DUAL TASK EFFECTS ON LANGUAGE PRODUCTION IN SENTENCE AND DISCOURSE CONTEXTS IN PARKINSON'S DISEASE

By

JONATHAN PAUL WILSON

A DISSERTATION PRESENTED TO THE GRADUATE SCHOOL OF THE UNIVERSITY OF FLORIDA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE OF DOCTOR OF PHILOSOPHY

UNIVERSITY OF FLORIDA

2013
To my family for their support and encouragement
ACKNOWLEDGMENTS

I thank the chair and members of my supervisory committee for their careful mentoring, Dr. Chris Hass for project design, analysis and recruitment, the staff and members at the UF Libraries for their informed and professional research assistance, the participants in my projects for their honest and open participation, the student members of the Language Over the Lifespan lab for their invaluable assistance with coding and transcription, and the National Institute of Health for its generous support. In particular, I thank my colleagues, Audrey Hazamy and Dr. Elizabeth Stegemöller for their invaluable contribution to recruitment, testing, analysis, student supervision and coding. I also thank my parents and Kostas for their loving encouragement, which motivated me to complete my program of study.
# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACKNOWLEDGMENTS</td>
<td>4</td>
</tr>
<tr>
<td>LIST OF TABLES</td>
<td>8</td>
</tr>
<tr>
<td>LIST OF FIGURES</td>
<td>9</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>10</td>
</tr>
<tr>
<td>CHAPTER</td>
<td></td>
</tr>
<tr>
<td>1 INTRODUCTORY OVERVIEW</td>
<td>12</td>
</tr>
<tr>
<td>2 LITERATURE REVIEW</td>
<td>16</td>
</tr>
<tr>
<td>Physical Effects in Parkinson’s disease</td>
<td>16</td>
</tr>
<tr>
<td>Cognition in Parkinson’s disease</td>
<td>20</td>
</tr>
<tr>
<td>Attention Allocation</td>
<td>23</td>
</tr>
<tr>
<td>Effects of Healthy Aging</td>
<td>24</td>
</tr>
<tr>
<td>Effects of Parkinson’s Disease</td>
<td>26</td>
</tr>
<tr>
<td>Language Production in Parkinson’s disease</td>
<td>31</td>
</tr>
<tr>
<td>General Summary</td>
<td>40</td>
</tr>
<tr>
<td>3 METHODS</td>
<td>46</td>
</tr>
<tr>
<td>Overview</td>
<td>46</td>
</tr>
<tr>
<td>Participants</td>
<td>47</td>
</tr>
<tr>
<td>Cognitive Assessments</td>
<td>48</td>
</tr>
<tr>
<td>Experimental Tasks</td>
<td>51</td>
</tr>
<tr>
<td>General Procedure</td>
<td>51</td>
</tr>
<tr>
<td>Task 1: Picture Description Experiment</td>
<td>56</td>
</tr>
<tr>
<td>Materials</td>
<td>56</td>
</tr>
<tr>
<td>Procedure</td>
<td>56</td>
</tr>
<tr>
<td>Scoring</td>
<td>57</td>
</tr>
<tr>
<td>Task 2: Discourse Production Experiment</td>
<td>57</td>
</tr>
<tr>
<td>Materials</td>
<td>57</td>
</tr>
<tr>
<td>Procedure</td>
<td>58</td>
</tr>
<tr>
<td>Scoring</td>
<td>58</td>
</tr>
<tr>
<td>Design and Analyses</td>
<td>60</td>
</tr>
<tr>
<td>4 RESULTS</td>
<td>64</td>
</tr>
<tr>
<td>Sentence Production</td>
<td>64</td>
</tr>
<tr>
<td>Quantitative Measures</td>
<td>64</td>
</tr>
<tr>
<td>Overall word count</td>
<td>64</td>
</tr>
</tbody>
</table>
Sentence length......................................................................................... 64
Number and proportion of nouns ............................................................ 65
Number and proportion of verbs .............................................................. 65
Number and proportion of adjectives ....................................................... 66
Number and proportion of pronouns ....................................................... 67
Number of verbs per sentence................................................................. 67
Number of prepositions ........................................................................... 68
Number of words before main verb ......................................................... 68
Number of modifiers for each noun phrase ............................................. 68
Summary..................................................................................................... 68
Qualitative Measures ............................................................................... 69
Propositional density ................................................................................ 69
Concreteness and word frequency ........................................................... 69
Syntactic complexity .............................................................................. 69
Type-token ratio ...................................................................................... 70
Action Verb Content ............................................................................... 70
Content word hypernymy ....................................................................... 71
Information completeness ....................................................................... 71
Grammaticality ......................................................................................... 72
Summary..................................................................................................... 72
Discourse Production .............................................................................. 73
Quantitative Measures ........................................................................... 73
Overall word count .................................................................................. 73
Sentence length ....................................................................................... 73
Number and proportion of nouns ............................................................ 74
Number and proportion of verbs .............................................................. 74
Number and proportion of adjectives ....................................................... 75
Number and proportion of pronouns ....................................................... 75
Number of verbs per sentence................................................................. 76
Number of prepositions ........................................................................... 76
Number of words before main verb ......................................................... 76
Number of modifiers for each noun phrase ............................................. 76
Summary..................................................................................................... 76
Qualitative Measures ............................................................................... 77
Propositional density ................................................................................ 77
Concreteness and imageability ................................................................. 77
Syntactic complexity .............................................................................. 78
Type-token ratio ...................................................................................... 78
Verb frequency ........................................................................................ 78
Action Verb Content ............................................................................... 78
Content word hypernymy ....................................................................... 79
Cohesion ................................................................................................... 79
Coherence ................................................................................................ 80
Summary..................................................................................................... 80
Regression Analyses for Sentence Production ........................................ 81
Quantitative Measures ........................................................................... 81
Qualitative Measures
Regression Analyses for Discourse Production
Quantitative Measures

5 DISCUSSION

Lexical Selection
Information Integration
Information Monitoring
Implications
Future Directions
Conclusion

APPENDIX

A PARTICIPANT WITH PARKINSON’S DISEASE DISCOURSE SAMPLE
B HEALTHY OLDER ADULT CONTROL DISCOURSE SAMPLE
LIST OF REFERENCES
BIOGRAPHICAL SKETCH
<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>page</th>
</tr>
</thead>
<tbody>
<tr>
<td>3-1</td>
<td>Rotated solution for factor analysis</td>
<td>61</td>
</tr>
<tr>
<td>3-2</td>
<td>Dependent variables collected in language tasks</td>
<td>62</td>
</tr>
<tr>
<td>4-1</td>
<td>Simple effects &amp; interaction for quantity measures of sentence production</td>
<td>92</td>
</tr>
<tr>
<td>4-2</td>
<td>Simple effects &amp; interaction for quality measures of sentence production</td>
<td>92</td>
</tr>
<tr>
<td>4-3</td>
<td>Simple effects &amp; interaction for quantity measures of discourse</td>
<td>93</td>
</tr>
<tr>
<td>4-4</td>
<td>Simple effects &amp; interaction for quality measures of discourse</td>
<td>93</td>
</tr>
<tr>
<td>4-5</td>
<td>Predictors for effects (p=&lt;.055) of quantity measures of sentence production</td>
<td>94</td>
</tr>
<tr>
<td>4-6</td>
<td>Predictors for effects (p=&lt;.055) of quality measures of sentence production</td>
<td>94</td>
</tr>
<tr>
<td>4-7</td>
<td>Predictors for effects (p=&lt;.055) of quantity measures for discourse</td>
<td>95</td>
</tr>
<tr>
<td>4-8</td>
<td>Predictors for effects (p=&lt;.055) of quality measures of discourse</td>
<td>96</td>
</tr>
<tr>
<td>Figure</td>
<td>Description</td>
<td>Page</td>
</tr>
<tr>
<td>--------</td>
<td>-----------------------------------------------------------------------------</td>
<td>------</td>
</tr>
<tr>
<td>3-1</td>
<td>Sample stimuli used in the 0-Back task.</td>
<td>63</td>
</tr>
<tr>
<td>4-1</td>
<td>Task by Group interaction for use of passive verbs in sentence production</td>
<td>97</td>
</tr>
<tr>
<td>4-2</td>
<td>Task by Group interaction for use of participle verbs in sentence production</td>
<td>97</td>
</tr>
<tr>
<td>4-3</td>
<td>Task by Group interaction for completeness during sentence production</td>
<td>98</td>
</tr>
<tr>
<td>4-4</td>
<td>Task by Group by Complexity for grammaticality during sentence production</td>
<td>98</td>
</tr>
<tr>
<td>4-5</td>
<td>Task by Group interaction for local coherence during discourse</td>
<td>99</td>
</tr>
</tbody>
</table>
Language production is impaired in people with Parkinson’s disease (PPD), although controversy exists over which aspects of language are affected. The language impairments in PPD are attributed to disease related changes within prefrontal cortex. This study investigated language production during sentence production and discourse during single and dual task (stationery cycling) conditions.

Each participant (40 people with Parkinson’s disease and 19 controls) completed a battery of cognitive tasks and two language tasks while riding a stationary exercise bicycle and again as a single task. Participants described simple and complex picture events using single sentences and, in a separate task, provided three minutes of discourse. We predicted that both the quality and quantity of language production would be impaired in PPD, and that cognitive factors, including executive function, working memory capacity and slower general processing speed would account for group differences.

While the sentence production task revealed evidence of dual task effects, the discourse task was more sensitive in highlighting language impairments in PPD. More
diverse and concrete nouns were produced in both language tasks under dual task conditions. Nouns became less specific and more imageable for PPD during discourse. The number of action verbs also increased in both production tasks during the dual task for both groups. Syntactic complexity differences between groups were evident in both language tasks. PPD used shorter less complex sentences during sentence production and discourse, and also conveyed less propositional information during discourse. Differences in processing speed and information updating successfully predicted group differences in language performance in both tasks. In conclusion, discourse is affected by Parkinson’s disease on multiple levels affecting syntactic and information complexity due to poorer executive function and slower processing speed and word choice is relatively well preserved. Independent direct effects of Parkinson’s disease on aspects of language production were also observed. Finally, language elicitation tasks are differently sensitive to dual task effects with greater dual task effects observed during a highly constrained language production task.
CHAPTER 1
INTRODUCTORY OVERVIEW

Parkinson disease is a highly prevalent neurodegenerative movement disorder whose motor characteristics are well described. Disease pathogenesis is associated with slow deterioration of nigro-striatal pathways limiting dopamine production and leading to cardinal motor symptoms; tremor, rigidity and bradykinesia. Mild cognitive symptoms often appear early in the disease course associated with reduced dopamine uptake within prefrontal cortex. Cognitive characteristics include early executive, and working memory impairments and bradyphrenia. In contrast, while motor speech and language comprehension deficits are well documented, less is known about how cognitive and task demands support language production in this clinical population. Similarly, the effects of a dual motor task on language production in PPD are unknown. The dual task literature however, would predict that language production should suffer due to divided processing resources between the two tasks. However, activation of motor cortices may actually facilitate / improve some aspects of language use (Rodriguez, 2010) due to the association of areas of somatotopic motor cortex with action word production.

In this explorative investigation, PPD were contrasted with a healthy control population. Both groups completed a battery of twelve cognitive tasks and two language production tasks, single sentence picture description (with 20 trials per session), and extended discourse production (for 3-minutes). Participants completed both tasks as a single task and as a dual task (i.e. while concurrently riding on a stationery exercise bicycle at a self-selected rate) on separate dates. The order of tasks within sessions was fixed while session order (i.e. single or dual task first) was
counterbalanced. Production responses were transcribed for off-line coding. Picture descriptions were then manually coded for information completeness and grammaticality, and online software was used to code for quantitative and qualitative characteristics of language production for each participant and in each task.

The first aim of this study was to determine whether people with Parkinson’s disease were impaired in quantitative characteristics of language production during two types of language production tasks during simple and dual task conditions. A second aim was to determine whether these individuals were also impaired in qualitative characteristics of language production during the same tasks and conditions. A final aim was to determine the extent to which a range of cognitive measures accounted for group level differences in language production.

A general prediction was that, due to the condition of motor cortex in people with Parkinson’s disease, both sentence production and discourse production would be impaired in both the qualitative and quantitative aspects of sentence and discourse production. In particular, it was predicted that action verbs would be most impaired and that people with Parkinson’s disease would compensate by using a greater number of other word types. Additionally, it was predicted that critical aspects of language production would improve both quantitatively and qualitatively in the group of individuals with Parkinson’s disease under dual conditions. Specifically, it was predicted that the cycling dual task would facilitate production of action verbs due to priming of motor cortex by the cycling task. Finally, it was predicted that most group level differences would be attributable to individual differences in cognition.
The cycling dual task had broader effects on picture description for both groups than expected, while the discourse production task was more sensitive in highlighting group level differences. We attribute these different patterns to cueing effects. The picture description provides external cues for high frequency words and actions, while discourse production requires extended internal cueing, a documented deficit in people with Parkinson’s disease (Brown & Marsden, 1987), to maintain acceptable levels of topic coherence and cohesion. In contrast, picture description is a more constrained behavior and entails further attentional demands relative to discourse production leading to dual task effects.

There was some quantitative evidence that people with Parkinson’s disease used fewer verbs than controls in both tasks. Additionally, people with Parkinson’s disease also used fewer adjectives and pronouns than controls in both tasks and conditions. People with Parkinson’s disease also produced fewer plural nouns and more proper nouns during discourse. Noun use also increased for both groups under dual task conditions, but did not differ between tasks, while overall word counts were lower in the dual task. These findings indicate pervasive lexical effects in Parkinson’s disease with relative preservation of noun use. Finally, while the cycling dual-task increased the production of action verbs, as predicted, this effect was not greater for people with Parkinson’s disease than controls in either task. Thus, the dual task improved aspects of verb production and noun production in both groups.

As predicted, the quality of responses was also affected by Parkinson’s disease. Group effects were most prevalent in discourse production and were associated with a simplified syntax which conveyed less propositional content with impaired information
structure (e.g., coherence and cohesion). By contrast, dual task effects were most prevalent in the sentence production task, in which participants used fewer words overall, produced shorter less complex sentences containing fewer verbs per sentence, and produced fewer passive sentences. Contrary to predictions, the dual task did not improve these qualitative characteristics and had mixed effects on other quantitative and qualitative measures of production for both groups. For example, in dual task conditions sentence lengths and syntactic complexity decreased as words became less frequent during sentence production, while lexical diversity tended to decrease in both tasks, and the specificity of verbs increased but only during discourse.

Finally, as predicted, both quantitative and qualitative measures in both picture description and discourse production tasks were sensitive to differences in cognitive impairment, particularly processing speed and poorer information updating. However, unexpectedly group level differences in a number of measures of syntactic complexity, information completeness during picture description and aspects of cohesion and coherence during discourse production were impervious to cognitive factors and were exclusively predicted by group membership. The implications of these findings will be discussed in detail.
CHAPTER 2
LITERATURE REVIEW

Physical Effects in Parkinson’s disease

Parkinson’s disease (PD) in sporadic form is a highly prevalent neurodegenerative illness of idiopathic origin associated with slow deterioration of the substantia nigra pars compacta and chronic depletion of dopamine production levels in the brain affecting the nigro-striatal system (Bartels and Leenders, 2009). Prevalence is reported at between 0.5 to 1% of people between the ages 65 to 69, rising to 1 to 3% among people 80 years of age and older (Nussbaum, R.L., Ellis, C.E., 2003) and incidence is 13.4 per 100,000 persons (Stephen K. Van Den Eeden, S.K, Tanner, C.M., Bernstein, A.L., Fross, R.D., Leimpeter, A., Bloch, D.A., Nelson, L.M., 2003). While pathogenesis is primarily associated with advanced years at onset, cases of young onset Parkinson’s disease are often highlighted (Mayeux, Denaro, Hemenegildo, Marder, Tang, Cote & Stern, 1992). During initial clinical presentation, cardinal symptoms, bradykinesia, rigidity and tremor at rest often present asymmetrically (Braak, Tredici, de Vos, Jansen Steur, & Braak, 2003; Bartels et al., 2009) and motor symptoms appear to respond well to dopaminergic therapies, a differential characteristic (Braak, Tredici, de Vos, Jansen Steur, & Braak, 2003). Bradykinesia describes slowing of voluntary movement (Berardelli, Rothwell, Thompson, & Hallett, 2001), rigidity is defined as increased passive resistance to stretch movement (Berardelli, Sabra, & Hallett, 1983), and tremor refers to involuntary extraneous movement at rest (Carr, 2001). Other physical features associated with PD include slowed initiation of movements (Warabi, Fukushima, Olley, Chiba, & Yanagisawa, 2011) and failing motor automaticity (Wu and Hallett, 2005).
The subcortical basis for these physical impairments appears to be deterioration of the substantia nigra due to Lewy body pathology (Bartels et al., 2009). Healthy dopamine regulation along nigro-striatal pathways becomes disrupted due to the disease process leading to volumetric reductions of the striatum (caudate nucleus and putamen). PD is also shown to be associated with thalamic dysregulation which increases longitudinally with disease duration (Peran, Cherubini et al., 2010; Strupp, 2010). Dopaminergic therapies which aim to restore dopamine levels have palliative effects on the motor system at early stages, and the effectiveness of such treatments for movement disorders diminishes late in the disease course (Marsden, & Parkes, 1977; Rascol, Payoux, Ory, & Ferreira, 2003). In particular, there is evidence that dopaminergic restriction appears to affect functioning of the nigro-striatal system sub-regionally accounting for the prominence of motor symptoms early in the disease course. For example, longitudinal studies in PD and healthy adults using positron emission tomography (PET) indicate that posterior striatal structures (posterior putamen) are more vulnerable to dopamine depletion than anterior structures (anterior putamen and head of the caudate nucleus) (Strupp, 2010; Jueptner, Firth, Brooks, Frackowiak, & Passingham, 1996; Lehericy, van der Moorete et al., 1998; Lehericy, Ducros, Van De Moorete, Francois, Thivard, Poupon, . . Kim, 2004).

An influential theory of basal ganglia function asserts that deterioration of subcortical nuclei is associated with white matter degeneration of cortico-striato-pallidal-thalamocortical circuits which impair cortically mediated functions regionally (Crosson, 1999, Alexander, DeLong, & Strick, 1986). In particular, it is asserted that sub-cortical nuclei are connected to regions of motor, oculomotor, dorsolateral prefrontal, lateral
orbitofrontal and anterior cingulate cortex along functionally and anatomically segregated white matter tracts (Alexander, DeLong, & Strick, 1986). Specifically, with respect to motor symptoms, deterioration of the putamen due to reduced levels of dopamine uptake leads to deleterious cortical effects primarily involving pre-motor, supplementary motor and dorsolateral pre-frontal cortex. Further, fMRI data indicate that physical impairments in people with Parkinson’s disease (PPD) are associated with a pattern of reduced activation of primary motor cortex together with reduced activation of supplementary motor planning cortex according to disease severity and staging (Tessa, Lucetti, Diciotti, Paoli, Cecchi et al., 2011). The pathophysiological basis of motor control impairments is at present unclear. However an influential theory is that motor impairment in PD reflects the condition of prefrontal cortex (Rodriguez-Oroz et al., 2009; Middleton et al., 2002). In particular, it is asserted that functioning of the pre-motor, supplementary motor, and dorsolateral prefrontal cortex are hypoactive in PD due to denervation (of the striatum) affecting cortico-striato-pallidal-thalamocortical control circuits (Rodriguez-Oroz et al., 2009; Middleton et al., 2002). In support, a number of imaging studies of healthy controls and PPD have shown that both the caudate nucleus and the dorsolateral prefrontal cortex are preferentially activated during the performance of executive tests requiring endogenous generation of novel cognitive sets (category fluency) (Grahn, Parkinson, & Owen, 2008; Monchi, Petrides, Meja-Constain, & Starfella, 2007). It is hypothesized that the caudate nucleus and dorsolateral prefrontal cortex modulate cognitive control while the putamen and supplementary motor cortex modulate habituated stimulus-response learning (Grahn et al., 2008). An alternative account is proposed by Nishio and colleagues (2010) and by
Watson and colleagues (2010) who present imaging data that prefrontal cortical volumes are pathologically reduced early in the disease process and posit that motor impairments in PD are thus due to underlying cortical impairments rather than due to an underlying disconnection syndrome.

