. Within the motor domain, they utilize different motor strategies, including decreased turn distance and increased turn time, when performing a task in a complex physical environment, such as an unplanned change in direction. Within a complex social environment, individuals demonstrate challenges dividing attention, presented by a decrease in performance when more than one task is performed simultaneously. A combination of a complex social and physical environment during a walking turn task has not been investigated in this population. This review acknowledges the findings of research teams to date, however, the lack of research investigating the strategies used while individuals with PD perform an unplanned turn with and without cognitive loading remains limited. The strategies those with PD use within this challenging environment is crucial for the field of rehabilitation to understand in order to maximize the knowledge and treatment for the PD population.

Dissertation Proposal

Individual enablement relies heavily on the motor performance within complex, active environments. Active environments consist of unanticipated obstacles which require individuals to maintain motor flexibility during unplanned changes in direction and/or speed. Furthermore, active participation in the community often requires individuals to perform multiple tasks simultaneously, requiring individuals to utilize attentional resources towards environmental changes while also responding with appropriate motoric strategies to ensure safety. This requirement often results in diminished quality of one or more tasks due to individual limits of attentional capacity.(Yogev□Seligmann et al., 2012) While there is ecological validity in exploring conventional dual-task paradigms, investigating the influence of complex environments on activity performance further develops our understanding of the association between the environmental and motor organization.

Turning is a complex task which requires greater cognitive demands than straight-line walking(Lowry et al., 2012) and is substantially more challenging when performed as an unplanned activity within a task-shifting paradigm.(Conradsson, D et al., 2018; Conradsson et al., 2017; Knobl et al., 2012) Task-shifting, or the ability to change behavioral goals, requires an individual to use motoric flexibility and attentional resources while transitioning between disparate tasks.(Ravizza & Carter, 2008) People with Parkinson's disease (PD) demonstrate impaired unplanned turning performance compared with healthy older adults. Specifically, people with PD demonstrate decreased turn distance and velocity as well as increased turn duration.(Conradsson, D et al., 2018; Conradsson et al., 2017; Knobl et al., 2012) Together, these movement characteristics suggest that people with PD demonstrate compromised unplanned turning performance.(Conradsson, D et al., 2018; Conradsson et al., 2017; Knobl et al., 2012)

Balance impairment is suggested to be a significant contributor to turning performance in people with PD.(Cheng FY et al., 2014) In fact, balance impairments are thought to have a greater influence on turning performance than lower extremity strength, freezing of gait, or disease severity.(Cheng FY et al., 2014) Postural control is multifactorial with components such as attention affecting it.(Fay B. Horak, 2006; Pollock AS et al., 2000) People with PD demonstrate impairments in both postural control and attention, leading to an increased risk of falls while performing complex tasks.(Cheng FY et al., 2014; Stylianou et al., 2011; Yogev et al., 2008) When performing more than one task, the attention to postural control becomes limited, causing greater instability and a higher threat to safety.(Yogev□Seligmann et al., 2012) Our understanding of the influence of postural control on unplanned turning performance while cognitively loaded, however, remains limited.

People with PD also demonstrate increased difficulty performing multiple tasks due to attentional demands. Attention, as a construct, greatly affects the activity of turning and successful participation in the community.(Shumway-Cook A & Woollacott MH, 2000) People with PD demonstrate decreased automaticity of movement resulting in the need to utilize attentional resources for motoric activities and thus greater relative difficulty performing multiple tasks simultaneously.(Yogev□Seligmann et al., 2012)

Proactive, pre-planned turning is compromised when attention is limited, most likely due to the increase in attentional demands needed for walking in this population.(de Souza Fortaleza et al., 2017; Spildooren et al., 2010; Stuart Samuel et al., 2017) Although existing literature in this area is limited, the influence of attentional demands has received increased attention recently as the association between cognitive function and turning in individuals with PD is identified.(de Souza Fortaleza et al., 2017; Spildooren et al., 2010; Stuart Samuel et al., 2017)

Our understanding of the influence of limited attention on unplanned turning performance and the role of attention on motor organization within complex environments among people with PD is limited. For active community participation, individuals with PD must be able to safely and effectively negotiate unplanned obstacles while simultaneously performing cognitive tasks. Investigating the motor organization within this challenging environment has the opportunity to further develop the field's understanding of motor control and the influence of attention as well as allow for the development of rehabilitation interventions to maximize the enablement of individuals with PD.

Specific Aim: To determine the influence of cognitive demands on unplanned turning among people with PD.

- Research Question #1: How does cognitive loading affect unplanned turning among people with Parkinson's disease?
    - Hypothesis #1: Individuals with Parkinson's disease will demonstrate (a) decreased turn distance and/or (b) increased turn time during unplanned turning while cognitively loaded compared to not cognitively loaded.
- Research Question #2: What is the relationship between cognitive flexibility, as evidenced by trail-making test B and/or trail-making test B-A (deltaTMT), and unplanned turn distance or duration while cognitively loaded among people with Parkinson's disease?
    - Hypothesis #2: Cognitive flexibility will be positively associated with turn distance and negatively associated with turn duration during dual-task trials.

Methods:

Population:

Participation of human subjects will be approved by the institutional review board prior to enrollment in this study.

15 individuals with PD will be recruited for this study. This is based on Conradsson 2017's effect size for turn distance as Cohen's d = 0.70,(Conradsson et al., 2017) power as 0.80, and $p<0.05$. This calculation was determined by GPower based off within subjects means.

Inclusion criteria: Diagnosis of PD by a physician, ON Parkinsonian medications, able to ambulate 10 meters with or without cane, a Mini Mental state score of at least 24, age 60 or older, and those who are rated from 1-4 on the Hoehn and Yahr scale.

Exclusion criteria: Diagnosis of neurological disease or disorder other than PD, recent surgery or condition that could impact walking performance, uncontrolled cardiovascular conditions, inability to read or understand English, those who are legally blind, and those who use an assistive device which provides support greater than the support of a cane, and those who are rated greater than 4 on the Hoehn and Yahr scale.

A convenience sample will be used to obtain participants in the Washington, DC metro area. Recruitment of participants will include strategies of advertising with flyers in the local community, emails, online newsletters, word of mouth within the Parkinson community in the Washington, DC metro area. In-services will be given to local support groups as well as local allied health clinicians, nurses and physicians. Each group will receive flyers to post and hand out to potential subjects.

Experimental Procedures:

After successful screening of eligible participants, participants will read, comprehend, and sign the informed consent. Testing will take place at GMU Rehabilitation Science Functional Performance Lab.

Part A: Single Task- Cognitive: Individuals will complete the cognitive task, serial subtraction by 3's starting at a randomly selected number of the following: 206, 223, 249, or 290 in a seated position.[12] A researcher will note the accuracy of the responses for 60 seconds.[12]

Part B: Single Task- Motor: Participants will stand at a designated start position located 2 meters away from a pressure-sensitive Zeno walkway. He or she will then be instructed to ambulate straight and stop at the designated marked line located 2 meters past the mat (a total of 10 meters walking). A green light at the end of the walkway will be randomly activated manually to indicate when a turn is to be completed. If the light turns on following gait initiation, the participant will turn around immediately and walk back. Thirty trials will be completed. Fourteen trials (14/30) will comprise of straight-line walking trials where the light is not activated. The remaining 16 trials (16/30) will consist of trials in which the light will be activated. Within the 16 trials, 8 trials (8/30) will be performed with the light activating while the participant is ambulating within a designated location of 3.5-5 meters from starting position. The final 8 trials (8/30) will be performed with the light activating while the participant is ambulating within a designated location of 5-7.5 meters from the starting position. The timing of the light activation will be noted visually when the right limb is in push off within the specific designated location. All trials will be randomized for each participant. Following this, individuals will be asked to perform 3 trials of preplanned turning in each direction at a designated turning location located 5 meters from the starting position.

Part C: Posturography: Participants will be asked to stand quietly for 30 seconds on the Balance Tracking System.

Part D: Dual Task: The walking scenarios in Part B will be repeated with cognitive distraction. Participants will be asked to perform serial subtraction by 3's starting with a randomized number listed above. During the completion of this phase, a research assistant will note the error rate of the cognitive task performance.

Part B and D will randomized for each subject.

Statistical Analysis:

Data analysis will be performed on Stata 14.1. Data will be reported as individual means and standard deviations from multiple trials and ensemble averages for people with PD. A paired t-test will be performed to assess differences between cognitively loaded and unloaded conditions. A Pearson's correlation will be performed to investigate the relationship between mediolateral sway and turn distance.

