INFORMATION TO USERS

This manuscript has been reproduced from the microfilm master. UMI films the text directly from the original or copy submitted. Thus, some thesis and dissertation copies are in typewriter face, while others may be from any type of computer printer.

The quality of this reproduction is dependent upon the quality of the copy submitted. Broken or indistinct print, colored or poor quality illustrations and photographs, print bleedthrough, substandard margins, and improper alignment can adversely affect reproduction.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyright material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each original is also photographed in one exposure and is included in reduced form at the back of the book.

Photographs included in the original manuscript have been reproduced xerographically in this copy. Higher quality 6” x 9” black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.

UMI
A Bell & Howell Information Company
300 North Zeeb Road, Ann Arbor MI 48106-1346 USA
313/761-4700 800/521-0600
COGNITIVE ASPECTS OF MOTOR CONTROL:
THE EFFECT OF TARGET ATTRIBUTES ON
GENERATION OF MOVEMENT

by

Berta Leis

Copyright © Berta Leis 1998

A Dissertation Submitted to the Faculty of the
COLLEGE OF NURSING
In Partial Fulfillment of the Requirements
For the Degree of
DOCTOR OF PHILOSOPHY
In the Graduate College
THE UNIVERSITY OF ARIZONA

1998
As members of the Final Examination Committee, we certify that we have read the dissertation prepared by Berta Leis entitled Cognitive Aspects of Motor Control: The Effect of Target Attributes on Generation of Movement and recommend that it be accepted as fulfilling the dissertation requirement for the Degree of Doctor of Philosophy.

Joyce A. Verran, RN, PhD, FAAN  
Carrie Jo Braden, RN, PhD  
Jean E. Davis, RN, PhD  
Alfred Kaszniak, PhD  
Geoffrey Ahern, PhD, MD  
July 15, 1998  
July 15, 1998  
July 15, 1998  
July 15, 1998  
July 15, 1998

Final approval and acceptance of this dissertation is contingent upon the candidate's submission of the final copy of the dissertation to the Graduate College.

I hereby certify that I have read this dissertation prepared under my direction and recommend that it be accepted as fulfilling the dissertation requirement.

Joyce A. Verran  
Dissertation Director  
July 30, 1998
Statement by Author

This dissertation has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library to be made available to borrowers under rules of the Library.

Brief quotations from this dissertation are allowable without special permission, provided that accurate acknowledgement of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the copyright holder.

Signed: Berta Luu
Acknowledgements

Many individuals contributed to the success of my dissertation. I am especially thankful to the members of my dissertation committee: Dr. Joyce Verran, Dr. Carrie Braden, Dr. Jean Davis, Dr. Alfred Kaszniak, and Dr. Geoffrey Ahern. Each member eagerly shared intellectual insights with me, offering a unique blend of intellectual ideas and knowledge that enhanced my development as a scientist. Their generosity and enthusiasm for intellectual exchange significantly contributed to my experience. In addition, each member served as an exemplary model of behavior shown in their integrity and honesty with others.

I was especially fortunate to have Dr. Joyce Verran serve as my chair. Her continual support, insightful advice, wit, and humor empowered and grounded me during this complex process. I am also very grateful to Dr. Suzanne Van Ort for her example of excellence as a nurse scientist and human being. My warmest thank you to Dr. Pamela Reed, Dr. Adela Allen, and Dr. Beverly Rosenthal for their continual interest and support towards me throughout my doctoral education.

I am grateful to many others for their cheerful support, kindness, and generosity throughout my doctoral program, in particular, Alice Pasvogel, Dr. Tsh-Ching Shang, and Jie Hu. In addition, I am grateful to John Lewis and Lynda Ramirez for their selflessness towards me throughout my doctoral studies.

I am also thankful to Dr. Erwin Montgomery for his receptiveness for intellectual exchange prior to his departure from Tucson and for his willingness to share the Human Motor Control laboratory in my quest to collect data for my dissertation research.

Finally, my unlimited gratitude to my brothers, Dr. Joe Leis, Dr. Art Leis, and Dr. Jorge Leis for their love, support and continual interest in my success.
Dedication

This dissertation is dedicated to my parents, Jose and Berta Leis, for serving as sources of inspiration and stability throughout this process. My parents have been my anchors of strength during this process and forever inspiring in their day to day dedication to their goals and pursuits in life.
TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>LIST OF FIGURES</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>LIST OF TABLES</td>
<td>12</td>
</tr>
<tr>
<td>ABSTRACT</td>
<td>13</td>
</tr>
</tbody>
</table>

CHAPTER

I. INTRODUCTION

Statement of the Problem ........................................................................... 14
Do Persons with PD have Cognitive Abnormalities Generating Movement ........ 20
Expectancy .................................................................................................. 22
Movement Initiation and Execution ......................................................... 23
Purpose of the Study .................................................................................. 24
Hypotheses .................................................................................................. 27
Significance of the Study .......................................................................... 32
Summary ....................................................................................................... 34

II. REVIEW OF LITERATURE AND CONCEPTUAL FRAMEWORK

Introduction ............................................................................................... 36
Cognitive Dysfunction in Parkinson’s Disease ............................................. 36
Dorsolateral Prefrontal Circuit ................................................................... 37
Motor Circuit .............................................................................................. 39
Anterior Cingulate Circuit ......................................................................... 40
Is there Evidence that Motor and Cognitive Symptoms have a Common Substrate or Mechanism ................................................................. 41
Do Persons with PD have Abnormalities in Generating Movement ............... 46
External Visual Information for Movement Control ..................................... 48
Movement Initiation and Execution ........................................................... 52
How Can One Separate Cognitive Aspects From Motor Function When Only Motor Performance Can Be Measured ......................................................... 55
Expectancy .................................................................................................. 56
Diminished Shifting Capacity ....................................................................... 57
Motor Sequencing Operations ...................................................................... 59
Conceptual Framework ................................................................................ 60
## TABLE OF CONTENTS - Continued

<table>
<thead>
<tr>
<th>Description of Conceptual Framework</th>
<th>60</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cognitively Derived Target Attributes</td>
<td>60</td>
</tr>
<tr>
<td>Expectancy, Shifting Capacity, and Set</td>
<td>62</td>
</tr>
<tr>
<td>Movement Initiation and Execution</td>
<td>63</td>
</tr>
<tr>
<td>Limitations of Conceptual Framework</td>
<td>64</td>
</tr>
<tr>
<td>Assumptions</td>
<td>65</td>
</tr>
<tr>
<td>Summary</td>
<td>65</td>
</tr>
</tbody>
</table>

### III. METHODOLOGY

| Introduction | 67 |
| Setting | 67 |
| Research Design | 69 |
| Determining the Time Required to Process the Explicit Target Location Versus the Inferred Target Location | 70 |
| Determining if Motor Performance is Influenced by Prior Target Type | 71 |
| Determine the Critical Time Periods (CTP) Involved in the Central Generation of Movement | 73 |
| Population Sample | 75 |
| Variables and Instruments | 77 |
| Independent Variables | 77 |
| Dependent Variables | 78 |
| Instruments | 81 |
| Data Collection Protocol | 85 |
| Data Management | 86 |
| Data Analysis | 89 |
| Hypothesis 1 | 89 |
| Hypothesis 2 | 90 |
| Hypothesis 3 | 90 |
| Research Question 1 | 91 |
| Research Question 2 | 91 |
| Summary | 92 |
TABLE OF CONTENTS - Continued

IV. Results of Data Analysis
   Sample Characteristics ........................................... 93
   Findings Related to Research Hypotheses ......................... 95
      Hypothesis 1 .................................................... 95
      NTC Task at Go Time 0 (target presents simultaneously with Go signal) .......................... 96
      Results .......................................................... 97
      Hypothesis 2 .................................................... 108
      NTC Task at Go Time 0 ......................................... 111
      NTC Task at Go Time 1000 ..................................... 111
      Results .......................................................... 111
      Hypothesis 3 .................................................... 112
      Target Change Task: Go Time 0 - Target Change 300 ............ 118
      Results .......................................................... 121
      Target Change Task: Go Time 0 - Target Change 500 .......... 122
      Nominal Level Data ............................................... 122
      Results .......................................................... 123
      Interval Level Data .............................................. 124
      Findings Across Target Types Broken Down By Shifting Condition .................................. 125
      Findings By Target Type Broken Down by Like and Like to Unlike Shifting Conditions ............. 126
      Findings by Final Target Type Separated by Initial Target Type .................................... 127
   Summary ............................................................. 127
      Target Change Task: Go Time 0 - Target Change 700 .......... 130
      Results .......................................................... 131
   Research Question 1 ................................................ 132
TABLE OF CONTENTS - Continued

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>9</td>
</tr>
</tbody>
</table>

Target Change Task: Go Time 0 - Target
  Change 300 ........................................... 135
  Results ................................................. 135
Target Change Task: Go Time 0 - Target
  Change 500 ........................................... 136
  Results ................................................. 137
Target Change Task: Go Time 0 - Target
  Change 700 ........................................... 138
  Results ................................................. 138
Research Question 2 ................................... 139

Summary .................................................. 142

V. DISCUSSION OF FINDINGS
  Introduction ........................................... 145
  Movement Initiation ................................... 146
    Set Shifting ........................................ 148
  Movement Execution .................................... 151
    Movement Strategy ................................... 151
    Specifying Trajectory ................................ 155
    Methodological Limitations .......................... 156
    Methodological Changes Recommended .................. 158
  Nursing Science ......................................... 159
  Nursing Implications .................................... 161
Summary .................................................. 162

APPENDIX A DESCRIPTION OF NEUROPSYCHOLOGICAL TASKS. 166
APPENDIX B HUMAN SUBJECT'S APPROVAL ..................... 170
APPENDIX C INSTRUCTIONS TO PARTICIPANTS ............... 176
REFERENCES .............................................. 178
LIST OF FIGURES

<table>
<thead>
<tr>
<th>FIGURE</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>FIGURE 1</td>
<td>Explicit and Inferred Targets</td>
<td>28</td>
</tr>
<tr>
<td>FIGURE 2</td>
<td>Conceptual framework</td>
<td>61</td>
</tr>
<tr>
<td>FIGURE 3</td>
<td>Experimental set-up</td>
<td>68</td>
</tr>
<tr>
<td>FIGURE 4</td>
<td>Organization of tasks</td>
<td>69</td>
</tr>
<tr>
<td>FIGURE 5</td>
<td>Hypothetical results of set effect of initial target</td>
<td>73</td>
</tr>
<tr>
<td>FIGURE 6</td>
<td>Referent level conceptual framework</td>
<td>80</td>
</tr>
<tr>
<td>FIGURE 7</td>
<td>Median premotor RT by target at Go time 0</td>
<td>99</td>
</tr>
<tr>
<td>FIGURE 8</td>
<td>Explicit target Go time 1000 raw scores by subject</td>
<td>103</td>
</tr>
<tr>
<td>FIGURE 9</td>
<td>Inferred target Go time 1000 raw scores by subject</td>
<td>104</td>
</tr>
<tr>
<td>FIGURE 10</td>
<td>Explicit target Go time 0 raw scores by subject</td>
<td>105</td>
</tr>
<tr>
<td>FIGURE 11</td>
<td>Inferred target Go time 0 raw scores by subject</td>
<td>106</td>
</tr>
<tr>
<td>FIGURE 12</td>
<td>Median premotor RT by target at Go time 0 and</td>
<td>109</td>
</tr>
<tr>
<td></td>
<td>Go time 1000</td>
<td></td>
</tr>
<tr>
<td>FIGURE 13</td>
<td>Median premotor RT by MT inferred target</td>
<td>113</td>
</tr>
<tr>
<td>FIGURE 14</td>
<td>Raw premotor RT scores by MT inferred target</td>
<td>114</td>
</tr>
<tr>
<td>FIGURE 15</td>
<td>Median premotor RT by MT explicit target</td>
<td>115</td>
</tr>
</tbody>
</table>
LIST OF FIGURES - Continued

Page

FIGURE 16, Raw premotor RT scores by MT explicit target. ..................116
FIGURE 17, Median MT by target at Go time 0 .............................117
FIGURE 18, Median MT by target at Go time 0 and Go time 1000. ....119
FIGURE 19, Median second premotor RT for like to unlike shifting condition. .................................128
FIGURE 20, Median second premotor RT to final explicit target . .......129
# TABLES

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>Sample Characteristics</td>
<td>95</td>
</tr>
<tr>
<td>Table 2</td>
<td>Intraclass Correlations</td>
<td>101</td>
</tr>
<tr>
<td>Table 3</td>
<td>Hypothesis 1</td>
<td>110</td>
</tr>
<tr>
<td>Table 4</td>
<td>Hypothesis 2</td>
<td>120</td>
</tr>
<tr>
<td>Table 5</td>
<td>Hypothesis 3</td>
<td>133</td>
</tr>
<tr>
<td>Table 6</td>
<td>Research question 1</td>
<td>140</td>
</tr>
<tr>
<td>Table 7</td>
<td>Summary of Findings</td>
<td>144</td>
</tr>
</tbody>
</table>
The purpose of this research was to investigate cognitive aspects involved in generation of voluntary movement. Findings from previous studies indicate cognitive processes influence fundamental movement parameters. More specifically, the researcher investigated the effect of target attributes on movement initiation and execution in seven nondemented patients with idiopathic Parkinson's disease (iPD) off medication. Persons with iPD demonstrate deficits in cognitive functions presumed to be dependent upon circuitry between the basal ganglia and the cerebral cortex.

Participants employed rapid arm extension movements to explicitly identified targets (explicit target) and targets inferred from indirect cues (inferred target). Reaction time (RT) and movement time (MT) measured movement initiation and execution, respectively. Reaction time, defined as the time involved in cognitively inferring target destination and initiating movement, was partitioned into premotor RT and motor RT. Movement to the explicit versus inferred targets was kinematically equivalent; therefore, differences in RT and MT related to a difference in cognitive operations involved in generating movement to the target type.

The study results indicated nondemented iPD patients were impaired in initiating and executing movement across targets containing different attributes
compared to neurologically intact controls backward matched for age and education. However, both groups benefited from advanced information in initiating movement to the explicit and inferred targets. Secondly, study results indicated that nondemented iPD patients were impaired in initiating movement to a final target when shifting from a prior target. Neuropsychological measures of shifting capacity did not correlate with movement initiation to the final target in patients with iPD. Thirdly, study results indicated that program for motor execution, in terms of specifying trajectory to the explicit and inferred targets, may be impaired in patients with iPD.

Findings from this research suggest the basal ganglia are involved in processing cognitively derived target attributes into plans and programs for movement. Findings may contribute to knowledge about target attributes that optimizes motor performance in persons with iPD and results in nursing interventions and rehabilitative therapies that capitalize on use of appropriate target attributes to alleviate altered movement in afflicted persons.
CHAPTER I
INTRODUCTION

Statement of the Problem

Parkinson's disease (PD) is a chronic neurological disease that affects movements, often producing severe disability. Although PD produces bradykinesia, clinical and experimental observations suggest that PD does not simply slow all movements. There may be circumstances that facilitate or worsen movement. These circumstances are neither physical nor mechanical and may be more cognitive in nature. For example, Parkinsonian persons may freeze up in doorways or at a closet entrance, yet easily initiate walking by throwing a cap on the ground in front of them and then stepping over it (Dunne et al. 1987). This suggests the individual's movement patterns are tailored to target characteristics and raises questions about how the brain incorporates these cognitive aspects into planning movements.