Empirical evidence also suggests that the difficulty of the motor task can influence performance when it is used in a dual (or concurrent) task. It is self-evident that some motor tasks, like walking, are more difficult than others and require more planning before movement is initiated (Shumway-Cook, Guralnik, Phillips … Ferrucci, 2007). Thus, simpler motor tasks, such as cycling, tend to be initiated faster than more complex motor tasks. With a rhythmic task like cycling, planning demands are low because the same movements are repeated. Furthermore, the motion of one leg pushing a pedal will cue the timing and magnitude of the movement of the other leg. In effect, in cycling the same areas of motor planning cortex are activating at a fixed interval, priming the cortex and releasing motor plans to primary motor cortex. In PPD the problem is slow initiation of movements which may potentially be reversed by support characteristics of the cycling task.

In support, case series and survey evidence has been presented by Snijders and colleagues (2011; 2010) showing that cycling behaviors are strikingly better preserved than walking in a group of individuals with PD, a phenomena which may be related to kinesia paradoxica, a phenomena in which normal motor function is restored due to exogenous sensorimotor cueing (Snijders et al., 2011). With specific reference to this dissertation, I therefore hypothesize that a cycling task will have beneficial effects on motor control in PPD and will generalize to language performance during dual (multi-
tasking) conditions by increasing the stability of motor performance and by reducing concurrent planning demands compared to for example walking.

**Cognition in Parkinson’s disease**

Investigations into cognitively impaired populations and healthy aging describe language production as a complex behavior supported by limited cognitive resources including attention, executive function, working memory and processing speed (Thornton & Light, 2006; Altmann, & Troche, 2011; Ullman, Corkin, Coppola, Hickok, Growdon, Koroshetz, & Pinker, 1997; Ullman, 2004). Critically, some aspects of cognition are subtly impaired even at early stages of PD over and above effects associated with healthy aging while cognitive effects on language production have not yet been fully described. A further interest, directly relevant to the current dissertation is the putative relationship between planning of actions and cognitive control, tested under dual task conditions. I hypothesize that the proximal cause of degraded dual task performance impairment in PPD is the cortical and subcortical degeneration associated with PD. In support, dual-task studies in healthy adults suggest that both tasks compete for limited cognitive resources, and show that interference effects between tasks are further exaggerated by PD (Marchese, Bove, & Abbruzzese, 2003; Oliveira, Gurd, Nixon, Marshall, & Passingham, 1998, O’Shea, Morris, & Iansek, 2002). Thus, cognitive performance in PD is of direct relevance to this dissertation since language production appears moderated by both cognition and action planning in PD, and the potential interactions of these tasks remain largely unreported.

While motor symptoms tend to characterize initial clinical presentation, cognitive deficits in PD are often reported without clear evidence of dementia or even mild cognitive impairment (Watson and Leverenz, 2010; Nishio, Hirayama, Takeda et al.,
Indeed, it is estimated that cognitive deficits in early stage PD are present in up to 40% of PPD (Rodriguez-Oroz, Jahanshahai, Krack, Litvan, Macias, Bezard, & Obeso, 2009; Aarsland, Andersen, Larsen, Lolk, & Kragh-Sorensen, 2003; Aarsland et al., 2004; Cahn et al., 1998; Cummings, 1988; Pirozzolo, Hansch, Mortimer, Webster, & Kuskowski, 1982b). For example, at early clinical stages, executive function, memory and visuoperceptual deficits have often been observed (Watson et al., 2010) including evidence of bradyphrenia, defined as generalized psychomotor slowing (Rogers, Lees, Smith, Trimble, & Stern, 1986, 1987). As the disease progresses, the effects and degree of cognitive impairments increases and many PPD convert to dementia late in the disease course due to an emergent cortical pathology (Aarsland, Andersen, Larsen, Lolk, Nielsen & Kragh-Sorensen, 2001).

Reported cognitive impairments in this population include specific deficits in planning behaviors, problem-solving abilities, difficulty with categorizing and clustering information into meaningful semantic sets, as well as problems with set-shifting, inhibition, visuospatial processing and more globally with aspects of attention processing (Rodriguez-Oroz et al., 2009; Altgassen, Phillips, Kopp, & Kliegel, 2007; Koerts, Leenders, & Brouwer, 2009; Muslimovic, Post, Speelman, & Schmand, 2005; Cooper et al., 2009; Uc et al., 2005). Thus, tasks which require active manipulation of domain general information including shifting of cognitive sets, rather than serial updating or simple recall, are most impaired in PPD (Altgassen et al., 2007; Bublak, Muller, Gron, Reuter, & von Cramon, 2002; Hoppe, Mueller, Werheid, Thoene, & von Cramon, 2000; Muslimovic et al., 2005; Werheid et al., 2002). For example, Altgassen and colleagues (2007) observed no impairments in immediate, verbatim verbal or visual
memory tasks in PPD but revealed impairments in more complex cognitive behaviors involving storage, updating and set-shifting. Similarly, storage and updating problems were also evident during digit and word ordering tasks across a number of studies examining cognitive performance in PPD (Hoppe et al., 2000; Richards, Cote, & Stern, 1993; Werheid et al., 2002). Muslimovic and colleagues (2005) have also reported that individuals with PD were most impaired in tasks assessing either attention or executive function, and that over 60% of PPD were impaired in tasks assessing psychomotor speed and/or controlled processing. Thus, the basis for these cognitive impairments in PD appear to be due to hypometabolism in areas of pre-frontal cortex involved in cognitive control (dorsolateral pre-frontal cortex) as outlined above.

The implications for the current dissertation are that tasks requiring executive control processes and processing speed are impaired in people with PD. In contrast, it appears that immediate verbatim recall is relatively well preserved. The practical significance for this dissertation is that short-term memory tasks which include storage, updating and set-shifting processes, such as the N-Back task, will be impaired in PD, potentially due to recruitment of dorsolateral prefrontal cortex which is hypoactive in PPD. It is also suggested that activation of prefrontal cortex (involved in cognitive control and planning behaviors) will interact with motor planning cortex under dual task conditions, and that the direction and magnitude of such effects is determined by the complexity of the concurrent motor task. Consequently, it is predicted that aspects of language production will be impaired in PD due to reduced cognitive capacity. In particular, that constrained sentence production will be slower and less accurate with respect to information content relative to healthy older adults (HOA) performance, due
to increased planning demands requiring executive control and set-shifting under timed constraints. I further predict that discourse production will be impaired in PD due to psychomotor slowing and the reduced ability to incorporate new information into an organized grammatical and semantic message structure requiring high levels of cognitive control and memory updating to maintain structural cohesion, information complexity, and topic coherence.

**Attention Allocation**

The relevance of attention allocation for PPD is that language production in everyday life does not always occur as a single task. People commonly are expected to communicate while engaged in complex concurrent sensorimotor tasks like walking, shopping, or driving. People are required to allocate attention or other domain general resources dynamically according to contextual circumstances to maintain performance levels on both tasks. As will be reviewed below, evidence suggests that multi-tasking or dual-tasking becomes increasingly difficult for people with PD and older adults. However, it is currently unknown how language production is affected in PD relative to HOA when a motor task and a language production task are performed concurrently.

A widely accepted theory of dual-task effects is the capacity sharing model (Pasher, 1994; Yogev-Seligmann, Hausdorff, & Giladi, 2008) which asserts that interference or task slowing due to changes in attention allocation occurs when cognitive and motor tasks compete for planning resources. Of particular relevance to this project is the question whether documented cognitive and motor planning problems in people with PD interact at a resource level impairing sentence and discourse levels of language performance.
Effects of Healthy Aging

Experimental evidence suggests that dual-task interference between cognitive and motor tasks (for example walking) increases with normal aging (Kemper et al., 2006; Li, Lindenberger, Freund, & Baltes, 2001) and according to the degree of cognitive differences (Holtzer, Burright, & Donovick, 2004). In general however, healthy adults tend to balance task priorities well during dual tasks and allocate resources dynamically to accommodate a more attention demanding task. In particular, dual-task studies which have investigated effects of aging on walking speed, such as the study by Shumway-Cook and colleagues (2007), report that as the difficulty of the concurrent distractor task increases (walking around obstacles, walking with weights, walking and talking) dual-task effects in older adults (over 65 years) increase, leading to slower walking speed, in contrast to younger controls. A further study by Plummer-D’Amato and colleagues (2011) also reports increased dual task interference in older adults (slower gait speed) during concurrent cognitive tasks (an auditory Stroop task and a speech task) compared to younger controls.

However, there is evidence that effects of a motor dual-task on language production in older adults may be prioritized differently by healthy older adults. In particular, it is hypothesized that during concurrent language production younger and older speakers can accommodate to dual task demands in many different ways. In particular, Kemper and colleagues (2003) demonstrated during concurrent walking, finger tapping and ignoring distracting auditory stimuli that younger adults’ speech production was more affected by dual-task conditions than older adults, affecting sentence length and the grammatical complexity of sentences produced. However, a follow up study by the same group in 2005, indicated that older adults allocate cognitive resources differently.
resources differently from younger adults. In particular, the researchers showed that there were baseline differences in grammatical complexity and that as the difficulty of the motor tasks increased (walking, walking with weights, walking and climbing steps) young adults produced simplified sentences, while older adults, who were already using simpler sentences, became less fluent.

More typical dual task effects have also been demonstrated with respect to interference from language tasks on motor performance for both young and older healthy adults. In particular, performing language and motor tasks simultaneously can lead to bidirectional interactions, as reported by Kemper and colleagues (2005) (discourse production while walking or finger tapping). In a further study by Kemper, Schmalzried, Hoffman, & Herman (2010) using a digital pursuit rotor task it was reported that when the complexity of the motor task increased, both groups changed comparably in speech fluency, information content and syntactic complexity.

Dual task effects have also been investigated with respect to effects of a motor task on cognitive performance in young and older adults. In contrast to other motor tasks, strenuous cycling improves performance in some cognitive abilities and not others, specifically tests of executive functioning, working memory, tone discrimination, and visual search (Tomporowski, 2003; Sjoeberg, 1975; Lucas et al., 2001; Audifren et al., 2008; Audifren et al., 2009). These facilitatory dual task effects are typically attributed to increases in physiological state arousal associated with strenuous cycling affecting prefrontal functioning in healthy adults (Audifren et al., 2008).

Plummer-D'Amato et al. (Plummer-D'Amato et al., 2008) have also reported that discourse production in particular has significant effects on gait performance in
individuals recovering from stroke, and interference due to a discourse production task is greater than interference produced by either concurrent working memory (WM) or executive function (EF) tasks. These studies demonstrate that language and motor tasks interfere with each other in dual task experiments, particularly in populations with already impaired cognitive resources, such as stroke survivors and older adults.

These separate studies suggest that language performance during a motor dual task can be protected by using a reduced language register, which only becomes vulnerable when the demands of the concurrent task increase. In particular, when the motor task becomes sufficiently demanding, the motor task will result in dual task interference affecting multiple language measures. While speech rate and fluency are most vulnerable in older populations, semantic and syntactic processing become impaired as attention is taxed well beyond capacity. Thus, motor effects on language production are not limited to motor interference and may include cognitive interference on language performance. In support, a number of studies have shown that both propositional content (Power, 1985) and grammaticality of sentences (Hartsuiker & Barkhuysen, 2006) are impaired when performing a simultaneous memory task. In summary, it has been shown that older individuals with reduced cognitive resources are most vulnerable to attention allocation affecting motor, cognitive and language task performance under dual task conditions.

**Effects of Parkinson’s Disease**

It has been widely observed that cognitive capacity is reduced in PD and that PPD are increasingly vulnerable to dual task interference effects (Yoge-Seligmann et al., 2008). These effects are not domain specific and evidence suggests that both cognitive and motor (Ho, Iansek, & Bradshaw, 2002) and motor and motor (Brown, & Jahanshahi,
1998) interference during dual task experiments increase in PPD. Specifically, motor performance decrements in PD occur during concurrent motor tasks (Benecke, Rothwell, Dick, Day, & Marsden, 1986), and during concurrent cognitive tasks (Marchese, Bove, & Abbruzzese, 2003; Oliveira, Gurd, Nixon, Marshall, & Passingham, 1998). As Marchese and colleagues (2003) and O’Shea and colleagues (2002) have demonstrated, concurrent cognitive tasks impair both gait and balance in PD. More recent studies by Kemps and colleagues (2005) and Yogev and colleagues (2005) also report exaggerated differences in motor performance between healthy older adults (HOA) and people with PD when distracter tasks are more cognitively demanding.

Dual task effects in Parkinson’s disease have also been reported with respect to motor interference from language or speech tasks. For example, Ho and colleagues (2002) examine walking while talking in a task that involves repeating sentences and reported increased reductions in both stride length and walking speed as the complexity of sentences increases. Critically however, it is noted that none of these studies report dual task effects on language production (Brown & Marsden, 1991; Morris, Iansek, Smithson, & Huxham, 2000; Rochester et al., 2004). Indeed performance on cognitive or language tasks used as distracter tasks are rarely reported in any of these studies. For example, Ho, Iansek and Bradshaw (2002) examined the effects of performing a visuo-manual tracking task which involved continuously monitoring the position of a randomly moving needle, and making fine motor adjustments using a joystick to counter the direction of movement, while counting or producing general discourse. The researchers reported that discourse, in particular, causes significantly greater dual task effects on motor speech measures for individuals with PD than for healthy controls, but
do not report any dual task effects on discourse. In particular, the researchers argue that vulnerabilities in PD and healthy adults are observed for complex task behaviors in favor of less complex task behaviors during dual tasking. Indeed, the researchers report that the speech of PD patients declined both in volume and fluency and in many cases speech production stopped altogether as motor task difficulty increased. Thus, deficits in attention in PD were further attested by better performance on conversational tasks than continuous speech tasks and by an observed strategy of task switching from the speech task to the motor task rather than multi-tasking to maintain performance levels on the motor task (Ho et al., 2002).

Yogev and colleagues (2005) may also be the only study that reports bidirectional dual task effects in PD. The researchers found significant dual task effects on cognitive and language tasks in both the PD and control groups, but that only the PD group experienced a dual task effect on gait, particularly in the language comprehension task. These studies suggest that language based tasks may be particularly demanding of cognitive resources. However, the degree to which language production is vulnerable to dual task interference in PD remains an unanswered question.

The hypothesized vulnerability of automaticity (the ability to perform habitual tasks and behaviors without requiring high levels of attention) in PD which appears independent of behavioral domain or stimulus modality and may be graded to the extent that simpler tasks are more vulnerable to effects associated with PD than more complex tasks. In support, Holmes and colleagues (2010) performed a dual task paradigm in PD in which postural control and balance, a simple motor task, was shown to be more vulnerable to dual task interference from generating a monologue than rote repetition, a
language-task requiring less cognitive control, which was prioritized by individuals with PD (Holmes, Jenkins, Johnson, Adams, & Spaulding, 2010). Further, as Bialystock and colleagues (2008) have demonstrated under conditions in which task switching is required by the dual task experiment, PD patients give preference to the exogenously cued task over another task and tend to avoid required switch costs. For this experiment the dual task was to prepare a virtual breakfast, setting a table while foods were being cooked for specific times (food preparation). In particular, the researchers found that during a complex visuo-motor task requiring cognitive control including planning, updating, working memory, and monitoring, priority was given to the cued task over another less complex related visuo-motor scenario requiring less cognitive control.

Thus, it appears that people with PD may prioritize tasks differently than healthy adults, favoring more complex tasks irrespective of behavioral domain or stimulus modality, perhaps by allocating cognitive resources exclusively to one task to avoid switch costs (Bialystock et al., 2008). This appears to be the case even when the less complex motor task is critical (e.g. balance) to task performance and safety (Holmes et al., 2010). This pattern of behavior in PPD contrasts with older adults who maintain cognitive flexibility between tasks, as demonstrated by Doumas and colleagues (2009) and Li and colleagues (2001). The reason for this difference in PPD is unclear and may reflect a general shift in attention allocation away from more automatic behaviors due to difficulties with shifting of cognitive sets in PD, an effect which may be reversed by exogenous verbal cues demonstrated in the study by Bialystock and colleagues (2008).

The neural substrates of dual task effects in PPD, to our knowledge, have only been explored in one fMRI study to date. In this study it was found that motor to motor
and cognitive to motor interference showed similar patterns of activation (Wu & Hallett, 2008) suggesting that dual tasking activates circumscribed regions of the brain independently of behavioral domain or stimulus modality. Overlapping activation of dual task areas compared to single tasks was under-additive, indicating that process overlap regionally was not driving dual task interference effects (Wu et al., 2008) in contradiction of bottleneck processing accounts of dual task interference (e.g. Ruthruff, Pashler, & Klaassen, 2001). Bottleneck processing accounts assert that dual task effects are the result of two tasks competing for activation of the same area of cortex resulting in a process bottleneck leading to bidirectional slowing (Ruthruff, Pashler, & Klaassen, 2001). The study by Wu and colleagues (2008) also showed that PD patients demonstrated increased activation in the cerebellum, prefrontal, middle frontal, parietal, and temporal cortex during dual tasks compared to age-matched controls and that increased activity in these regions was positively correlated with increased dual task interference (Wu et al., 2008). This finding of increased prefrontal activation in particular is consistent with the findings of Holtzer and colleagues (2005) who determined that executive functioning is the most important single predictor of dual task performance in healthy adults. In the fMIRI study by Wu and colleagues (2008) the only area exclusively and consistently activated (compared to single task) during all dual tasks was the precuneus which was more active for PD patients than controls (Wu et al., 2008). The precuneus is a region of parietal cortex involved in the processing of self-related mental imagery at rest (Cavanna & Trimble, 2005).

The implications of this literature for this dissertation is that dual task effects are exaggerated in PD and that when the distracter motor task is complex, for example,
during walking or visuo-motor tracking, interference effects may become exaggerated in PPD. However, it is noted that effects of a motor task on language performance in PD have not been investigated. There is some evidence from studies of healthy older adults that a motor dual task interferes with sentence and discourse levels of production and that a similar pattern of effects may be expected for people with Parkinson’s disease. However, it should also be noted that the choice of dual task will also likely effect language performance, as has been demonstrated in healthy adult populations. In particular, there is evidence that concurrent cycling can improve some aspects of cognition but not others. Moreover, due to the low cognitive demands of cycling and repetitive activation of the motor system, some aspects of language production require activation of the motor system, such as action verbs which may be generally facilitated by cycling. Indeed, conceptual content may improve generally under dual task conditions in PD. I predict these improvements will be specific to people with PD due to documented impairments in motor performance typically involving hypometabolism of the frontal lobes affecting dual task language production.

**Language Production in Parkinson’s disease**

In effect, for people with PD, as processing demands increase language performance deteriorates.