Proposal Signature List

THE INFLUENCE OF COGNITIVE LOADING ON UNPLANNED TURNING AMONG PEOPLE WITH PARKINSON'S DISEASE

by

Caity Bryson, PT, DPT, MSPT, SCS
A Dissertation Proposal
Submitted to the
Graduate Faculty
of
George Mason University
in Partial Fulfillment of
The Requirements for the Degree
of
Doctor of Philosophy
Rehabilitation Science

Committee:

_______________ Dr. Clinton Wutzke, PhD
Committee Chair and First Reader

_______________ Dr. Andrew A. Guccione, PT, Ph.D, DPT, FAPTA
Second Reader, Department Chair

_______________ Dr. John Collins, PhD
Third Reader, Statistician

Date: December 10, 2018

Fall Semester 2018
George Mason University
Fairfax, VA

Example Dissertation Assessment Sheet

TPD Assessment

Date:___/___/2019

Participant: TPD13

BP	HR	Height(cm)	Weight(kg)

DOB: ___/___/___ MMSE:______ H&Y: ________

Diagnosis date:_______

Seated Serial Substraction by 3's in 60s

Start number (circle): 206 223 249 290 Total numbers stated: ______ Accuracy:______

Single Task

1. E	TPD13_ST_1	
2. S		
3. S		
4. L		
5. E		
6. S		
7. E		
8. S		
9.E		
10. S		
11.E		
12.S		
13. S		
14. S		
15. E		
16.S		
17.L		
18. S		
19.S		
20.L		
21.L		
22. S		
23. E		
24. S		
25. L		
26.L		
27. L		
28.E		
29. L		
30.S		

TPD Assessment

Date:___/___/2019 Participant: TPD13

Preplanned turns:

Right x 3 TPD13_R_# Left x 3 TPD13_L_#

Posturography: ***TAKE OFF SHOES!!!!!***

Trial	Comfortable EO	Narrow EO	Comfortable EC	Narrow EC
Total Sway				

Dual Task

1. E	TPD13_DT_1	4	
2. S		4	
3. S		3	
4. E		2	
5. L		4	
6. S		3	
7. L		3	
8. S		3	
9.S		2	
10. S		4	
11.S		1	
12.E		4	
13. S		2	
14. L		3	
15. L		1	
16.L		3	
17.L		4	
18. L		4	
19.S		2	
20.S		4	
21.S		2	
22. L		1	
23. E		1	
24. S		3	
25. E		1	
26.E		2	
27. E		4	
28.E		1	
29. S		2	
30.S		2	

Questionnaires: FOQ:____ ABC:____ TMT:____ MOCA:____

TPD Assessment

Date:___/___/2019 Participant: TPD13

TUG (2) 1. Time:___:___ 2. Time: ___:___ Filename: TPD13_TUG_T#

10 meter walk: PWS: 1. Time:___:___ 2. Time:___:___ TPD13_10MW_P_#

FWS: 1. Time:___:___ 2. Time:___:___ TPD13_10MW_F_#

Functional Gait Assessment Score:_______ TPD13_FGA_Speed

TPD13_FGA _HT_Horiz

TPD13_FGA_HT_Vertical

TPD13_FGA_Pivot

TPD13_FGA_Obstacle

TPD13_FGA_Narrow

TPD13_FGA_EC

TPD13_FGA_Back

Strength testing:

Muscle group	Right X 3	Left
Hip abduction		
Hip external rotation		
Hip extension		
Hip flexion		
Knee flexion		
Knee extension		
Ankle DF		
Ankle PF		

Cutaneous sensation: Y=Yes, N=No If intact sensation is not noted, than work down the list

Force – g	Heel	5th met	1st Met	Hallux	Arch
.4 (3x)	R: L:	R: L:	R: L:	R: L:	R: L:
.6 (3x)	R: L:	R: L:	R: L:	R: L:	R: L:
1 (3x)	R: L:	R: L:	R: L:	R: L:	R: L:
1.4 (1x)	R: L:	R: L:	R: L:	R: L:	R: L:
2	R: L:	R: L:	R: L:	R: L:	R: L:
4	R: L:	R: L:	R: L:	R: L:	R: L:
6	R: L:	R: L:	R: L:	R: L:	R: L:
8	R: L:	R: L:	R: L:	R: L:	R: L:
10	R: L:	R: L:	R: L:	R: L:	R: L:
15	R: L:	R: L:	R: L:	R: L:	R: L:

TPD Assessment

Date:___/___/2019 **Participant: TPD13**

Notes:

Informed Consent

GEORGE MASON UNIVERSITY

Department of Rehabilitation Science
4400 University Drive, MS 2G7, Fairfax, Virginia 22030
Phone: 703-993-1950; Fax: 703-993-6073

INFORMED CONSENT

THE INFLUENCE OF COGNITIVE LOADING ON UNPLANNED TURNING AMONG PEOPLE WITH PARKINSON'S DISEASE: Person with Parkinson's Disease

RESEARCH PROCEDURES

This research is being conducted to understand the effects of cognitive loading on unplanned turning in people with Parkinson's Disease. If you agree to participate, we will evaluate your functional abilities as a person with Parkinson's Disease. Your assessment will evaluate your health history; your muscle strength and power; your motor function including balance and gait, and self-confidence as they contribute to your abilities to perform activities of daily living successfully.

Inclusion/Exclusion Criteria

Inclusion criteria for individuals with PD include: Diagnosis of PD by a physician, ON Parkinsonian medications, able to ambulate 10 meters with or without cane, a Mini Mental state score of at least 24, age 60 or older.

Exclusion criteria for individuals with PD include: Diagnosis of neurological disease or disorder other than PD, recent surgery or condition that could impact walking performance, uncontrolled cardiovascular conditions, inability to read or understand English, those who are legally blind, and those who use an assistive device which provides support greater than the support of a cane.

Examination Procedures

The specific examination procedures will depend on your personal characteristics and health history. The total testing session will last approximately 2 hours. You will complete a variety of questionnaires, including health history and self-confidence in doing specific functional movements. We will also ask that you answer questions regarding your date of birth, gender, race, level of education, affected limb and limb dominance, health habits, diagnosis date, and health history. We will also measure your heart rate, blood pressure, height and weight. We will ask for your emergency contact in the event that an emergency should occur. You may be asked to complete other assessments including:

- Balance and gait– may be measured by self-report questionnaires, observation, or digital data collected by walking on the surface of special devices. You may be asked to perform specific movements with or without assistive devices or ambulation aids. You may be asked to walk across a pressure sensitive mat or stand on a balance board. (65 minutes).

- Muscle strength and cutaneous sensation– Muscle strength may be measured by asking you to perform certain movements against resistance a given number of times. You may be asked to move slowly with precision, or as quickly as you can, and asked to repeat these movements. Resistance may be applied by hand, by a handheld dynamometer, or body weight. Cutaneous sensation may be measured by asking you if you feel certain areas of your feet when touched by a thin filament (30 minutes)
- Activities of daily living, balance confidence, and cognitive function – may be measured by self-report questionnaires and/or observation. You may be asked to perform specific movements with or without assistive devices (20 minutes).

Videotaping and audiotaping

Testing sessions may be videotaped and audiotaped. You have the right to decline taping at any given point. Videos and audio will be used to assist with data processing and teaching purposes. To the extent possible, you will be videotaped in ways that will diminish facial recognition. Video/audio material (photos, videos, audio) will remain on a secure computer with login required, only accessed by the researchers of the study, and will be deleted after 5 years following completion of the study. You also may request at any time that your videotapes be completely erased immediately either while participating in the study or after your participation has ended.

Time Commitments

Participants will need to be available for approximately 2.5 hours of testing conducted over a single session.

RISKS

The foreseeable risks or discomforts are similar to the risks that you take when exercising or engaging in moderate physical activity on your own, with or without supervision, at home or in a gym or other facility. The level of exercise or physical activity is controlled by you, and you will not be asked to engage in any activity that you believe is beyond your ability or tolerance.

You may have some minor discomfort during testing procedures that are similar to any temporary discomfort that you may experience in a routine medical examination or annual physical examination.

You may experience some discomfort from any of the testing procedures including muscle fatigue, muscle or joint soreness, and lightheadedness during or in the hours following testing. Straining a muscle or spraining a ligament is a very small possibility following or during testing.

The risks of exercise testing are generally low, although sometimes medical complications do occur. During exercise and moderate physical activity, certain changes in heart rate and rhythm, blood pressure, and respiratory rate are expected, but abnormal or unanticipated changes are small possibilities. Every effort will be made to minimize these risks.

Although rare in occurrence the most serious risks of exercise testing include sudden death, heart attack, dizziness, chest pain or tingling in the arm, jaw, or back, shortness of breath, and/or extreme fatigue. Please let the researcher know if you experience any of these symptoms during testing activities.

In case of injury during testing procedures, the George Mason University research team may provide basic first aid. If appropriate, the staff will call the emergency response team. Neither George Mason University nor the investigators have funds available for payment of medical treatment for injuries that you may sustain while participating in this research. Should you need medical care, you or your insurance carrier will be responsible for payment of the expenses required for medical treatment.

BENEFITS

There are no benefits to you as a participant other than to further the research of interventions designed for people with PD.

CONFIDENTIALITY

The data in this study, including audio/video, will be confidential. All participants will be assigned an identification number after agreeing to participate, and all de-identified data will be stored using this identification number. The signed informed consent and the identification number linking data to individuals will be stored by the lead researcher in a locked cabinet in a locked office along with any other forms or papers that have protected personal or health information. Only members of the research team will have access to this information. The de-identified data could be used for future research without additional consent from participants. Video/audio data will also be stored on a GMU research computer with login required and only accessed by the researchers. The video/audio recordings and rest of the study data will be stored for 5 years after study closure. Identifiers will be stored for 2 years after completion of the study.

PARTICIPATION

Your participation is voluntary, and you may withdraw from the study at any time and for any reason. If you decide not to participate or if you withdraw from the study, there is no penalty or loss of benefits to which you are otherwise entitled. There are no costs to you or any other party except transportation to and from testing or training sessions and parking in compliance with University regulations.

Your participation in testing may be stopped at any time by a member of the research team without your consent for reasons that include a belief by the research team that continued testing may affect your health or safety; you are unable to follow or adhere to testing or training instructions; or other administrative reasons that require your withdrawal.

You may receive information from the testing including: height, weight, blood pressure, heart rate, and performance on testing measures of balance, walking, and confidence.

CONTACT

This research is being conducted by Dr. Clinton Wutzke, Department of Rehabilitation Science, at George Mason University. He may be reached at 703-993-1903 for questions or to report a research-related problem. You may contact the George Mason University Institutional Review Board Office at 703-993-4121 if you have questions or comments regarding your rights as a participant in the research.

This research has been reviewed according to George Mason University procedures governing your participation in this research.

CONSENT

I have read this form, all of my questions have been answered by the research staff, and I agree to participate in this study.

☐ I grant permission to videotape my image and likeness as part of this research study.

☐ I DO NOT grant permission to videotape my image and likeness as part of this research study.