The research investigated the cognitive processes involved in motor control. Persons with idiopathic PD were the probe to understanding cognition in motor control. In this research, cognitive processes refer to the extraction of information that may not be apparent in the physical attributes of the stimuli. Knowledge of cognitively derived target characteristics and context shapes movement in terms of where, when, and how one reaches for or walks toward a
target (Colley & Beech, 1998; Harrington & Haaland, 1991; Marteniuk, MacKenzie, Jeannerod, Athenes & Dugas, 1987; Marteniuk, MacKenzie, & Leavitt, 1988; Weiss, Stelmach, & Hefter, 1997). Although context includes environmental variables like lighting and temperature, it is not limited to such variables. In this research, context referred to the role of expectancy in influencing movement parameters. However, critical to ‘cognitive aspects of motor control’ is that the cognitive processes affect fundamental movement parameters such as velocity, reaction time, and trajectory.

Cognitive processes influencing movement can be considered in a trivial or non-trivial sense. The trivial sense is uninteresting in that it is obvious and non-controversial. It does not require a tight link between the cognitively derived target characteristics and the fundamental parameters of movement produced. In addition, in the trivial sense, the cognitively derived characteristics do not reduce, in a meaningful way, the range of motor behaviors that can be produced. Thus, individuals may use any number of approaches. An example of a trivial sense of cognitive processes in motor control is goal directed behavior where cognitive operations determine the relevant object of motor action such as in deciding to grasp a glass of water, rather than a can of oil, to quench thirst, or maneuvering around a chair in the middle of a room to avoid bumping into it. An
individual may use various approaches in reaching and grasping the glass of water, or in maneuvering around the chair, all of which may be effective.

The *non-trivial* sense in which cognitive processes influence movement is illustrated in the fact that the fundamental movement parameters of motor control (trajectory, velocity, and response time) are affected by knowledge of target characteristics that may not be apparent in the physical attributes of the target (cognition) (Colley & Beech, 1998; Harrington & Haaland, 1991; Marteniuk, MacKenzie, Jeannerod, Athenes & Dugas, 1987; Marteniuk, MacKenzie, & Leavitt, 1988; Weiss, Stelmach, & Hefter, 1997). This knowledge of target characteristics is cognitively inferred. Unlike the *trivial* sense, cognitively derived target characteristics exert direct effect on fundamental movement parameters. More specifically, the fundamental motor parameters, in terms of kinetics\(^2\), are affected by the cognitively derived information. For example, individuals climb concrete stairs more rapidly and less tentatively than stairs made of rotted wood, even if both stairs are the same dimensions (Colley & Beech, 1988). Therefore, kinematic variables cannot account for the differing gait patterns. In both situations, the movement would be kinematically\(^3\) equivalent, yet the person's stepping movements and gait pattern differ. An implication is that cognitive inferences based on knowledge of the properties of concrete and rotted wood resulted in the different stepping movements.
The *non-trivial* sense may involve programming of an optimal movement strategy when other less optimal strategies are possible. Movement strategy is defined as the individual’s approach to a problem such as moving slowly, quickly, accurately, or carefully, depending on the target conditions. For example, an individual may slowly and carefully grasp a light bulb to avoid breaking it rather than quickly grasping the light bulb and breaking it in the process. The former illustrates an optimal movement strategy that is reflected in fundamental movement parameters such as velocity profile (Marteniuk et al., 1987).

Findings from several studies support the *non-trivial* sense in which cognitive processes influence the fundamental movement parameters (Harrington & Haaland, 1991; Marteniuk et al., 1987; Marteniuk et al., 1988; Weiss, Stelmach, & Hefter, 1997). Marteniuk et al., (1987) showed persons use different reaching and grasping movements to a light bulb relative to a tennis ball. Findings showed movement trajectories to the two objects differed; specifically, persons spent more time in the deceleration phase to the light bulb, presumably to avoid breaking the light bulb with contact. Both objects had a diameter of 6 cm and involved identical 30 cm movements. This implies knowing the different properties of light bulb (fragility) or tennis ball (toughness) affected the person’s reaching and grasping movements. Thus, fundamental movement
parameters such as acceleration and deceleration are directly affected by knowledge derived from cognitive inferences regarding the stability of the object to be grasped.

Marteniuk et al., (1987) also demonstrated that a person's goal and intended action affects movement strategy. In the first part of the movement, participants were asked to reach and grasp a wooden disk (1 cm thick and 4 cm diameter) placed 30 cm in front of them. In the second part of the movement (intent component), participants were to either throw the disk into a cardboard box (20 by 40 by 15 cm) 15 cm away and to the left of the disk, or place it in a tight fitting well (4.1 cm in diameter) 10 cm to the left of the object. Although the two movement conditions differed only in what subject was asked to do after the disk had been grasped, differences in grasping the disks in the two movement conditions occurred. Specifically, in grasping the wooden disk, more time was spent in the deceleration phase when participants intended to place the disk in the tight fitting well (prior to fitting it in the well) compared to throwing it in the box. This finding suggests that movement strategy is influenced by the person's goal and intentions. More specifically, cognitive inferences regarding target attributes (box or tight fitting well) exert influence on fundamental movement parameters. When precision was required, as when planning to place the disk in a tight fitting well, a longer deceleration phase occurred. Thus, an intended
action in the second part of the movement (placing disk in well) facilitated construction of the appropriate movement strategy in the first part of the movement (moving accurately).

Collectively, these results support the conclusion that knowledge of cognitively inferred target characteristics (stability) and intended action (to place or throw an object) affect movement. Furthermore, these examples illustrate that persons may employ a repertoire of movement strategies, but use the strategy most appropriate for the task at hand based on cognitively derived inferences regarding target attributes.

The fact that incorporating the cognitively derived target characteristics to determine movement parameters may be "subconscious" does not exclude this operation as being cognitive. The case of HM shows perceptual-motor information processing and learning can take place independent of what one can recall (Milner, Corkin, & Teuber, 1968). HM was a patient who had a bilateral temporal lobectomy (removed hippocampus, amygdala, entorhinal cortex) for treatment of progressive seizures. From one session to the next HM showed improvement in procedural tasks such as mirror drawing (See Description of Tasks, Appendix A), yet he did not recall that he had previously performed the task. This illustrates that cognitive processes may occur without awareness of these processes taking place.
Do Persons with PD have Cognitive Abnormalities Generating Movement?

Persons with PD may have deficits in employing the appropriate movement strategy to targets as seen in marked differences in movement parameters between Parkinsonian patients and controls. Sanes (1985) showed that decreases in target size or increases in the distance separating two targets resulted in slower movement times in PD patients compared with controls. Also, Parkinsonian patients were not able to maximize speed and increase their velocities with increasing target size as compared with healthy controls (Montgomery & Nuessen, 1990).

In another study, PD patients showed no difference in movement times when moving to bounded (target with mechanical stop) versus unbounded targets whereas healthy controls decreased their movement times to bounded targets (Montgomery, Gorman, & Nuessen, 1991). Also, Waters and Strick (1981) showed that moving carefully to an unbounded visual target in a ballistic flexion task resulted in antagonist bursts in healthy controls, whereas, banging against a mechanical stop resulted in no antagonist activity. When antagonist activity was present, the ballistic movement was decelerated to the unbounded target whereas an absence of antagonist activity resulted in continued acceleration to the mechanical stop. These findings suggest cognitive
inferences regarding target boundness affect fundamental movement parameters differently in healthy controls compared with persons with PD.

More specifically, healthy controls are able to use appropriate movement strategies given the target characteristics. Controls used a movement strategy involving less accuracy when banging against the mechanical stop compared with more accuracy and precision when moving to the unbounded target. In contrast, Parkinsonian persons employ movement strategies that do not optimize to all situations. They may use simplified strategies for movement (Montgomery, 1995) that may not be the most appropriate for the task given the target characteristics and contextual conditions. The use of simplified strategies may be more apparent in nontrivial cases where target demands limit the range of behaviors that are effective and require the use of an optimal strategy.

**Expectancy**

Motor performance is affected not only by cognitively derived target characteristics but also by the individual's level of expectation. Expectancy may arise from the subjects' knowledge about the nature of the input they will receive (Posner, 1986). The expectation of a specific stimulus affects preparation for a specific response.

Expectancy may be seen in various modalities. In motor control, the notion of expectancy is seen in the phenomena of set. The motor cortex,
supplementary motor area, caudate, and putamen each contain 'set' neurons that show increased discharge rate following an instructional stimulus that specifies the direction of an upcoming limb or the forthcoming go signal (Jaeger, Gilman, & Aldridge, 1993; Tanji & Kurata, 1985). Thus, set neurons fire before the stimulus to move (e.g., go signal). Behaviorally, this results in shortened reaction times once the movement-triggering stimulus occurs. This suggests that set neurons may have a role in initiation of movement.

Set neuronal activity may be altered in PD. More specifically, single neuron recordings show that set cells may change their firing rate with dopamine depletion (Watts, Mandir, & Montgomery, 1989). Therefore, prolonged reaction times in Parkinsonian patients may be related to impaired set cell activity (Montgomery et al. 1991).

Expectancy is also seen in the psychological concept, shifting capacity. Shifting capacity is defined as the ability to alter the predisposition to respond in one way when there is an external change of task or a self-directed initiative that requires another alternative to be chosen and executed (Richards, Cote, & Stern, 1993). Shifting capacity may be diminished in PD as measured by tests such as the Wisconsin Card Sort Task (WCST) and the Trailmaking test part-B (TMT Part-B) (Brown & Marsden, 1990; Cools et al.
Movement Initiation and Execution

Cognitively derived knowledge of a visual target may differentially affect movement initiation and execution. Evidence suggests that the motor program specifying initiation is separate from the program specifying trajectory (execution) and that timing of trajectory specification and movement initiation may be physiologically distinct (Montgomery et al. 1991; Montgomery & Buchholz, 1991). Thus, the study design must enable movement initiation and execution to be separated otherwise a differential effect of cognitively derived target attributes on movement initiation or execution may be canceled out.

Programming target acquisition may be an important basal ganglia function that is disturbed in PD. Parkinsonian patients show slowing of movement specific to target conditions, but not general slowing of all movements. Loss of striatal dopamine appears to affect motor execution by programming movement speed too slow for target conditions (Montgomery & Buchholz, 1991; Montgomery & Nuessen, 1990; Montgomery et al., 1991*). Therefore, the timing involved in the program that specifies trajectory to different types of cognitively derived targets may be differentially affected in PD.
Purpose of the Study

The purpose of this research is to investigate cognitive processes involved in generation of voluntary movement. This research involves several subpurposes. Foremost, the researcher investigated the effects of cognitively derived information from targets on movement initiation and movement execution in Parkinsonian patients off Parkinson’s medication and neurologically intact controls matched for age and gender.

The targets in this study (inferred and explicit targets) differentially involved cognitive activity, in that knowledge of target destination in one of the conditions is not apparent in the target attributes, but rather is derived from cognitive inferences regarding the target attributes (see figure 1). The inferred target contains one vertical and one horizontal cue which are used to infer the target location whereas the explicit target contains a single cue used to specify the target location. Both target types contain vertical and horizontal lines placed at right angles to each other; however, the spatial arrangement of the features differ. The inferred target requires the individual to relate two separate cues in space to infer the correct destination. Each cue in isolation points to two possible destinations making each separate cue ambiguous. Because of this ambiguity, each cue in the inferred target condition has to be analyzed and related to the other cue in order to move to the correct destination.
Additionally, this research investigated the hypothesis that expectancy is manifested in motor and psychological modalities. Various conditions of set shifting were studied, such as those involving changes from like to like target types (e.g., explicit to explicit) and like to unlike target types (e.g., explicit to inferred target). A goal of the study was to determine if set to the initial target type affected cognitive processing to the final target type when a shift occurred. Secondly the research examined the relationship between the tests of motor function and scores on neuropsychological tasks that assess shifting capacity such as the Wisconsin Card Sorting Test (WCST) and the Trailmaking Test Part B (TMT-part B). A correlation between measures of expectancy in the motor and psychological modalities would imply the possibility that the operations underlying these measures share a common substrate, probably the basal ganglia.

Furthermore, the research investigated the effects of cognitively derived target attributes on critical time periods (CTP) involved in the central generation of movement. Central generation of movement involves central representations, such as motor programs, which contain information regarding timing and sequencing of movements. More specifically, the research examined the timing involved in the program for motor execution, in terms of specifying trajectory to
the explicit and inferred targets. CTP$^{[ra]}$ refers to the critical time period in which movement trajectory is specified.

An analogy of a real life experience can be used to clarify CTP$^{[ra]}$ in motor control. A racquetball game requires the individual to swing a racket to contact a small ball (target) in motion. When the ball curves unexpectedly, the individual may need to alter the trajectory of the arm movement mid-strike in order to contact the ball at the new target location. If it is too late to change the trajectory, the racket may stop at the initial and final target locations, producing a double trajectory. This would suggest that the CTP$^{[ra]}$ of the arm movement to the initial target location has already been specified. In the case where the racket goes directly to the final target location, a single trajectory is produced. This would imply the CTP$^{[ra]}$ to the initial target location has not been specified.

**Hypotheses**

In order to describe the study hypotheses, a brief explanation of the study methods is necessary. In this study participants employed rapid arm extension movements to explicit or inferred targets appearing on a computer monitor screen (See Figure 1). A reaction-time paradigm was used. At designated times, the initial target stayed on the screen (No Target Change task: NTC) or the initial target was turned off and a second target appeared (Target Change task: TC). Presentation of tasks was weighted towards the no target change
task, setting up an expectation to move to the initial target location. Other conditions included targets changing in location and type from the initial target.

Participants made a single movement in the NTC-task, producing one reaction time (RT) defined as the $RT_{\text{single}}$. Alternatively, participants sometimes made two separate movements when the target location change occurred. In the case of a double movement there was a $RT_{\text{initial}}$ associated with the initial movement to the initial target and a $RT_{\text{second}}$ associated with movement to the final target.

Figure 1. Explicit and inferred targets

*Figure 1a* indicates 9 locations on the computer monitor screen where the explicit and inferred targets appeared. The target was randomly assigned to one of the nine locations. *Figure 1b* identifies the explicit target at location 1 whereas *figure 1c* identifies the inferred target at location 1. The inferred target requires the individual to relate the vertical and horizontal cues in space to infer the correct destination.
The investigator tested the following hypotheses:

**Hypothesis 1**

Parkinsonian patients off Parkinson's medication (PD Off) compared to neurologically intact controls (NC) will have prolonged premotor reaction times (RT) to the inferred target compared to the explicit target.