Only a small number of studies have expressly investigated effects of cognitive impairment on language use in PD. These studies have primarily focused on investigating the relationship between cognition and sentence comprehension. Indeed, a relatively consistent finding is that sentence comprehension is impaired in individuals with PD only when presented sentences are syntactically complex (Angwin, Chenery, Copland, Murdoch, & Silburn, 2005, 2006; Grossman, et al., 1991; Grossman, Carvell, Stern, Gollomp, & Hurtig, 1992; Grossman, et al., 2000; Hochstadt, Nakano, Lieberman, & Friedman, 2006; Lieberman, et al., 1992). Syntactic complexity effects during comprehension in PD have also been attributed to various impairments in cognitive resources (Grossman, et al., 1991; Grossman, et al., 2000) including: reduced processing speed (Angwin, et al., 2005, 2006), impairments in sequencing and task switching behaviors (Lieberman, 2001), reductions in verbal working memory (Caplan & Waters, 1999), and phonological memory (Lieberman, 2001). These apparently inconsistent findings across studies may be attributed to differences in sentence stimuli, presentation methodology, and the cognitive abilities assessed. As Hochsatdt, Naknann, Lieberman, and Friedman (2006), point out it is likely that multiple cognitive resources interact during sentence comprehension in PD.

Very few studies have investigated language production in PD. Indeed, in a recent review, Altmann and Troche (2011) draw specific attention to several dimensions of language production that have been found to be impaired in PD: information content,
grammaticality and fluency. A general finding for people with PD relative to their health peers is that information content is significantly reduced during language production tasks, including object and picture description, responses to rhetorical prompts, and story generation (Bayles, 1990; Cummings, Darkins, Mendez, Hill, & Benson, 1988; Illes, Metter, Hanson, & Iritani, 1988; Murray, 2000). For example, in an early study Illes and colleagues (1988) elicited several minutes of discourse from individuals with PD using leading questions. Subsequent analyses revealed that the proportion of referential comments and interjections is significantly reduced compared to healthy older adults (Illes, et al., 1988). This study indicates that PPD produce less elaborated speech and that information structure is simplified without significant evidence of normal monitoring to engage the listener. A further study by Small and colleagues (1997) investigated written productions of healthy older adults and individuals with PD from sentences provided on the Mini Mental Status Exam (MMSE) which revealed that information content was only reduced in sentences by individuals with increased dementia severity. One of the few studies to explicitly investigate effects of message complexity on information content during sentence level production is a study by Troche and Altmann (2012). In this experiment, adults with and without PD describe simple (two actor) and complex (three actor) pictures that are presented offline. While the group with PD produced a lower proportion of sentences with complete information overall, the magnitude of the effects of the complexity manipulation on completeness of information was equivalent between groups. These findings suggest that, while information content may be reduced PPD, increasing message generation demands does not have a disproportionate effect on information content in PD during sentence
level production. Wilson and Altmann (submitted) reported a similar study, using the same stimuli that were presented by computer in a single task and during a cycling dual task. Results confirmed that PPD were vulnerable to effects of information complexity particularly during dual task conditions which affected response times, grammaticality, and information completeness but not fluency. Further, this study also demonstrated that processing speed predicted decreased performance on all sentence measures in PD and that grammaticality scores were also influenced by working memory conditions and vocabulary knowledge.

Similarly, there are also inconsistent findings in the literature with respect to grammaticality. Ullman and colleagues (1997) tested regular and irregular verb production in patient groups (including PPD) by asking participants to read and complete sentences with missing verbs (e.g. “Every day I dig a hole. Just like every day, yesterday I _____ a hole.”). It was reported that PPD had particular difficulty forming regular verb endings (rush/rushed) in contrast to relatively well preserved use of irregular verbs (drive/drove). The researchers account for this finding according to a Declarative/Procedural model of verb production in which syntactic rules (procedures) are disrupted due to the condition of basal ganglia and frontal cortex while declarative memory stores (supporting use of irregular verb forms) remain relatively well preserved due to the condition of temporal cortex in PPD. A number of further studies also report that grammaticality is impaired during a range of language production tasks and that syntactic complexity of responses tends to be further reduced in PPD (Holtgraves, McNamara, Cappaert, & Durso, 2010; Murray, 2000; Troche & Altmann, 2012). In contrast, a number of other studies report the opposite finding, that grammaticality is
unimpaired in PD (Illes, et al., 1988; Murray & Lenz, 2001; Small, et al., 1997). This difference across studies can perhaps be accounted for by task demands. For example, Murray (2000) finds that individuals with PD produce fewer grammatical sentences during extended picture description, while, in a separate study analyzing conversational discourse, Murray and Lenz (2001) find that Parkinson’s patients are as grammatical as healthy older adults in their productions across a broad range of syntactic measures (Murray & Lenz, 2001). Thus, Murray and Lenz point out that there is an important difference in elicitation tasks: Picture description may be a more resource intensive behavior than conversation due to the constraints it places on content, and that effects of grammaticality in PD may be only apparent when the production task is sufficiently demanding. This hypothesis is further supported by the previously mentioned study by Troche and Altmann (2012) using picture description. This study reports that participants with PD produced fewer grammatical sentences overall than healthy older adults, and that these effects were exaggerated when message complexity increased. However, in a sentence repetition task, the participants with PD did not differ in grammaticality from the healthy older adults. In summary, there are only inconsistent findings with respect to grammatical sentence production in persons with PD, although a careful reading of literature suggests that grammatical impairments are only revealed during more constrained language production tasks, requiring generation of specific information under specific conditions.

We are aware of only three language production studies that measure fluency effects in PD. This lack of reporting may be due to a wide-spread assumption that all dysfluency in PD is due to motor speech deficits (Illes, 1989). However, in an early
study of spontaneous discourse, Iles and colleagues (1988) report that the proportion of silent hesitations increases in the speech of PD participants. Further support for fluency impairment in persons with PD during sentence production is provided by the study by Walsh and colleagues (2011) who found that both response times and fluency of responses are generally impaired during a repetitive reading task (Walsh & Smith, 2011). However, Walsh and colleagues (2011) found no effects of syntactic complexity affecting fluency during their repeated sentence reading task. Similarly, Troche and Altmann (2012) report no effects of syntactic complexity on sentence repetition fluency, although the group of adults with PD was also less fluent than healthy older adults. However, in their picture description task, they find that fluency is disproportionately impaired in PD when message complexity increases. Troche and Altmann (2012) attribute the difference between tasks to the increased demands of message generation and lexical access in the picture description task. In summary, relative to healthy older adults, fluency during language generation tasks is generally impaired in PD, and the difference from healthy older adults is exacerbated when message complexity increases.

**Verb processing during single word production.** Of direct relevance to this dissertation, there is compelling evidence that action word processing is impaired in people with PD. In particular, it is documented that action naming to pictures is impaired in contrast to relatively well preserved object naming (Cotellia, Borronib, Manentic, Zanettib, Arevalo, Cappa & Padovani 2007; Rodríguez-Ferreiroa, Menéndez, Ribacoba & Cuetos, 2009). Additionally, studies have shown that verb fluency (a category fluency task) is impaired in people with PD (McDowd, Hoffman, Rozek, Lyons,
Pahwa, Burns, & Kemper, 2011; Signorini, & Volpato, 2006; Piatt, Fields, Paolo, Koller, Troster, 1999; Raskin, Sliwinski, & Borod, 1992; Hanley, Dewick, Davies, Playfer, & Turnbull, 1990; Bayles, Trosset, Tomoeda, Montgomery, & Wilson, 1993; Downes, Sharp, Costall, Sagar, & Howe, 1993; Peran, Rascol, De´Monet, Celsis, Nespoulous, Dubois, & Cardebat, 2003). It is hypothesized that action word impairments in people with PD are due to hypometabolic functioning of motor planning cortex which supports verb selection to a greater extent than noun selection (Peran, Rascol, De´Monet, Celsis, Nespoulous, Nespoulous, Dubois, & Cardebat, 2003). With respect to verbal fluency both Signori and colleagues (2006) and Peran and colleagues (2002) have shown that action word fluency is an area of greater impairment in PD than other category fluency tasks and is positively associated with executive function impairments by Piatt and colleagues (2006). However, McDowd and colleagues (2011) used a more extensive neuropsychological battery and determined that action word fluency impairments in PD are due to speed of processing factors rather than difficulties accessing semantic information, or problems with executive control.

In support, neuroimaging studies of neurologically healthy adults using fMRI have revealed that words associated with body parts activate the same somatotopic areas of motor planning and motor execution cortex as the same physical actions performed in neurologically healthy adults (Hauk, Johnsrude, & Pulvermüller, 2004; Tettamanti, Buccino, Saccuman, Gallese, Danna, Scifo, Fazio, Rizzolatti, Cappa, & Perani, 2006). These findings are also supported by EEG (Shtyrov, Hauk, & Pulvermüller, 2004) and MEG studies (Näätänen, Tervaniemi, Sussman, & Paavilainen, & Winkler, 2001) which confirm that temporal activation patterns in hemodynamic responding to action words
are not due to a post-lexical response behaviors. Rather, activation patterns are directly related to lexico-semantic stages of speech production. Extending this body of work further, Kemmerer and colleagues (2008) used fMRI and a semantic similarity judgment task to identify specific activation patterns associated with semantic features using different verb classes. The researchers discovered that action features of verbs were associated with activation of primary motor and premotor cortices, and revealed that motion features were associated with activation within posterolateral temporal cortices, that contact features were associated with activation across the intraparietal sulcus and the inferior parietal lobule, and that change of state features were associated with activation of ventral temporal cortex. Further research by Kemmerer and colleagues (2012) has demonstrated that individuals with traumatic brain injuries involving the left hemisphere were impaired in action word comprehension and verb production and localized effects using lesion imaging to inferior frontal, pre-central and motor and pre-motor cortices. These same areas are shown to be hypometabolic in PPD.

In summary, both action verb naming and category fluency are impaired in PPD, potentially due to reduced activation of motor planning cortex. The implications of this finding for the current dissertation are that verb production may also be impaired in language production tasks for people with PD at sentence and discourse levels. This could potentially affect both the quality and quantity of information provided during language production. This conjecture is due to the central syntactic and semantic role that verbs appear to play in sentence and discourse levels of production. While effects of verb impairment have not been explicitly investigated in individuals with PD I make the following predictions based on the literature outlined above.
Specifically, I hypothesize that a breakdown in the selection and use of verbs will impair the overall quality of sentences produced by people with PD. In particular, I predict that the effect of verb impairment in PD during the generation of single sentences and discourse would lead to a mean reduction in the amount of information produced during speech, and would further reduce coherence during discourse. Furthermore, I predict that propositional density would decrease as compensation to maintain information density and fluency. Specifically, I hypothesize that reductions in action verb content would be compensated by increased production of nominal and descriptive words in individuals with PD. Thus, the number of nominals and other supporting word classes would increase in single sentences to compensate for slowed access to action verbs. In particular, I predict that both the number of modifiers per noun phrase and the number of words before a main verb would increase due to slower access to verbs during sentence planning. With respect to discourse production, I predict that both cohesion and coherence would be reduced due to decreased working memory capacity in PPD. I further predict verb frequency effects, such that more frequent verbs and more abstract verbs are routinely selected by people with PD compared to HOA and that type-token ratio for verbs will also be reduced. In effect, more familiar and less imageable light verbs will characterize PD language performance together with reduced diversity of different verb types.

Specific predictions for language effects associated with concurrent cycling are more challenging. However, based on the findings that cycling is generally unimpaired in PD due to low cognitive demands on balance and leg movements and that concurrent cycling improves aspects of cognition in healthy adults, I predict that action verb
production will be generally facilitated during both language tasks under dual task conditions due to increased activation of motor cortex without competing attention demands. In effect, both quantitative and qualitative measures of language production would normalize during dual task conditions in PD due to motor priming effects.

**General Summary**

The theory of embodied cognition asserts that concept knowledge supporting language production is grounded in sensorimotor cortex (Lakoff, & Johnson, 1980). In particular, there is functional magnetic resonance imaging (fMRI) evidence that action words associated with body parts activate the same somatotopic areas of motor planning and motor execution cortex as the same physical actions in neurologically healthy adults (Hauk, Johnsrude, & Pulvermüller, 2004; Tettamanti, Buccino, Saccuman, Gallese, Danna, Scifo, Fazio, Rizzolatti, Cappa, & Perani, 2006). These findings are also supported by both electroencephalographic (Shtyrov, Hauk, & Pulvermüller, 2004) and magnetoencephalographic (Näätänen, Tervaniemi, Sussman, & Paavilainen, & Winkler, 2001) approaches. A further fMRI study by Kemmerer and colleagues (2008) in healthy adults provides evidence that action verbs, in particular action features of verbs are associated with activation of primary motor and premotor cortices, in contrast to verbs associated with motion, contact and change of state features or nouns. These findings in healthy adults are important in the context of documented differences in action word processing in PPD.

In particular, both verb naming (Cotelli, Borroni, Manenti, Zanetti, Arevalo, Cappa & Padovani 2007; Rodríguez-Ferreiroa, Menéndez, Ribacoba & Cuetos, 2009) and verb fluency (a category fluency task) are shown to be impaired in PPD (Signorini,& Volpato, 2006; Piatt, Fields, Paolo, Koller, Troster, 1999; Raskin, Sliwinski, & Borod, 1992;
Hanley, Dewick, Davies, Playfer, & Turnbull, 1990; Bayles, Trosset, Tomoeda, Montgomery, & Wilson, 1993; Downes, Sharp, Costall, Sagar, & Howe, 1993; Peran, Rascol, De’Monet, Celsis, Nespoulous, Dubois, & Cardebat, 2003). It has been hypothesized that the neural substrate for verb impairment is impairment of motor planning cortex resulting from degeneration of the basal ganglia in PPD affecting connecting tracts (Peran, Rascol, De’Monet, Celsis, Nespoulous, Dubois, & Cardebat, 2003) in particular, due to white matter degeneration of a cortico-striato-pallidal-thalamocortical circuit which connect regions of basal ganglia with motor planning cortex (Alexander, DeLong & Strick, 1986). However, it remains untested whether verb impairments in PD during single word production are also apparent during sentence and discourse production and whether such effects vary due to differences in cognitive abilities, and task difficulty, and whether these effects are exaggerated by multi-tasking conditions. Thus, the purpose of this dissertation was to investigate whether task demands and cognitive factors increase language production difficulties in people with Parkinson’s disease (PPD). On these bases, I outline the specific aims of this project and make the following group level predictions about sentence and discourse level production during single tasks and effects of concurrent cycling.

My first specific aim is to determine whether people with PD and healthy adults differ in quantitative characteristics of language production during single task and dual task conditions and whether group differences can be detected using online coding programs. Specific measures will include basic word counts, and word counts for each word class, together with the number of words before main verbs and modifiers per noun phrase. Specifically, I predict that the PD group will produce fewer verbs and an
increased number of other words (nouns, adjectives and adverbs) as compensation. I predict that PD participants will include more nominals before main verbs and more modifiers per noun phrase. I further predict that these effects will be exaggerated during single sentence production for pictures with more entities to describe. With respect to cycling effects, I predict an interaction between group and dual task, such that quantification of language produced will improve during dual task for adults with PD but not for healthy older adults. Specific predictions are that cycling will increase the number of action verbs produced by people with PD and reduce the number of other word classes. Additionally, due to facilitation of verb access, I predict that there will be fewer words before main verbs and fewer modifiers per noun phrase. The basis for this prediction is the hypothesis that a cycling task facilitates motor preparation in PD and increases excitation of primary motor cortex facilitating the production of verbs during sentence and discourse production.

My second specific aim is to determine whether people with PD and healthy adults differ in quantitative characteristics of language production during single task and dual task conditions and whether group differences can be detected using online coding programs. Specific measures will include propositional density, type-token ratio for verbs, lexical frequencies, concreteness, imageability, hyponymy, action verb content and information completeness and grammaticality for sentences and cohesion and coherence metrics for discourse production. With respect to group level differences, as above we predict that verb production will be impaired in the PD group. This hypothesis is consistent with predictions of the single word production literature which indicates that people with PD have greater difficulty producing verbs than naming objects. Due to
reduced use of verbs we predict that the PD group will show reduced propositional content, reduced variety of verbs indexed by type token ratio, reduced action verb content, concreteness indexed by verb hypernymy and an increased reliance on high frequency verbs compared to healthy older adults. On more global measures of information content, I predict that information content will be reduced for single sentences and that coherence but not cohesion will be reduced at a group level in PD compared to healthy adult controls. With respect to cycling, for the reasons outlined in the previous section I predict that cycling will generally facilitate information completeness for sentences and will reduce verb effects associated with discourse production, in particular affecting coherence. Additionally, I predict that propositional density will increase; a greater variety of verbs will be selected during production behaviors and that action verb content will increase due to priming effects of the motor task affecting action verb semantic fields.

My final specific aim is to determine whether cognitive abilities in the single task will predict performance during sentence and discourse production in people with PD and healthy older adults during both single and dual task conditions. Specific measures to be predicted are information completeness for sentences, propositional density and cohesion and coherence for discourse. Further measures will include any dependent variable showing main effects of group or interactions including quantitative measures of verb use, and frequency and qualitative measures of action verb content and type-token ratio. With respect to predictors I cannot determine what factors will be extracted during factor analysis for entry into regression but based on previous literature using similar tasks I predict the inclusion of executive function, working memory, and
processing speed factors. My specific predictions with respect to performance are that processing speed, executive function and group will together predict information completeness for sentences. Alternatively I predict that cohesion and coherence metrics will be predicted by a model which contains group, working memory, and processing speed for discourse. With respect to propositional density which is a shared measure between sentence and discourse level tasks I predict an effect of group and working memory. My rationale for making these predictions is that people with PD will be slower to process information, will exhibit problems with cognitive control and will have a reduced ability to manipulate information structures which include updating and shifting of cognitive sets. These problems will manifest differently in different language tasks which place different levels task demands on the language production system. A sentence production task which involves describing simple and complex pictures under time constraints will require the ability to quickly inhibit information during lexical selection and continuously switching between pictures. Simultaneously, the speaker must, maintain other information active in short term storage to support sentence planning, which requires intact executive functioning and speed of processing. In contrast, discourse production is less constrained with respect to lexical selection and more subject to information demands during sentence construction requiring intact working memory. For discourse each utterance is placed within the context of the goals of discourse and the topic selected. As such, the discourse task places high resource demands on working memory, which may be impaired in PD, associated with a reduced ability to actively store and manipulate information. Additionally, there are fewer time
constraints on language production in discourse than in a timed sentence production task.
CHAPTER 3
METHODS

Overview

This dissertation is an investigation of language production in people with Parkinson’s disease. Forty adults with Parkinson’s disease were recruited for this study and an additional 19 healthy older adults served as experimental controls. The experimental protocol consisted of a battery of twelve neuropsychological tests and two language tasks. These cognitive tests included measures of basic processing speed, controlled processing, domain-specific working memory, and executive function. Two language production tasks were included, a sentence production task and a task in which participants respond to open ended questions. Both the cognitive battery and experimental language tasks were presented to participants as a single task, seated in front of a computer monitor, and as a dual task, riding a stationary exercise bicycle while performing cognitive and language tasks. Discourse production consisted of 3 minutes of connected speech on a given topic; the sentence production task consisted of describing pictured events at two levels of information complexity (simple and complex pictures). Quantitative and qualitative measures of language production were collected and analyzed to determine effects of group, dual task and cognitive variability on language performance. Thus, the experimental design consisted of two language tasks tested with respect to two groups (healthy older adults and people with Parkinson’s disease) under single and dual task conditions. Individual responses were coded for multiple measures of both quantitative and qualitative indicators of language production performance using manual coding and online corpus analysis software described below.
Participants

Forty individuals with Parkinson’s disease (age 65.3, ±10.03) and 19 healthy older adults (age 72.4, ±9.76) participating in this study. Healthy older adults were older than the Parkinson’s group, \( t(1,57) = -2.477, p = .016 \), while there was no significant difference between the educational experience of people with Parkinson’s disease (17.2 years, ±4.04) and healthy older adults (18.4 years, ±2.00), \( p = .260 \). All individuals with Parkinson’s disease scored between 2 and 3 on the modified Hoehn and Yahr scale (indicating mild to moderate bilateral disability) and were recruited from the Center for Movement Disorders and Neurorestoration at the University of Florida, in Gainesville, Florida. Healthy older adults were separately recruited from the Speech, Language and Hearing Sciences participant pool at the University of Florida and through contact lists provided by the Department of Physiology and Kinesiology, through word of mouth and flyers distributed at local church and exercise venues.