____________________________ ______________________

Name **Date of Signature**

____

Signature

Standardized Mini-Mental State Examination

Name of patient:		DOB:	/ /	Name of examiner:		Date of test:	/ /

Standardised Mini-Mental State Examination (SMMSE)

Please see accompanying guidelines for administration and scoring instructions

Say: *I am going to ask you some questions and give you some problems to solve. Please try to answer as best you can.*

1. Allow ten seconds for each reply. **Say:**

   a) *What year is this?* (accept exact answer only) /1
   b) *What season is this?* (during the last week of the old season or first week of a new season, accept either) /1
   c) *What month is this?* (on the first day of a new month or the last day of the previous month, accept either) /1
   d) *What is today's date?* (accept previous or next date) /1
   e) *What day of the week is this?* (accept exact answer only) /1

2. Allow ten seconds for each reply. **Say:**

   a) *What country are we in?* (accept exact answer only) /1
   b) *What state are we in?* (accept exact answer only) /1
   c) *What city/town are we in?* (accept exact answer only) /1
   d) <At home> *What is the street address of this house?* (accept street name and house number or equivalent in rural areas) /1
   <In facility> *What is the name of this building?* (accept exact name of institution only)/1
   e) <At home> *What room are we in?* (accept exact answer only) /1
   <In facility> *What floor of the building are we on?* (accept exact answer only) /1

3. **Say:** *I am going to name three objects. When I am finished, I want you to repeat them. Remember what they are because I am going to ask you to name them again in a few minutes* (say slowly at approximately one-second intervals).

   Ball Car Man

   For repeated use: Bell, jar, fan; bill, tar, can; bull, bar, pan

   Say: *Please repeat the three items for me* (score one point for each correct reply on the first attempt) /3

   Allow 20 seconds for reply; if the person did not repeat all three, repeat until they are learned or up to a maximum of five times (but only score first attempt)

4. **Say:** *Spell the word WORLD* (you may help the person to spell the word correctly). **Say:** *Now spell it backwards please* (allow 30 seconds; if the person cannot spell world even with assistance, score zero). Refer to accompanying guide for scoring instructions (score on reverse of this sheet)

   /5

5. **Say:** *Now what were the three objects I asked you to remember?* /3

   (score one point for each correct answer regardless of order; allow ten seconds)

6. Show wristwatch. **Ask:** *What is this called?* /1

   (score one point for correct response; accept 'wristwatch' or 'watch'; do not accept 'clock' or 'time', etc.; allow ten seconds)

1

7. **Show pencil.** **Ask**: *What is this called?* /1

(score one point for correct response; accept 'pencil' only; score zero for pen; allow ten seconds for reply)

8. **Say:** *I would like you to repeat a phrase after me: No ifs, ands, or buts* /1

(allow ten seconds for response. Score one point for a correct repetition. Must be exact, e.g. no ifs or buts, score zero)

9. **Say:** *Read the words on this page and then do what it says* /1

Then, **hand** the person the sheet with CLOSE YOUR EYES (score on reverse of this sheet) on it. If the subject just reads and does not close eyes, you may repeat: *Read the words on this page and then do what it says*, a maximum of three times. See point number three in Directions for Administration section of accompanying guidelines. Allow ten seconds; score one point only if the person closes their eyes. The person does not have to read aloud.

10. **Hand** the person a pencil and paper. **Say:** *Write any complete sentence on that piece of paper* (allow 30 seconds. Score one point. The sentence must make sense. Ignore spelling errors). /1

11. **Place** design (see page 3), pencil, eraser and paper in front of the person. **Say:** *Copy this design please.* Allow multiple tries. /1

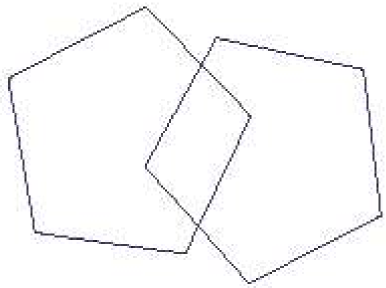
Wait until the person is finished and hands it back. Score one point for a correctly copied diagram. The person must have drawn a four-sided figure between two five-sided figures. Maximum time: one minute.

12. **Ask** the person if he is right or left handed. Take a piece of paper, hold it up in front of the person and say the following: *Take this paper in your right/left hand* (whichever is non-dominant), *fold the paper in half once with both hands and put the paper down on the floor.*

Takes paper in correct hand_________	/1
Folds it in half___________	/1
Puts it on the floor________	/1
TOTAL TEST SCORE:	**/30**
ADJUSTED SCORE:	/

The SMMSE tool and guidelines are provided for use in Australia by the Independent Hospital Pricing Authority under a licence agreement with the copyright owner, Dr D. William Molloy. The SMMSE Guidelines for administration and scoring instructions and the SMMSE tool must not be used outside Australia without the written consent of Dr D. William Molloy.

Molloy DW, Alemayehu E, Roberts R. Reliability of a standardized Mini-Mental State Examination compared with the traditional Mini-Mental state Examination. *American Journal of Psychiatry*, Vol. 14, 1991a, pp.102-105.



Time:

D	L	R	O	W

= ☐

CLOSE YOUR EYES

3

Health History Form

THE INFLUENCE OF COGNITIVE LOADING ON UNPLANNED TURNING AMONG PEOPLE WITH PARKINSON'S DISEASE

HEALTH HISTORY FORM

Participant ID #:_______________ Gender: _______________

Date of Birth:_________________ *PD Only*: Diagnosis Date:______

Height(cm):______ Weight(kg): ______ BP: ______ HR: ______

Emergency Contact:_______________________Relationship:________________Phone #:___________

What is your dominant: *a) Arm*: ☐ Right ☐ Left *b) Leg*: ☐ Right ☐ Left

For PD Only: Which limb is more affected by the disease? ☐ Right ☐ Left Other:_____________

SOCIAL/CULTURAL

Race (Optional: Check all that apply)

☐ American Indian or Alaska Native
☐ Asian
☐ Black or African American
☐ Hispanic or Latino
☐ Native Hawaiian or Other Pacific Islander
☐ White
☐ Other:_________

Language (Optional: Check all that apply)

☐ English understood
☐ Interpreter needed
☐ Language you speed most often:________

Education (Optional: Circle highest grade level completed)

Grades: 1 2 3 4 5 6 7 8 9 10 11 12

Some College / Technical School

College Graduate Graduate School

Do you use: (Optional: Circle all that apply)

Cane Hearing aids

Walker or rollator Glasses

Other:___________________________

GENERAL HEALTH / HEALTH HABITS

Health Rating Please rate your health (Optional): Excellent Good Fair Poor

Exercise (Optional)

Do you exercise beyond normal daily activities and chores?

☐ Yes Describe the exercise: ____

How many days/week: ______ How many minutes:_______

☐ No

THE INFLUENCE OF COGNITIVE LOADING ON UNPLANNED TURNING AMONG PEOPLE WITH PARKINSON'S DISEASE

HEALTH HISTORY FORM

MEDICAL HISTORY (Please check all medical diagnoses and conditions that apply)

☐ Anemia
☐ Arthritis
☐ Bleeding Disorders
☐ Cancer: ___________
☐ Chemical Dependency
☐ Communicable Disease
  ☐ HIV+ ☐ VRE ☐ MRSA
  ☐ E Coli ☐ Scabies
☐ Depression
☐ Diabetes
☐ Dizziness
☐ Emphysema
☐ Gout
☐ Heart Disease
☐ High Blood Pressure
☐ Irregular or Rapid Heart Beat
☐ Joint Replacement
☐ Kidney Problems
☐ Osteoporosis
☐ Pacemaker
☐ Parkinson's Disease
☐ Current Pregnancy
☐ Stroke
☐ Thyroid Problem

☐ *Other medical condition not listed above:*____

FALLS (Please check)

Are you concerned about falling? ☐ Yes ☐ No

Have you fallen in the last year? ☐ Yes ☐ No   If yes, Date:

Have you fallen more than 2 times? ☐ Yes ☐ No

Has any resulted in injury? ☐ Yes ☐ No

SURGERIES/HOSPITAL PROCEDURES (Please list the procedure and date)

____

____

ALLERGIES / DRUG INTERACTIONS

____

____

CURRENT MEDICATIONS

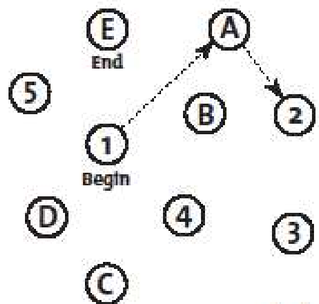
Medication Name	Dose	Frequency	Reason	Time Since Start

Montreal Cognitive Assessment

MONTREAL COGNITIVE ASSESSMENT (MOCA)

NAME :
Education : Date of birth :
Sex : DATE :

		POINTS
VISUOSPATIAL / EXECUTIVE		



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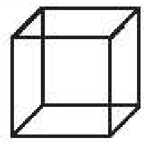


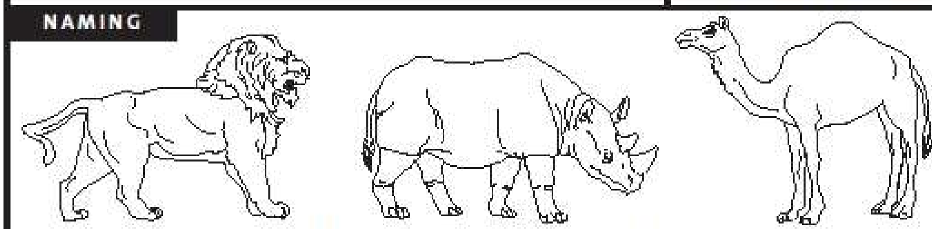
Copy cube

[ ]

Draw CLOCK (Ten past eleven) (3 points)

[ ] Contour [ ] Numbers [ ] Hands __/5

NAMING



[ ] [ ] [ ] __/3

MEMORY

Read list of words, subject must repeat them. Do 2 trials. Do a recall after 5 minutes.