Combining and relating the individual features of the inferred target may be more cognitively demanding compared with processing the explicit target. The increased cognitive complexity associated with the inferred target may contribute to prolonged response time particularly in PD. Persons with PD may have depleted central processing resources as suggested by deficits in dual task paradigms (Malapani, C., Pillion, B., Dubois, B., & Agid, Y, 1994). Dual task paradigms require the participant to perform two cognitive tasks concurrently. The demands of the inferred target may exceed available resources and result in disproportionately longer response times in PD.

**Hypothesis 2**

PD Off patients will have prolonged movement time (MT) to the explicit and inferred targets compared with NC subjects. However, PD Off patients will have equivalent MTs to the inferred and explicit targets whereas NC subjects will have prolonged MTs to the explicit target.
Different movement strategies may be involved in response to the explicit versus the inferred targets. The inferred target is likened to a bounded target (Montgomery et al., 1991; Waters & Strick, 1981) or tennis ball (Marteniuk et al., 1987) because it may not require a careful movement strategy whereas the explicit target is likened to the unbounded target (Montgomery et al., 1991; Waters & Strick, 1981) or light bulb (Marteniuk et al., 1987) because it may require a movement strategy involving accuracy.

Hypothesis 3

PD Off compared with NC subjects will have prolonged premotor $RT_{second}$ when shifting from the prior target to an unexpected change in target type (e.g., explicit target to inferred target) compared to shifting from a prior target to another like target (e.g., explicit target to explicit target).

Set to the prior target type may affect cognitive processing to the final target type. Shifting from the prior target to an unexpected change in target type (like to unlike target type) requires a change in the individual's response bias to the initial target type. Unlike controls, persons with PD may not easily change their bias to respond to the initial target type, especially with a shift from a like to unlike final target type. A shorter $RT_{second}$ to a like final target (e.g., inferred to inferred target) would suggest that set from the initial target may facilitate cognitive processing to the like final target type whereas prolonged $RT_{second}$ to
an unlike final target type (e.g., explicit to inferred target) would suggest that set from the initial target inhibits cognitive processing to the unlike final target type.

In addition, two research questions were explored.

**Research Question 1**

The CTP$^{\text{traj}}$ to the inferred target type will significantly differ from the CTP$^{\text{traj}}$ to the explicit target type in PD Off patients compared to NC subjects.

It was anticipated that the participant would make a single movement to the second target location if the target location change occurred before the program that specifies trajectory to the initial target (i.e. CTP$^{\text{traj}}$), otherwise the participant would make two movements to the second target location when the target location change occurred after the program that specifies trajectory to the initial target (i.e. CTP$^{\text{traj}}$), a movement to the initial target location, and then a second movement to the second target location. The earliest time of target location change in which the participant could not change the trajectory (thus producing a double movement) identified the time trajectory to the initial target was specified (i.e. CTP$^{\text{traj}}$), (Montgomery et al., 1991).

**Research Question 2**

Second reaction time will be positively related to measures of cognitive shifting capacity (e.g., WCST, TMT Part-B) in PD Off as compared to NC
subjects. An increase in number of perseverative errors in the WCST in the TMT Part-B indicated diminished shifting capacity. Perseveration refers to the tendency to emit the same verbal or motor response despite its inappropriateness for the task demand.

**Significance of the Study**

The incidence of PD in the general population is 160/100,000. Incidence rates of PD rise in relation to the expected increase in life expectancy of the general population. For the segment of the population over 65, incidence is nearly 2% or 2000/100,000. After the fourth decade, incidence rate increases about tenfold so that by age 75, there are 120 to 140 new cases per 100,000 per year. Presently, the segment of the population over 65 years is increasing faster than any other age group. When the baby boom generation reaches advanced age, the age of greatest risk for PD, they could launch an epidemic of PD. This may have tremendous economic, physical, and emotional costs to the Parkinsonian person and society.

The neuroscientific basis and practical applicability of cognitively derived information from targets in motor control is poorly understood. This research may provide insights about how the brain uses cognitively derived information from targets to control movement and result in practical environmental changes that optimize mobility for the person with PD.
More specifically, findings from this study may allow inferences regarding whether the basal ganglia are involved in processing cognitively derived target information into plans and programs for movement. Studying the time required to process the inferred versus explicit target locations may reveal how cognitively derived target attributes affects the motor strategy that is employed. In addition, clarifying the timing involved in the program that specifies trajectory may aid in identifying stages in information processing relevant to a cognitive motor task.

Additionally, findings from this research may contribute to knowledge about how information contained in cognitively derived targets that optimizes motor performance, autonomy, and safety of persons with PD. Nurses can use cognitively derived target attributes to reduce movement abnormalities (e.g., start hesitation and movement arrest). For example, if it were shown that processing of explicit cues facilitates movements, then the patient’s behavior and environment can be modified to use explicit cues. Nursing interventions can be modified to capitalize on use of explicit cognitively derived targets and reduce use of inferred cues. For example, an explicit cue can be placed at the foot of the bed to help the patient get out of bed, thus contributing to enhanced quality of life for the person with PD.
Results from this study may also add to knowledge of shifting capacity in persons with PD. Dimensions of diminished shifting capacity may be revealed, such as conditions which accentuate and minimize the ability to shift from one behavior to another. If decreased shifting capacity were found, nurses could structure a patient's environment that minimizes shifting, e.g., use cognitively similar stimulus, methods or instructions. Additionally, nurses could allow patients more time in situations requiring shifting of cognitive set.

Summary

Parkinson's disease produces deficits in cognitive operations underlying generation of voluntary movement. More specifically, PD may interfere with the ability to employ the most appropriate movement strategy given the target demands. Using an inappropriate movement strategy may be manifested in inability to initiate step and arrests in execution. Altered movement has a significant impact on quality of life and ability to perform activities of daily living.

Cognitively derived target attributes may optimize motor performance in the person with PD. Specifically, a target that contains appropriate cognitive information may enable the Parkinsonian person to construct an optimal movement strategy, thus resulting in improved movement. Knowledge derived from this study may contribute to knowledge of cognitive processes in motor performance and ultimately help nurses and other health professionals develop
rehabilitation programs more appropriate to the abilities and disabilities of persons with PD.
CHAPTER II

REVIEW OF LITERATURE AND CONCEPTUAL FRAMEWORK

Introduction

Chapter one describes how cognitive processes may be involved in motor control and that Parkinson's disease (PD) is a model to understanding cognitive processes in movement. This review addresses cognitive dysfunction in PD framed within an anatomical framework. The concepts, expectancy, movement initiation, and movement execution are discussed. In addition, cognitive deficits in PD and particularly the reliance of persons with PD on external visual cues is addressed. Lastly, the conceptual framework for this research is presented.

Cognitive Dysfunction in Parkinson's Disease

The close link between the basal ganglia (BG) and the cerebral cortex underlies the proposed cognitive functions of the BG (Marsden, 1982; Stern, 1993; Strick, 1993). Neuronal pathways that link the BG to the cortex project to cortical areas e.g., prefrontal cortex (Pillion, Dubois, & Agid, 1996). The input nuclei of the BG, the caudate and putamen, receive substantial projections from diverse regions of cerebral cortex including motor, sensory, prefrontal, and limbic cortical areas. Basal ganglia output, via the internal segment of the globus pallidus, influences widespread regions of the frontal lobes (Strick, 1993). Parallel basal ganglia-thalamocortical circuits that link the BG with the frontal
cortex have been identified via anterograde and retrograde cellular transport (Alexander, Delong, & Strick, 1986; Middleton & Strick, 1994). Basal ganglia-thalamocortical circuits pertinent to the present discussion include the dorsolateral prefrontal circuit, motor circuit, and anterior cingulate circuit (Alexander, Delong, & Strick, 1986). Each circuit involves a different portion of the frontal lobe; however, the combined output of these circuits projects to the entire frontal lobe. Lesions of the striatum may interfere with functioning of these circuits and with cognitive functions they support (Dubois et al. 1995).

**Dorsolateral Prefrontal Circuit**

The dorsolateral prefrontal circuit is implicated in planning and flexibility (Dubois et al., 1995). Planning refers to the ability to form novel strategies for solving problems and to consider consequences of behavior whereas flexibility refers to the ability to use alternative solutions or various approaches in problem solving (Kolb & Whishaw, 1996). Nondemented patients with PD share many of the characteristic cognitive deficits observed in patients with frontal lobe impairment (Bondi, Kaszniak, Bayles, & Vance, 1993; Lange et al., 1992; Gotham, Brown, & Marsden, 1988). These cognitive deficits include difficulty planning or sequencing behavior, monitoring ongoing behavior, and modulating behavior to continue to meet task demands (Brown & Marsden, 1990; Stern, 1993) as evidenced by diminished shifting capacity and the inability to reorganize
behavior according to the requirements of the task (Cools et al., 1984a).

Patients with basal ganglia disease may have impaired ability to not only establish a set, but to switch back and forth between task specific behavioral sets when dependent on internal cues for direction. External cues may aid the PD patient in establishing and maintaining set and in task specific planning (Saint-Cyr, Taylor & Nicholson, 1995).

Given the close relationship between the BG and the frontal cortex, it is not surprising that damage to the BG may induce frontal lobe dysfunction. Behavioral symptoms observed in frontal lobe pathology such as inertia, reduced activity, blunted affect, and stereotypies/compulsions have been reported following focal BG lesions (Dubois, et al., 1995). Nondemented patients with unilateral dorsolateral caudate lesions (Mendez, et al., 1989) reportedly show decreased motivation, decreased spontaneous verbal or motor activity, and social withdrawal. These behaviors also occur in nondemented patients with bilateral pallidal lesions (Strub, 1989).

On neuropsychological testing, patients with focal BG lesions have been impaired on tasks requiring problem solving, planning, and sequencing, such as the Wisconsin Card Sorting Test (WCST), the Stroop test and tests of Verbal fluency (Mendez, et al., 1989; Strub, 1989). Deficits in executive functions related to focal BG lesions may be due to difficulty in maintaining correctly
generated efficient strategies and to disorders of attentional control (Dubois et al., 1995). Additionally, patients with focal BG lesions have shown decreased immediate and delayed recall of episodic and semantic items along with intact recognition memory on tasks such as the California Verbal Learning Test (Mendez, et al., 1989). Furthermore, task performance that is frequently affected by frontal lobe lesions, such as that on delayed alternation tasks (Denny-Brown et al., 1976), has also been disrupted after focal BG lesions (see Appendix A: Description of tasks).

The dorsolateral prefrontal circuit links the BG with the prefrontal cortex. Inputs to the BG portion of the dorsolateral prefrontal circuit arrive in the dorsolateral head of the caudate nucleus. The caudate then projects back to the prefrontal cortex via the internal segment of the globus pallidus, ventral anterior and dorsomedial nuclei of the thalamus, and the supplementary motor area (Alexander, Delong, & Strick, 1986; Alexander & Crutcher, 1990).

Motor Circuit

The motor circuit underlies preparation to move and execution of movement (Alexander, Delong, & Strick, 1986; Alexander & Crutcher, 1990). This circuit may be involved in establishing set and constructing appropriate motor strategies to specific target conditions. Set cells, which fire based on anticipated action, are found in the supplementary motor area (SMA) and
putamen, components of the motor circuit (Alexander, Delong, & Strick, 1986; Alexander & Crutcher, 1990). Dopamine depletion, as in PD, may result in impaired set activity (Saint-Cyr, Taylor, & Nicholson, 1995).

The motor circuit links the BG with the SMA and motor cortex. Inputs to the BG portion of the motor circuit arrive at the putamen, although the neighboring areas of the caudate nucleus also receive inputs. The putamen then projects back to the motor cortex via the internal segment of the globus pallidus, ventral-lateral thalamus, and SMA (Alexander, Delong, & Strick, 1986; Alexander & Crutcher, 1990).

**Anterior Cingulate Circuit**

Motivational processes involved in movement control may be affected due to disruption in the anterior cingulate circuit. The anterior cingulate circuit is implicated in drive, motivation, and initiation of behavior (Dubois et al., 1995; Mogensen, Jones, & Yim, 1980). Patients with focal lesions of the globus pallidus and dorsolateral caudate nucleus show behavioral inertia as in marked decreased activity, e.g., not spontaneously engaging in ordinary activity like reading or conversation. An external cue may help the patient initiate behavior as if the cue was able to compensate for the lack of internal stimulation (Naville, 1922). For instance, a patient may not spontaneously engage in conversation but will appropriately respond when asked questions.
The anterior cingulate circuit links the ventral striatum (nucleus accumbens and olfactory tubercle) with the anterior cingulate area cortex. Inputs to the BG portion of this circuit arrive in the nucleus accumbens, the key structure linking the limbic system and basal ganglia. The nucleus accumbens receives 1) dopaminergic input from fibers that arise medial to the substantia nigra in the ventral tegmental area in the midbrain and 2) connections from the hippocampus, amygdala, inferior and superior temporal gyri (Alexander, Delong, & Strick, 1986; Mogensen, Jones, & Yim, 1980). Outputs from the nucleus accumbens relay to the internal segment of the globus pallidus, dorsomedial thalamus and influence orbital and prefrontal cortex (Nolte, 1991).

Is there Evidence that Motor and Cognitive Symptoms have a Common Substrate or Mechanism?

Various studies have investigated whether motor and cognitive symptoms share a common substrate however study findings vary markedly. Various approaches are used in these studies. A common substrate is inferred when 1) the disease process or treatment (e.g., lesion, levodopa, or dopamine agonist) that affects the cognitive measure also affects the motor measure, 2) the researcher manipulates a cognitive task and observes 'analogous' changes in the motor domains, and 3) the researcher manipulates a motor task (difficult stance) and
observes 'analogous' changes in cognitive domain (impaired performance in visual-spatial task).

Wilson, Kaszniak, Klawans, and Garron (1980) tested the hypothesis that slowing in PD is manifested in cognitive and motoric levels. The authors examined retrieval from short-term memory in nondemented young and old PD patients using the Sternberg paradigm (see Appendix A: Description of tasks). Memory scanning was significantly slowed in PD patients with advanced age (65 years and older); however, both patient groups were on PD medication. In order to determine if there was a drug effect on memory scanning speed, patients were divided into subgroups, those taking versus not taking 1) dopaminergic drugs and 2) cholinergic drugs. There were no differences between the drug subgroups in the slopes of the reaction times-set size function. This suggests memory scanning speed was not differentially affected by Parkinson's medications and that slowed memory scanning speed in the old PD group was a function of the disease effect. Moreover, the findings implicate the basal ganglia in cognitive and motoric slowing (bradyphrenia and bradykinesia, respectively) in nondemented persons with PD.

Pullman et al., (1988) findings suggest motor and cognitive symptoms of PD have a common substrate, the basal ganglia. Pullman et al., (1988) controlled medication and looked at the relationship between plasma levodopa medication level, simple reaction times (SRT), and choice reaction times (CRT). Findings
showed that SRT was prolonged in persons with PD as compared to a control group, but SRTs were not differentially affected by various levodopa levels. CRTs were not different from controls at the highest infusion rate but were prolonged when infusion was decreased to the middle and lowest rates. This suggests cognitive deficits in nondemented PD patients may improve after reestablishing dopaminergic transmission with levodopa therapy and dopaminergic mechanisms may underlie CRTs.