Inclusion criteria for the Parkinson’s disease group were monolingual, ambulatory individuals between the ages of 30-80 years with a confirmed diagnosis of Parkinson’s disease. Further criteria included a modified Hoehn and Yahr scale score between 1 and 3 in the “on” medication state and a stable response to anti-parkinsonian and/or psychotropic medication. Exclusion criteria were signs of secondary or atypical Parkinsonism, or symptoms of cognitive impairment. Any individual with a history of falls, depression or generalized anxiety was excluded from participating. Healthy older adults were separately recruited from the Speech, Language and Hearing Sciences participant pool at the University of Florida and through the contact lists described above. The inclusion criteria for controls were monolingual, neurologically healthy individuals (i.e. MMSE > 24) between the ages of 30-85 years. Exclusion criteria were
relevant recent history of speech-language therapy, major psychiatric disorder, falls, or
the use of medication later shown to alter cognitive functioning. All participants had
normal vision or corrected to normal vision and signed an Informed Consent approved
by the University of Florida Healthy Science Center Institutional Review Board prior to
enrollment in this project.

**Cognitive Assessments**

Each participant completed a battery of cognitive tests during each session. These tests included measures of basic processing speed, controlled processing, domain-specific working memory, and executive function (Colcombe & Kramer, 2003). Processing speed was assessed using three tasks. In the “Star” task, participants verbally responded “go” when a large blue star appears on a monitor screen at variable inter-stimulus intervals. In the “Pa” task, when prompted, participants said “pa” as many times as they could in 10 seconds. In an adapted version of the digit symbol substitution test, participants viewed an array of non-verbal symbols (letters in the Korean alphabet) paired with digits and one larger symbol displayed below. Participants were required to say the number of the digit associated with the featured symbol. Dependent variables were response times for the star and digit symbol tasks, the number of “pa” produced in the “Pa Task” and accuracy in the adapted digit symbol task.

Controlled processing was assessed using two tasks: In the visual 0-Back task, participants viewed a continuous series of non-verbally-encodable tic-tac-toe figures containing two dots, and responded “yes” or “no”, based on whether the current figure matched a pre-specified target figure introduced at the beginning of the task, as shown in Figure 3-1. In the Stroop color naming task, participants named colors as quickly as
possible. Four bolded X’s appeared in the center of a black screen in either a red, blue or green font. The dependent variable for these two tasks was response time.

Working memory was assessed using two visual and two verbal working memory tasks. Visual working memory was assessed with a visual 1-back task and a novel visual working memory task. In the visual 1-back task, participants viewed a continuous series of the same tic-tac-toe figures as above, and responded “yes” or “no”, based on whether the current figure matched the one shown immediately before it. In the visual working memory task, participants viewed a series of the tic-tac-toe figures one at a time, followed by an array showing the same number of symbols. Analysis ranged from 1-4 figures, but the 1-figure condition was excluded from analysis due to its similarity with the 1-Back task. Participants were asked to determine whether the array presented the same figures in the same order as the sequence just viewed. The verbal working memory tasks consisted of two digit span tasks in which participants repeated increasingly long lists of single digits either forwards (verbatim) or backwards (in reverse order). The dependent variable for working memory tasks was the percentage of correct trials.

Executive function was assessed using three tasks. In a version of the operation span task, participants were shown and instructed to remember 6-consonant strings, and were asked to repeat these back in presentation order following verification responses of 0-4 single-step arithmetic solutions (e.g. 3+2=5 for a “yes” response and 3+2=1 for a “no” response). The dependent variable was the total number of letters recalled in correct order per trial. In the 2-Back task, participants viewed a continuous series of the tic-tac-toe figures and responded “yes” or “no” based on whether the
The current figure matched the figure shown two screens before it. The dependent variable was the proportion of “yes” trials correctly identified. Finally, the Stroop color word task required participants to name the color font of a series of color words displayed in incongruent color fonts (e.g. the word RED presented in a green font). The dependent variable was the response time for this task and the response time for this task less the response time for the Stroop color naming task, (i.e., the Interference score).

Since one of the specific aims of this project was to assess the influence of individual differences in cognitive abilities between people with Parkinson's disease and healthy older adults on measures of language production I performed principal components analysis on cognitive measures to identify orthogonal factors suitable for use in linear regression. The following cognitive measures were included in the factor analysis: digit spans forward and backward accuracy, visual memory task accuracy, overall operation span accuracy, Stroop task color naming and color word naming response times, 0-Back response times, 1-Back response times, 2-Back accuracy for “yes” trials, digit symbol substitution response times, star task response times, and the number of “pa’s” produced in the “Pa Task”. The results of this analysis using Varimax procedures successfully identified 3 separate orthogonal factors. Based on the factor loading in Table 3-1, the first factor, which accounted for 36.8% of the variance, was named the processing speed factor, because the largest factor loadings included Stroop response times, digit symbol substitution response times, the star task response times, 0 and 1-Back response times and articulation speed. The second factor, which accounted for 16.5% of the variance, was named the working memory factor since the strongest factor loadings were to 2-Back accuracy, visual memory task accuracy and
operation span accuracy. Finally, the third factor, which accounted for 8.8% of the variance, was named the updating factor since the strongest factor loadings were to 2-Back accuracy, visual memory and operation span accuracy. Information updating is a sub-process of executive function (Miyake, Friedman, Emerson, Witzki & Howarter, 2000) which requires monitoring and coding new information for task relevance and revising stored information appropriately. These three orthogonal cognitive factors were used in the regression analyses described below.

**Experimental Tasks**

**General Procedure**

Each participant was randomly assigned to one of two groups. One group undertook a single-task session first followed by a dual-task session within 7 days and the remaining participants performed the dual-task session first followed by the single-task session within 7 days. This procedure was employed to control for practice effects associated with task demands. Single-task sessions were conducted with participants seated in a comfortable, quiet room, free from other distractions, with all stimuli presented on a 15.6 inch widescreen laptop computer. The dual-task session was conducted with participants concurrently riding a stationary exercise bicycle at a self-selected comfortable rate in a laboratory under quiet conditions projected onto a back-lit projection screen located within 4 meters of the seated participant. Participant safety and comfort was continuously monitored at baseline and during the dual tasks using a heart rate monitor and paired sensor. Prior to testing, the seat on the exercise bike was adjusted for each participant. Participants were instructed not to cycle during information screens or between tasks. During both single and dual task sessions participants wore a wireless headset microphone for voice recording. Recording
sensitivity was calibrated prior to testing for each participant. Each session was recorded for transcription, scoring, and reliability analysis. Voice responses were collected as mp3 files. Additionally, a digital master audio recording of the entire session was collected as a backup procedure. Following the session participant responses were transcribed verbatim.

**General scoring.** Sentences and discourse were transcribed verbatim. Coding procedures consisted of qualitative and quantitative measures of language performance as itemized in Table 3-2. Quantitative measures were defined as measures of specific information content while qualitative measures were defined as information measures describing information characteristics. Quantitative coding consisted of global word counts and proportions obtained using CPIDR (Brown, Snodgrass, & Covington, 2007a). The researchers report high levels of agreement between human raters and CPIDR for both propositional counts and density ratings. Similarly, high levels of reliability have also been reported with respect to discourse and picture description samples collected from individuals with stroke aphasia (Altmann, Hazamy, Carvajal, Benjamin, Rosenbek and Crosson, in press). Sentence transcriptions were entered into CPIDR to obtain sentence by sentence proportion counts and word-class tagging. Word-class tags from CPIDR were then exported to an Excel spreadsheet to obtain word counts by word class, word class proportions and to extract lists of verbs produced to calculate number of verbs per sentence. Responses were subsequently entered into Coh-Metrix software (Graesser, McNamara, Louwerse, & Cai, 2004) to obtain counts for number of words before main verbs, number of modifiers per noun phrase, and action verb content. Reliability (Duran, McCarthy, Graesser, & McNamara, 2007) and
construct validity (McNamara, Ozuru, Graesser, & Louwerse, 2006) of coherence and cohesion indices calculated by Coh-Metrix has been demonstrated using published text samples. The software has also been used to investigate language proficiency in second language learners (Crossley, Salsbury, & McNamara, 2011), effects of healthy aging (Kemper, Bontempo, Schmalzried, McKedy, Tagaliaferri, & King, 2013) and stroke aphasia (Levy, Hoover, Waters, Kiran, Caplan, Berardino, & Snadberg, 2012). Qualitative coding consisted of measures of information content including propositional density, type-token ratios for nouns and verbs (based on lemma types), verb frequency, action verb content, noun and verb hypernymy and measures of concreteness and frequency. Three additional measures were collected, syntactic similarity, syntactic complexity and Flesch-Kincaid grade reading level. All of these scores were obtained using Coh-Metrix. Propositional density is the amount of propositional information provided, controlling for total number of words produced. Propositional density and number of propositions was extracted using CPIDR and was based on trimmed discourse and sentence transcriptions. Trimming involved the removal of filler words, repetitions, task commentary, false starts and abandoned utterances. Trimming is a standard practice in the calculation of propositional information, including density scores (Turner & Green, 1977; Nicholas & Brookshire, 1988; Kemper & Sumner, 2001), the purpose of which is to control for calculation of false estimates. False estimates arise due to analysis of the same propositional content (inflated density scores) or by increasing word counts without producing more propositions (reduced density scores). All other corpus based analysis for coding used untrimmed sentence and discourse samples. Type-token ratio is the number of unique words (called types) divided by the
number of tokens (occurrences) of these words. Each unique word in a text is considered a word type. Verb type-token ratio calculates specific ratios based on verb lemmas as types. Lower ratios indicate more repetition of verbs, thus less diversity of verb choice. Action verb content is referred to as “intentional content” in Coh-Metrix and represents the number of verbs that are action related performed by animate entities. The higher the incidence of intentional actions in a text, the more the text is assumed to convey goal-driven content (Landauer, Foltz, & Laham, 1998). Verb hypernymy is a measure of the mean number of levels in a conceptual taxonomic hierarchy superordinate to a main verb. A word having more hypernym levels is more concrete and a word with fewer hypernym levels is more abstract (e.g. broil would have 3 levels: do, make, cook). Propositional density was coded by CPIDR; Type-token ratio for verbs (based on lemmas), action verb content, noun and verb hypernymy, concreteness and word frequency for content words and for all words together were collected from Coh-Metrix. Concreteness rating are values indexed from the MRC Psycholinguistic database (Coltheart, 1981) that provide a measure of how concrete or abstract a word is with lower scores indicating a less concrete word (e.g. happiness) and higher scores indicating a more concrete word (e.g. ball). Written word frequencies for content words collected from Coh-Metrix were frequency values abstracted from the CELEX online database (Max Planck Institute for Psycholinguistics, 2001). Lists of verbs were also entered into the Corpus of Contemporary American English (Davis, 2010) to obtain spoken word verb frequencies using a larger corpus of 450 million words. Syntactic similarity scores collected from Coh-Metrix quantify the proportion of intersecting tree nodes between adjacent sentences (local syntactic similarity) and all combination of
sentences (global syntactic similarity). Higher values indicate use of a greater proportion of syntactically similar sentences and lower values indicate a lower proportion of syntactically similar sentences. For example, the sentences, “The boy chased the dog.” and “The dog chased the car.” have a mean syntactic similarity value of 1, indicating a high level of local syntactic similarity, while the sentences “The boy chased the dog.” and “Chasing balls is good.” have a mean syntactic similarity value of 0.211, indicating a low level of local syntactic similarity. Syntactic complexity scores (called “syntactic simplicity” in Coh-Metrix) are z-scores representing the mean number of words per sentence controlling for the frequency of simple (familiar) and complex (unfamiliar) syntactic structures. Higher scores indicate simpler sentences (e.g. “The boy chased the ball” obtains a z-score of 1.353) while lower scores indicate more complex sentences (e.g. “The ball was being chased by the boy” obtains a z-score of 0.523). Finally, the Flesch-Kincaid grade reading level collected in Coh-Metrix calculates the Reading Ease Score and converts this to a U.S. grade-school level score (grades 0 through 12). Higher scores indicate more complex vocabulary and syntactic structure and, thus, less readable texts, while lower scores indicate simpler, more readable texts.

Counts of specific subtypes of verbs were included in our analysis to determine specificity and complexity effects in verb use. These included casual or causative verbs which are a type of action verb that identify a highly specific cause-effect relationship between animate entities. In contrast, use of agentless passive verbs omit agents from sentences and thus provide a low level of information specificity. Syntactic complexity effects were further examined at a lexical level using simple verbs, such as 3rd person
singular verbs, and more complex verb constructions, such as verbs appearing as past and present participles.

**Task 1: Picture Description Experiment**

**Materials**

Stimulus materials for the picture description experiment consisted of 40 black and white line drawings selected from previous studies investigating constrained sentence level production demands (Bock, Loebell, & Morey, 1992; Troche & Altmann, 2012) and the Kempler Comprehension Test (2003). The final selection of stimulus materials was determined by pilot testing on groups of 30 healthy older and 30 younger adults who described the 40 pictures included in this project (Wilson & Altmann, submitted). Participants’ responses that were fluent, grammatical and complete (i.e., mentioned all actors [animate entities] in the picture together with an appropriate action) were deemed accurate overall. Using this procedure, 2 separate lists were created, each containing 20 pictures matched for accuracy and response time. Each list consisted of 10 two-actor pictures in the simple condition, and 10 three actor pictures in the complex condition. Participants were randomly assigned to different list orders. Pictures were displayed on a standard computer monitor in the single task and on a projector screen in the dual task at a screen resolution set to 640 x 480 pixels using MediaLab (Jarvis, 2006b) running DirectRT (Jarvis, 2006a) programs. Each picture remains visible for 5500ms after the initiation of a verbal response to reduce working memory demands and record the response.

**Procedure**

At the beginning of the sentence generation task, participants were instructed to produce one sentence that describes the event in the picture and were reminded to
include all actors in the picture while avoiding the use of pronouns. Participants were also informed that each picture would remain visible for a short while after they began speaking, and were cautioned that they should continue their sentence even if the picture disappeared while they were still speaking. Pictures remained visible until the participant responded and for 5500ms after they began speaking. Complex 3-actor and simple 2-actor pictures were presented randomly for each participant. Each picture trial was initiated manually by the experimenter using a wireless mouse-click to ensure the participant’s previous utterance was completed before advancing to the next picture trial.

**Scoring**

Scoring measures are outlined under general scoring above. Additionally, information completeness and grammaticality were coded only for sentences produced in the Picture Description experiment. These information completeness and grammaticality measures consisted of manual coding for each sentence, as binary measures of whether a response was complete or not and whether the response was grammatical or not. A complete response was defined as a response which included all items of critical information, including all animate entities together with an appropriate action. A grammatical response was defined as a syntactically acceptable response, i.e. a response which did not contain any grammatical error.

**Task 2: Discourse Production Experiment**

**Materials**

Stimulus materials for the discourse production experiment consisted of four open ended questions selected from previous studies investigating discourse level production demands among younger and older adults (Kemper, Herman, & Lian, 2003; Kemper,
These questions were: “What do you think was the most important invention of the last 100 years and why?”; “What do you think was the most important event in the last 100 years and why?”; “Please tell me about a person who had an important impact on your life.”; “Please tell me about a vacation or event from your past that you remember very well.”. Participants were randomly assigned to different questions. Questions were centered on a white background in black Arial font at 24 points.

Procedure

At the beginning of the discourse task, participants were instructed that they would be provided with a topic which they should talk about for 3 minutes and that they should take time to prepare their response and then indicate when they were ready to begin. The question prompt was then presented to participants and the trial was initiated when the participant signaled they were ready to begin. The prompt remained visible for a further 3 minutes while their response was recorded at which point the screen changed to a “Thank you” screen indicating the end of the experiment. Discourse production was recorded as mp3 sound files.

Scoring

Scoring measures are outlined under the general scoring section above. Qualitative coding unique to the discourse task included measures of cohesion and coherence. Cohesion refers to the structural unity of discourse production indexed by the use of syntax and lexical structures in text which provide for cohesive ordering of information content (Graesser, McNamara, Louwerse, & Cai 2004). Local cohesion refers to the extent to which lexical structures do or do not (binary) reference adjacent sentences and global cohesion refers to the extent to which lexical structures do or do
not (binary) reference all sentence combinations. Local and global measures collected from Coh-Metrix include noun, argument, stem, content word and anaphor overlap. Higher numbers for all measures of cohesion indicate greater cohesion. Noun overlap refers to the mean number of sentences which contain nouns which match each other exactly (e.g. “boy” and “boys” would not overlap) locally or globally. Argument overlap refers to the mean number of sentences which contain nouns and pronouns (arguments) which match each other locally or globally. Stem overlap refers to the mean number of sentences which contain noun lemmas (stems, e.g. “draw”) which match other content words (nouns, verbs, adjectives, and adverbs, e.g. “drew, drawn”) in other sentences either locally or globally. Content word overlap refers to the proportion of explicit content words which match each other locally or globally. Anaphor overlap refers to the mean number of sentences which contain an anaphor (noun or pronoun) which references another noun or pronoun used in an earlier sentence either locally or globally. Verb cohesion is a global measure of cohesion which references the degree to which there are overlapping verbs in the text. Coherence refers to the semantic unity of discourse production (calculated using latent semantic analysis), and describes the degree to which sets of words in sentences overlap conceptually within a shared semantic space (a statistical construct based on co-occurrences within a large written word corpus). Scores represent conceptual similarity measured as cosine similarity between adjacent sentences (local coherence) and all other sentence combinations (global coherence) on a scale of 0 to 1. Larger cosine values represent more conceptually similar sentences, hence more coherent discourse, and smaller cosine values represent more conceptually distinct sentences, hence less coherent discourse.
Local coherence refers to the degree to which adjacent sentences overlap with each other and global coherence refers to the degree to which all sentence combinations overlap with each other within shared semantic space. For example two identical sentences have a cosine value of 1.0, indicating perfect local coherence; two conceptually similar sentences: “The boy chased the ball.” and “The boy chased the bat.” have a cosine value of 0.81, indicating a high level of local coherence; while two conceptually distinct sentences: “The boy chased the ball.” and “The dog chased the car.” have a cosine value of 0.02, indicating a low level of local coherence.