	FACE	VELVET	CHURCH	DAISY	RED
1st trial					
2nd trial					

No points

ATTENTION

Read list of digits (1 digit/ sec.). Subject has to repeat them in the forward order [ ] 2 1 8 5 4
Subject has to repeat them in the backward order [ ] 7 4 2 __/2

Read list of letters. The subject must tap with his hand at each letter A. No points if ≥ 2 errors
[ ] FBACMNAAJKLBAFAKDEAAAJAMOFAAB __/1

Serial 7 subtraction starting at 100 [ ] 93 [ ] 86 [ ] 79 [ ] 72 [ ] 65
4 or 5 correct subtractions: **3 pts**, 2 or 3 correct: **2 pts**, 1 correct: **1 pt**, 0 correct: **0 pt** __/3

LANGUAGE

Repeat : I only know that John is the one to help today. [ ]
The cat always hid under the couch when dogs were in the room. [ ] __/2

Fluency / Name maximum number of words in one minute that begin with the letter F [ ] ____ (N ≥ 11 words) __/1

ABSTRACTION

Similarity between e.g. banana - orange = fruit [ ] train – bicycle [ ] watch - ruler __/2

DELAYED RECALL

Has to recall words WITH NO CUE	FACE [ ]	VELVET [ ]	CHURCH [ ]	DAISY [ ]	RED [ ]	Points for UNCUED recall only	__/5
Optional: Category cue							
Optional: Multiple choice cue							

ORIENTATION

[ ] Date [ ] Month [ ] Year [ ] Day [ ] Place [ ] City __/6

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www.mocatest.org

Normal ≥ 26 / 30 **TOTAL** __/30
Add 1 point if ≤ 12 yr edu

Trail Making Test

Trail Making Test (TMT) Parts A & B

Instructions:

Both parts of the Trail Making Test consist of 25 circles distributed over a sheet of paper. In Part A, the circles are numbered 1 – 25, and the patient should draw lines to connect the numbers in ascending order. In Part B, the circles include both numbers (1 – 13) and letters (A – L); as in Part A, the patient draws lines to connect the circles in an ascending pattern, but with the added task of alternating between the numbers and letters (i.e., 1-A-2-B-3-C, etc.). The patient should be instructed to connect the circles as quickly as possible, without lifting the pen or pencil from the paper. Time the patient as he or she connects the "trail." If the patient makes an error, point it out immediately and allow the patient to correct it. Errors affect the patient's score only in that the correction of errors is included in the completion time for the task. It is unnecessary to continue the test if the patient has not completed both parts after five minutes have elapsed.

Step 1:	Give the patient a copy of the Trail Making Test Part A worksheet and a pen or pencil.
Step 2:	Demonstrate the test to the patient using the sample sheet (Trail Making Part A – *SAMPLE*).
Step 3:	Time the patient as he or she follows the "trail" made by the numbers on the test.
Step 4:	Record the time.
Step 5:	Repeat the procedure for Trail Making Test Part B.

Scoring:

Results for both TMT A and B are reported as the number of seconds required to complete the task; therefore, higher scores reveal greater impairment.

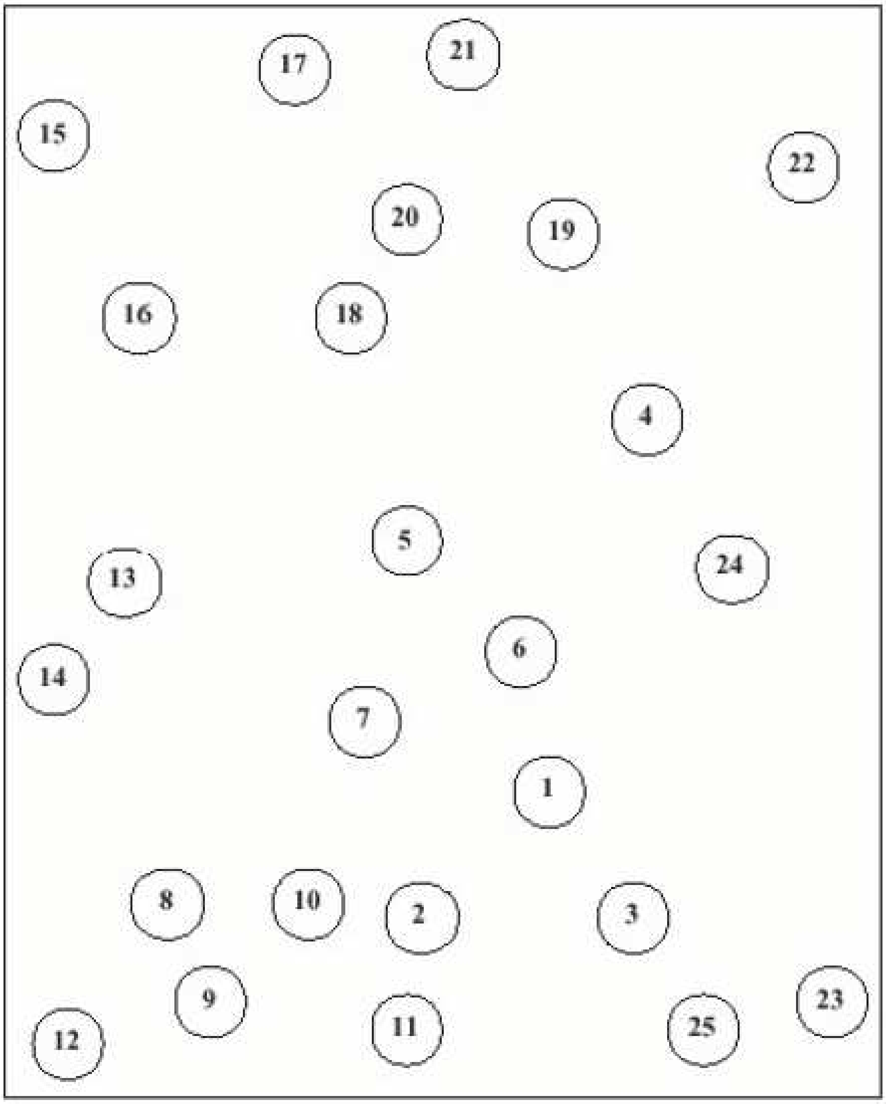
	Average	Deficient	Rule of Thumb
Trail A	29 seconds	> 78 seconds	Most in 90 seconds
Trail B	75 seconds	> 273 seconds	Most in 3 minutes

Sources:

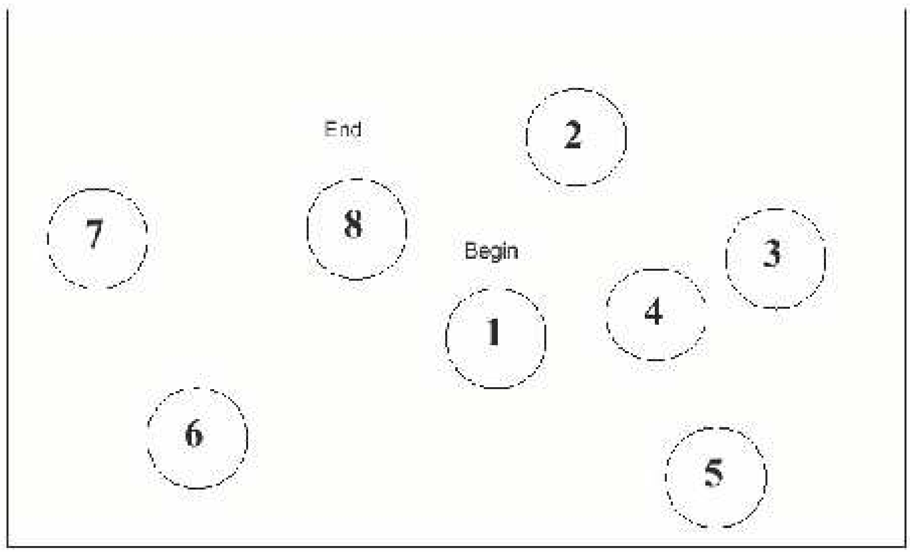
- Corrigan JD, Hinkeldey MS. Relationships between parts A and B of the Trail Making Test. *J Clin Psychol*. 1987;43(4):402–409.
- Gaudino EA, Geisler MW, Squires NK. Construct validity in the Trail Making Test: what makes Part B harder? *J Clin Exp Neuropsychol*. 1995;17(4):529-535.
- Lezak MD, Howieson DB, Loring DW. *Neuropsychological Assessment*. 4th ed. New York: Oxford University Press; 2004.
- Reitan RM. Validity of the Trail Making test as an indicator of organic brain damage. *Percept Mot Skills*. 1958;8:271-276.