Findings from Fernandez-Ruiz et al., (1995) suggest that damage to the substantia nigra may account, not only for motor changes seen in 1-methyl-4-phenyl-1,2,3,6-tetrahydropyridine (MPTP) induced Parkinsonism, but for impaired performance on the spatial delayed response task. Following MPTP administration and resultant substantia nigra damage, monkeys exhibit deficits in tasks sensitive to frontal-striatal system dysfunction such as impaired performance on a spatial delayed response task. This task requires the monkey to remember the location of food after a short delay of 10 to 60 seconds. MPTP treated monkeys perform similarly to prefrontal or striatal lesioned monkeys on the spatial delay task (Fernandez-Ruiz, Doudet, & Aigner, 1995).

Contrary to the above, Rafal, Posner, Walker, and Friedrich (1984) did not find a relationship between cognitive and motor measures. The researchers investigated if slowed information processing as measured by increased reaction
time was linked to slowness of movement (bradykinesia). Six PD patients serving as their own controls were tested. The patients exhibited bradykinesia when off medication; when patients were on medication, bradykinesia was alleviated. Patients fixated on a cross on the central position of a screen and were asked to press a key (i.e., motor task) whenever an asterisk appeared either to the left or the right of center. The asterisk was preceded by a cue indicating where (left or right) to expect the asterisk to appear. On 20% of the trials the cue was invalid (i.e., cue appeared to the left of center when the asterisk appeared on the right). The cue preceded the appearance of the asterisk by 50, 150, 550, or 1000 milliseconds.

There was no significant effect of drug treatment on reaction times, that is, when patients were on medications, reaction times did not shorten although bradykinesia was alleviated. Patients showed clear validity effects (i.e., reaction times were faster for valid trials across all intervals between the cue and appearance of the asterisk) and demonstrated this pattern when on and off medication. Findings thus showed that speed of information processing was independent of motor performance suggesting slowed information processing and bradykinesia do not share a common mechanism.

The Girotti et al. (1986) findings also did not support a relationship between cognitive and motor measures. Girotti et al. (1986) measured cognitive and mood changes in twenty-one patients with idiopathic PD on levodopa therapy. Patients
experienced severe ON-Off fluctuations. During the 'off' phase motor disability is maximal, presumably correlating with decreased striatal dopaminergic transmission whereas during the 'on' phase, motor improvement is maximal, presumably correlating with optimal striatal dopaminergic transmission (Dubois & Pillion, 1992). Each patient served as his own control and was tested once when OFF and once when ON. No changes in cognition occurred between the ON and OFF conditions in tests of attention, verbal fluency, and memory although a significant worsening of mood from the ON to OFF phase occurred. This suggests that dopaminergic dysfunction does not underlie cognitive changes in PD.

Kerr, Condon, and McDonald (1985) manipulated a motor task (difficult stance) and inferred a common substrate when they observed "analogous" changes in the cognitive domain (impaired performance in visual-spatial task). They tested healthy adults on the Brooks (1968) spatial and nonspatial (verbal) memory tasks either while maintaining a difficult standing position (Tandem Romberg position) or sitting. Maintaining the difficult standing position during presentation of the memory items affected recall of the spatial task but not nonspatial memory performance (verbal task). Balance steadiness did not differ during the two memory tasks. The authors concluded that cognitive spatial processing and regulation of standing posture rely on similar neural mechanisms.
Many variables may contribute to the inconsistent findings among studies. The variability of cognitive findings compared with more consistent movement slowing in PD may have a neurophysiological basis. In idiopathic PD, the putamen had larger and more consistent dopamine loss than the caudate nucleus as measured by F-labeled 6-fluoro-dopa PET (Kish, Shannak, & Hornykkiewicz, 1988). Therefore, variable dopamine depletion in the caudate compared with more consistent dopamine depletion in the putamen may account for variability in cognitive findings. Secondly, cognitive symptoms may be dose dependent. If anti-Parkinson's medication is titrated to motor symptoms such as tremor or bradykinesia, the dose may be too small or too large for optimal control of cognitive symptoms. Yet the dose cannot be increased or decreased because it would result in dyskinesia (abnormal involuntary movements) or conversely marked slowness of movement that would disrupt activities of daily living.

Do Persons with PD have Cognitive Abnormalities in Generating Movement?

Parkinson's disease produces deficits in cognitive processes underlying generation of voluntary movement. Cognitive processes in movement in PD are impaired in that persons with PD do not appropriately modify movement parameters based on the target characteristics and context. For example, persons with PD do not use optimal movement strategies but rather select a simplified strategy that may not be the most appropriate for the target characteristics and context (Montgomery,
1995). This may be manifested in bradykinesia (difficulty initiating movements and slowed movements). Bradykinesia is not a general slowing of all movements but rather a slowing of movement specific to target conditions. Loss of striatal dopamine affects motor execution by generating movement speed too slow for target conditions (Montgomery & Nuessen, 1990; Montgomery, Nuessen, & Gorman, 1991*).

Use of simplified strategies may relate to defective motor planning and programming. Motor plans and programs are abstract central representations proposed to account for planning where, how, and when to move. Motor planning is thought to be severely compromised in PD (Marsden, 1982). PD persons may use simplified strategies because they may not be able to construct an appropriate motor program.

Another example of cognitive abnormalities in movement generation is seen in the difficulty PD patients exhibit in shifting from one motor plan to another (Bertardelli et al., 1986; Cools et al., 1984b). The BG may be involved in switching motor programs when shifting to a new behavior is required (Cools et al. 1984a & 1984b). Diminished shifting capacity may parallel impairments in switching motor programs in PD. In both cases, striatal dopamine depletion provides a common pathophysiological basis for the changes (Richards, Cote, & Stern, 1993).
Yet, another example of cognitive abnormalities in motor generation is the increased reliance on visual information for movement control displayed by patients with PD (Cooke, Brown, & Brooks, 1978; Flowers, 1976; Beuter et al., 1990; Stern, 1993). Many patients with PD have learned to use visual targets to enhance movement, thus rehabilitating themselves. PD patients have a characteristic shuffling gait in which they take short steps and have difficulty in starting to walk, often "freezing" on the spot. Upon presentation of appropriate visual targets, patients with PD can move with the ease of a normal person. For example, these patients may use a cane as a portable visual target to facilitate walking (Dunne, Hankey, & Eddis, 1987). The cane is turned upside down and the handle is placed a few inches off the ground in front of the foot. The patient then steps over the handle (which serves as the target). Use of the visual target "unfreezes" the patient, enabling the patient to start walking.

External Visual Information for Movement Control

Studies in motor performance (Beuter et al., 1990; Cooke, Brown, & Brooks, 1978; Dunne, Hankey, & Eddis, 1987; Flowers, 1976; Purdon-Martin, 1967), neurophysiology (Viallet et al., 1987; Aldridge, Anderson, and Murphy, 1980) and neuropsychology (Brown & Marsden, 1988; Flowers & Robertson, 1985; Flowers, 1978) demonstrate the potential use of visual targets in motor control.
Physiological evidence showing BG neurons respond to visual targets has been provided using electrophysiological techniques. Montgomery and Buchholz (1991) found neurons in the caudal striatum and motor cortex related to reaching the target. Viallet et al., (1987) compared motor performance of normal and substantia nigra (SNr) lesioned monkeys making pointing movements with and without visual feedback towards stationary targets. Monkeys with lesioned SNr had prolonged reaction times and a slowing of movement speed when visual targets were suppressed. Aldridge, Anderson, and Murphy (1980) trained monkeys to perform a tracking task that involved flexion and extension of the wrist at the onset of a visual target. Aldridge et al., (1980) demonstrated via single unit recording, neurons in the globus pallidus (74%) and caudate (37%) that were activated during movement initiated by the visual target. Neurons in the globus pallidus (73%) and caudate (72%) were also activated by the visual target in a no-movement condition. This implies that the caudate and globus pallidus may be involved in planning movement to the visual target.

Studies in motor performance show a pattern of visual targets placed on the floor (e.g., stripes, sheets of white writing paper or triangular rods) has beneficial effects on PD patients gait. A series of stripes, placed at right angles along the path in front of the PD patient helped the patient initiate walking
(Purdon-Martin, 1967). In addition, PD patients stepped over paper sheets placed on the ground in front of them and doubled the length of their step (Forssberg, Johnels, and Steg, 1984). In a more recent study, brightly colored triangular rods placed along a walkway resulted in decreased double support times (both feet simultaneously in contact with ground), increased stride length (distance between two consecutive heel strikes ipsilaterally), and increased step length (distance between two consecutive heel strikes) (Bagley et al., 1991). However, in these studies, the researchers did not systematically investigate the specific characteristics of the visual targets that lead to improvement in gait.

Neuropsychological research has tested the hypothesis that PD patients show increased reliance on external cues in task specific planning. Performance on tasks that require cognitive flexibility or internally-guided behavior is frequently impaired in PD (Brown & Marsden, 1988; Flowers & Robertson, 1985; Gotham, Brown, & Marsden, 1988; Richards, Cote, & Stern, 1993). These tasks include 1) concept formation and rule finding tasks, e.g., WCST; delayed response tasks, 2) set-shifting tasks, e.g., Odd-Man-Out; Trail Making test 3) set-maintenance, e.g., word fluency; Stroop test and 4) problem solving, e.g., tower tasks (see Appendix A: Description of tasks). When external cues are provided, PD patients may perform similar to controls. Brown and Marsden (1988) tested PD patients on a cued and uncued version of the Stroop task (Stroop, 1935).
The Stroop test requires one to switch from processing one attribute of a stimulus to another, e.g. meaning of the word versus the color of ink words are written in. In the cued condition, patients were given an external cue (e.g., INK or WORD) before each trial signaling the relevant attribute "color of ink or meaning of word. In the uncued condition, PD patients had to rely on their own internal cues. Idiopathic PD patients performed normally when the external cues were provided but were impaired in the uncued condition without external cues. In contrast, controls performed similarly in both conditions (Brown & Marsden, 1988).

These findings lend support to Stern's (1993) hypothesis that the BG are involved in task specific planning and modulation of ongoing activity without external guidance (Stern, 1993). The findings also lend support to Taylor and Saint-Cyr's (1992) assertion that deficits on neuropsychological tasks do not occur when the material is presented in an organized form or when the task provides explicit guidelines against which to check progress.

Persons with PD may be compensating for the inability to form internally generated response strategies by increased reliance on external cues. Use of simplified strategies may be a symptom of the inability to generate appropriate strategies for the specific task conditions. Impaired response strategies may account for why persons with PD rely on external cues to initiate and execute
movement. External guidance enables movements to be controlled during execution or through ongoing monitoring of the movements as they are produced (Flowers, 1976; Stelmach, Phillips, & Chau, 1989).

**Movement Initiation and Execution**

Cognitive aspects of movement may differentially affect movement initiation and execution. Movement initiation refers to preparatory processes to move and movement onset whereas movement execution refers to movement onset to movement completion. Knowledge of cognitively derived target characteristics may lower the threshold for initiation thus priming the muscles involved in producing the movement. This may facilitate recruitment and synchronization of motor units thus shortening reaction times (RT). Reaction time is a measure of the time required for stimulus processing, decisionmaking, and initiation of response (Schmidt, 1988).

The reaction time period may be separated into premotor and motor reaction times (Pullman, Watts, Juncos, Chase, & Sanes, 1988; Sheridan, Flowers, & Hurrel, 1987). Premotor RT is thought to reflect central processes involved in decisionmaking and preparation to move. It is operationally defined as the interval between a go signal to move and the first agonist muscle bursts. Motor RT reflects peripheral processes involved in mobilizing the musculature and is operationally defined as the interval from the first agonist muscle burst to movement onset. Prolonged Motor RT suggests decreased efficiency in motor recruitment and
synchronization. Motor recruitment refers to the ability to recruit motor units (motor neuron and the muscle fibers it innervates) based on the level of force required whereas motor synchronization refers to the ability to time/coordinate the firing of various motor units to achieve the desired force for the task at hand.

Target attributes may also affect movement execution. Fitts (1954) showed that movement time, rather than reaction time, may be an index of cognition. This appears to be task dependent. In a study by Montgomery et al., (1991), movement times between PD patients and controls making wrist motions to bounded (target with mechanical stop) versus unbounded targets significantly differed whereas reaction times did not. More specifically, PD patients showed no difference in movement times when making wrist motions to bounded versus unbounded targets whereas healthy controls decreased their movement times to bounded targets. This illustrates that information contained in a visual target may exert its effect on movement execution rather than movement initiation.

Evidence suggests movement initiation and execution have different underlying mechanisms, thus explaining why initiation and execution may be affected differently by cognitive processes in movement. Montgomery and Buchholz (1991) found that neurons in the BG and motor (MC) responding to a go signal not only changed activity prior to neurons responding to movement-onset but that movement-onset neurons in the BG and MC changed activity prior to target
acquisition neurons. Thus, neurophysiological evidence suggests the timing of trajectory specification (a component of movement execution) and movement initiation may be physiologically distinct.

Findings by Montgomery et al., (1991) also suggest movement initiation and execution have different underlying mechanisms. This study examined a patient’s ability to alter a trajectory in response to changing target locations occurring before and after a go signal. Even after the onset of the agonist EMG (agonist bursts occurred before movement execution), movement execution in terms of single or double trajectories could be changed. This suggests that trajectory of a movement (which has a role in execution) may be altered even after the movement has been initiated.

Montgomery et al. (1991) also found that the time of the initial movement onset was different in single versus double trajectories. In single trajectories, the mean onset of initial movement was 290 ms after target location change whereas in double trajectories, the time of initial movement onset was 200 ms after the target location change. During this 90 ms time window the trajectory was respecified to the new target location which enabled performance of one smooth movement to the new location. This suggests that the program specifying trajectory occurs 90 ms after the program specifying initiation of movement (Montgomery et al. 1991).
Collectively, evidence suggests that the motor program specifying initiation is not only separate from the program specifying trajectory but the program specifying trajectory occurs after the program specifying initiation of movement (Montgomery et al. 1991). The implication is that the study design must take this knowledge into account when investigating the effects of cognitive processes on motor control. Reaction time needs to be considered separately from movement time since it is possible reaction time and movement time may be affected differently by target characteristics.

**How Can One Separate Cognitive Aspects From Motor Function When Only Motor Performance Can Be Measured?**

Cognitive operations underlying motor function can be studied using mental chronometry, defined as the time course of information processing in the human nervous system (Posner, 1978). Behavioral techniques used in mental chronometry, such as in the reaction time paradigm, require the participant to complete a task and emit an overt response. Insights from behavior may only be gained by carefully designing a performance task that will reveal underlying mental processes and related neurophysiological mechanisms.

The approach employed in this research was to design two tasks that had kinematically similar motor requirements, but that differ in the level of cognitive processing required. In this research, movement kinematics were
controlled, thus, removing kinematics as a confounding variable.