Design and Analyses

Specific Aims 1 and 2 were addressed using a series of two-way ANOVAs for each dependent variable to assess group level differences and dual task effects in sentence and discourse production. Dependent variables are detailed in Table 3-2. Specific Aim 3 was addressed using a series of hierarchical linear regressions. For each dependent variable showing a group main effect or interactions, I performed hierarchical stepwise linear regression analysis using the three extracted cognitive factor scores defined above in the first step, and the group predictor group in the second step. This approach analyzed the relative contribution of cognitive abilities to language performance and sought to determine whether group differences in cognitive abilities were due solely to cognitive abilities or whether the disease also contributed independently to performance. Bonferroni adjustment was applied for multiple comparisons showing effects below a critical alpha of .05.
Table 3- 1. Rotated solution for Factor analysis.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Processing Speed</th>
<th>Working Memory</th>
<th>Information Updating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digit Span Forward - Accuracy</td>
<td>-.885</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Digit Span Backward - Accuracy</td>
<td>.872</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stroop XXX - Response Time</td>
<td>.525</td>
<td>-.437</td>
<td></td>
</tr>
<tr>
<td>Stroop Color Word - Response Time</td>
<td>.915</td>
<td></td>
<td></td>
</tr>
<tr>
<td>0-Back - Response Time</td>
<td>.734</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-Back - Response Time</td>
<td>.756</td>
<td>-.218</td>
<td></td>
</tr>
<tr>
<td>Digit Symbol Substitution - Response Time</td>
<td>.811</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Star Task - Response Time</td>
<td>.780</td>
<td></td>
<td></td>
</tr>
<tr>
<td>2-Back - Accuracy</td>
<td>.803</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual Memory (levels 2- 4) - Accuracy</td>
<td>.299</td>
<td>.716</td>
<td></td>
</tr>
<tr>
<td>Operation Span - Accuracy</td>
<td>-.466</td>
<td>.296</td>
<td>.348</td>
</tr>
<tr>
<td>Pa Task - Number</td>
<td>-.475</td>
<td>.349</td>
<td></td>
</tr>
</tbody>
</table>

Note: Extraction method – Principal Component Analysis
Table 3-2. Dependent variables collected in language tasks and programs used to extract data.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Program Used</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Quantitative</strong></td>
<td></td>
</tr>
<tr>
<td>Word Count</td>
<td>Coh-Metrix</td>
</tr>
<tr>
<td>Mean Length Of Utterance</td>
<td>Coh-Metrix</td>
</tr>
<tr>
<td>Number of Nouns</td>
<td>CPIDR &amp; Excel</td>
</tr>
<tr>
<td>Number of Verbs</td>
<td>CPIDR &amp; Excel</td>
</tr>
<tr>
<td>Number of Adjectives</td>
<td>CPIDR &amp; Excel</td>
</tr>
<tr>
<td>Number of Pronouns</td>
<td>CPIDR &amp; Excel</td>
</tr>
<tr>
<td>Number of Verbs per sentence</td>
<td>Coh-Metrix</td>
</tr>
<tr>
<td>Number of words before main Verb</td>
<td>Coh-Metrix</td>
</tr>
<tr>
<td>Number of modifiers per noun phrase</td>
<td>Coh-Metrix</td>
</tr>
<tr>
<td><strong>Qualitative</strong></td>
<td></td>
</tr>
<tr>
<td>Propositional Density</td>
<td>CPIDR</td>
</tr>
<tr>
<td>Type-Token ratio for verbs</td>
<td>Coh-Metrix</td>
</tr>
<tr>
<td>Verb frequency</td>
<td>MRC Psycholinguistic database</td>
</tr>
<tr>
<td>Action Verb Content</td>
<td>Coh-Metrix</td>
</tr>
<tr>
<td>Verb hypernymy</td>
<td>Coh-Metrix</td>
</tr>
<tr>
<td>Information Completeness*</td>
<td>Manual Coding</td>
</tr>
<tr>
<td>Grammaticality*</td>
<td>Manual Coding</td>
</tr>
<tr>
<td>Cohesion**</td>
<td>Coh-Metrix</td>
</tr>
<tr>
<td>Coherence**</td>
<td>Coh-Metrix</td>
</tr>
</tbody>
</table>

* Picture description experiment only; ** Discourse production experiment only
Figure 3-1. Sample stimuli used in the 0-Back task.
CHAPTER 4
RESULTS

Sentence Production

The purpose of this section is to address specific aims 1 and 2 of this project with respect to sentence production. Repeated measures ANOVAs were performed for each quantitative and qualitative dependent variable to assess group level effects and interactions with task conditions. Significance was set at a critical alpha of .05 and explorations of significant interaction below .05 were Bonferroni corrected for multiple comparisons, as shown in Table 4-1 and Table 4-2. Means and standard errors have been reported for each simple effect and interaction. The dependent measures of grammaticality and information completeness included an additional level of analysis, testing for effects of picture complexity.

Quantitative Measures

Overall word count

There was a simple effect of task, $F(1,56)=12.294$, $p=.001$; all participants produced fewer words during dual task (192.582, ± 7.6) compared to single task (207.517, ± 7.85). However, there was no simple effect of group ($p=.759$) or interaction ($p=.482$). There were no group level differences in word counts resulting from sentence trimming in either single ($p=.741$) or dual tasks ($p=.506$).

Sentence length

All participants produced fewer words per sentence, $F(1,58)=9.965$, $p=.003$, during dual task (10.124, ± 4.00) compared to single task (10.963, ± 4.35). Variability in sentence length (i.e. Standard Deviation) tended to be less during dual task conditions (3.398, ± 2.16) compared to single task (3.682, ± 2.13) but this task level contrast was
not significant ($p=.061$). There was also no simple effect of group ($p=.513$; $p=.382$) or interaction ($p=.382$; $p=.911$) for either measure.

**Number and proportion of nouns**

The number of nouns for all participants, $F(1,58)=4.741$, $p=.034$, was larger in the dual task (328.333, ±8.102) compared to the single task (312.836, ±6.625). There was, however, no simple effect of group ($p=.537$) or interaction ($p=.249$) for this measure. For all participants, the proportion of nouns of all types produced tended to increase in the dual task (.401, ±.004) compared to the single task (.321, ±.007). However, this trend did not reach significance, $F(1,56)=3.286$, $p=.075$ and there was no simple effect of group ($p=.118$) or interaction ($p=.131$).

**Number and proportion of verbs**

There was no simple effect of group ($p=.167$), task ($p=.514$) or interaction ($p=.111$) for the total number of verbs of all types produced; however three verb forms showed interesting patterns. There was a significant interaction between group and task for the number of verbs using the agentless passive voice, $F(1,58)=7.872$, $p=.007$, as shown in Figure 4-1. Post hoc analysis with Bonferroni correction indicated that people with Parkinson’s disease (PD) produced fewer verbs of this type (.672, ±.346) than controls (2.084, ±.509) only in dual task conditions, $p=.025$, and equivalent numbers during single task conditions (PD 1.287, ±.365; Controls .450, ±.536), $p=.202$. However, there were no simple effects of group ($p=.559$) or task ($p=.209$) for this measure. There was also a tendency for the dual task to affect the production of verbs in the past participle form differently for each group, such that production of this verb type was more frequent in dual task conditions (3.632, ±.928) compared to single task conditions (1.684, ±.500) for controls, $p=.034$, but not for people with Parkinson’s disease (1.769, ±.647; 1.949,
However, this interaction only approached significance, \( F(1,56) = 3.795, p = .056 \), and there were also no significant simple effects of group \( (p = .276) \) or task \( (p = .111) \).

Analysis further revealed that control subjects tended to use a greater proportion of verbs of all types in the dual task \((31.007, \pm 5.076)\) compared to the single task \((22.132, \pm 1.063)\), while people with Parkinson’s disease tended to show no difference between the number of verbs produced in dual \((21.279, \pm 3.543)\) and single tasks \((23.115, \pm 7.424)\). However, this interaction only approached significance, \( F(1,56) = 3.194, p = .079 \), and there was no simple effect of group \( (p = .193) \) or task \( (p = .245) \). With respect to verb subtypes, people with Parkinson’s disease \((.0673, \pm .008)\) used a smaller proportion of third-person singular verbs than controls \((.097, \pm .001), F(1,56) = 4.012, p = .050\). There was, however, no simple effect of task \( (p = .307) \) or interaction \( (p = .115) \) for this measure. There was also a significant three-way interaction affecting the proportion of verbs in past participle used in single and dual tasks between groups, \( F(1,56) = 5.342, p = .025 \), as shown in Figure 4-2. Controls used a greater proportion of past participle verbs in dual task \((.020, \pm .005)\) compared to single task \((.008, \pm .003), p = .013\), while people with Parkinson’s disease exhibited no difference in the proportion of past participle verbs used between dual \((.009, \pm .003)\) and single task \((.010, \pm .002), p = .731\). In contrast, there were no simple effects for either group \( (p = .354) \) or task \( (p = .060) \) for this measure.

**Number and proportion of adjectives**

As predicted, the number of adjectives produced for people with Parkinson’s disease \((16.410, \pm .243)\) was lower overall than for controls \((25.735, \pm 3.559), F(1,58) = 4.690, p = .034\). There was, however, no simple effect of task \( (p = .258) \) or
interaction ($p=.838$) for this measure. People with Parkinson’s disease tended to produce a smaller proportion of adjectives of all types (.015, ±.003) than controls (.022, ±.004). However this trend was not significant, $F(1,56)=3.188$, $p=.080$, and there was no simple effect of task ($p=.605$) or interaction ($p=.541$).

**Number and proportion of pronouns**

There were no simple effects of group, task or interaction for the number and proportion of pronouns of all types produced; however, particular subtypes of pronouns tended to show group differences. People with Parkinson’s disease (1.564, ±.330) produced fewer possessive pronouns than controls (2.895, ±0.472) overall, $F(1,56)=5.336$, $p=.025$. There was, however, no simple effect of task ($p=.961$) or interaction ($p=.794$) for this measure. People with Parkinson’s disease (1.410, ±.326) also tended to produce fewer wh-pronouns than controls (2.526, ±.467), but this trend was not quite significant, $F(1,56)=3.838$, $p=.055$, and there was no effect of task ($p=.825$) or interaction ($p=.523$). Indeed, people with Parkinson’s disease (.661, ±.162) also tended to produce a smaller proportion of Wh-pronouns than controls (1.223, ±.232). However this trend again only approached significance, $F(1,56)=3.934$, $p=.052$, and there was no simple effect of task ($p=.734$) or interaction ($p=.301$).

**Number of verbs per sentence**

All participants produced fewer verbs per sentence in the dual task (2.156, ±.099) compared to the single task (2.333, ±.094), $F(1,56)=5.024$, $p=.029$. However, there was no simple effect of group ($p=.464$) or interaction ($p=.300$).
Number of prepositions

There was no simple effect of group ($p=.170; p=.269$), task ($p=.494; p=.930$) or interaction ($p=.610; p=.298$) for the number of prepositions or prepositional density produced by participants.

Number of words before main verb

There was no simple effect of group ($p=.166$), task ($p=.501$), or interaction ($p=.356$) on the mean number of words produced before main verbs.

Number of modifiers for each noun phrase

There was no simple effect of group ($p=.416$), task ($p=.560$), or interaction ($p=.109$) on the number of number of modifiers for each noun phrase.

Summary

The preceding analyses have revealed pervasive simple effects of task associated with reduced word counts, fewer words per sentence, and fewer verbs used in sentences in dual task conditions for all participants. At the level of word class, the number of nouns increased in dual task conditions. In contrast, on the dual task did not affect the number or proportion of verbs, adjectives, pronouns or prepositions produced. Group differences are further reported; people with Parkinson’s disease produced fewer singular verbs, adjectives and possessive pronouns overall than controls. People with Parkinson’s disease were also insensitive to dual task effects associated with increased use of participle verbs in dual task by control subjects and produced fewer passive verbs than controls, but only in dual task conditions. There were, however, no group level effects on the number or proportion of nouns, adjectives or prepositions produced.
**Qualitative Measures**

**Propositional density**

All participants produced fewer propositions during the dual task (65.355, ±3.832) compared to the single task (72.804, ±3.972), $F(1,56)=10.078, \ p=.002$. In contrast, there was no simple effect of group ($p=.768$) or interaction ($p=.136$) for this measure. There was also no simple effect of group ($p=.562$), task ($p=.119$) or interaction ($p=.277$) for propositional density.

**Concreteness and word frequency**

All participants used more concrete words of all types during dual task (5.065, ±.168) compared to single task conditions (4.774, ±.169), $F(1,58)=6.551, \ p=.013$. There was, however, no simple effect of group ($p=.991$) or interaction ($p=.396$) for this measure. Similarly, concreteness of content words (i.e. nouns, verbs and adjectives), $F(1,58)=6.061, \ p=.017$, increased in dual task (537.185, ±5.370) compared to single task conditions (529.541, ±5.509) for all participants. There was, however, no simple effect of group ($p=.797$) or interaction ($p=.509$) for this measure. Similarly, there was also a trend for increased imageability in dual task conditions (554.634, ±4.789) compared to the single task (549.540, ±5.016) but this was only marginally significant, $F(1,58)=3.254, \ p=.076$. Both groups also used lower frequency content words in dual task (2.145, ±.020) compared to single task conditions (2.194, ±.019), $F(1,58)=5.565, \ p=.022$, and there was no significant simple effect of group ($p=.676$) or interaction ($p=.373$).

**Syntactic complexity**

All participants produced syntactically *less* complex sentences during dual task (1.337, ±.159) compared to single task conditions (1.094, ±.147), $F(1,58)=5.787$,
There was, however, no simple effect of group \((p=0.645)\) or interaction \((p=0.487)\).

Similarly, all participants’ grade reading level (a measure based on syntactic complexity) was lower in dual task conditions \((2.940, \pm 0.202)\) compared to single task conditions \((3.314, \pm 0.194)\), \(F(1,58)=8.184, p=0.006\). There was, however, no simple effect of group \((p=0.394)\) or interaction \((p=0.877)\).

**Type-token ratio**

All participants tended to produce a greater number of lexically diverse words overall (higher type-token ratios) in dual task \((0.381, \pm 0.010)\) compared to single task conditions \((0.363, \pm 0.010)\). However, this trend was not significant, \(F(1,58)=3.787, p=0.056\), and neither the simple effect of group \((p=0.832)\) nor the interaction term \((p=0.662)\) was significant for this measure. There was also no simple effect of group \((p=0.685)\), task \((p=0.135)\), or interaction \((p=0.341)\) when type-token ratio was limited to content word lemmas.

**Action Verb Content**

As predicted, all participants produced a higher number of action verbs in dual task \((74.910, \pm 4.302)\) compared to single task conditions \((67.989, \pm 3.905)\), \(F(1,58)=4.342, p=0.042\). There were also marginal group differences in the effects of dual task on the number of action verbs produced. Controls tended to increase the number of action verb content under dual task conditions \((76.980, \pm 7.112)\) compared to the single task \((63.674, \pm 6.456)\), \(p=0.019\), while people with Parkinson’s disease tended to be impervious to dual task effects \((72.841, \pm 4.841; 72.304, \pm 4.395)\), \(p=0.886\). However, this interaction only showed a trend toward significance, \(F(1,58)=3.695, p=0.059\), and there was no simple effect of group \((p=0.766)\) for this measure.
Content word hypernymy

All participants produced more specific nouns and verbs (larger noun and verb hypernymy) in dual task conditions (2.503, ±.053) compared to single task (2.397, ±.045), $F(1,58)=5.540$, $p=.022$. There was, however, no simple effect of group ($p=.466$) and no significant interaction ($p=.344$). In contrast, hypernym measures for nouns and verbs separately were not significant. There was also no simple effect of group ($p=.864$; $p=.554$), task ($p=.605$; $p=.192$), or interaction ($p=.246$; $p=.602$) for either measure of verb or noun hypernymy.

Information completeness

There was a simple effect of picture complexity on information completeness, $F(1,56)=56.389$, $p=.0001$. All participants provided more complete information describing simple (.737, ±.022) compared to complex pictures (.567, ±.737). Unexpectedly, people with Parkinson’s disease also provided more informative sentences (.713, ±.030) than controls (.592, ±.043), $F(1,56)=5.460$, $p=.023$. These simple effects were secondary to a significant group interaction with task and picture complexity, $F(1,56)=4.871$, $p=.031$, as shown in Figure 4-3. Post hoc analysis using Bonferroni correction revealed that group level performance advantages for people with Parkinson’s disease for both simple ($p=.020$) and complex pictures ($p=.007$) were significant in the single task, and eliminated in the dual task for simple ($p=.068$) and complex pictures ($p=.495$). In the single task, people with Parkinson’s disease produced more informative descriptions than controls, both for simple (PD .800, ±.029; Controls .679, ±.041) and complex pictures (PD .646, .043; Controls .437, ±.061). In contrast, there were no group level differences in dual task conditions, either for simple
Grammaticality

There was a simple effect of picture complexity for grammaticality, $F(1,56)=4.727$, $p=.034$. All participants produced fewer grammatical errors (larger accuracy scores) describing simple (.783, ±.031) compared to complex pictures (.755, ±.032). This simple effect was secondary to a significant group interaction with picture complexity, $F(1,56)=5.322$, $p=.025$, as shown in Figure 4-4. Post hoc analysis using Bonferroni correction revealed that people with Parkinson’s disease produced more grammatical errors describing complex pictures (.730, ±.037) compared to simple pictures (.790, ±.035), $p=.0001$, in contrast, there were no differences in control performance between complex (.779, ±.053) and simple picture descriptions (.777, ±.050) for this measure, $p=.936$. There was, however, no simple effect of group ($p=.774$), task ($p=.817$), or interaction between group and task ($p=.992$), between task and complexity ($p=.472$) or between group, task and complexity ($p=.855$) for grammaticality.

Summary

Pervasive simple effects of task were revealed that were associated with reduced propositional density, decreased syntactic complexity and lower grade reading level scores. Action verb use increased in dual task for all participants and both nouns and verbs were more specific under dual task conditions. Type-token ratios also tended to be lower in the dual task, although this effect of task was not significant ($p=.056$). In contrast, there was no task level effect for verb frequency and group level differences reported were limited to information completeness only. All participants produced more information in single task than dual task conditions. In addition, people with Parkinson’s
disease provided more complete information than controls in single task conditions. There were, however, no reported group level differences for propositional density, syntactic complexity, type-token ratio, verb frequency, action verb content, or for noun or verb hypernymy.

**Discourse Production**

The purpose of this analysis is to address specific aims 1 and 2 of this dissertation project. The same procedure detailed above was performed for each quantitative and qualitative dependent variable collected in the discourse production task, as shown in Table 4-3 and Table 4-4. In contrast to the sentence production task, separate analysis and measures for information completeness and grammaticality were not collected or performed. However, measures of coherence and cohesion were added.

**Quantitative Measures**

**Overall word count**

There was no simple effect of group ($p=.113$), task ($p=.609$), and no interaction ($p=.251$) for overall word counts. There was also no group level difference in word counts resulting from trimming discourse ($p=.161$) in either task ($p=.868$).

**Sentence length**

Overall people with Parkinson’s disease (14.201, ±.428) produced fewer words per sentence, $F(1,54)=11.344$, $p=.001$, with decreased variability (8.236, ±.260) in sentence length (i.e. Standard Deviation), $F(1,54)=7.497$, $p=.008$, compared to controls (16.675, ±.597; 9.457, ±.362). There was however no effect of task ($p=.297$; $p=.103$) and no interaction ($p=.621$; $p=.842$) for either mean sentence length or sentence variability.
Number and proportion of nouns

The number of noun phrases produced by all participants increased significantly in the dual task (378.761, ±4.772) compared to the single task (364.296, ±4.316), $F(1,54)=5.588, p=.022$. However, there was no simple effect of group ($p=.673$) and no interaction with task ($p=.544$) for this measure. In addition, people with Parkinson’s disease produced fewer plural nouns (16.014, ±1.019), $F(1,54)=6.043, p=.017$, and more proper nouns (13.216, ±.954) than controls (20.316, ±1.423; 9.342, ±1.331), $F(1,54)=5.596, p=.022$. However, there was no simple effect of task ($p=.155; p=.387$) and no interaction ($p=.918; p=.171$) for either measure. There was also no simple effect of group ($p=.517$), task ($p=.604$), and no interaction ($p=.374$) for the number of nouns of all types produced. The total proportion of noun phrases produced showed no significant simple effect of group ($p=.241$), task ($p=.977$) or interaction ($p=.705$). However, people with Parkinson’s disease (3.801, ±2.46) produced a higher proportion of proper nouns than controls (2.495, ±.344), $F(1,54)=9.547, p=.003$. However there was no simple effect of task ($p=.569$) and no interaction ($p=.167$) for this measure.