Trail Making Test Part A

Patient's Name: ______________________ Date: ______________

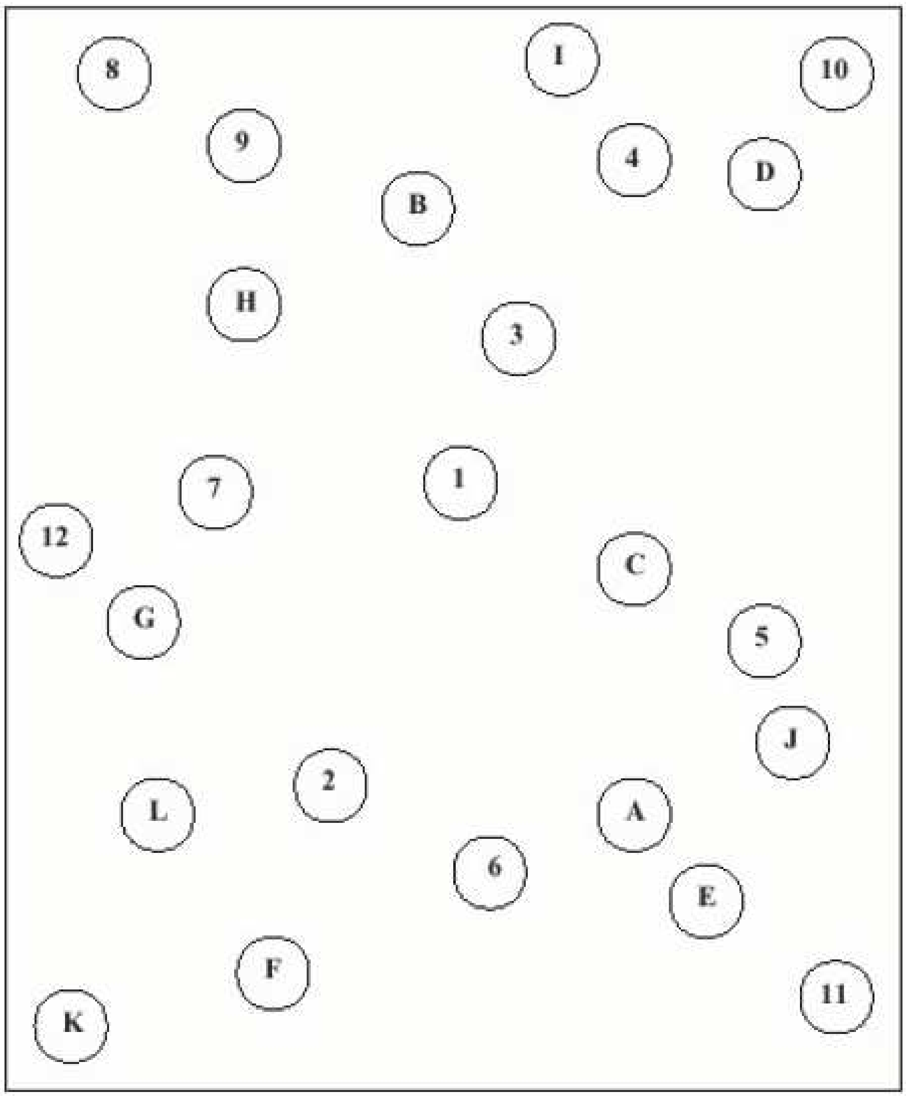


Trail Making Test Part A – *SAMPLE*

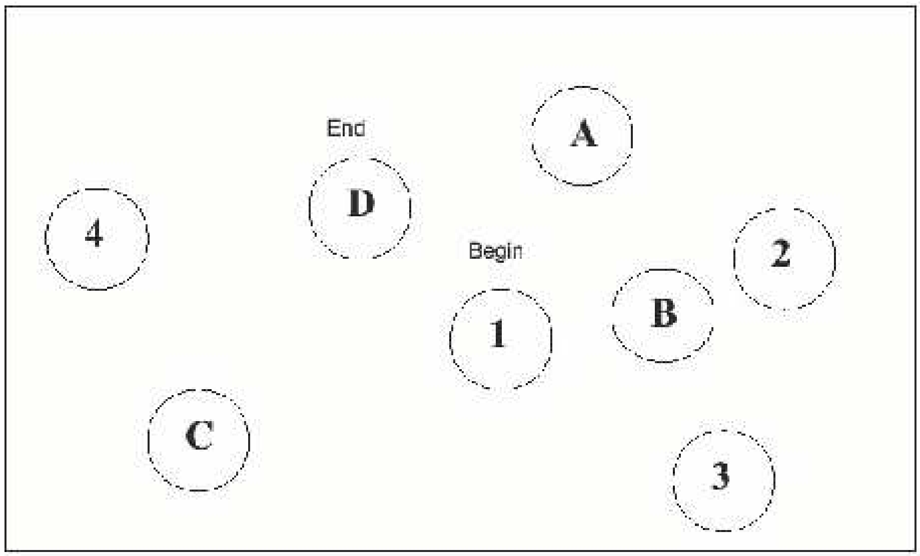


Trail Making Test Part B

Patient's Name: ______________________________ Date: ____________________



Trail Making Test Part B – *SAMPLE*



Freezing of Gait Questionnaire

Appendix B

B.1. Freezing of Gait Questionnaire (FOGQ)

B.1.1. During your worst state—Do you walk:

0 Normally
1 Almost normally—somewhat slow
2 Slow but fully independent
3 Need assistance or walking aid
4 Unable to walk

B.1.2. Are your gait difficulties affecting your daily activities and independence?

0 Not at all
1 Mildly
2 Moderately
3 Severely
4 Unable to walk

B.1.3. Do you feel that your feet get glued to the floor while walking, making a turn or when trying to initiate walking (freezing)?

0 Never
1 Very rarely—about once a month
2 Rarely—about once a week
3 Often—about once a day
4 Always—whenever walking

B.1.4. How long is your longest freezing episode?

0 Never happened
1 1–2 s
2 3–10 s
3 11–30 s
4 Unable to walk for more than 30 s

B. 1.5. How long is your typical start hesitation episode (freezing when initiating the first step)?

0 None
1 Takes longer than 1 s to start walking
2 Takes longer than 3 s to start walking
3 Takes longer than 10 s to start walking
4 Takes longer than 30 s to start walking

B. 1.6. How long is your typical turning hesitation: (freezing when turning)

0 None
1 Resume turning in 1–2 s
2 Resume turning in 3–10 s
3 Resume turning in 11–30 s
4 Unable to resume turning for more than 30 s

References

[1] Giladi N, McMahon D, Przedborski S, Flaster E, Guillory S, Kostic V, Fahn S. Motor blocks in Parkinson's disease. Neurology 1992;42:333–9.

[2] Giladi N, Kao R, Fahn S. Freezing phenomenon in patients with parkinsonism. Mov Disord 1992;12:302–5.

[3] Fahn S. The freezing phenomenon in parkinsonism. In: Fahn S, Hallet M, L0der HO, Marsden CD, editors. Advances in neurology, vol. 65. Philadelphia, PA: Lippincott-Raven Publishers, 1995. p. 53–63.

[4] Nieuwboer A, De Weerdt W, Dom R, Lesaffre EA. A frequency and correlation analysis of motor deficits in Parkinson patients. Disabil Rehabil 1998;20:142–50.

[5] Narabayashi H, Kondo T, Nagatsu T, Hayashi A, Suzuki T. DL-threo-3,4-dihydroxyphenylserine for freezing symptom in parkinsonism. In: Hassler RG, Christ JF, editors. Advances in neurology, vol. 40. New York: Raven Press, 1984. p. 497–552.

[6] Achiron A, Ziv I, Goren M, Goldberg H, Zoldan Y, Sroka H, Melamed E. Primary progressive freezing gait. Mov Disord 1993;8:293–7.

[7] Fahn S, Marsden CD, Calne DB, Goldstein M, editors. Recent developments in Parkinson's disease, vol. 2. Florham Park, NJ: Macmillan Health Care Information, 1987. p. 153–63 (also p. 293–304).

[8] Huges AJ, Daniel SE, Kilford L, Lees AJ. Accuracy of clinical diagnosis of idiopathic Parinsons's disease—a clinico pathological study of 100 cases. J Neurol Neurosurg Psychiatry 1992;55:181–4.

[9] Hoehn MM, Yahr MD. Parkinsonism: onset, progression and mortality. Neurology 1967;17:427–42.

[10] Burleigh-Jacobs X, Horak FB, Nutt JG, Obeso JA. Step initiation in Parkinson's disease: influence of levodopa and external sesnory triggers. Mov Disord 1997;12:206–15.

[11] Stern GM, Lander CM, Lees AJ. Akinetic freezing and trick movements in Parkinson's disease. J Neural Transm 1980;16(Suppl.):137–41.

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Activities-Specific Balance Confidence Scale

ACTIVITIES-SPECIFIC BALANCE CONFIDENCE (ABC) SCALE

Appendix 1

Client Name: ____________Date: ____________Therapist: ______________

*THE ACTIVITIES-SPECIFIC BALANCE CONFIDENCE (ABC) SCALE**

For each of the following activities, please indicate your level of self-confidence by choosing a corresponding number from the following rating scale:

0%	**10**	**20**	**30**	**40**	**50**	**60**	**70**	**80**	**90**	**100%**
No confidence								**completely confident**		

"How confident are you that you will not lose your balance or become unsteady when you . . .

1. . . . walk around the house? ___%
2. . . . walk up or down stairs? ___%
3. . . . bend over and pick up a slipper from front of a closet floor? _______%
4. . . . reach for a small can off a shelf at eye level? _____%
5. . . . stand on tip toes and reach for something above your head? ________%
6. . . . stand on a chair and reach for something? _____%
7. . . . sweep the floor? ___%
8. . . . walk outside the house to a car parked in the driveway? __%
9. . . . get into or out of a car? ___%
10. . . . walk across a parking lot to the mall? _____%
11. . . . walk up or down a ramp? ___%
12. . . . walk in a crowded mall where people rapidly walk past you? ___%
13. . . . are bumped into by people as you walk through the mall? ________%
14. . . . step onto or off of an escalator while you are holding onto a railing? ______%
15. . . . step onto or off an escalator while holding onto parcels such that you cannot hold onto the railing? _____%
16. . . . walk outside on icy sidewalks? _____%

ACTIVITIES-SPECIFIC BALANCE CONFIDENCE (ABC) SCALE

Appendix 2

Confidence in Mobility (a.k.a. Falls Efficacy Scale –FES)

Directions: Ask subject or have him/her fill out this questionnaire:

"How confident are you that you can…[*activity 1-10 below*]…without falling?"

Ask the subject to rate his/her confidence on a scale of 1-10 (1=extreme confidence; 10=no confidence at all).

Name: ____________________________ Date: ________________

"How confident are you that you can……[ ]………. without falling?"