Therefore, differences in performance, as measured by reaction times and movement times, relate to a difference in the cognitive operations involved in generating movement to the target type rather than differences in the motoric task.

**Expectancy**

Motor control is affected by the individual's subjective expectancy. The notion of expectancy is reflected in the phenomena of set. In motor control, set refers to the degree to which expectation of a specific stimulus facilitates movement execution. The caudate, putamen, and supplementary motor area contain set neurons that may represent a neural correlate of one of the preparatory aspects of motor control referred to as motor set (Alexander & Crutcher, 1990). Firing of set neurons temporally precedes the stimulus to move (e.g., go signal) and shortens the RT once the movement triggering stimulus occurs.

Whereas intact set may result in shortened RTs, abnormal set functions may contribute to akinesia and lengthened RTs. Akinesia refers to difficulty initiating movement and the absence of associated movement such as decreased arm swing with walking or the loss of facial expression. More specifically, disruption of set neurons in the supplementary motor area may delay response of the neurons to appearance of the go signal. Additionally, set neurons may continue firing when the
go signal stops, interfering in efficient recruitment and synchronization.

Decreased efficiency in motor unit recruitment and synchronization may contribute to akinesia as manifested by prolonged Rts.

**Diminished Shifting Capacity**

One aspect of expectancy is manifested in the phenomena of shifting capacity. PD patients demonstrate diminished shifting capacity as seen in impaired performance on the Wisconsin Card Sort Test (WCST) (Milner, 1963). The WCST is a test of flexibility of behavior and response inhibition. Response inhibition refers to the ability to inhibit automatic responses that are inappropriate in the given context (Kolb & Whishaw, 1996). The WCST requires the formation of strategies to solve novel problems and the switching of these strategies in response to fluctuating task demands (Lezak, 1983). In the WCST, subjects sort cards containing stimuli that differ by three physical criteria: color, shape, and number. The subject must shift between these criteria as the basis for sorting but is not warned that there will be a shift in sorting criteria. After one criterion for sorting is established, the examiner shifts to another rule without informing the subject. The subject must then shift to the new criteria, that is, modulate behavior to continue to meet task demands of accurate sorting. Nondemented PD patients, compared with controls, may not shift to the new sorting criteria and thus not meet task demands of accurate sorting (Brown & Marsden, 1988; Stern, 1987; Stern, 1993).
The WCST is sensitive to frontal lobe integrity (Taylor & Saint-Cyr, 1992). Milner (1963) administered the WCST to patients with frontal lobe lesions. Patients with lesions of the dorsolateral prefrontal cortex achieved fewer sorting categories than patients with lesions to the other lobes (controls), (e.g., temporal, parietal, parietotemoro-occipital, orbitofrontal plus temporal). In addition, patients with lesions of the dorsolateral prefrontal cortex continued to sort on a previously correct criterion and had significantly more perseverative errors. Perseveration refers to the tendency to emit the same verbal or motor response despite its inappropriateness for the task demand. Eighteen of twenty-five of the patients with lesions of the dorsolateral prefrontal cortex were tested on the WCST preoperatively and then 18 days later postoperatively after surgery for progressive seizures (Milner, 1963). Postoperatively, patients with lesions of the dorsolateral prefrontal cortex showed an increase in perseverative errors and achievement of less categories even though one would expect WCST performance to improve on a second occasion (postoperatively) from practice effects. In contrast, the control lesion groups showed a slight although insignificant improvement in WCST category and perseveration scores postoperatively. This finding supports the contention that performance on the WCST reflects frontal lobe integrity.

Diminished shifting aptitude not only is displayed in the psychological modality (e.g., word production, sorting and categorization) but may be manifested
in the motor modality. These motor and cognitive phenomena may reflect a single dysfunctioning process that influences different levels of behavior (Cools et al., 1984a, 1984b; Flowers & Robertson, 1985; Stern, 1993).

**Motor Sequencing Operations**

Difficulty modulating performance in patients with PD is seen in motor sequencing operations where a change in task demand is imposed midway through execution (Cools et al., 1984a). Motor sequencing involves ordering various components of the sequence into a chain of movements (Kolb & Whishaw, 1996). Modulation requires that patients with PD modify their motor strategy in response to new or unexpected stimuli. For example, patients with PD, tracking a target moving in a regular pattern across an oscilloscope screen, had difficulty tracking accurately when the target disappeared momentarily from the screen (Flowers, 1978). The difficulty was most pronounced when the target disappeared at a point where a shift in the direction of the target was about to occur. This also illustrates the difficulty PD patients encounter when external guidance, that is, the moving target (Stern, 1987; Stern, 1993). When guided by external cues, some patients with PD can control tracking in a motor task in the same manner as healthy controls (Beuter et al., 1990).
Conceptual Framework

Description of Conceptual Framework for this Research

Cognitive processes in movement refers to modification of fundamental movement parameters based on knowledge of the and a prior state affecting the processing of subsequent information in the notion of expectation and set. Fundamental movement parameters in this research refer to response time (reaction time and movement time). Expectancy is a mediating variable through which cognitively derived target characteristics may affect reaction time and movement time (See figure 2; referent level in chapter 3).

Cognitively Derived Target Attributes

Cognitive processes refer to the extraction of information that may not be apparent in the physical attributes of the stimuli that leads to the behavior. Knowledge of cognitively derived target characteristics shapes movement in terms of where, when, and how one reaches for or walks toward a target and thus is involved in determining movement parameters (Colley & Beech, 1998; Harrington & Haaland, 1991; Marteniuk, MacKenzie, Jeannerod, Athenes & Dugas, 1987; Marteniuk, MacKenzie, & Leavitt, 1988; Weiss, Stelmach, & Hefter, 1997).
Figure 2. Conceptual Framework

Cognitive Information

Expectancy

Movement

Target Attributes

Set

Initiation

Execution

Explicit Target

Inferred Target

WCST
TMT-Part B

Reaction Time (RT)

Movement Time (MT)

WCST: Wisconsin Card Sort Test
TMT-Part B: Trailmaking Part B
This study incorporates two target types (explicit versus inferred) and changes target type and location before or during movement execution. Thus, participants must program movement to varying target conditions.

**Expectancy, Shifting Capacity, and Set**

One aspect of expectancy is manifested in the phenomena of set and shifting capacity. PD patients demonstrate abnormal set and diminished shifting capacity. Impaired set activity may contribute to prolonged reaction time (initiation) in the motor task when a change in target type occurs. Thus, expectancy may influence movement initiation. Diminished shifting capacity may also be seen in performance on the Wisconsin Card Sorting test and the Trailmaking test-Part B, in terms of increased number of perseverative errors (Brown & Marsden, 1990). It is hypothesized that the number of perseverative errors in the WCST and TMT-Part B will positively correlate with reaction time to the final target type when a change in target type occurs.

In this study, a weighting towards the "no target change" task was expected to produce a response bias to the initial target type. A change in one's response bias was required when there was a shift to an unexpected target type and location. Thus, set to the prior target type may affect cognitive processing (reaction times) to the final target type.
Requiring a shifting component increases the task demand (Richards, Cote, & Stern, 1993). This shift may place more demands on central processing resources of the person with PD by introducing an effort demanding component that exceeds the resources available to the PD patient. The addition of a change in target may raise task difficulty to a level at which performance becomes significantly impaired. Therefore, prolonged second RTs to the unexpected target condition in PD patients was expected to correlate with higher scores in measures of cognitive shifting capacity.

**Movement Initiation and Execution**

Movement initiation and movement execution are reflected in reaction time and movement time, respectively. A reaction time (RT) paradigm is used to access the pattern of cognitive operations that underlies movements. The RT is thought to reflect central processes involved in decisionmaking and preparation to move (premotor RT) and peripheral processes involved in mobilizing the musculature (motor RT) (Pullman, Watts, Juncos, Chase, & Sanes, 1988; Sheridan, Flowers, & Hurrel, 1987).

Prolonged RT in patients with PD may be a valid indicator of impaired movement initiation (Evarts et al., 1981; Montgomery, et al., 1991; Sheridan, Flowers, & Hurrel, 1987; Stelmach, Teadale, & Phillips, 1992; Waters & Strick, 1981), although there have been inconsistent findings in reaction time
studies related to methodological differences such as whether or not medications that affect motor performance are controlled, the type of task used, the amount of time subjects are allowed to practice performance tasks, selection criteria, and sample size. In contrast to RT, movement time (MT) has been consistently prolonged in PD, perhaps related to the consistently severe dopamine depletion in the caudal striatum. Prolonged MT may be a valid indicator of impaired execution (Evarts et al., 1981; Montgomery, et al., 1991; Sheridan, Flowers, & Hurrel, 1987; Stelmach, Teadale, & Phillips, 1992; Waters & Strick, 1981).

Limitations of Conceptual Framework

Definitional Perspective

Drawbacks related to a definitional perspective are present. This perspective assumes a one-to-one direct comparison between construct and operational definition. This may not be the case. For example, seemingly, RT represents the time involved in movement initiation. However, movement initiation and the RT period may not correspond on a one to one basis. Rather, one could argue that motor RT demarcates the beginning of movement execution. This is reasonable given that the first agonist bursts are necessary to drive and activate the muscles involved in overcoming inertial force from the limb.
Assumptions

This conceptual framework acknowledges that central representations of movement such as motor plans and programs may exist and these representations develop through experience acquired in person-environment interactions. This notion of central representations reflecting person-object interactions is compatible with Klatzky et al., (1993), who suggests cognitive representations of interactions with objects, such as motor plans and motor programs, result in motor strategies specific to the object.

Mediator

An assumption of mental chronometry is that cognitive processes cannot be directly measured. Cognitive processes in movement cannot be directly measured but rather must be inferred by changes in movement parameters. If knowledge of target characteristics significantly impacts movement parameters, a mediator is indirectly supported.

Summary

Persons with PD may have deficits preparing, initiating, and executing movement to targets conditions. Consequently, patients with PD may use simplified strategies that do not optimize to all situations. Appropriate external cues may normalize performance on neuropsychological and motor tasks in persons with PD. PD patients benefit from external cues, perhaps related to
deficits in internally driven response strategies whereas controls perform similarly in cued and uncued conditions.

The impact of external cues on movement may be mediated through cognitive factors related to motor control such as the information contained in targets and expectancy. The information contained in targets may enable the person with PD person to employ an optimal movement strategy whereas expectancy may affect movement to the target by lowering the threshold for initiation. The former would implicate the basal ganglia in processing cognitively derived target attributes into plans and programs for movement. A practical implication is both cognitively derived target characteristics and set may optimize movement in persons with PD.
CHAPTER III

METHODOLOGY

Introduction

In this chapter, the research design, study sample, setting, variables, data collection protocol, data management and data analysis plan are discussed. The setting for this research is discussed initially because information pertinent to setting is presumed in study design, which then follows.

Setting

The setting for this research was in a laboratory at the University of Arizona, Department of Neurology. Participants sat in front of a computer monitor that displayed nine target panels in a 3x3 matrix (See figure 1). The participants held a stylus in their preferred hand on a home base. After a random hold time of 0.5 to 1.5 seconds, an auditory go signal instructed the participant to move the stylus from the homebase to the target. Participants were asked to respond quickly and move as rapidly as possible. At specified times, the initial target remained on the computer screen (No target change, [NTC task]) or the initial target was extinguished and a second target appeared (Target change task [TC task]). Target type and/or location changed at 300 milliseconds (ms), 500 ms, and 700 ms after presentation of the initial target. The go signal was presented at time 0, 100 ms, 250 ms, 500 ms, and 1000 ms
after presentation of the initial target. The time of target change was random but weighted towards the NTC-task (50%); thus, ensuring the subject’s first intention was to move to the initial target location. A weighting towards the NTC task was expected to produce a response bias. Presumably, a change in one’s response bias is required when there is a shift to an unexpected target type and location.

Figure 3a: The subject held a stylus on home base. Nine locations were indicated on the computer monitor screen where the explicit and inferred targets appear. The locations for the explicit and inferred targets were randomly assigned to one of the 9 positions. Figure 3b: identifies the explicit target at location 8. Following an auditory go signal, the subject moved the stylus and placed it on the target. If there was no change in target location, the trial ended. Figure 3c: If there was a change in target location, the initial target was extinguished and a second target appeared. The subject moved the stylus to the second target (e.g., inferred target at location 5).
Research Design

This research employed a two group experimental design involving a neurologically intact control group (NC) and a group of patients with Parkinson' disease off medication (PD Off). The design involved manipulation of an independent variable, target type which included the explicit and inferred targets. The flow diagram depicted in Figure 4 shows the organization of the tasks. In the explicit loop, the initial target was always an explicit target whether or not a target change occurred. Whereas, in the inferred loop, the initial target was

![Flow Diagram]

Figure 4. The flow diagram demonstrates organization of the various tasks.
always an inferred target whether or not a target change occurred. Within the TC task, the initial target changed to a like target (e.g., explicit to explicit target or inferred to inferred target) or to an unlike target (e.g., explicit to inferred target or inferred to explicit target).

The research design enabled the researcher to: 1) determine the time that was required to process the explicit target type versus the inferred target type, 2) determine if motor performance is influenced by the prior target type, and 3) determine the critical time periods (CTP) involved in the central generation of movement. An explanation of each of these follows.

**Determining the Time Required to Process the Explicit Target Location Versus the Inferred Target Location**

In the NTC task at Go time of 0 (NTC-Go-0), RT reflects the time involved cognitively inferring the target destination and mobilizing the musculature to lift the stylus. However, in the NTC at Go 1000 task (NTC-Go-1000, initial target presents 1000 ms before go signal), cognitively inferring the target destination probably has occurred already and the RT reflects mobilizing the musculature to lift the stylus. Presumably, the RT in the NTC-Go-1000 task is shorter than the RT in the NTC-GO-0 task. During a substantial part of RT, the EMG is silent, but late in the RT period, the EMG is activated and immediately precedes mobilizing the musculature. Thus the time involved in cognitively inferring the target
destination might be determined by subtracting the RT in the NTC-Go-1000 task from RT in the NTC-Go-0 task. Therefore, \( RT_{\text{NTC-Go-0}} - RT_{\text{NTC-Go-1000}} \) = time required for cognitive processing (CPT). Additionally, CPT explicit target = \( RT_{\text{NTC-Go-0 explicit}} - RT_{\text{NTC-Go-1000 explicit}} \) and CPT inferred target = \( RT_{\text{NTC-Go-0 inferred}} - RT_{\text{NTC-Go-1000 inferred}} \).

**Determining if Motor Performance is Influenced by Prior Target Type**

The study design enabled an effect of initial target set on cognitive processing time (CPT) of the final target to be tested. As previously described, CPT to the final target can be determined by subtracting the RT involved in mobilizing the musculature from the time involved in cognitively inferring the target destination and mobilizing the musculature. This method can be used to determine CPT to the final target when a target changes from a prior 1) explicit target to another explicit target explicit-explicit, 2) explicit target to an inferred target explicit-inferred, 3) inferred target to an inferred target inferred-inferred, and 4) inferred target to explicit target inferred-explicit.