Number and proportion of verbs

The number of verbs produced showed no simple effects of group ($p=.179$), task ($p=.924$), and no interaction ($p=.396$). In contrast, both participant groups produced fewer verbs using past and present participles in dual task (16.885, ±.945) compared to the single task (20.170, ±1.122), $F(1,54)=6.029, p=.017$. However, there was no simple effect of group ($p=.238$) and no interaction ($p=.651$) for this measure. Additionally, people with Parkinson’s disease (29.828, ±1.303) used a higher number of causal verbs than controls (25.119, ±1.819), $F(1,54)=4.430, p=.040$. There was however, no simple effect of task ($p=.164$) and no interaction ($p=.331$) for this measure. Both participant
groups produced a smaller proportion of verbs in present and past participle during dual task conditions (.035, ±.003) compared to single task conditions (.042, ±.002), $F(1,54)=4.667, p=.035$. However there was no simple effect of group ($p=.983$) and no interaction ($p=.802$) for this measure. There was also no simple effect of group ($p=.676$), task ($p=.497$) and no interaction ($p=.800$) for the proportion of all verbs produced.

**Number and proportion of adjectives**

As predicted, the number of adjectives for people with Parkinson’s disease (16.410, ±.243) was lower overall than for controls (25.735, ±3.559), $F(1,58)=4.690, p=.034$. There was, however, no simple effect of task ($p=.258$) or interaction ($p=.838$) for this measure. People with Parkinson’s disease tended to produce a smaller proportion of adjectives of all types (.015, ±.003) than controls (.022, ±.004). However this trend was not significant, $F(1,56)=3.188, p=.080$, and there was no simple effect of task ($p=.605$) or interaction ($p=.541$). There was no simple effect of group ($p=.245$), task ($p=.920$) and no interaction ($p=.317$) for the proportion of all adjectives produced.

**Number and proportion of pronouns**

The total number of pronouns showed no significant simple effects of group ($p=.159$), task ($p=.258$), and no interaction ($p=.282$). Similarly, there was no simple effect of group ($p=.732$), task ($p=.193$) and no interaction ($p=.294$) for the proportion of pronouns of all types produced by participants. People with Parkinson’s disease (1.811, ±.201) produced fewer wh-pronouns than controls (2.711, ±.280), $F(1,54)=6.831, p=.012$. However, there was no simple effect of task ($p=.653$) and no interaction ($p=.566$) for this measure. Additionally, people with Parkinson’s disease (.531, ±.055) tended to produce a smaller proportion of Wh-pronouns than controls (.700, ±.076).
However, this trend was not significant, $F(1,54)=3.250, p=.077$, and there was no simple effect of task ($p=.469$) and no interaction ($p=.554$).

**Number of verbs per sentence**

People with Parkinson’s disease (2.762, ±0.078) produced fewer verbs per sentence than controls (3.248, ±0.109), $F(1,54)=13.025, p=.001$. There was however no simple effect of task ($p=.257$) and no interaction ($p=.488$) for this measure.

**Number of prepositions**

People with Parkinson’s disease (39.932, ±1.911) produced fewer prepositions than controls (46.947, ±2.666), $F(1,54)=4.574, p=.037$. However, there was no simple effect of task ($p=.870$) and no interaction ($p=.499$) for this measure. The number of prepositional phrases produced was also reduced in people with Parkinson’s disease (97.368, ±2.682) compared to controls (107.236, ±3.743), $F(1,54)=4.592, p=.037$, while there was no simple effect of task ($p=.742$) and no interaction ($p=.527$).

**Number of words before main verb**

There was no simple effect of group ($p=.460$), task ($p=.777$), and no interaction ($p=.975$) on the number of words produced before main verbs.

**Number of modifiers for each noun phrase**

There was no simple effect of group ($p=.410$), task ($p=.420$), and no interaction ($p=.221$) on the number of number of modifiers for each noun phrase.

**Summary**

In contrast to findings for sentence production, pervasive group level effects were revealed for discourse. Simple effects of group were associated with reduced sentence length and fewer verbs produced per sentence by people with Parkinson’s disease compared to controls. At a lexical level, people with Parkinson’s disease produced a
more proper nouns, more causal verbs but fewer plural nouns, fewer adjectives overall, fewer wh-pronouns, fewer prepositions and fewer prepositional phrases than controls. In contrast, there were no group level differences in word counts, or the number and proportion of verbs and pronouns produced overall. Additionally, the groups did not differ significantly in the number of words produced before main verbs, and the number of modifiers produced for each noun phrase. Task level differences are also reported. The number of noun phrases produced decreased in dual task conditions for all participants. Both participant groups also used fewer verbs in participle form in dual task conditions. In contrast, task level effects were not reported for word counts, sentence length, number and proportion of nouns, verbs, pronouns, adjectives overall. There was also no significant effect of task for either the number of words used before main verbs or the number of modifiers used for each noun phrase.

**Qualitative Measures**

**Propositional density**

The propositional density produced was lower for people with Parkinson’s disease (.465, ±.005) than controls (.492, ±.007), $F(1,54)=10.414, p=.003$. However, there was no simple effect of task ($p=.542$) or interaction ($p=.374$) for this measures. Similarly, the number of propositions produced was lower for people with Parkinson's disease (160.135, ±7.020) than controls (185.921, ±9.796), $F(1,54)=4.578, p=.037$. However, there was no simple effect of task ($p=.857$) or interaction ($p=.113$) and for this measure.

**Concreteness and imageability**

Words of all types became less concrete in dual task conditions (.085, ±.109) compared to single task (.385, ±.133), $F(1,54)=4.191, p=.046$. However, there was no simple effect of group ($p=.572$) or interaction ($p=.658$) for this measure. In contrast, for
all participants, under dual task conditions *content* words became more concrete (370.301, ±3.603) compared to single task conditions (360.229, ±3.597), $F(1,54)=5.722$, $p=.020$, and more imageable (404.987, ±3.299) compared to single task conditions (394.941, ±3.644), $F(1,54)=5.481$, $p=.023$. There were no other significant effects in these analyses.

**Syntactic complexity**

People with Parkinson’s disease produced syntactically simpler sentences (.060, ±.075) compared to controls (-.301, ±.104), $F(1,54)=7.871$, $p=.007$. There was however, no simple effect of task ($p=.623$) and no significant interaction with group ($p=.694$). Similarly, grade reading level of discourse produced by people with Parkinson’s disease (6.213, ±.256) was lower than controls (7.247, ±.357), $F(1,54)=5.545$, $p=.022$. There was, however, no simple effect of task ($p=.394$) or interaction (.999) for grade reading level.

**Type-token ratio**

Neither the analysis of type-token ratio for all words or for content word lemmas revealed any significant effects. There was no simple effect of group ($p=.200$; $p=.328$, respectively), task ($p=.246$; $p=.057$) or interaction ($p=.611$; $p=.280$).

**Verb frequency**

There was no simple effect of group ($p=.463$), task ($p=.637$), and no interaction ($p=.999$) on spoken word frequency for verbs.

**Action Verb Content**

There was no simple effect of group ($p=.118$), task ($p=.077$), and no interaction ($p=.827$) on the number of action verbs produced.
Content word hypernymy

Both participant groups produced more specific verbs under dual task conditions (1.479, ±.021) compared to single task (1.426, ±.022), F(1,54)=4.005, p=.050, but there was no simple effect of group (p=.449) or interaction (p=.620) for verb hypernymy. In contrast, people with Parkinson’s disease (6.311, ±.057) produced less specific nouns than controls (6.525, ±.080), F(1,54)=4.717, p=.034. There was, however, no simple effect of task (p=.633) and no interaction (p=.515) for noun hypernymy.

Cohesion

People with Parkinson’s disease produced fewer cohesive arguments (.402, ±.014) than controls (.473, ±.020), F(1,54)=8.282, p=.006, used fewer referring anaphors both locally (.533, ±.020) than controls (.619, ±.027), F(1,54)=6.558, p=.013, and globally (.260, ±.015) than controls (.336, ±.021), F(91,54)=8.830, p=.004, and used fewer temporal connective words (15.405, ±.915) than controls (18.614, ±1.277), F(1,54)=4.170, p=.046. Moreover compared to controls, people with Parkinson’s disease produced sentences with more syntactic similarity locally (PD=.123, ±.005; HOA=.103, ±.007), F(1,54)=5.537, p=.022, and globally (PD = .108, ±.003; HOA=.095, ±.005), F(1,54)=5.043, p=.029. This suggests that people with Parkinson’s disease produced less variability in their sentence structures than controls. There was, however, no simple effect of task and no interaction with group in either analysis. For both groups, the dual task (.932, ±.109) resulted in reduced verb cohesion compared to the single task (1.274, ±.105), F(1,54)=5.805, p=.019, while there was no simple effect of group (p=.216) and no interaction (p=.098). No other measures of cohesion were significant.
Coherence

There was a significant group interaction with task for local coherence, \( F(1.54)=4.145, p=.047 \), as shown in Figure 4-5. Post hoc analysis using Bonferroni correction revealed that local coherence was equivalent between single (.142, ± .008) and dual tasks (.150, ± .008) for people with Parkinson’s disease, \( p=.418 \). In contrast, controls tended to be more coherent in single task (.177, ± .012) than in dual task (.150, ± .011) conditions however, this contrast was not significant, \( p=.060 \). Thus, people with Parkinson’s disease (.142, ± .008) were less locally coherent than controls (.177, ± .012), \( p=.020 \), only in the single task, but there were no group level differences between people with Parkinson’s disease (.150, ± .008) and controls (.150, ± .011) in dual task conditions, \( p=.974 \). There was also no simple effect of either group (\( p=.137 \)) or task (\( p=.283 \)) on this single measure of local coherence. Global coherence, by contrast, was unaffected by group (\( p=.115 \)), task (\( p=.564 \)), and there was no significant interaction (\( p=.261 \)).

Summary

Pervasive simple effects of group on discourse were revealed that were associated with a reduced proportion and number of propositions produced by people with Parkinson’s disease compared to controls. Syntactic complexity and grade reading level was reduced in people with Parkinson’s disease associated with the production and less locally and globally cohesive ties which were also less locally coherent.

People with Parkinson’s disease produced sentences whose syntax was more similar between sentences both locally and globally. At a lexical level people with Parkinson’s disease also produced less specific nouns than controls. In contrast, no group level effects were reported for global coherence, type-token ratio, verb frequency, action verb
content, and hypernymy. There were also some effects of the dual task reported. Both groups of participants used more specific verbs under dual conditions and verb cohesion was generally reduced in the dual task compared to the single task. In contrast, there were no reported task level effects for propositional density, syntactic complexity, type-token ratio, verb frequency, action verb content and coherence.

**Regression Analyses for Sentence Production**

The purpose of this analysis is to address specific aim 3 of this dissertation project. Analysis consisted of a series of hierarchical linear regressions for each dependent variable showing a simple effect of group or interaction with group. Cognitive factors were entered stepwise in the first level of the regression, followed by forced entry of group in the subsequent step. The predictors of performance for sentence production are displayed in Table 4-5 and predictors of performance for discourse are presented in Table 4-6.

**Quantitative Measures**

There was no significant predictor of the number of agentless passive voice verbs used in single task conditions. In contrast, individual differences in the number of agentless passive voice verbs used in dual task conditions was predicted only by the group factor accounting for 8.3% of variance in scores ($\beta=.288$, $R^2=.083$, $F(1,59)=5.263$, $p=.025$).

Individual differences in the number of past participle verbs used in single task conditions was predicted only by the working memory factor accounting for 7.7% of score variance ($\beta=.278$, $R^2=.077$, $F(1,57)=4.787$, $p=.033$). The influence of the group factor was not significant in improving the model fit, $p=.557$. Individual differences in the number of past participle verbs used in dual task conditions was predicted by two
factors accounting for 14.0% of score variance ($R^2=.140$, $F(1,56)=5.195$, $p=.026$). The working memory factor ($R^2=.093$, $\beta=\.305$, $p=.019$), and the processing speed factor ($R^2=.077$, $\beta=-.277$, $p=.026$) predicted the number of past participles produced in dual task conditions. The influence of the group factor was not significant in improving the model fit, $p=.729$.

There was no significant predictor of number of adjectives in single task conditions. In contrast, individual differences in the number of adjectives produced in dual task conditions was predicted only by the group factor accounting for 7.5% of score variance ($\beta=.273$, $R^2=.075$, $F(1,58)=4.670$, $p=.035$). There was no significant predictor of the number of wh-pronouns produced in single task conditions. However, there was a marginal effect of group ($\beta=.246$, $R^2=.061$, $F(1,57)=3.681$, $p=.060$) accounting for 6.1% of score variance in single task conditions. In contrast, individual differences in the number of wh-pronouns produced in dual task conditions was predicted only by the updating factor accounting for 7.8% of score variance ($\beta=.279$, $R^2=.078$, $F(1,57)=4.818$, $p=.032$) while the influence of the group factor was not significant in improving the model fit, $p=.828$. There was no significant predictor of the proportion of wh-pronouns produced in single task conditions. In contrast, individual differences in the proportion of wh-pronouns produced in dual task conditions was predicted only by the updating factor accounting for 9.3% of score variance ($\beta=.304$, $R^2=.093$, $F(1,57)=5.817$, $p=.019$) while the influence of the group factor was not significant in improving the model fit, $p=.584$. 
There were no significant cognitive or group predictors of the proportion all verbs, the proportion of 3rd person singular verbs, or the number of possessive pronouns produced by participants.

**Summary.** Processing speed, working memory and information updating predicted group level differences in quantitative sentence production. Slower processing and poorer working memory predicted reduced use of past participle verbs in dual task conditions, while only poorer working memory predicted differences in single task conditions. Both the number and proportion of wh-pronouns under dual task conditions were predicted by the updating factor. Group differences not accounted for by our measures of cognitive processing included fewer passive verbs and fewer adjectives and wh-pronouns in single task conditions. In contrast, there were no significant cognitive or group predictors for overall word count, mean sentence length, mean sentence variability, number of nouns, noun proportion, verb proportion, singular verb proportions, number of possessive pronouns, or verbs per sentence in either single of dual task conditions. There were also no significant predictors for number of adjectives or wh-pronoun proportions in single task conditions.

**Qualitative Measures**

There was no significant cognitive predictor of information completeness for either single or dual task conditions and simple and complex pictures. However, in single task conditions group differences accounted for 8.3% of score variance ($\beta=-.314$, $R^2=.083$, $F(1,58)=6.237$, $p=.015$) for simple pictures and 13.0% of score variance ($\beta=-.360$, $R^2=.130$, $F(1,58)=8.494$, $p=.005$) for complex pictures. In contrast, there were no cognitive predictors or group level effects affecting information completeness in dual task conditions for either simple or complex pictures.
Individual differences for grammaticality in single task conditions were predicted by two factors for simple pictures accounting for 29.3% of score variance, \((R^2 = .293, F(1,56) = 11.583, p = .0001)\), and by three factors for complex pictures accounting for 33.5% of score variance, \((R^2 = .335, F(1,55) = 9.231, p = .017)\). The processing speed factor \((R^2 = .230, \beta = -.480, p = .0001)\), and the working memory factor \((R^2 = .063, \beta = .250, p = .030)\) predicted the grammaticality of sentences describing simple pictures in single task conditions. The influence of the group factor again was not significant in improving the model fit, \(p = .187\). The processing speed factor \((R^2 = .149, \beta = -.386, p = .003)\), the working memory factor \((R^2 = .112, \beta = .334, p = .005)\), and the updating factor \((R^2 = .074, \beta = .272, p = .005)\) predicted the grammaticality of sentences describing complex pictures in single task conditions. The influence of the group factor was not significant in improving the model fit, \(p = .433\). Individual differences for grammaticality in dual task conditions were predicted only by the processing speed factor which accounted for 6.8% of score variance for simple pictures \((R^2 = .068, \beta = -.260, F(1,57) = 4.132, p = .047)\) and 10.8% of score variance for complex pictures \((R^2 = .108, \beta = -.329, F(1,57) = 6.917, p = .011)\). The influence of the group factor was not significant in improving the model fit for either simple (\(p = .513\)) or complex pictures (\(p = .956\)) in dual task conditions. There were no significant cognitive or group level predictors of the number of action verbs produced.

**Summary.** There were no cognitive or group level predictors for number of prepositions, concreteness overall, concreteness for content words, written word frequency for content words, syntactic complexity, grade reading level, type-token ratio, number of action verbs, and hypernymy for either single or dual task conditions.
However, information completeness in single task conditions for both simple and complex pictures was predicted by the group factor. There were, however, no cognitive or group predictors in dual task conditions for this measure. Slower processing speed predicted fewer grammatical sentences at all levels of picture complexity, both during single and dual task conditions. However, during the single task the production of fewer grammatical sentences was also associated with poorer working memory both when participants described simple and complex pictures. Poorer updating performance also predicted use of fewer grammatical sentences, but only when participants described complex pictures in dual task conditions.

**Regression Analyses for Discourse Production**

The same regression procedure reported above for sentence production was applied to discourse measures to address specific aim 3 of this project, as shown in Table 4-7 and Table 4-8.

**Quantitative Measures**

Individual differences in mean sentence length used in single task conditions was predicted only by the group factor accounting for 14.4% of score variance ($R^2 = .144$, $\beta = .380$, $F(1,55) = 9.260$, $p = .004$). Similarly, individual differences in mean sentence length used in dual task conditions was predicted only by the group factor accounting for 9.4% of score variance ($R^2 = .094$, $\beta = .307$, $F(1,56) = 5.838$, $p = .019$).

There was no significant predictor of sentence length variability used in single task conditions. However, individual differences in sentence length variability in dual task conditions was predicted only by the group factor accounting for 8.3% of score variance ($R^2 = .083$, $\beta = .289$, $F(1,56) = 5.092$, $p = .028$).
There was no significant predictor of plural noun counts used in single task conditions. However, individual differences in plural noun counts used in dual task conditions was predicted by two factors accounting for 27.7% of score variance ($R^2 = .277$, $F(1,55) = 10.820$, $p = .0001$). The processing speed factor ($R^2 = .175$, $\beta = -.418$, $p = .001$), and the updating factor ($R^2 = .102$, $\beta = .319$, $p = .007$) predicted the number of plural nouns produced in dual task conditions. The influence of the group factor was not significant in improving the model fit, $p = .507$.

Individual differences in proper noun counts used in single task conditions was predicted only by the updating factor accounting for 7.7% of score variance ($R^2 = .077$, $\beta = -.278$, $F(1,55) = 4.620$, $p = .036$). The influence of the group factor was not significant in improving the model fit, $p = .081$. While there was no significant predictor of proper noun counts used in dual task conditions. Individual differences in proper noun proportions used in single task conditions was predicted only by the updating factor accounting for 16.4% of score variance ($\beta = -.406$, $R^2 = .164$, $F(1,55) = 10.828$, $p = .002$). The influence of the group factor was not significant in improving the model fit, $p = .334$. There were no significant predictors of proper noun proportions used in dual task conditions. Similarly, there were no significant cognitive or group predictors for number of causal verbs or number of adjectives in either the single or the dual task.

There was no significant predictor of wh-pronoun counts used in single task conditions. In contrast, individual differences in wh-pronoun counts in dual task conditions was predicted by the group factor, accounting for 8.7% of score variance ($R^2 = .087$, $\beta = .294$, $F(1,56) = 5.305$, $p = .025$). There were no significant cognitive or group level predictors for wh-pronoun proportions in single task conditions. However,
although the group factor accounted for 5.6% of score variance (β=.236, R²=.056) in dual task conditions, this was not significant F(1,56)=3.316, p=.074.