1 2 3 4 5 6 7 8 9 10
extreme confidence ←——————————→ no confidence at all

Score	*Activity*
	Take a bath or shower
	Reach into cabinets or closets
	Prepare meals not requiring carrying heavy or hot objects
	Walk around the house
	Get in and out of bed
	Answer the door or telephone
	Get in and out of a chair
	Get dressed and undressed
	Light housekeeping
	Simple shopping
	TOTAL SCORE

Reliability: Internal consistency: = .90[1] Test-retest: (r=.71) in 18 cognitively intact seniors over 65.

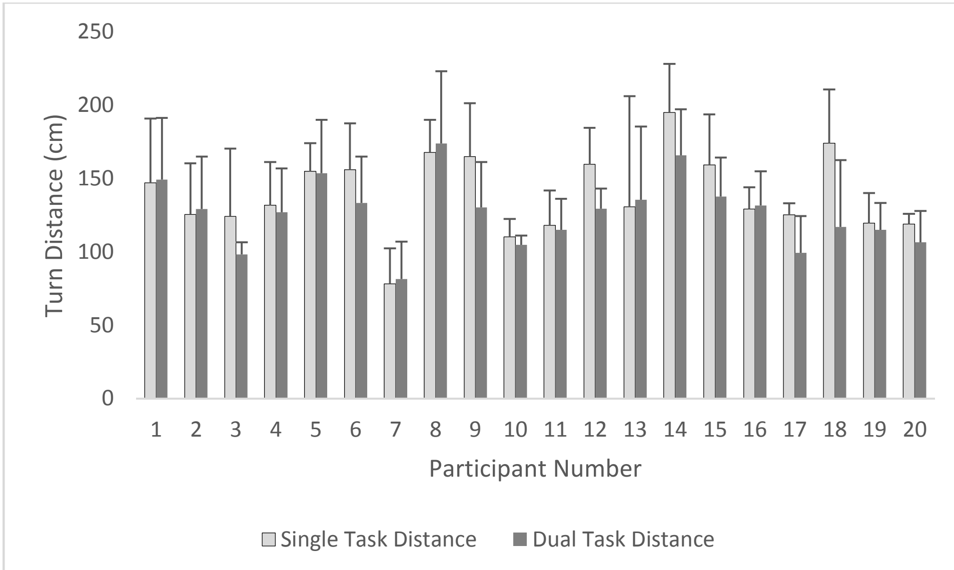

Figure 9: Individual means (SD) of turn distance during single-task walking (left column) and walking with cognitive loading (right column).

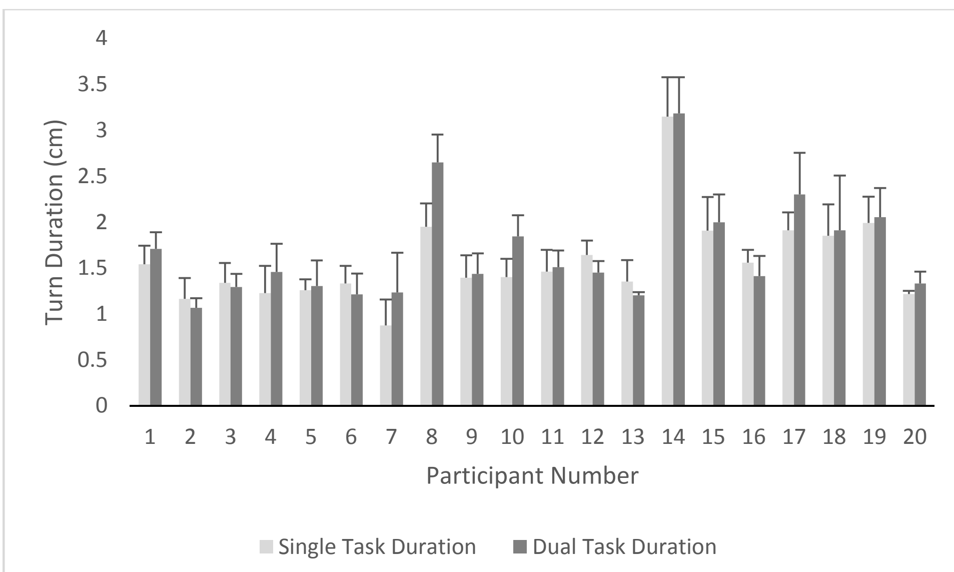

Figure 10: Individual means (SD) of turn duration during single-task walking (left column) and walking with cognitive loading (right column).

REFERENCES

Allen, N. E., Schwarzel, A. K., & Canning, C. G. (2013). *Recurrent Falls in Parkinson's Disease: A Systematic Review* [Research article]. Parkinson's Disease. https://doi.org/10.1155/2013/906274

Almeida, Q. J., Wishart, L. R., & Lee, T. D. (2003). Disruptive influences of a cued voluntary shift on coordinated movement in Parkinson's disease. *Neuropsychologia*, *41*(4), 442–452. https://doi.org/10.1016/S0028-3932(02)00155-0

Armbruster, D. J. N., Ueltzhöffer, K., Basten, U., & Fiebach, C. J. (2012). Prefrontal cortical mechanisms underlying individual differences in cognitive flexibility and stability. *Journal of Cognitive Neuroscience*, *24*(12), 2385–2399. https://doi.org/10.1162/jocn_a_00286

Army Individual Test Battery. (1944). Manual of directions and scoring. *War Department, Adjunct General's Office, Washington, DC.*

Ashburn, P. A., Stack, E., Ballinger, C., Fazakarley, L., & Fitton, C. (2008). The circumstances of falls among people with Parkinson's disease and the use of Falls Diaries to facilitate reporting. *Disability and Rehabilitation*, *30*(16), 1205–1212. https://doi.org/10.1080/09638280701828930

Benecke, R., Rothwell, J. C., Dick, J. P. R., Day, B. L., & Marsden, C. D. (1987). DISTURBANCE OF SEQUENTIAL MOVEMENTS IN PATIENTS WITH PARKINSON'S DISEASE. *Brain*, *110*(2), 361–379. https://doi.org/10.1093/brain/110.2.361

Biundo, R., Weis, L., Pilleri, M., Facchini, S., Formento-Dojot, P., Vallelunga, A., & Antonini, A. (2013). Diagnostic and screening power of neuropsychological testing in detecting mild cognitive impairment in Parkinson's disease. *Journal of Neural Transmission (Vienna, Austria: 1996)*, *120*(4), 627–633. https://doi.org/10.1007/s00702-013-1004-2

Ble, A., Volpato, S., Zuliani, G., Guralnik, J. M., Bandinelli, S., Lauretani, F., Bartali, B., Maraldi, C., Fellin, R., & Ferrucci, L. (2005). Executive Function Correlates with Walking Speed in Older Persons: The InCHIANTI Study. *Journal of the American Geriatrics Society*, *53*(3), 410–415. https://doi.org/10.1111/j.1532-5415.2005.53157.x

Brach, J. S., Berlin, J. E., VanSwearingen, J. M., Newman, A. B., & Studenski, S. A. (2005). Too much or too little step width variability is associated with a fall history in older persons who walk at or near normal gait speed. *Journal of Neuroengineering and Rehabilitation*, *2*, 21. https://doi.org/10.1186/1743-0003-2-21

Brown, M. J. N., & Almeida, Q. J. (2011). Evaluating dopaminergic system contributions to cued pattern switching during bimanual coordination. *European Journal of Neuroscience*, *34*(4), 632–640. https://doi.org/10.1111/j.1460-9568.2011.07773.x

Cheng FY, Yang YR, Wang CJ, Wu YR, Cheng SJ, Wang HC, & Wang RY. (2014). Factors Influencing Turning and Its Relationship with Falls in Individuals with Parkinson's Disease. *PLoS ONE*, *9*(4).

Chong, R. K. Y., Horak, F. B., & Woollacott, M. H. (2000). Parkinson's disease impairs the ability to change set quickly. *Journal of the Neurological Sciences*, *175*(1), 57–70. https://doi.org/10.1016/S0022-510X(00)00277-X

Chopra, P., Castelli, D. M., & Dingwell, J. B. (2018). Cognitively Demanding Object Negotiation While Walking and Texting. *Scientific Reports*, *8*. https://doi.org/10.1038/s41598-018-36230-5

Conradsson, D, Paquette, C, & Franzen, E. (2018). Turning Stability in Individuals With Parkinson Disease | Ovid. *Journal of Neurologic Physical Therapy*, *42*, 241–247.

Conradsson, D., Paquette, C., Lökk, J., & Franzén, E. (2017). Pre- and unplanned walking turns in Parkinson's disease – Effects of dopaminergic medication. *Neuroscience*, *341*, 18–26. https://doi.org/10.1016/j.neuroscience.2016.11.016

Cools, A. R., Bercken, J. H. van den, Horstink, M. W., Spaendonck, K. P. van, & Berger, H. J. (1984). Cognitive and motor shifting aptitude disorder in Parkinson's disease. *Journal of Neurology, Neurosurgery & Psychiatry*, *47*(5), 443–453. https://doi.org/10.1136/jnnp.47.5.443

Cools, R., Barker, R. A., Sahakian, B. J., & Robbins, T. W. (2001a). Enhanced or Impaired Cognitive Function in Parkinson's Disease as a Function of Dopaminergic Medication and Task Demands. *Cerebral Cortex*, *11*(12), 1136–1143. https://doi.org/10.1093/cercor/11.12.1136

Cools, R., Barker, R. A., Sahakian, B. J., & Robbins, T. W. (2001b). Mechanisms of cognitive set flexibility in Parkinson's disease. *Brain*, *124*(12), 2503–2512. https://doi.org/10.1093/brain/124.12.2503

Cummings, S. R., Nevitt, M. C., & the Study of Osteoporotic Fractures Research Group. (1994). Non-skeletal determinants of fractures: the potential importance of the mechanics of falls. *Osteoporosis International*, *4*(1), S67–S70. https://doi.org/10.1007/BF01623439