The difference in set related to the initial target type on the CPT of final target can be determined by comparing the RT difference between CPT explicit-explicit and CPT inferred-explicit and comparing the RT difference between CPT
explicit-inferred and CPT inferred-inferred. Thus, set difference related to the initial target type on a final explicit target type = CPT inferred-explicit - CPT explicit-explicit and set difference related to an initial target type on a final inferred target type = CPT inferred-inferred - CPT explicit-inferred.

Additionally, the set effect of an initial explicit target on the CPT of a like versus unlike final target can be determined by noting the RT difference between CPT explicit-explicit and CPT explicit-inferred. In the same way the set effect of an initial inferred target on the CPT of a like versus unlike final target can be determined by noting the RT difference between CPT inferred-inferred and CPT inferred-explicit.

Figure 5 shows hypothetical results plotting the set effect of the initial target type on the CPT of a like versus unlike final target. Findings such as these might suggest an initial like target facilitates cognitive processing of a final like target but inhibits cognitive processing of a final unlike target. Also the hypothetical data show that an initial explicit target facilitates processing of a final explicit target to greater a degree than an initial inferred target to a final inferred target; therefore, the facilitary set effect is dependent on the prior target type.
Furthermore, the hypothetical data show the set effect of a like to unlike final target is not dependent on the direction of change.

Figure 5. Set effect of the initial target type on the CPT of a like versus unlike final target.

Determine the Critical Time Periods (CTP) Involved in the Central Generation of Movement

This research explored at what point in time a person is committed to executing movement (CTP\textsuperscript{traj}). CTP\textsuperscript{traj} refers to the critical time period in which movement trajectory is specified. More specifically, instructions have already
been sent to the motor system and it is too late to call the instructions back; thus movement is already committed to the initial target. The research design enabled one to determine when movement trajectory is specified by varying the timing of target location changes before and after the go signal, similar to the methods of Montgomery, et al., (1991).

It was thought that the participant would make a single movement to the second target location if the target location change occurred before the program that specifies trajectory to the initial target, whereas, the participant would make a movement to the initial target location and then a second movement to the second target location if the target location change occurred after the program that specifies trajectory to the initial target (Montgomery et al., 1991). Presumably, if a very early target change occurred such as 700 ms before the go signal, the participant might move directly to the final target, bypassing the initial target. Alternatively, if a very late target change occurred such as 700 ms after the go signal, the participant might move to the initial target and make a second movement to the final target.

A preponderance of single movements would indicate commitment to the initial target did not occur and the change in target occurred before the CTP\textsuperscript{ traj}. Alternatively, a preponderance of double movements, such as in very late target changes, would indicate commitment to the initial target did occur and the
change in target occurred after the CTP\textsuperscript{[ra]}'. The earliest time of target location change in which the participant could not modify trajectory to the initial target (producing a double movement) identified the time trajectory to the initial target was specified.

**Population Sample**

Study inclusion criteria for PD patients and neurologically intact controls (NC) were: patients and controls must be alert, understand spoken English, have normal or corrected vision, not exhibit any illness that interferes with arm movement (i.e., arthritis), and be capable of giving informed consent. Additionally, patients and controls could not be currently diagnosed with or have a history of other central nervous system disease.

Patients in the experimental group were diagnosed with idiopathic PD as designated by a history of levodopa responsiveness and the presence of two of four of the cardinal symptoms (tremor, rigidity, bradykinesia, postural instability). Only patients with adult onset PD in Hoehn and Yahr Stages 2 or 3 (Hoehn & Yahr, 1967) were included. Stage 2 refers to bilateral disease without impairment of balance, whereas, stage 3 refers to bilateral disease with some postural instability. Patients in Stage 2 or 3 are physically independent.

A NC group backward matched for age and education was used. Age-matched NCs were used to separate disease effects of PD from effects of
normal aging. Age related changes include slowness of information processing (Salthouse, 1985; Van Gorp, Satz, & Mitrushina, 1990); diminished shifting capacity (Hinkin et al. 1990; Birren & Shaie, 1985; Van Gorp & Mahler, 1990) and a reduction in the number of dopaminergic neurons in the substantia nigra (Haug et al. 1983; Hinkin et al. 1990). Education-matched NC enable the effect of education on a reaction time paradigm to be removed as an alternative explanation. Education may affect the speed of mental processing as measured by simple and choice reaction times.

In order to be included in this study, all patients and controls met cutoff scores for screening tests. Patients and controls were screened for comprehension deficits, depression, and impaired ability to discern line angles. Screening tests included: the Minimental State Exam (cutoff: 24), the Token test (cutoff: 23), the Beck Depression Inventory (cutoff: 10), and the Benton Visual Line Orientation test (cutoff: 19).

Patients were recruited from the Movement Disorders Clinic of the University of Arizona College of Medicine Department of Neurology, community physicians and the local chapter of the American Parkinson's Disease Association chapter. Controls were recruited by word of mouth.
Variables and Instruments

Independent Variables

The independent variables were: Group, Target Type, Go Time, and Target Change. This study varied 1) target types in shift and no shift conditions, 2) timing of the Go signal, and 3) timing of target changes (see figure 6 for referent level of conceptual framework).

Group included the PD Off group and NC group. PD patients were tested following an overnight fast of at least 8 hours from medications (PD-Off group); this was a drug minimum state (Montgomery, Gorman, & Nuessen, 1991).

Target type included the inferred and explicit targets. The inferred target contained one vertical and one horizontal cue, which were used to infer the target location, whereas the explicit target contained a single cue used to specify the target location.

Go Time: The go signal was presented at time 0 and 1000 ms after presentation of the initial target. Go time 0 indicated that the go signal sounded simultaneously with presentation of the initial target. Go time 1000 indicated that the go signal sounded 1000 ms after presentation of the initial target.

Target Change: Target type and location changed at 300 ms, 500 ms, and 700 ms after presentation of the initial target. For example, target change 300 coupled with Go time 0 indicated that the initial target presented simultaneously
with the go signal; 300 ms later the initial target was extinguished and a second target appeared.

**Dependent Variables**

Participants made a single movement in the NTC-tasks or when the change in target location occurred early relative to the go signal. In this case there was one RT defined as the $RT_{\text{single}}$ and one MT defined as $MT_{\text{single}}$. Participants made two separate movements when the target location change occurred late relative to the go signal. In the case of a double movement there was a $RT_{\text{initial}}$ and $MT_{\text{initial}}$ associated with the initial movement to the initial target and a $RT_{\text{second}}$ and $MT_{\text{second}}$ for movement to the final target.

$RT_{\text{single}}$ and $RT_{\text{initial}}$ were operationalized as the time (ms) from the go signal to lifting the stylus off the home base. $MT_{\text{single}}$ was operationalized as the time from the stylus lifting off of home base to placement on the target. $MT_{\text{initial}}$ was operationalized as the time from lifting off the home base to the time of trajectory change to the final target location. $RT_{\text{second}}$ was operationalized as the time between the change in target location and the change in the movement trajectory towards the final target. $MT_{\text{second}}$ was operationalized as the time between the change in trajectory towards the final target and reaching the final target.
The reaction time period was partitioned into premotor RT and motor RT. Premotor RT reflects central processes involved in decisionmaking and preparation to move whereas motor RT reflects peripheral processes involved in mobilizing the musculature. In the case of a single movement there was one premotor RT defined as premotor $RT_{\text{single}}$ and one motor RT defined as motor $RT_{\text{single}}$. In the case of a double movement there was a premotor $RT_{\text{initial}}$ and a motor $RT_{\text{initial}}$ associated with the initial movement to the initial target and a premotor $RT_{\text{second}}$ and a motor $RT_{\text{second}}$ for movement to the final target.

Premotor $RT_{\text{single}}$ and premotor $RT_{\text{initial}}$ were operationally defined as the time from the go signal to the first agonist burst whereas motor $RT_{\text{single}}$ and motor $RT_{\text{initial}}$ were operationally defined as the time from the first agonist burst to lifting the stylus off the home base. Premotor $RT_{\text{second}}$ was operationalized as the time between the change in target location and the first agonist burst before the change in the movement trajectory towards the final target. Motor $RT_{\text{second}}$ was operationally defined as the interval of time from the first agonist burst and the change in the movement trajectory towards the final target.
Figure 6. Referent Level of Conceptual Framework

WCST: Wisconsin Card Sort
TMT-B Trailmaking Test Part B
Participants operated near their physiological limits on RT and MT measures. This minimized confounding influences such as inattention, and decreased motivation. Operation near physiological limits was accomplished by allowing sufficient practice and frequent rests to avoid fatigue. Operation near physiological limits was evidenced by distribution of RTs that were skewed towards shorter times (Montgomery, Gorman and Nuessen 1991).

**Instruments**

**Screening Tests**

Four neuropsychological tests were used to determine the subject's eligibility to participate in this study: the Mini-mental State Exam (MMSE) (Folstein, Folstein, & McHugh, 1975), the Token test (De Renzi & Faglioni, 1978), the Benton Visual Line Test (BVLT) (Benton, Varney, & Hamsher, 1978) and the Beck Depression Inventory (BDI) (Beck et al., 1961). The MMSE, Token test, BVLT and BDI provide measures of cognitive function, deficits in auditory comprehension, participant's ability to judge angles of lines critical in performing the inferred target condition, and depressive state, respectively.

Impaired cognitive function may interfere with the participant's ability to perform the motor tasks in this research. Decreased spatial contrast and depression may act as confounds in a RT paradigm and therefore inadvertently
contribute to a 'treatment effect' and type I error. More specifically, impaired contrast sensitivity may act as a confound in a RT paradigm if a delay in detecting the target when it becomes visible on the screen contributes to decreased processing speed in the stimulus identification stage of information processing. Decreased contrast sensitivity and visual-spatial deficits in judging the angles of lines have been found in PD patients (Huber & Cummings, 1992; Mestre et al. 1990, Raskin, Borod, & Tweedy, 1990). Depressed PD patients may be impaired in the speed of mental processing compared to nondepressed Parkinsonians as measured by simple reaction times (Cooper, Sagar, Tidswell, & Jordan, 1994); this may be due to difficulty concentrating, and slowed thinking.

Cutoff scores for the MMSE, Token test, BVLT, and BDI, indicative of severe impairment (24, 23, 19, 10, respectively) were used to exclude impaired participants from the study sample.

Reliability of the MMSE (reliability coefficient = 0.82 to.98), Token test (reliability coefficient = 0.92 to 0.94), the BVLT (reliability coefficient = 0.89 to 90) and BDI (reliability coefficient = 0.86) have been established in normal and brain damaged groups.

Neuropsychological tests included the WCST and Trailmaking test-part B (TMT-part B). In the WCST (Heaton, 1981), subjects sort cards containing stimuli that differ along three physical criteria: color, shape, and number. The
participant must use external feedback from the examiner to shift between the three criteria as the basis for sorting the cards. Nondemented PD patients, as compared to controls, are less likely to infer the appropriate sorting criteria from the examiner's feedback. An increase in number of perseverative errors is related to diminished shifting capacity. The WCST has demonstrated adequate construct and predictive validity in normal and brain damaged groups (Heaton, 1981).

The TMT-part-B (AITB, 1944) requires the participant to simultaneously scan and alternate between a set of numbers and a set of letters. Reliability (reliability coefficient = 0.66 to.86) has been established in normal and brain damaged groups (Goldstein & Watson, 1989; Snow, W., Tierney, M., Zorzitto, M., fisher, R., & Reid, D.,1989). Parallel forms for the WCST and TMT-part B are not available. Therefore, participants received the WCST and TMT-part B on one occasion.

The Unified Parkinson's Disease Rating Scale (UPDRS; Stern, 1988) was used to rate the presence and severity of the PD. The UPDRS has adequate concurrent and convergent validity.

Movement Quantification Instrumentation

Movement trajectory information was acquired to determine whether the participant produced a single or double movement in the target change task and
to determine the time of trajectory change to the final target during a double movement. Movement trajectory was measured as movement of the stylus from the home base to the target. The stylus was attached to a mechanical arm coupled to a gimbal apparatus with three potentiometers. The potentiometers measured angular rotations in the horizontal and vertical planes as well as the length of the mechanical arm. Potentiometer output was acquired on a pc computer using Labview, in which the voltages were electronically stored. Each point in space occupied by the stylus was translated into a set of spherical coordinates represented in the voltages across the potentiometers. The spherical coordinate system was then converted to a Cartesian system.

Potentiometers were calibrated between each session of data collection. In addition, the potentiometers were checked for linearity during the data collection phase. A linear relationship between potentiometer voltage readings and distance in terms of the length (cm) of the arm was found within the range relevant to the task in this study.

Electromyelographic (EMG) data was acquired in order to partition the RT period into a premotor and motor component. EMG data was acquired via a standard amplifier interfaced to a pc computer using Labview. Surface EMG measured muscle electrical activity in the right upper extremity in the triceps, anterior deltoid, and pectoralis major muscles. Raw EMG data was rectified and
integrated using root mean squared processing (RMS). Filtered EMG data was sampled at 100HZ. For each participant, the rectified and integrated EMG signal was displayed on an oscilloscope to ensure adequate electrode placement and to adjust signal amplification.

Other data points acquired on a pc computer included the go signal time, stylus liftoff, stylus touchdown, and target change time. In addition, header data on the motor task was acquired via Labview on a pc computer. Header data included Target type, go signal time and target change time.

Data Collection Protocol

The study was explained to participants and informed consent obtained prior to screening or performing the tests. Human Subjects approved the study under an umbrella project (Appendix B). If the participant met study criteria, four data collection sessions per participant were scheduled. Administration of the explicit loop, inferred loop, WCST and TMT-part B were counterbalanced across the four test sessions. The motor portion of the UPDRS was administered each test session. Prior to data collection, participants sat in front of the computer monitor to practice the motor task (placing stylus on target that appears on monitor screen). Participants received standardized instructions regarding the protocol (Appendix C). Subsequently, surface electrodes were attached over the participant’s skin on the triceps, anterior deltoid, and pectoralis major of the right
upper extremity. The EMG signal was displayed on an oscilloscope to ensure adequate electrode placement. The room was darkened and data collection began. Participants completed either the explicit or inferred loop during one test session.

Data Management

For this dissertation, five conditions were analyzed, two conditions in the NTC task and three conditions in the TC task. The conditions were 1) Go time 0 and Go time 1000 in the NTC task, and 2) Go time 0 coupled with target change at 300 ms, 500 ms, and 700 ms in the TC task.

Approximately 120 trials per participant were gathered across four sessions of data collection for each NTC condition. Eighteen trials per participant per NTC condition were selected for analysis via a random number generator (Excel 97). The trials were representative of the nine target locations in the 3x3 matrix. In addition, the trials were representative of the early, middle, and latter parts of the sessions. This cancelled out the effect of fatigue on the dependent measures.

Approximately 40 trials per participant were gathered across four sessions of data collection for each TC condition. Approximately twenty trials per participant per TC condition were selected for analysis via a random number
generator (Excel 97). More specifically, the trials selected for analysis included ten trials in the like to like condition and ten trials in the like to unlike condition.