Individual differences in number of prepositions used in single task conditions were predicted only by the updating factor accounting for 10.2% of score variance (R²=.102, β=.319, F(1,55)=6.251, p=.015). The influence of the group factor was not significant in improving the model fit, p=.249. Individual differences in the number of prepositions used in dual task conditions was predicted by two factors accounting for 21.4% of score variance (R²=.214, F(1,55)=7.507, p=.0001). The updating factor (R²=.146, β=-.382, p=.003), and the processing speed factor (R²=.068, β=-.261, p=.033) predicted the number of prepositions produced in dual task conditions. The influence of the group factor was not significant in improving the model fit, p=.382.

Individual differences in number of verbs per sentence used in single task conditions was predicted only by the group factor accounting for 15.0% of score variance (R²=.150, β=.387, F(1,55)=9.686, p=.003). Similarly, individual differences in number of verbs per sentence used in dual task conditions was predicted only by the group factor accounting for 7.0% of score variance (R²=.070, β=.264, F(1,56)=4.200, p=.045). There were no significant predictors of syntactic complexity used in single task conditions.

**Summary.** Processing speed and information updating but not working memory predicted group level differences in quantitative discourse production. Slower processing speed and poorer updating scores predicted a reduced number of plural nouns and prepositions in dual conditions only. Those individuals with poorer updating skills produced fewer prepositions in both single and dual task conditions and more
proper nouns in single task conditions only. Group differences not accounted for by measures of cognitive processing included: sentence length in single task, and sentence length, variability and number of verbs produced per sentence in both single and dual task conditions. The number of wh-pronouns produced was also predicted by group membership, but only in single task conditions.

**Qualitative Measures**

Individual differences in proposition density used in single task conditions was predicted only by the processing speed factor accounting for 12.4% of score variance ($R^2=.124$, $\beta=-.352$, $F(1,55)=7.784$, $p=.007$). The influence of the group factor was not significant in improving the model fit, $p=.489$. Individual differences in proposition density used in dual task conditions was predicted only by the processing speed factor accounting for 19.3% of score variance ($R^2=.193$, $\beta=.439$, $F(1,56)=13.404$, $p=.001$).

The influence of the group factor ($\beta=.243$, $R^2=.054$) was not significant in improving the model fit, $p=.052$. However, individual differences in the number of propositions used in single task conditions was predicted by three factors accounting for 38.2% of score variance ($R^2=.382$, $F(1,53)=10.913$, $p=.0001$). The processing speed factor ($R^2=.151$, $\beta=-.389$, $p=.003$), and the working memory factor ($R^2=.158$, $\beta=.398$, $p=.001$), and the updating factor ($R^2=.072$, $\beta=-.269$, $p=.016$) predicted the number of propositions produced in single task conditions. The influence of the group factor was not significant in improving the model fit, $p=.695$. Similarly, individual differences in the number of propositions used in dual task conditions was predicted by two factors accounting for 26.7% of score variance ($R^2=.267$, $F(1,55)=10.041$, $p=.0001$). The updating factor ($R^2=.146$, $\beta=.383$, $p=.003$), and the processing speed factor ($R^2=.121$, $\beta=-.348$, $p=.004$)
predicted the number of propositions produced in dual task conditions. The influence of the group factor was not significant in improving the model fit, $p=.188$.

Individual differences in syntactic complexity used in dual task conditions was predicted only by the group factor accounting for 10.5% of score variance ($R^2=.324$, $\beta=-.324$, $F(1,56)=6.572$, $p=.013$). There were no significant predictor of reading grade level in single task conditions, although the influence of group ($R^2=.058$, $\beta=.242$) approached significance in dual task conditions, $F(1,56)=3.479$, $p=.067$.

There was no significant predictor of noun hypernymy used in single task, however, the influence of group ($\beta=.244$, $R^2=.059$) was marginally significant, $F(1,55)=3.476$, $p=.068$). There was however, no significant predictor of noun hypernymy used in dual task conditions.

Individual differences in argument cohesion in single task conditions was predicted by two factors accounting for 20.4% of score variance ($R^2=.204$, $F(1,54)=6.905$, $p=.002$). The processing speed factor ($R^2=.140$, $\beta=-.374$, $p=.004$), and the updating factor ($R^2=.064$, $\beta=.253$, $p=.042$) predicted argument cohesion in single task conditions. The influence of the group factor was not significant in improving the model fit, $p=.129$. There was however, no significant predictor of argument cohesion in dual task conditions.

Individual differences in local anaphor cohesion used in single task conditions was predicted only by the updating factor accounting for 8.2% of score variance ($R^2=.082$, $\beta=.285$, $F(1,55)=4.881$, $p=.031$). The influence of the group factor was not significant in improving the model fit, $p=.550$. Individual differences in local anaphor cohesion used in
Individual differences in global anaphor cohesion used in single task conditions was predicted only by the updating factor accounting for 10.9% of score variance ($R^2=.109$, $\beta=.330$, $F(1,55)=6.734$, $p=.012$). The influence of the group factor was not significant in improving the model fit, $p=.289$. Individual differences in global anaphor cohesion used in dual task conditions was predicted only by the group factor accounting for 7.5% of score variance ($R^2=.075$, $\beta=.273$, $F(1,56)=4.516$, $p=.038$).

There was no significant cognitive or group level predictor of number of temporal connective words used in single task conditions. Individual differences in the number of temporal connective words produced in dual task conditions was predicted only by the updating factor accounting for 7.7% of score variance ($R^2=.077$, $\beta=.278$, $F(1,56)=4.691$, $p=.035$). The influence of the group factor was not significant in improving the model fit, $p=.716$.

There was no significant cognitive or group level predictor of local syntactic similarity in single task. Individual differences in local syntactic similarity in dual task conditions was predicted only by the group factor accounting for 11.7% of score variance ($R^2=.117$, $\beta=-.343$, $F(1,56)=7.455$, $p=.008$). There was no significant cognitive or group level predictor of global syntactic similarity in single task. Individual differences in global syntactic similarity in dual task conditions was predicted only by the group factor accounting for 7.5% of score variance ($R^2=.075$, $\beta=-.275$, $F(1,56)=4.572$, $p=.037$).

Individual differences in local coherence in single task conditions was predicted only by the group factor accounting for 9.9% of score variance ($R^2=.099$, $\beta=.315$,
**Summary.** Processing speed, working memory and information updating predicted several group level differences in qualitative discourse production. Slower processing speeds predicted reductions in the number and density of propositions, and reduced argument cohesion in the single task. Slower processing speed was also associated with individuals producing less propositional information in dual task conditions. Poorer working memory, in contrast, only predicted the production of fewer propositions only under single task conditions. Poorer updating skills in contrast, had pervasive effects on qualitative measures. In particular, poorer updating was associated with reductions in propositional density during dual task, number of propositions both in single and dual task, argument cohesion in single task, local anaphor cohesion in both single and dual task conditions, global anaphor cohesion only in single task conditions and fewer connective words during dual task conditions only. Group level membership, that is having Parkinson’s disease, predicted propositional density, syntactic complexity, local anaphor cohesion, global anaphor cohesion, and both global and local syntactic similarity only under dual task conditions. Group membership also predicted local coherence during single task conditions.
Table 4-1. Simple effects and interaction for quantitative measures of sentence production showing significance and marginal significance.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Group Effect</th>
<th>Dual Task Effect</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total word count</td>
<td>p=.001^</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sentence length</td>
<td>p=.003^</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sentence variability</td>
<td>p=.061^</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noun - count</td>
<td>p=.034</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noun proportion</td>
<td>p=.075</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Agentless passive verb - count</td>
<td>p=.007</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Past participle verb - count</td>
<td>p=.056</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verb proportion</td>
<td>p=.079</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verb 3rd person sing. - proportion</td>
<td>p=.050*</td>
<td></td>
<td>p=.025</td>
</tr>
<tr>
<td>Adjective - count</td>
<td>p=.034*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Possessive pronoun - count</td>
<td>p=.025*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wh-pronoun - count</td>
<td>p=.055*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wh-pronoun - proportion</td>
<td>p=.052*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbs per sentence</td>
<td>p=.029^</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: * indicates PD scored lower on this measure than controls; ^ denotes dual task interference.

Table 4-2. Simple effects and interaction for qualitative measures of sentence production showing significance and marginal significance.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Group Effect</th>
<th>Dual Task Effect</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Preposition - count</td>
<td>p=.002^</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concreteness - all words</td>
<td>p=.013</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concreteness - content words</td>
<td>p=.017</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Word frequency - content words</td>
<td>p=.022^</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syntactic complexity</td>
<td>p=.019^</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade reading level</td>
<td>p=.006^</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type-token ratio - all words</td>
<td>p=.056</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action verb - count</td>
<td>p=.042</td>
<td>p=.059</td>
<td></td>
</tr>
<tr>
<td>Hypernymy - nouns and verbs</td>
<td>p=.022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Information completeness**</td>
<td>p=.031</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grammaticality**</td>
<td>p=.025</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: * indicates PD scored lower on this measure than controls; ^ denotes dual task interference.
** Analysis of this dependent variable included the independent variable picture complexity.
Table 4- 3. Simple effects and interaction for quantitative measures of discourse production showing significance and marginal significance.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Group Effect</th>
<th>Dual Task Effect</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sentence length</td>
<td>p=.001*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Sentence length variability</td>
<td>p=.008*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Noun phrase - count</td>
<td>p=.022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plural noun - count</td>
<td>p=.017*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proper noun - count</td>
<td>p=.022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proper noun - proportion</td>
<td>p=.003</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participle verb - count</td>
<td>p=.017^</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Participle verb - proportion</td>
<td>p=.035^</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Causal verb - count</td>
<td>p=.040</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Adjective - count</td>
<td>p=.034*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wh-pronoun - count</td>
<td>p=.012*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wh-pronoun - proportion</td>
<td>p=.077*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepositions - count</td>
<td>p=.037*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verbs per sentence</td>
<td>p=.001*</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: * indicates PD scored lower on this measure than controls; ^ denotes dual task interference.

Table 4- 4. Simple effects and interaction for qualitative measures of discourse production showing significance and marginal significance.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Group Effect</th>
<th>Dual Task Effect</th>
<th>Interaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Proposition density</td>
<td>p=.003*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proposition - count</td>
<td>p=.037*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concreteness - all words</td>
<td>p=.046^</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Concreteness - content words</td>
<td>p=.020</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Imageability - content words</td>
<td>p=.023</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Syntactic complexity</td>
<td>p=.007*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Grade reading level</td>
<td>p=.022*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Type-token ratio - content words</td>
<td>p=.057</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Action verb - count</td>
<td>p=.077</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypernymy - verb</td>
<td>p=.050</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypernymy - noun</td>
<td>p=.034*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argument cohesion</td>
<td>p=.006*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local anaphor cohesion</td>
<td>p=.013*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global anaphor cohesion</td>
<td>p=.004*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temporal connective word - count</td>
<td>p=.046*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local syntactic similarity</td>
<td>p=.022</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global syntactic similarity</td>
<td>p=.029</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Verb cohesion</td>
<td>p=.019^</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local coherence</td>
<td>p=.047</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Note: * indicates PD scored lower on this measure than controls; ^ denotes dual task interference.
### Table 4-5. Predictors for significant and marginal (p=<.055) effects for quantitative measures of sentence production.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Processing Speed</th>
<th>Working Memory</th>
<th>Updating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>R²</td>
<td>Beta</td>
</tr>
<tr>
<td>Agentless passive voice verb - dual task</td>
<td>0.288</td>
<td>0.083</td>
<td></td>
</tr>
<tr>
<td>Past participle verb count - single task</td>
<td></td>
<td>0.278</td>
<td>0.077</td>
</tr>
<tr>
<td>Past participle verb count - dual task</td>
<td>-0.277</td>
<td>0.077</td>
<td>0.305</td>
</tr>
<tr>
<td>Adjective count - dual task</td>
<td></td>
<td>0.273</td>
<td>0.075</td>
</tr>
<tr>
<td>Wh-pronoun count - single task</td>
<td></td>
<td>0.246</td>
<td>0.061</td>
</tr>
<tr>
<td>Wh-pronoun count - dual task</td>
<td></td>
<td>0.279</td>
<td>0.078</td>
</tr>
<tr>
<td>Wh-pronoun proportion - dual task</td>
<td></td>
<td>0.304</td>
<td>0.093</td>
</tr>
</tbody>
</table>

### Table 4-6. Predictors for significant and marginal (p=<.055) effects for qualitative measures of sentence production.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Processing Speed</th>
<th>Working Memory</th>
<th>Updating</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>R²</td>
<td>Beta</td>
</tr>
<tr>
<td>Information completeness - simple single task</td>
<td>-0.314</td>
<td>0.099</td>
<td></td>
</tr>
<tr>
<td>Information completeness - complex single task</td>
<td>-0.360</td>
<td>0.130</td>
<td></td>
</tr>
<tr>
<td>Grammaticality - simple single task</td>
<td>-0.480</td>
<td>0.230</td>
<td>0.250</td>
</tr>
<tr>
<td>Grammaticality - complex single task</td>
<td>-0.386</td>
<td>0.149</td>
<td>0.334</td>
</tr>
<tr>
<td>Grammaticality - simple dual task</td>
<td>-0.260</td>
<td>0.068</td>
<td></td>
</tr>
<tr>
<td>Grammaticality - complex dual task</td>
<td>-0.329</td>
<td>0.108</td>
<td></td>
</tr>
</tbody>
</table>
Table 4- 7. Predictors for significant and marginal (p=<.055) effects for quantitative measures of discourse production.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Processing Speed</th>
<th>Working Memory</th>
<th>Updating</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta R^2</td>
<td>Beta R^2</td>
<td>Beta R^2</td>
<td></td>
</tr>
<tr>
<td>Sentence length - single task</td>
<td></td>
<td></td>
<td></td>
<td>0.38 0.144</td>
</tr>
<tr>
<td>Sentence length - dual task</td>
<td></td>
<td></td>
<td></td>
<td>0.30 0.094</td>
</tr>
<tr>
<td>Sentence length variability - dual task</td>
<td></td>
<td></td>
<td></td>
<td>0.28 0.083</td>
</tr>
<tr>
<td>Plural noun count - dual task</td>
<td>-0.418 0.175</td>
<td></td>
<td>0.319 0.102</td>
<td></td>
</tr>
<tr>
<td>Proper noun count - single task</td>
<td></td>
<td>-0.278 0.077</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proper noun proportion - single task</td>
<td></td>
<td>-0.406 0.164</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Wh-pronoun count - dual task</td>
<td></td>
<td></td>
<td>0.29 0.087</td>
<td></td>
</tr>
<tr>
<td>Prepositions count - single task</td>
<td></td>
<td>0.319 0.102</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Prepositions count - dual task</td>
<td>-0.261 0.068</td>
<td></td>
<td>0.38 0.146</td>
<td></td>
</tr>
<tr>
<td>Verbs per sentence - single task</td>
<td></td>
<td></td>
<td></td>
<td>0.38 0.150</td>
</tr>
<tr>
<td>Verbs per sentence - dual task</td>
<td></td>
<td></td>
<td></td>
<td>0.26 0.070</td>
</tr>
</tbody>
</table>
Table 4-8. Predictors for significant and marginal (p<=.055) effects for qualitative measures of discourse production.

<table>
<thead>
<tr>
<th>Measure</th>
<th>Processing Speed</th>
<th>Working Memory</th>
<th>Updating</th>
<th>Group</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Beta</td>
<td>R^2</td>
<td>Beta</td>
<td>R^2</td>
</tr>
<tr>
<td>Proposition density - single task</td>
<td>-0.352</td>
<td>0.124</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proposition density - dual task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Proposition count - single task</td>
<td>-0.389</td>
<td>0.151</td>
<td>0.398</td>
<td>0.158</td>
</tr>
<tr>
<td>Proposition count - dual task</td>
<td>-0.348</td>
<td>0.121</td>
<td>0.383</td>
<td>0.146</td>
</tr>
<tr>
<td>Syntactic complexity - dual task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Argument cohesion - single task</td>
<td>-0.374</td>
<td>0.140</td>
<td>0.253</td>
<td>0.064</td>
</tr>
<tr>
<td>Local anaphor cohesion - single task</td>
<td></td>
<td></td>
<td>0.285</td>
<td>0.082</td>
</tr>
<tr>
<td>Local anaphor cohesion - dual task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global anaphor cohesion - single task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global anaphor cohesion - dual task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Temporal connective word count - dual task</td>
<td>0.278</td>
<td>0.077</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local syntactic similarity - dual task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Global syntactic similarity - dual task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Local coherence - single task</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Figure 4-1. PD produced fewer passive verbs than controls only in dual task.

Figure 4-2. Controls used more participle verbs in dual task in contrast to PPD.
Figure 4-3. PD provided more critical information than controls only in single task.

Figure 4-4. PD were less grammatical in the dual task compared to the single task.
Figure 4-5. Controls became more locally coherent than PD only in the single task.
CHAPTER 5
DISCUSSION

The effects of a dual task on language production in Parkinson’s disease have not been investigated in the literature; thus, findings from this project extend the literature on language production in this population. In this exploratory study, our findings revealed broad thematic differences between language tasks. While the effects of a cycling dual task were prominent during picture description, the discourse production task was more sensitive in capturing differences in language use between people with Parkinson’s disease and healthy controls. As has been observed by Murray and Lenz (2001) picture description is a more constrained behavior which can also be more resource intensive due to the increased demands it puts on lexical selection. This study revealed that while dual task effects are prominent in the sentence production task, these effects were not greater in people with Parkinson’s disease. It is noted however, that the picture description task also provided participants with external cues for high frequency words and actions. Thus, while at a resource level the picture description task may have been more demanding than the dual task, word choice is externally supported. In contrast, discourse production is associated with reduced resource demands but requires extended internal cueing to support sustained message generation. Internal cueing, as in the discourse production task, is difficult for people with Parkinson’s disease (Brown & Marsden, 1987) and may explain why both group differences in quantitative and qualitative language impairments were evident in discourse production but not in the picture description task. In particular, this study finds evidence of impairments in lexical selection, information integration at syntactic and information levels, and information monitoring. These findings will be discussed below.
Lexical Selection

Measures of word choice in both language production tasks were subject to the effects of the cycling dual task and provided little evidence that word choice is impaired in people with Parkinson’s disease. As predicted, participants produced more nouns in both language tasks during cycling. These nouns tended to be lower frequency words which were also more concrete in both language tasks and more specific in the picture description task. This finding, that noun use is relatively well preserved across two language tasks, extends the findings from the single word production literature that object naming is relatively unaffected by Parkinson’s disease (Cotellia, Borronib, Manentic, Zanettib, Arevalo, Cappa & Padovani 2007; Rodríguez-Ferreiroa, Menéndez, Ribacoba & Cuetos, 2009). Thus, broad effects of the dual task on noun choice affecting both the quantity and quality (frequency and concreteness) of nouns produced were evident in both language production tasks but were not more prominent in Parkinson’s disease.

We attribute this effect to two factors. First, we attribute dual task facilitation for nouns in dual task conditions to increases in cortical excitation bilaterally. We speculate that this pattern of cortical excitation is associated with sustained activation of distributed semantic memory stores which facilitate noun selection. Second, we attribute the lack of increased dual task effects in people with Parkinson’s disease due to the broader finding in the literature that noun use is relatively well preserved. Thus, the dual task would elicit no additional resource demands above those experiences by healthy controls. There was however a single group difference in the quality of nouns produced – nouns used in the dual task discourse were less specific for people with Parkinson’s disease than nouns selected by controls. We attribute this group effect in
discourse to a general deterioration of information structure at a lexical level due to the increased task demands for message generation in the discourse task.