Dajani, D. R., & Uddin, L. Q. (2015). Demystifying cognitive flexibility: Implications for clinical and developmental neuroscience. *Trends in Neurosciences*, *38*(9), 571–578. https://doi.org/10.1016/j.tins.2015.07.003

Dalrymple-Alford JC, M. M., Nakas CT, L. L., Graham C, Crucian GP, Melzer TR, Kirwan J, Keenan R, Wells S, Porter RJ, Watts R, & Anderson TJ. (2010). The MoCA: Well-suited screen for cognitive impairment in Parkinson disease. *Neurology*, *75*(19). https://n.neurology.org/content/moca-well-suited-screen-cognitive-impairment-parkinson-disease

Davis, J. C., Marra, C. A., Najafzadeh, M., & Liu-Ambrose, T. (2010). The independent contribution of executive functions to health related quality of life in older women. *BMC Geriatrics*, *10*, 16. https://doi.org/10.1186/1471-2318-10-16

de Souza Fortaleza, A. C., Mancini, M., Carlson-Kuhta, P., King, L. A., Nutt, J. G., Chagas, E. F., Freitas, I. F., & Horak, F. B. (2017). Dual task interference on postural sway, postural transitions and gait in people with Parkinson's disease and freezing of gait. *Gait & Posture*, *56*, 76–81. https://doi.org/10.1016/j.gaitpost.2017.05.006

Dirnberger, G., & Jahanshahi, M. (2013). Executive dysfunction in Parkinson's disease: A review. *Journal of Neuropsychology*, *7*(2), 193–224. https://doi.org/10.1111/jnp.12028

Downes, J. J., Roberts, A. C., Sahakian, B. J., Evenden, J. L., Morris, R. G., & Robbins, T. W. (1989). Impaired extra-dimensional shift performance in medicated and unmedicated Parkinson's disease: Evidence for a specific attentional dysfunction. *Neuropsychologia*, *27*(11), 1329–1343. https://doi.org/10.1016/0028-3932(89)90128-0

Elshehabi, M., Maier, K. S., Hasmann, S. E., Nussbaum, S., Herbst, H., Heger, T., Berg, D., Hobert, M. A., & Maetzler, W. (2016). Limited Effect of Dopaminergic Medication on Straight Walking and Turning in Early-to-Moderate Parkinson's Disease during Single and Dual Tasking. *Frontiers in Aging Neuroscience*, *8*. https://doi.org/10.3389/fnagi.2016.00004

Faria, C. de A., Alves, H. V. D., & Charchat-Fichman, H. (2015). The most frequently used tests for assessing executive functions in aging. *Dementia & Neuropsychologia*, *9*(2), 149–155. https://doi.org/10.1590/1980-57642015DN92000009

Feldman, F., & Robinovitch, S. N. (2007). *Reducing hip fracture risk during sideways falls: Evidence in young adults of the protective effects of impact to the hands and stepping*.

Giladi, N., Shabtai, H., Simon, E. S., Biran, S., Tal, J., & Korczyn, A. D. (2000). Construction of freezing of gait questionnaire for patients with Parkinsonism. *Parkinsonism & Related Disorders*, *6*(3), 165–170. https://doi.org/10.1016/S1353-8020(99)00062-0

Giladi, Nir, Tal, J., Azulay, T., Rascol, O., Brooks, D. J., Melamed, E., Oertel, W., Poewe, W. H., Stocchi, F., & Tolosa, E. (2009). Validation of the freezing of gait questionnaire in patients with Parkinson's disease. *Movement Disorders*, *24*(5), 655–661. https://doi.org/10.1002/mds.21745

Gill, T. M., Murphy, T. E., Gahbauer, E. A., & Allore, H. G. (2013). Association of Injurious Falls With Disability Outcomes and Nursing Home Admissions in Community-Living Older Persons. *American Journal of Epidemiology*, *178*(3), 418–425. https://doi.org/10.1093/aje/kws554

Glaister BC, Bernatz GC, Klute GK, & Orendurff MS. (2007). Video task analysis of turning activities of daily living. *Gait & Posture*, *25*, 289–294.

Goldman, J. G., Holden, S., Ouyang, B., Bernard, B., Goetz, C. G., & Stebbins, G. T. (2015). Diagnosing PD-MCI by MDS Task Force criteria: how many and which neuropsychological tests? *Movement Disorders : Official Journal of the Movement Disorder Society*, *30*(3), 402–406. https://doi.org/10.1002/mds.26084

Hausdorff, J. M., Rios, D. A., & Edelberg, H. K. (2001). Gait variability and fall risk in community-living older adults: A 1-year prospective study. *Archives of Physical Medicine and Rehabilitation*, *82*(8), 1050–1056. https://doi.org/10.1053/apmr.2001.24893

Hirota, C., Watanabe, M., Sun, W., Tanimoto, Y., Kono, R., Takasaki, K., & Kono, K. (2010). Association between the Trail Making Test and physical performance in elderly Japanese. *Geriatrics & Gerontology International*, *10*(1), 40–47. https://doi.org/10.1111/j.1447-0594.2009.00557.x

Hobert, M. A., Meyer, S. I., Hasmann, S. E., Metzger, F. G., Suenkel, U., Eschweiler, G. W., Berg, D., & Maetzler, W. (2017). Gait Is Associated with Cognitive Flexibility: A Dual-Tasking Study in Healthy Older People. *Frontiers in Aging Neuroscience*, *9*. https://doi.org/10.3389/fnagi.2017.00154

Hoehn, M. M., & Yahr, Melvin D. (1967). Parkinsonism: onset, progression, and mortality. *Neurology*, *17*(5), 427–442.

Horak, F. B., Nutt, J. G., & Nashner, L. M. (1992). Postural inflexibility in parkinsonian subjects. *Journal of the Neurological Sciences*, *111*(1), 46–58. https://doi.org/10.1016/0022-510X(92)90111-W

Horak, Fay B. (2006). Postural orientation and equilibrium: what do we need to know about neural control of balance to prevent falls? *Age and Ageing*, *35*(suppl_2), ii7–ii11. https://doi.org/10.1093/ageing/afl077

Hulbert, S., Ashburn, A., Robert, L., & Verheyden, G. (2015). A narrative review of turning deficits in people with Parkinson’s disease. *Disability and Rehabilitation*, *37*(15), 1382–1389. https://doi.org/10.3109/09638288.2014.961661

Huxham F, Baker R, Morris ME, & Iansek R. (2008). Footstep adjustments used to turn during walking in Parkinson’s disease - Huxham - 2008 - Movement Disorders - Wiley Online Library. *Movement Disorders*, *23*(6), 817–823.

Institute of Medicine, Edward N Brandt (editor), & Andrew M Pope (editor). (1997). *Enabling America: Assessing the Role of Rehabilitation Science and Engineering*. National Academy Press.

Kalron, A., Dvir, Z., & Achiron, A. (2010). Walking while talking—Difficulties incurred during the initial stages of multiple sclerosis disease process. *Gait & Posture*, *32*(3), 332–335. https://doi.org/10.1016/j.gaitpost.2010.06.002

Killane, I., Donoghue, O. A., Savva, G. M., Cronin, H., Kenny, R. A., & Reilly, R. B. (2014). Relative association of processing speed, short-term memory and sustained attention with task on gait speed: a study of community-dwelling people 50 years and older. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *69*(11), 1407–1414. https://doi.org/10.1093/gerona/glu140

Knobl, P., Kielstra, L., & Almeida, Q. (2012). The relationship between motor planning and freezing of gait in Parkinson's disease. *J Neurol Neurosurg Psychiatry*, *83*(1), 98–101. https://doi.org/10.1136/jnnp-2011-300869

Kourtidou, P., Kasselimis, D., Potagas, C., Zalonis, I., & Evdokimidis, I. (2015). Effects of Mental Flexibility and Motor Dysfunction on Cognitive Performance in Patients With Parkinson's Disease. *Archives of Neuroscience*, *2*(3). https://doi.org/10.5812/archneurosci.21087

Laurie Lundy-Ekman. (2007). Basal Ganglia, Cerebellum, and Movement. In *Neuroscience: Fundamentals for Rehabilitation* (3rd ed., p. Chapter 10). Saunders, an imprpint of Elsevier Inc.

Lezak MD, Howison DB, & Loring DW. (2004). *Neuropsychological Assessment* (4th ed.). Oxford University Press.

Litvan, I., Goldman, J. G., Tröster, A. I., Schmand, B. A., Weintraub, D., Petersen, R. C., Mollenhauer, B., Adler, C. H., Marder, K., Williams-Gray, C. H., Aarsland, D., Kulisevsky, J., Rodriguez-Oroz, M. C., Burn, D. J., Barker, R. A., & Emre, M. (2012). Diagnostic Criteria for Mild Cognitive Impairment in Parkinson's Disease: Movement Disorder Society Task Force Guidelines. *Movement Disorders : Official Journal of the Movement Disorder Society*, *27*(3), 349–356. https://doi.org/10.1002/mds.24893

Logue, S. F., & Gould, T. J. (2014). The Neural and Genetic Basis of Executive Function: Attention, Cognitive Flexibility, and Response Inhibition. *Pharmacology, Biochemistry, and Behavior*, *0*, 45–54. https://doi.org/10.1016/j.pbb.2013.08.007

Lowry, K. A., Brach, J. S., Nebes, R. D., Studenski, S. A., & VanSwearingen, J. M. (2012). Contributions of cognitive function to straight- and curved-path walking in older adults. *Archives of Physical Medicine and Rehabilitation*, *93*(5), 802–807. https://doi.org/10.1016/j.apmr.2011.12.007

Mak, M. K. Y., & Pang, M. Y. C. (2009). Balance confidence and functional mobility are independently associated with falls in people with Parkinson's disease. *Journal of Neurology*, *256*(5), 742–749. https://doi.org/10.1007/s00415-009-5007-8

Maki B.E. (1997). Gait Changes in Older Adults: Predictors of Falls or Indicators of Fear? *Journal of the American Geriatrics Society*, *45*(3), 313–320.