Data management in this study involved the following:
1) selecting individual trials to analyze using random number tables generated via Excel 97,
2) matching the trial selected for analysis with correct header data (Target Type, Go Time, Target Change),
3) extracting kinematic landmarks determined by software developed using Labview. (These kinematic landmarks included stylus liftoff, stylus touchdown, go signal, first EMG burst, target change, and zero velocity between completion of the first movement and onset of the second movement.),
4) recording the results from steps 1, 2, and 3 on forms developed for this purpose,
5) intrarater reliability on the trials completed for each condition (approximately 20% of randomly chosen trials were checked and if necessary modified),
6) entering the data from the forms in step 4 into the spreadsheet,
7) computing the following dependent variables via Excel 97 using the kinematic landmarks in step 2: reaction time, premotor reaction time (single, initial, second) motor reaction time, and movement time (single, initial),

8) data cleaning, (Frequencies and plots of the dependent variables by group and/or by subject were run to check for errors.),

9) importing the spreadsheets into the SPSS statistical package,

10) writing the programs to prepare the data for statistical analysis. For example, a program was written and executed to collapse raw second reaction time scores into median values for each participant in the various shifting conditions (e.g., like to unlike condition, like to like condition), and

11) entering median scores for each participant into the spreadsheet and preparing the spreadsheet to use for statistical analysis e.g., labeling and defining variables.

Practical constraints limited the number of trials that could be analyzed, particularly in step 2 and step 3 of data management. For example, sometimes the trial selected for analysis did not match with the header data. In order to determine the correct header data, the researcher had to explore the landmark displayed for target change in the trials preceding and following the designated trial. In addition, the Labview program did not display the go signal in the
majority of the trials; therefore, the researcher had to determine the onset of
the go signal using the landmark displayed for target change in the specific
session.

Data Analysis

Hypothesis 1

Parkinsonian patients off medication (PD Off) compared to neurologically
intact controls (NC) will have prolonged premotor $RT_{single}$ and premotor $RT_{initial}$ to
the inferred target. This was analyzed in the No Target Change task (NTC)
when the target appears simultaneously with the go signal (Go time 0), before
the go signal (Go1000) and in the Target Change Task (TC) involving a double
movement.

Hypothesis 1 was analyzed with repeated measures analysis of variance
(Anova) with two levels of group (PD Off and NC) and two levels of target type
(explicit and inferred). An interaction was hypothesized between group and
target type. Specifically, the PD Off group was expected to have
disproportionately prolonged premotor $RT_{single}$ and premotor $RT_{initial}$ to the
inferred target. In addition, PD Off patients were expected to have prolonged
premotor $RT_{single}$ and premotor $RT_{initial}$ compared with controls (Main effect).
Hypothesis 2

PD Off patients will have prolonged MT_{single} and MT_{initial} to the explicit and inferred targets compared with NC subjects. However, NC subjects will have prolonged MT_{single} and MT_{initial} to the explicit compared to the inferred target whereas in PD Off patients, MT_{single} and MT_{initial} to the inferred and explicit targets will not differ. This was analyzed in the NTC task when the target appears simultaneously with the go signal (Go time 0), before the go signal (Go1000) and in the TC task involving a double movement.

Hypothesis 2 was analyzed with repeated measures ANOVA with two levels of group (PD Off and NC) and two levels of Target Type. PD Off patients were expected to have equivalent MTs to the explicit and inferred targets. In addition, controls were expected to have prolonged MT_{single} and MT_{initial} to the explicit target compared to the inferred target.

Hypothesis 3

PD Off as compared to NC subjects will have prolonged premotor RT_{second} when shifting from the prior target to an unexpected change in target type (e.g., explicit target to inferred target) as compared to shifting from a prior target to another like target (e.g., explicit target to explicit target). This was analyzed in the TC task involving a double movement (e.g., Go time 0 coupled with target change 500 ms).
This was analyzed with repeated measures ANOVA with two levels of group (PD Off and NC) and two levels shifting condition. The shift conditions included changes from 1) *like to like* final targets (i.e., explicit to explicit and inferred to inferred) and from 2) *like to unlike* final targets (i.e., explicit to inferred and inferred to explicit).

An interaction was hypothesized between group and shift condition. In particular, PD Off patients were hypothesized to have disproportionately prolonged premotor RT$_{\text{second}}$ in changes from like to unlike final targets.

**Research Question 1**

The CTP$^{\text{traj}}$ to the inferred target location will significantly differ from the CTP$^{\text{traj}}$ to the explicit target location in PD Off patients compared to NC participants. This was analyzed in the TC task coupling Go time 0 with target change at 300, 500, and 700 ms.

Chi-square was used to analyze the proportion of single versus double movements across groups and by groups in the TC task. In addition, Chi-Square was used to determine the probability of single or double movements based on the initial target type.

**Research Question 2**

Second premotor reaction time (premotor RT$_{\text{second}}$) will be positively related to perseverative errors on measures of cognitive shifting capacity (e.g.,
Wisconsin Card Sort Test (WCST), Trailmaking Test (TMT) Part-B) in PD Off compared to NC participants.

This was analyzed with Kendall's Tau in the Target Change Task coupling go time 0 and target change 500.

Summary

This research involved a reaction-time paradigm. Participants employed rapid arm extension movements to explicit or inferred targets appearing on a computer monitor. PD may affect the cognitive operations involved in generating movement to the inferred target differently than those involved in generating movement to the explicit targets. Use of PD patients off medication and age and gender matched controls enabled separation of disease effects and effects of normal aging.
CHAPTER IV

RESULTS OF DATA ANALYSIS

The purpose of this study on cognitive aspects of movement was to 1) investigate the effects of explicit and inferred targets on movement initiation and execution, 2) test the effect of set from a prior target type on initiation to a subsequent target type, and 3) investigate the timing involved in the program that specifies trajectory to the explicit and inferred targets.

The results of data analyses are presented in the following order: description and summary of sample characteristics, findings related to the research hypotheses and findings related to the research questions.

**Sample Characteristics**

Participants in the sample included seven persons with idiopathic related to Parkinson's disease off medication (PD Off) and seven neurologically intact controls (NC). A summarization of the demographics by group is presented in Table 1.

The age for PD Off patients ranged from 59 to 79 years (mean = 68.1, sd = 7.8). Patients were predominantly white (86%) and consisted of 71.5% males and 28.5% females. Most subjects had post-college education, (mean = 17.4 years, sd = 4.4). PD Off patients were in Hoehn and Yahr stages 2 or 3 with bilateral involvement and postural stability. Several patients had resting tremor
in the right hand. Despite resting tremor, patients were able to steady the stylus on homebase as indicated by accurate starts at the sound of the go signal. All patients were tested following an overnight fast of at least 8 hours off anti-Parkinson's medications. Medications consisted of control released sinemet, regular sinemet, and amantidine. None of the patients developed pronounced Parkinsonism (worsened symptoms) in the drug minimum state that would have prevented continued participation in the study.

The age for NC subjects ranged from 61 to 78 years (mean = 67.3, sd = 6.3). Females comprised 57% of the sample and males comprised 43%. The NC group consisted of four whites, two hispanics and one American Indian. Most participants had post-college education, (mean = 18.3 years, sd = 3.4).

The groups did not differ with respect to age, t (12) = 0.23, p = 0.8 or educational level, t (12) = -0.41, p = 0.7. However, differences occurred with respect to gender. The NC group was primarily female whereas the PD Off group was predominantly male. Logistic regression was used to predict gender from reaction time (RT), premotor RT, movement time (MT), and second premotor RT. Reaction time, premotor RT, MT, and premotor RT_{second} were not predictive for gender on any task conditions (p>0.05).
Table 1. Summary of Demographics for Patients and Subjects by Group

<table>
<thead>
<tr>
<th>CHARACTERISTIC</th>
<th>PD OFF GROUP</th>
<th>NC GROUP</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N</td>
<td>%</td>
</tr>
<tr>
<td>Age</td>
<td>Mean: 68.1</td>
<td>SD: 7.8</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>2</td>
</tr>
<tr>
<td>Race</td>
<td>White</td>
<td>6</td>
</tr>
<tr>
<td></td>
<td>Hispanic</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Indian</td>
<td>1</td>
</tr>
<tr>
<td>Education</td>
<td>Mean: 17.4</td>
<td>SD: 4.4</td>
</tr>
<tr>
<td></td>
<td>High School</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>College</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Post College</td>
<td>4</td>
</tr>
</tbody>
</table>

Findings Related to Research Hypotheses

Hypothesis 1

Patients with Parkinson's disease off medication (PD Off) compared to neurologically intact controls (NC) will have prolonged premotor reaction time \( (RT)_{\text{single}} \) and premotor \( RT_{\text{initial}} \) to the inferred target (Group-target interaction).
Hypothesis 1 was analyzed in the No Target Change task (NTC task) at Go time 0 and Go time 1000 and in the Target Change task involving a double movement (Target Change task e.g., Go time 0 coupled with Time of Target Change at 500 ms).

NTC Task at Go Time 0 (target presents simultaneously with Go signal)

Hypothesis 1 was analyzed using repeated measures analysis of variance (ANOVA) with two levels of group (PD Off and NC) and two levels of the within subjects variable, target type, (explicit and inferred).

Assumptions. Premotor RTsingle was positively skewed. Therefore, median premotor RTsingle scores were used. The median is the best measure of central tendency in a skewed distribution and is not affected by outliers related to errors of measurement. Nine data points per participant (raw scores) were aggregated into one median score.

In addition, intraclass correlations (ICC) were performed. Although ICCs are generally used to examine the mean (Verran et al., 1992; Verran et al., 1995), ICCs were performed to inspect intrasubject variability on the dependent measure. ICC involved conducting a one-way anova with premotor RTsingle as the dependent variable and subject number as the grouping variable. (ICC= (between group (BG) mean squares – within group (WG) means squares) / BG means squares). Intraclass correlations ranged from 0.54 to 0.9 indicating that
BG means squares were significantly larger than WG mean squares. PD Off patients had an ICC of 0.54 to the explicit target indicating greater intrasubject variability to the explicit target.

The homogeneity of variance assumption was met (Bartlett-Box test). PD Off and NC groups had equivalent variances on each repeated measure. More specifically, the standard deviation of PD Off (96.5) was not significantly different from the standard deviation of NC (42.0) on premotor $RT_{\text{single}}$ to the inferred target ($p = .063$); nor was the standard deviation of PD Off (55.3) significantly different from the standard deviation of NC (115.6) on premotor $RT_{\text{single}}$ to the explicit target ($p = .096$).

**Results.** The hypothesized interaction between group (PD Off) and target type (inferred vs explicit) was not statistically significant, $F (1, 12) = 1.44, p = 0.253$; a small effect size ($\eta^2 = .107$) and subsequent low power (0.196) most likely accounted for the nonsignificant finding. A sample size of 400 participants might have shown a statistically significant interaction (power level of 0.56) with the effect size of 0.107 (NCSS PASS, 1992).

A main effect for Group occurred. PD Off patients had longer premotor $RT_{\text{single}}$ across target types, $F (1, 12) = 5.89, p = 0.016$, (PD Off $M = 386$ ms; NC $M = 299$ ms). Figure 7 plots median premotor $RT_{\text{single}}$ scores for the explicit and
inferred targets by group for the NTC-GO-task. Note that premotor RT_{single} are prolonged in PD Off patients compared to controls.

There were no significant main or interaction effects involving RT_{single} and motor RT_{single}. A target main effect on motor RT_{single} was not significant, F (1, 12) = 3.32, p = 0.093, (Inferred target M = 167 ms; Explicit target M = 139 ms), (eta^2 = 0.2, power = 0.389). Otherwise, low effect sizes (0.025 to 0.125) and power levels ranging from .07 to .22 may have accounted for nonsignificant findings.

In summary, findings indicate premotor RT is lengthened in Parkinsonian patients off medication in a choice RT paradigm. Findings suggest that PD Off patients are not impaired in inferring target destination to the inferred target; however, the low power level may have accounted for the nonsignificant finding.

Comparing and Go time 0 (NTC-GO-0 task) and Go time 1000 (NTC-Go-1000 task i.e. target is presented 1000 ms before go signal sounds)

Premotor RT_{single} was compared in the NTC-GO-0 task and NTC-Go-1000 task to explore whether PD Off patients benefited from the 1000 ms interval in order to program movement to the inferred target. In the NTC-Go-1000 task, the target is presented early relative to the go signal (1000 ms before the go signal).
Figure 7. No Target Change Task Go 0: Premotor Reaction Time (ms)

Explicit Target

Inferred Target

<table>
<thead>
<tr>
<th></th>
<th>PD</th>
<th>NC</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>414.97</td>
<td>296.42</td>
</tr>
<tr>
<td>sd</td>
<td>47.30</td>
<td>42.50</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>PD</th>
<th>NC</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>357.55</td>
<td>302.116</td>
</tr>
<tr>
<td>sd</td>
<td>55.00</td>
<td>116.00</td>
</tr>
</tbody>
</table>
Thus, the participant's response may be preprogrammed with this advanced information, and reaction times may consequently be shortened.

A repeated measures ANOVA with two levels of group and two levels of the within subjects variable, Go Time (Go time 0 and 1000), was performed for each target type, explicit and inferred. A Go time main effect was expected, that is, shorter premotor RT_{single} and RT_{single} in the NTC-Go-1000 task. It was unclear if the 1000 ms time interval between presentation of the target and go signal would cancel the difference in processing time between groups to the inferred target. Therefore, a repeated measures ANOVA with two levels of group (PD Off and NC) and two levels of target type, (explicit and inferred) was also performed at Go time 1000.

Assumptions in NTC-Go-1000 Task. Each participant's raw scores were aggregated into a median premotor RT_{single} score due to a skewed distribution of premotor RT_{single} scores and the large within subject variability on premotor RT_{single} scores. The homogeneity of variance assumption was met for median premotor RT_{single} to the inferred target (Bartlett-Box test). The standard deviation of PD Off (58.2) was not significantly different from the standard deviation of NC (37.6) on median premotor RT_{single} to the inferred target (p = 0.31). PD Off and NC groups had statistically different variances on median premotor RT_{single} to the explicit target (PD Off: 24.2, NC: 65.3, p = 0.029). However, with equal sample
sizes, as is the case in this study, ANOVA is robust with regard to violations of homogeneity of variance (Shavelson, 1996).

Low intraclass correlations (ICC) occurred in the NC group to the inferred target (0.34) and in the PD Off group to the explicit target (-0.22). (see table 2).

Table 2. Intraclass Correlations on No Target Change Tasks for premotor RT

<table>
<thead>
<tr>
<th></th>
<th>Go-0 Task</th>
<th>Go-1000 Task</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Func</td>
<td>Inf</td>
</tr>
<tr>
<td>NC</td>
<td>0.82</td>
<td>0.74</td>
</tr>
<tr>
<td>PD</td>
<td>0.54</td>
<td>0.80</td>
</tr>
</tbody>
</table>

Results. Intraclass correlations (ICC). Low ICCs in NTC-Go-1000 may reflect the task condition. In NTC-Go-1000, the 1000 ms time interval between target presentation and go signal may have been long enough to cancel differences in processing time between subjects. Between subject variability decreased in the NTC-Go-1000 task compared to NTC-Go-0, although within subject variability remained comparable or slightly decreased. For example, the ICC of -0.22 in PD Off patients indicated that within subject variability on premotor RT<sub>single</sub> scores was greater than between subject variability; in fact, PD Off patients were more different from themselves than other members of their
group (see Figure 8). In controls, an ICC of 0.34 indicated that between
subject variability was only slightly larger than within subject variability (see
Figure 9).