As predicted, the cycling dual task also tended to facilitate the production of action verbs in both language tasks. However, there was no evidence that the dual task facilitated the production of action verbs more for people with Parkinson’s disease than for healthy controls. The quality of verbs also changed in the dual task in both language tasks. Action verbs were more specific under dual task conditions in both language tasks for both groups. We attribute these findings to predictions of the theory of embodied cognition (Lakoff, & Johnson, 1980) that, since verb production is associated with activation of motor cortices, activation of these cortices by a motor task (in this case concurrent stationery cycling) will facilitate production of word types associated with movement. In support, it is also noted that an action naming impairment has been identified in Parkinson’s disease during single picture naming (Cotellia, Borronib, Manentic, Zanettib, Arevalo, Cappa & Padovani 2007; Rodríguez-Ferreiroa, Menéndez, Ribacoba & Cuetos, 2009). However, we found no evidence that action verbs were impaired for people with Parkinson’s disease in either language task. Importantly, while the production of action verbs increased in dual task conditions, verb cohesion in discourse was generally reduced for all participants in dual task conditions, indicating that the production of additional action verbs did not improve the structure of information content.

As predicted, there was some evidence of group differences in the production of certain types of verbs. In particular, people with Parkinson’s disease produced significantly more causative verbs overall than healthy controls, in the discourse
processing tasks. The increased use of causative verbs during discourse is difficult to explain, however as with action verbs which specify a relational action by a single entity or between entities, causative verbs are used to indicate a directional relationship between entities and increased use of this verb type by people with Parkinson’s disease may indicate increased specificity in the use of verbs. However, it is noted that these differences, while significant, represented only a small number of verbs of this type. It may also be important that the comprehension of causative verbs in sentences is reduced for people with Parkinson’s disease (Geyer & Grossman, 1994).

**Information Integration**

There were pervasive differences in information integration at both syntactic and information levels associated with Parkinson’s disease and the cycling dual task. Impairments in information complexity in the language of people with Parkinson’s disease are widely reported in the literature (Altmann & Troche, 2011; Angwin, Chenery, Copland, Murdoch, & Silburn, 2005, 2006; Grossman, et al., 1991; Grossman, Carvell, Stern, Gollomp, & Hurtig, 1992; Grossman, et al., 2000; Hochstadt, Nakano, Lieberman, & Friedman, 2006; Lieberman, et al., 1992; Troche & Altmann, 2012), which contrasts with a relative preservation of lexical production noted by Illes and Meter (1988) and others (Cotella, Borronib, Manentic, Zanettib, Arevalo, Cappa & Padovani 2007; Rodríguez-Ferreiroa, Menéndez, Ribacoba & Cuetos, 2009).

People with Parkinson’s disease used fewer WH- pronouns in both language tasks. The decreased use of WH pronouns by people with Parkinson’s disease was predicted by poorer information updating during discourse. In contrast, in the picture description task, there were no significant cognitive predictors, although people with Parkinson’s disease produced fewer WH – pronouns in dual task conditions. Thus, the
current study found more evidence that people with Parkinson’s disease provided less elaborate sentences, as evidenced by fewer embedded clauses. Similarly, it was also noted that people with Parkinson’s disease also produced fewer possessive pronouns during picture description, an effect predicted only by the presence of disease.

Effects on measures of information complexity were more pervasive during discourse than during picture description. While people with Parkinson’s disease produced fewer adjectives in both language tasks, they produced fewer prepositions and conveyed less propositional information only during discourse. The communication of less propositional information and production of fewer prepositions in dual task conditions was predicted by slower processing speed and poorer information updating. In contrast, adjective use was only predicted by the presence of Parkinson’s disease, but only during picture description. Group deficits associated with Parkinson’s disease were also evident for measures of syntactic or structural complexity during discourse production. People with Parkinson’s disease also produced fewer present tense third person singular verbs but only in the sentence processing task and not for discourse. The production of fewer present tense third person singular verbs in the sentence production task is attributed to task demands associated with the picture description task. In particular, the picture description task constrains the choice of this verb type for simpler pictures (e.g. “the boy kisses/kissed the girl”) and is optional for the remaining pictures (e.g. “the boy chases the girl and the dog” versus “the girl and the dog were chased by the boy”). This suggests that people with Parkinson’s disease tended either to produce more conjoined subjects (“The girl and the boy are chasing the dog” or more past tense sentences (“The boy chased the girl”) or both. Understanding this
phenomenon will require more detailed analysis of exactly what syntactic forms were produced.

People with Parkinson’s disease tended to use shorter, less syntactically complex sentences with less variability which contained fewer prepositions, fewer adjectives and fewer verbs per sentence. Reductions in syntactic complexity, sentence length and variability and the number of verbs per sentence were predicted only by whether people had Parkinson’s disease. Thus, it appears that people with Parkinson’s disease showed differences in lexical choice which could result in less elaborate noun phrases and sentences; however, these lexical effects were not all due to the same underlying impairments. Some were traceable to cognitive deficits, some were attributable only to the disease itself, and another was not associated with any of the predictors used in the current study. Thus, the current study found evidence of general language impairments in Parkinson’s disease, particularly evident during discourse, affecting with the amount of information produced and syntactic complexity for both quantitative and qualitative measures of language production. In support, regression analysis indicates that these differences were predicted by disease state and, for some measures, by slower processing speeds and a decreased ability to manipulate and integrate new information with old (i.e. updating). Until now, there has been considerable disagreement over whether grammatical complexity is impaired in Parkinson’s disease (Altmann & Troche, 2011), but previous studies were more limited in scope and included fewer participants. The current study extends these findings by explicitly contrasting two language tasks, and incorporating a broader of measures of information and syntactic complexity at both quantitative and qualitative levels in a
larger group than has reported previously. In so doing, we have identified patterns of impairments that strongly support the conclusion of impaired syntactic complexity for people with Parkinson’s disease.

Syntactic complexity was also affected by the cycling dual task, but these effects were more evident in the sentence production task. During the dual task, participants described pictures using shorter and less structurally variable sentences which used fewer verbs per sentence and contained fewer prepositions. Consistent with these findings, sentences produced in the dual task also used simpler syntax at a lower grade reading level.

Evidence from group by task interactions suggests that the cycling dual task particularly impaired sentence complexity. For example under dual task conditions people with Parkinson’s disease tended to produce fewer passive verbs (hence passive sentence constructions). In contrast, healthy controls tended to use a greater proportion of verbs and more past participle verbs under dual task conditions, suggesting increased use of passive or perfective constructions. The decreased use of past participle verbs was predicted by slower processing speed and poorer information updating. Moreover, in the dual task all participants tended to use fewer verb participles during the discourse task.

**Information Monitoring**

There was evidence that information tracking was generally impaired in Parkinson’s disease. Group effects were pervasive in the discourse production task, while there was only limited evidence that information tracking was impaired in individuals with Parkinson’s disease during sentence production. These differences between tasks are due to different task demands between language tasks. The picture
description involved serial presentation of picture stimuli and was supported by external picture cues which remained on screen until a response was initiated. Thus, there was no requirement to maintain consistency, cohesion or coherence with previous utterances. While in contrast, the discourse production task involved extended production of new information that needed to be fully integrated with previous utterances. Thus, information monitoring constraints are greatest in the discourse production task, an interpretation which may explain why group effects were most apparent in this language tasks. Information monitoring deficits in people with Parkinson’s disease were apparent in increased grammatical errors in sentence production, and in impaired discourse cohesion and coherence. For example, during picture description individuals with Parkinson’s disease made more grammatical errors describing complex pictures than simple pictures. Considering that maintaining grammaticality entails tracking details of previous parts of a sentence, (e.g., the number and person of the subject, the tense of previously used verbs, whether a word needs a definite or indefinite article), it necessarily places a premium on information tracking. Indeed, information monitoring demands increased with picture complexity for people with Parkinson’s disease, leading to increased difficulty producing grammatical sentences, while controls had no additional difficulty as picture complexity increased either under single or dual task conditions. These picture complexity effects on grammaticality in both single and dual task conditions that primarily affected people with Parkinson’s disease were predicted by individual differences in processing speed. The rate of grammatical errors in single task conditions was also predicted by poorer working memory and reduced information updating ability, but, there were no additional
predictors for grammaticality under dual task conditions. The finding that use of
grammar is impaired in people with Parkinson’s disease during language production is a
common finding in the literature (Holtgraves, McNamara, Cappaert, & Durso, 2010;
Murray, 2000; Troche & Altmann, 2012), however it also possible that grammatical
errors increased when describing complex pictures because the message generation
demands increased (Troche and Altmann, 2012) or because there were more
opportunities for errors in multi-clause sentences.

During sentence production, it was revealed that people with Parkinson’s disease
provided more critical information content describing both simple and complex pictures
during single task conditions. There were no cognitive predictors to explain this
phenomenon in single or dual task conditions and the production of more complete
descriptions in the single task was only predicted by group. Thus, interpreting this effect
will require more detailed analysis of the information content of participants’ responses.
Since, this finding contrasts with the literature which indicates that information
completeness is impaired in people with the disease across a wide range of language
production tasks (Bayles, 1990; Cummings, Darkins, Mendez, Hill, & Benson, 1988;
Illes, Metter, Hanson, & Iritani, 1988; Murray, 2000).

More pervasive effects on separate measures of information monitoring were
revealed for discourse production compared to picture description, and there was no
effect of the dual task in any of these. In particular, people with Parkinson’s disease
produced a greater number of proper nouns, which was associated with increased
problems with information updating and slower processing speeds, suggesting slower
more impaired people may have had difficulty updating whom they were actually talking
about. Additionally, for people with Parkinson’s disease both local and global cohesion were impaired. Separate measures of cohesion including argument and anaphor cohesion at both local and global levels, showed similar patterns. Increased difficulty maintaining cohesion between adjacent sentences and within the discourse as a whole (i.e. global cohesion), was predicted by poorer information updating skills and by the presence of the disease. Thus, it appears that the ability to use connective words referring to previous sentences was generally impaired in Parkinson’s disease due to a reduced ability to monitor previous utterances and to updating these to provide well-structured communication during discourse. This is the first study to specifically track measures of cohesion in discourse production within this clinical population. Similarly, at an information level (coherence) people with Parkinson’s show the same pattern of impairment as at the structural level (cohesion). In particular, it was revealed that people with Parkinson’s disease produced sentences which were less coherent at a local level during discourse production. That is, sentences tended to introduce new information rather than referring to and expanding upon previous utterances. This group effect was only predicted by the presence of the disease. There were however, no group differences for global coherence. We attribute this finding to task design. During the discourse production task, the rhetorical prompt remains on the screen throughout the task and thus, provides a continuous external cue enabling participants to remain on topic throughout.

**Implications**

The broad implications of this study are that language tasks are not equivalent either in their difficulty for the groups tested or in how the dual task operates on language performance at both qualitative and quantitative levels of production. The
differences between these language tasks can be traced to differences in task and resource demands and cueing effects. This has implications for what conclusions may be drawn from this study. Thus, it appears that the cycling dual task only elicited effects during constrained sentence production and that dual task effects were generally absent during discourse. Dual task paradigms are traditionally associated with a pattern of interference for cognitive or motor performance and not with a pattern of facilitation observed for many of our language measures used in this project. Thus, a general prediction is that a dual task will interfere with performance in a cognitive task, or in this case, language production. However, we revealed evidence that the cycling task, a behavior which, as a single task is relatively well preserved in people with Parkinson’s disease, elicited facilitative effects on some quantitative and qualitative measures of picture description.

Since the general effects of a dual task on language production in people with Parkinson’s disease are not known, it is tempting to speculate what the effects of another type of dual task on language production might be. We attributed facilitation effects of the cycling task on language measures and the relative scarcity of dual task effects to the low attention demands of the cycling task and bilateral activation of motor cortices. Hence, we would predict that, as the attention demands of the motor task increase, a pattern of dual task interference would increase for multiple measures of language production for individuals with Parkinson’s disease.

A further implication of these findings is that discourse production is generally impaired in people with Parkinson’s disease. The pattern of our findings indicates that these group differences primarily impacted use of syntactic structures to convey
messages and information tracking. In contrast, there is relatively little indication that lexical effects were impaired in people with Parkinson’s disease relative to healthy controls. There is very limited evidence of lexical impairment affecting verb use, only for the use of causative verbs, which may not be impaired, while all other verb effects were grammatical. As predicted the use of action verbs in particular increased during cycling but this effect was no greater for people with Parkinson’s disease than controls. Rather, impairments in verb use were most evident within sentence complexity contexts. There were significant reductions in number of verbs used in each sentence during discourse for people with Parkinson’s disease. The evidence suggests that information structure during message generation was breaking down in Parkinson’s disease leading to reduced elaboration at lexical, syntactic and informational levels. In future studies, it might be fruitful to specifically contrast production of types of discourse with different syntactic structures in this population. For example, procedural discourse with high intentional content and a simplified syntactic structure might be contrasted with a discourse production task which emphasizes descriptive content and elaboration (i.e. increased use of adjectives, pronouns and nouns) using more complex syntactic structures to express information.

A final implication is that the pattern of our findings indicates that information tracking/monitoring is generally impaired for discourse in people with Parkinson’s disease but that there was one exception to this pattern. People with Parkinson’s disease were not impaired in global coherence, this conclusion seems suspect and, as has been detailed, may be an artifact of task design, in which a stimulus prompt externally cued topic coherence. In terms of planning an intervention, the current study
found that a constrained language task leads to more normal patterns of language use (i.e., more similar to healthy adults), affecting both the quantity and quality of information produced. Since, both syntactic complexity and cohesion are reduced in people with Parkinson’s disease use of a constrained picture description task which constrains both lexical and syntactic production closely may generalize well to everyday discourse for people with Parkinson’s disease. The potential benefit to individuals with Parkinson’s disease will be increased efficiency of communication promoting quality of life and reducing the burden on the speech-motor production system.

**Future Directions**

This project highlights the effect of a motor task on language performance. A pattern of facilitation and interference was produced and was not sensitive in identifying group differences across measures. This finding is not consistent with the dual task literature (e.g., Kemper et al., 2003; Plummer-D’Amato et al. 2010), likely due to the low attentional demands of the cycling task. Thus, a future direction for this line of research would be to vary the concurrent demands of the distractor task. This could be done at two levels, either by increasing the rate of stationery cycling during performance of the language tasks or by using a different motor task altogether. It may also be worthwhile to investigate dual task effects of cycling using an upper body ergometer. The benefit of this task is that somatotopic representation of the upper extremities is closer cortically to areas of cortex associated with language production. If effects observed in this project are maintained using the upper body ergometer then this has potential as a home-based therapy for people with Parkinson’s disease.

The project also highlights information complexity effects. The next step will be to analyze these complexity effects by manipulating the discourse task. This can be done
at a number of different levels. For example, we can vary the choice of production task (i.e. procedural versus descriptive versus autobiographical versus narrative discourse), or we can vary task demands by presenting a rhetorical prompt versus a picture prompt versus a picture sequence. Finally, analyzing the effects of picture complexity within this data set on individual measures of quantity and quality during picture description might be a fruitful future line of investigation. Additionally, analysis of the pattern of production errors made during picture description and discourse production could also be useful. Given the pervasive effects of information and syntactic complexity it seems warranted to investigate these questions by carefully examining the different effects of complexity within the existing data set.

Conclusion

In summary and with respect of our specific aims and predictions, we revealed evidence of pervasive effects of Parkinson’s disease on language production during discourse across multiple measures of quantity and quality. A pattern was revealed indicating that while the production of individual words was largely unaltered in Parkinson’s disease, there were pervasive effects on information and syntactic structure and on how that information was updating and maintained. Importantly, it was revealed that dual task effects, as predicted, affected the information structure by increasing action verbs production and also production of nouns generally. However, the dual task did not improve production of individual word types, which instead, showed evidence of impairment in Parkinson’s disease. Finally, it was shown that the many of the group differences in language production in the quantity and quality of information and syntactic structure and monitoring were predicted largely by differences in information processing speed and the ability to update and maintain new information efficiently.
APPENDIX A
PARTICIPANT WITH PARKINSON’S DISEASE DISCOURSE SAMPLE

I think I’d have to select… Several people have had an important impact on my life. But I think my father was one who probably had, would be the one that I would pick to single out for this. So I’ll look back and and say why. My father was, went through part of the twelfth grade. He didn’t complete high school. He went on to take some CPA training and and later on worked in a factory. But whatever job he was in, he did his very best. He gave all he was expected to give and more. He was totally honest. He was conscious all the time of other people’s feelings. He was, back to being honest, he was honest. He could go into the bank and shake hands with a guy and come out with money. He wouldn’t have to do anything, he could borrow money on handshakes is what I’m trying to say. He he was a quiet man. But when he spoke, he knew it would be best to listen. And we learned that lesson early on in life. He was he was kind to other people. He was charitable. And later on, it was how about the time I was in tenth or eleventh grade, my mother had diabetes, major problem. We didn’t have all the medications then that we have now, I believe. And my father looked after her basically for the rest of her life and then died about a year or two. Before she did, so it was actually, they called it an unknown disease. My best guess would have been gangrene. But they did some surgery and he passed away the same, the next day. But I think what I’m getting to make the long story longer. He was honest. He expected the same thing out of his children. And he got that because we had the example that he presented for us. He he was a Christian man. And he had a high ethical standard, he never, to my knowledge, never mistreated anyone.
My mother had a very important impact on my life. First, she was my mother. She gave me life. She was the one who nursed me when I was sick, played with me when I was small, helped me learn life’s lessons as a child and then again as a teenager and then also as an adult. She helped me through times of trial in my life. And when my brother died, she was the person I turned to for comfort. She was also the person who taught me how to be a woman. She learnt, taught me that family was important and as a mother you were the one who had to organize your family’s life and help each member do what their tasks were in their life and their tasks were as jobs within the household. She taught me how to be a giving person to the people around me. She taught me my life was more important when I gave it to others that I helped other people in ways that may not be tangible but would help them. She gave me ideas about the way to treat people, the way to treat animals. She helped me with advice about what marriage, after I was married, would be, what family life should be. So that I would raise my children in the way they should be raised. She also gave me an idea about what it was like to grow old. She showed me that how once your family left home, you were still important that you had an important job to do within your family with your husband within the world around you to help others in whatever ways that you could that they needed. She taught me what it was like to be without a husband, how to be a widow and how to still feel important in living and doing. She also taught me how to face life when you could no longer do the things that you needed to be doing. How to accept the fact that you are older that there are things you cannot do and how to gradually accept the fact you needed constant care and were not afraid about what life was giving you. And about
what death would mean. I probably would not have been able to give to others the way that I can. I, she was a Christian and she taught me how to be a Christian. This is an important part of my life.
LIST OF REFERENCES


BIOGRAPHICAL SKETCH

Jonathan Paul Wilson was born in Belfast, United Kingdom. The younger of two siblings, he grew up in the seaside town of Bangor and later Belfast, Northern Ireland. Jonathan graduated from his high school, the Royal Belfast Academical Institution in 1989. Jonathan continued into third level education and was awarded a B.A. (Hons.) in English language and literature from Queen’s University of Belfast in 1992. Following graduation, Jonathan worked in the information technology sector within the financial services industry and enrolled part-time in graduate studies in computing and information systems at the University of Ulster, Northern Ireland. Jonathan subsequently graduated with an advanced graduate diploma in computing and information systems from the University of Ulster, United Kingdom.

Jonathan elected to continue further academic studies in the U.S. on a full-time basis and was subsequently awarded an M.A. in communication sciences and disorders from the University of Florida in August 2008. Following graduation, Jonathan continued into the doctoral program in communication sciences and disorders combining his program of study with a 2 year clinical fellowship in speech language pathology. Jonathan is recognized as a board certified speech language pathologist by the American Speech Language and Hearing Association as of August 2010 and is expected to complete his Ph.D. program in August 2013. Upon graduation, Jonathan will take a tenure-track appointment with Midwestern University, IL, as an assistant professor where he will work as an independent research scientist and teacher in the field of speech language pathology specializing in the assessment and treatment of adult neurogenic disorders.