McKay, J. L., Lang, K. C., Ting, L. H., & Hackney, M. E. (2018). Impaired set shifting is associated with previous falls in individuals with and without Parkinson's disease. *Gait & Posture*, *62*, 220–226. https://doi.org/10.1016/j.gaitpost.2018.02.027

McKinlay, A. (2013). A review of cognitive and other non-motor problems in Parkinson's disease. *Aging Health; London*, *9*(1), 89–102. http://dx.doi.org.mutex.gmu.edu/10.2217/ahe.12.84

Montero-Odasso, M., Schapira, M., Soriano, E. R., Varela, M., Kaplan, R., Camera, L. A., & Mayorga, L. M. (2005). Gait velocity as a single predictor of adverse events in healthy seniors aged 75 years and older. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *60*(10), 1304–1309. https://doi.org/10.1093/gerona/60.10.1304

Nakamura, T., Meguro, K., & Sasaki, H. (1996). Relationship between Falls and Stride Length Variability in Senile Dementia of the Alzheimer Type. *Gerontology*, *42*(2), 108–113. https://doi.org/10.1159/000213780

Nasreddine, Z. S., Phillips, N. A., Bédirian, V., Charbonneau, S., Whitehead, V., Collin, I., Cummings, J. L., & Chertkow, H. (2005). The Montreal Cognitive Assessment, MoCA: A Brief Screening Tool For Mild Cognitive Impairment. *Journal of the American Geriatrics Society*, *53*(4), 695–699. https://doi.org/10.1111/j.1532-5415.2005.53221.x

Olchik, M.R., Ghisi, M., Freiry, A.M., Ayres, A., Schuh, A. F. S., Rieder, C. R. d. M., & Teixeira, A. D. (2017). Comparison Trail Making Test between individuals with Parkinson's disease and health controls: Suggestions of cutoff point. *Psychology*

& Neuroscience, *10*(1), 77–82. http://dx.doi.org.mutex.gmu.edu/10.1037/pne0000076

Owen, A. M., James, M., Leigh, P. N., Summers, B. A., Marsden, C. D., Quinn, N. P., Lange, K. W., & Robbins, T. W. (1992). FRONTO-STRIATAL COGNITIVE DEFICITS AT DIFFERENT STAGES OF PARKINSON'S DISEASE. *Brain*, *115*(6), 1727–1751. https://doi.org/10.1093/brain/115.6.1727

Parkinson's Foundation. (2017, October 13). *Understanding Parkinson's: Statistics*. Parkinson's Foundation. http://www.parkinson.org/Understanding-Parkinsons/Causes-and-Statistics/Statistics

Peterson, D. S., & Horak, F. B. (2016). Neural Control of Walking in People with Parkinsonism. *Physiology*, *31*(2), 95–107. https://doi.org/10.1152/physiol.00034.2015

Plummer-D'Amato, P., Altmann, L. J. P., Saracino, D., Fox, E., Behrman, A. L., & Marsiske, M. (2008). Interactions between cognitive tasks and gait after stroke: A dual task study. *Gait & Posture*, *27*(4), 683–688. https://doi.org/10.1016/j.gaitpost.2007.09.001

Pollock AS, Durward BR, Rowe PJ, & Paul JP. (2000). What is balance? *Clinical Rehabilitation*, *14*, 402–406.

Powell, L. E., & Myers, A. M. (1995). The Activities-specific Balance Confidence (ABC) Scale. *The Journals of Gerontology. Series A, Biological Sciences and Medical Sciences*, *50A*(1), M28-34. https://doi.org/10.1093/gerona/50a.1.m28

ProtoKinetics Movement Analysis (Version 5.08C1). (2013). [The Zeno Electronic Walkway Device: Platinum]. ZenoMetrics, LLC; ProtoKinetics, LLC.

Ravizza, S. M., & Carter, C. S. (2008). Shifting set about task switching: Behavioral and neural evidence for distinct forms of cognitive flexibility. *Neuropsychologia*, *46*(12), 2924–2935. https://doi.org/10.1016/j.neuropsychologia.2008.06.006

Robertson, C., & Flowers, K. A. (1990). Motor set in Parkinson's disease. *Journal of Neurology, Neurosurgery & Psychiatry*, *53*(7), 583–592. https://doi.org/10.1136/jnnp.53.7.583

Sawada, Y., Nishio, Y., Suzuki, K., Hirayama, K., Takeda, A., Hosokai, Y., Ishioka, T., Itoyama, Y., Takahashi, S., Fukuda, H., & Mori, E. (2012). Attentional Set-Shifting Deficit in Parkinson's Disease Is Associated with Prefrontal Dysfunction: An FDG-PET Study. *PLOS ONE*, *7*(6), e38498. https://doi.org/10.1371/journal.pone.0038498

Schaafsma, J. D., Giladi, N., Balash, Y., Bartels, A. L., Gurevich, T., & Hausdorff, J. M. (2003). Gait dynamics in Parkinson's disease: relationship to Parkinsonian features, falls and response to levodopa. *Journal of the Neurological Sciences*, *212*(1), 47–53. https://doi.org/10.1016/S0022-510X(03)00104-7

Scott, W. A. (1962). Cognitive Complexity and Cognitive Flexibility. *Sociometry*, *25*(4), 405–414.

Sheridan, P. L., & Hausdorff, J. M. (2007). The role of higher-level cognitive function in gait: executive dysfunction contributes to fall risk in Alzheimer's disease.

Dementia and Geriatric Cognitive Disorders, *24*(2), 125–137. https://doi.org/10.1159/000105126

Shumway-Cook A, & Woollacott MH. (2000). Attentional demands and postural control: the effect of sensorycontext. *The Journals of Gerontology: Series A*, *55*(1), M10–M16. https://doi.org/10.1093/gerona/55.1.M10

Smulders, K., Esselink, R. A., Bloem, B. R., & Cools, R. (2015). Freezing of gait in Parkinson's disease is related to impaired motor switching during stepping. *Movement Disorders*, *30*(8), 1090–1097. https://doi.org/10.1002/mds.26133

Spildooren, J., Vercruysse, S., Desloovere, K., Vandenberghe, W., Kerckhofs, E., & Nieuwboer, A. (2010). Freezing of gait in Parkinson's disease: The impact of dual-tasking and turning. *Movement Disorders*, *25*(15), 2563–2570. https://doi.org/10.1002/mds.23327

Stack, E., & Ashburn, A. (1999). Fall events described by people with Parkinson's disease: implications for clinical interviewing and the research agenda. *Physiotherapy Research International*, *4*(3), 190–200. https://doi.org/10.1002/pri.165

Stack, E. L., Ashburn, A. M., & Jupp, K. E. (2006). Strategies used by people with Parkinson's disease who report difficulty turning. *Parkinsonism & Related Disorders*, *12*(2), 87–92. https://doi.org/10.1016/j.parkreldis.2005.08.008

Stuart, S., Galna, B., Delicato, L. S., Lord, S., & Rochester, L. (2017). Direct and indirect effects of attention and visual function on gait impairment in Parkinson's disease:

influence of task and turning. *European Journal of Neuroscience*, *46*(1), 1703–1716. https://doi.org/10.1111/ejn.13589

Stuart Samuel, Galna Brook, Delicato Louise S., Lord Sue, Rochester Lynn, & Foxe John. (2017). Direct and indirect effects of attention and visual function on gait impairment in Parkinson's disease: influence of task and turning. *European Journal of Neuroscience*, *46*(1), 1703–1716. https://doi.org/10.1111/ejn.13589

Stylianou, A. P., McVey, M. A., Lyons, K. E., Pahwa, R., & Luchies, C. W. (2011). Postural sway in patients with mild to moderate Parkinson's disease. *The International Journal Of Neuroscience*, *121*(11), 614–621. https://doi.org/10.3109/00207454.2011.602807

Thigpen, M. T., Light, K. E., Creel, G. L., & Flynn, S. M. (2000). Turning difficulty characteristics of adults aged 65 years or older. *Physical Therapy*, *80*(12), 1174–1187.

Van Uem, J. M. T., Walgaard, S., Ainsworth, E., Hasmann, S. E., Heger, T., Nussbaum, S., Hobert, M. A., Micó-Amigo, E. M., Van Lummel, R. C., Berg, D., & Maetzler, W. (2016). Quantitative Timed-Up-and-Go Parameters in Relation to Cognitive Parameters and Health-Related Quality of Life in Mild-to-Moderate Parkinson's Disease. *PLoS ONE*, *11*(4). https://doi.org/10.1371/journal.pone.0151997

Woollacott, M., & Shumway-Cook, A. (2002). Attention and the control of posture and gait: a review of an emerging area of research. *Gait & Posture*, *16*(1), 1–14. https://doi.org/10.1016/S0966-6362(01)00156-4

Yogev, G., Giladi, N., Peretz, C., Springer, S., Simon, E. S., & Hausdorff, J. M. (2005). Dual tasking, gait rhythmicity, and Parkinson's disease: Which aspects of gait are attention demanding? *European Journal of Neuroscience*, *22*(5), 1248–1256. https://doi.org/10.1111/j.1460-9568.2005.04298.x

Yogev, G., Hausdorff, J. M., & Giladi, N. (2008). The Role of Executive Function and Attention in Gait. *Movement Disorders : Official Journal of the Movement Disorder Society*, *23*(3), 329–472. https://doi.org/10.1002/mds.21720

Yogev□Seligmann, G., Hausdorff, J. M., & Giladi, N. (2012). Do we always prioritize balance when walking? Towards an integrated model of task prioritization. *Movement Disorders*, *27*(6), 765–770. https://doi.org/10.1002/mds.24963

BIOGRAPHY

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