Low ICCs may also reflect characteristics of controls versus Parkinsonian
patients interacting with target type. Low ICCs at Go time 1000 occurred in the
PD subjects only to the explicit target and in controls only to the inferred target.
At Go time 0, PD Off patients also had a relatively low ICC (0.54) to the explicit
target (see Figure 10). Thus, PD Off patients exhibited a similar pattern of
variability in the NTC Go 0 and NTC Go 1000 tasks. In both tasks, Parkinsonian
patients had less between subject variability to the explicit target and greater
between subject variability to the inferred target (see figures 11 and 9).

Go Time Main Effects

Significant Go time main effects occurred regardless of group. Premotor
RT\text{single} and RT\text{single} were significantly shorter in the NTC-Go-1000 task to the
explicit and inferred targets.

\textit{Inferred target:} Premotor RT\text{single} was shorter at Go time 1000 (M = 187
ms) compared to Go time 0 (M = 355 ms), F (1, 12) = 39.95, p = 0.000. RT\text{single}
was also shorter at Go time 1000 (M = 318 ms) compared to Go time 0 (M = 531
ms), F (1, 12) = 48.62, p = 0.000. Although unexpected, motor RT\text{single} was
Figure 8. Explicit Target No Target Change Task Go1000 by subject
Figure 9. Inferred Target No Target Change Task Go1000 by subject
Figure 10. Explicit Target No Target Change Task Go 0 by subject
Figure 11. Inferred Target No Target Change Task Go 0 by subject
significantly shorter at Go time 1000 (M = 120 ms) compared to Go time 0 (M = 167 ms), F (1, 12) = 9.15, p = 0.005.

**Explicit target:** Premotor RT\textsubscript{single} was shorter at Go time 1000 (M = 217 ms) compared to Go time 0 (M = 330 ms), F (1, 12) = 18.15, p = 0.0005. RT\textsubscript{single} was also significantly shorter at Go time 1000 (M = 350 ms) compared to Go time 0 (M = 488 ms), F (1, 12) = 22.04, p = 0.0005. Motor RT\textsubscript{single} was equivalent at Go time 1000 (M = 126 ms) compared to Go time 0 (M = 139 ms), F (1, 12) = 2.31, p = 0.154, (power = 0.29).

**Group Main effect at Go time 1000.** No Group effect occurred. The PD Off and control groups had similar premotor RT\textsubscript{single} across target types, F (1, 12) = 2.42, p = 0.146, (PD Off M = 220 ms; NC M = 184 ms), power = 0.3. In addition, PD Off and control groups had similar RT\textsubscript{single} across target types, F (1, 12) = 0.22, p = 0.65, (PD Off M = 342 ms; NC M = 327 ms), although power was inadequate (0.066).

In summary, in the NTC-GO-0 task, a PD effect occurred. PD Off patients had longer premotor RT\textsubscript{single} across target types, F (1, 12) = 5.89, p = 0.016, (PD Off M = 386 ms; NC M = 299 ms). In contrast, a PD group effect was not present in the NTC-GO-1000 task. The PD and control groups had equivalent premotor RT\textsubscript{single} across target types, F (1, 12) = 2.42, p = 0.146, (PD Off M = 220 ms; NC M = 184 ms). Figure 12 plots premotor RT\textsubscript{single} for the explicit and
inferred targets by group for the NTC-GO-0 and NTC-Go-1000 tasks. Note that premotor RTs are shorter at Go time 1000 compared to Go time 0 and that the PD Off and NC groups have similar premotor RTsingle at Go time 1000. Findings indicate that the PD Off and NC groups benefited from advanced information to preprogram movements. In addition, findings suggest that the 1000 ms time interval between target presentation and go signal cancelled the difference in processing time between the PD and control groups. Table 3 summarizes the results of testing hypothesis 1.

Hypothesis 2

PD Off patients will have prolonged movement time (MT)single and MTinitial to the explicit and inferred targets compared with NC subjects (Group main effect). However, PD Off patients will have equivalent MTsingle and MTinitial to the inferred and explicit targets whereas NC subjects will have prolonged MTsingle and MTinitial to the explicit compared to the inferred target (Group-target interaction).

This was analyzed in the No Target Change task (NTC task) at Go time 0 and Go time 1000 and in the Target Change task involving a double movement (e.g., Go time 0 coupled with Time of Target Change at 500 ms).
Figure 12. No Target Change GO 0 and GO 1000 Task: Premotor Reaction Time (ms)
Table 3
Findings per Task and Condition for Hypothesis 1
INF: Inferred Target, EXP: Explicit Target, PD Off: Parkinson’s disease patients off medication, NC: Control

<table>
<thead>
<tr>
<th>Task</th>
<th>Condition</th>
<th>Analysis</th>
<th>Dependent Variable</th>
<th>Relationship To Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>No Target Change</td>
<td>Go Time 0</td>
<td>Repeated Measures Anova</td>
<td>Premotor RT&lt;sub&gt;single&lt;/sub&gt;</td>
<td>No Interaction effect: tended to be prolonged to INF target in PD Off Group Main effect: prolonged in PD Off across targets</td>
</tr>
<tr>
<td></td>
<td>Go Time 1000</td>
<td>Repeated Measures Anova</td>
<td>Premotor RT&lt;sub&gt;single&lt;/sub&gt;</td>
<td>No Group Main effect: PD Off and NC groups had equivalent premotor RT&lt;sub&gt;single&lt;/sub&gt; across target types</td>
</tr>
<tr>
<td>Target Change</td>
<td>Go Time 0 Target Change 300</td>
<td>Repeated Measures Anova</td>
<td>Premotor RT&lt;sub&gt;initial&lt;/sub&gt;</td>
<td>Few double trajectories available in PD Off. Premotor RT&lt;sub&gt;initial&lt;/sub&gt; not obtainable.</td>
</tr>
<tr>
<td>Target Change</td>
<td>Go Time 0 Target Change 500</td>
<td>Repeated Measures Anova</td>
<td>Premotor RT&lt;sub&gt;initial&lt;/sub&gt;</td>
<td>No Group Main effect: PD Off and NC groups had equivalent premotor RT&lt;sub&gt;initial&lt;/sub&gt; across target types No interaction effect</td>
</tr>
<tr>
<td>Target Change</td>
<td>Go Time 0 Target Change 700</td>
<td>Repeated Measures Anova</td>
<td>Premotor RT&lt;sub&gt;initial&lt;/sub&gt;</td>
<td>Premotor RT&lt;sub&gt;initial&lt;/sub&gt; not obtainable.</td>
</tr>
</tbody>
</table>
Hypothesis 2 was analyzed with repeated measures ANOVA with two levels of group (PD Off and NC) and two levels of Target Type. The homogeneity of variance assumption was met (Bartlett-Box test). PD Off and NC groups had equivalent variances on MT\textsubscript{single} to the inferred target, (sd: PD Off = 115, NC = 99, p = 0.73) and MT\textsubscript{single} to the explicit target (sd: PD Off = 123, NC = 123, p = 0.38). Intraclass correlations ranged from 0.85 to 0.95 in the PD Off and NC groups.

Hypothesis 2 was analyzed with repeated measures ANOVA with two levels of group (PD Off and NC) and two levels of Target Type. The homogeneity of variance assumption was met (Bartlett-Box test). PD Off and NC groups had similar variances on median MT\textsubscript{single} to the inferred target, (sd: PD Off = 155, NC = 86, p = 0.17) and median MT\textsubscript{single} to the explicit target (sd: PD Off = 112, NC = 111, p = 0.97). Intraclass correlations ranged from 0.92 to 0.95 in the PD Off and NC groups.

**Results.** The hypothesized group main effect occurred. Specifically, the PD Off group had significantly longer MT\textsubscript{single} across target types at Go time 0, (PD Off M = 645 ms; NC M = 431 ms), F (1, 12) = 17.8, p = .001, and at Go time 1000, (PD Off M = 638 ms; NC M = 395 ms), F (1, 12) = 16.9, p = .001. The
group main effect is clearly seen in figures 13, 15, and 17. Figure 18 plots $MT_{single}$ for the explicit and inferred targets by group for the NTC-GO-0 and NTC-Go-1000 tasks. Note that median scores are distributed toward longer $MT_{single}$ in the PD Off group.

There was no significant interaction effect involving $MT_{single}$. However, PD Off patients tended to have longer $MT_{single}$ to the inferred target at Go time 0 (PD Off $M = 697$ ms, NC $M = 432$ ms), $F (1, 12) = 3.75$, $p = .077$, power = 0.429, and Go time 1000 (PD Off $M = 673$ ms, NC $M = 393$ ms), $F (1, 12) = 2.63$, $p = .131$, power = 0.32.

In summary, the findings indicate that Parkinsonian patients off medication are impaired in executing movement to the explicit and inferred targets. In addition, findings suggest that Parkinsonian patients off medication may use simplified movement strategies to the inferred and explicit targets. Contrary to hypothesis 2, controls may also use similar movement strategies to the explicit and inferred targets. Table 4 summarizes the results of testing hypothesis 2.

**Hypothesis 3**

PD Off compared to NC subjects will have prolonged second premotor reaction time ($RT_{second}$) when shifting from the prior target to an unexpected change in target type (e.g., explicit target to inferred...
Figure 13. Inferred Target: No Target Change Task Go 0
Figure 14. Inferred Target: No Target Change Task Go 0 Raw Data
Figure 15. Explicit Target: No Target Change Task Go 0
Figure 16. Explicit Target: No Target Change Task Go 0 Raw Data
Figure 17. No Target Change GO 0: Movement Time (ms)
target) as compared to shifting from a prior target to another like target (e.g., explicit target to explicit target).

Hypothesis 3 was analyzed in the Target Change task involving a double movement (e.g., Go time 0 & Time of Target Change at 300 ms, Go time 0 & Time of Target Change at 500 ms, Go time 0 & Time of Target Change at 700 ms).

**Target Change Task: Go Time 0-Target Change 300** (Initial target presents simultaneously with go signal; 300 ms later the initial target is extinguished and a second target appears)

The PD Off group produced few double trajectories in this condition; therefore, second premotor reaction time (premotor RT\textsubscript{second}) were not available for statistical analysis. However, nominal level data on group and movement type were analyzed by chi-square (2 x 2) with two levels of group (PD Off and NC) and two levels of movement (single and double).

First, nominal level data were analyzed across target change conditions (like to like and like to unlike target changes) and across target types (explicit and inferred). Secondly, nominal level data were analyzed across target types separated by like to like and like to unlike target change conditions. The like to unlike target change condition included trials that represented an initial explicit target and final inferred target and an initial inferred target and final explicit
Figure 18. No Target Change GO 0 and GO 1000 Task: Movement Time (ms)
Table 4
Findings per Task and Condition for Hypothesis 2
INF: Inferred Target, EXP: Explicit Target, PD Off: Parkinson's disease patients off medication, NC: Control

**HYPOTHESIS 2**
PD Off patients will have prolonged movement time (MT) across target types. However, PD Off patients will have equivalent MT to the two target types whereas NC subjects will have prolonged MT to the explicit target.

<table>
<thead>
<tr>
<th>Task</th>
<th>Condition</th>
<th>Analysis</th>
<th>Dependent Variable</th>
<th>Relationship To Hypothesis</th>
</tr>
</thead>
</table>
| No Target Change          | Go Time 0 | Repeated Measures Anova | Movement $T_{single}$ | Group Main effect: prolonged in PD Off across target types  
No Interaction effect: tended to be prolonged in PD Off to INF target                                           |
|                           | Go Time 1000 | Repeated Measures Anova | Movement $T_{single}$ | Group Main effect: prolonged in PD Off across target types  
No Interaction effect                                                                                          |
| Target Change             | Go Time 0 Target Change 300 | Repeated Measures Anova | Movement $T_{initial}$ | Few double trajectories available in PD Off. Could not obtain $T_{initial}$                                  |
| Target Change             | Go Time 0 Target Change 500 | Repeated Measures Anova | Movement $T_{initial}$ | Group Main effect: prolonged in PD Off across target types, PD Off $M = 530$.ms, NC $M = 356$ ms, $F (1, 12) = 17.8$, $p = 0.001$ |
| Target Change             | Go Time 0 Target Change 700 | Repeated Measures Anova | Movement $T_{initial}$ | Could not obtain $T_{initial}$                                                                                  |
target. The *like to like* target change condition included trials that represented an initial explicit target and final explicit target *and* an initial inferred target and final inferred target. Finally, nominal level data were analyzed by target type and separated by *like to like* and *like to unlike* target change conditions. For example, in the inferred loop, the *like to unlike* target change condition included trials representing an initial inferred target and final explicit target. The *like to like* target change condition included trials representing an initial inferred target and final inferred target.

Chi-square assumptions were met. Observations were measured as frequencies. Each observation fell in only one cell of the design and each observation was independent of every other observation. In addition, the observed values of $\chi^2$ with one degree of freedom were corrected for continuity via the Yates correction (Shavelson, 1996).

**Results.** There were significant differences between groups in type of movement produced ($\chi^2 = 37.07$, df = 1, $p = 0.000$). Specifically, the PD Off group produced a higher rate of single movements (observed = 135, expected = 111) and the NC group produced a higher rate of double movements (observed = 67, expected = 43), (see tables 5 and 7). There were also significant differences between groups in shifts from 1) *like to like* ($\chi^2 = 17.79$, df = 1, $p = 0.00006$), and 2) *like to unlike* targets ($\chi^2 = 20.9$, df = 1, $p = 0.00001$). More
specifically, the PD Off group produced a higher rate of single movements and the NC group produced a higher rate of double movements. This pattern occurred in shifts from the inferred to inferred target ($\chi^2 = 19.64$, df = 1, $p = 0.00003$), the explicit to inferred target ($\chi^2 = 14.9$, df = 1, $p = 0.00011$), and the inferred to explicit target ($\chi^2 = 4.94$, df = 1, $p = 0.026$). The same pattern of movements occurred in shifts from the explicit to explicit target although no significant between group differences occurred ($\chi^2 = 0.504$, df = 1, $p = 0.477$). These results suggest that the critical time period involved in specifying trajectory (CTP$^{*\alpha}$) occurred within 300 ms of target presentation in the NC group whereas in PD Off patients, the CTP$^{*\alpha}$ usually did not occur within the 300 ms time window (see research question 1).

**Target Change Task: Go Time 0-Target Change 500** (Initial target presents simultaneously with go signal; 500 ms later the initial target is extinguished and a second target appears).

Nominal level data and double trajectory interval level data were available in this condition. Nominal level data were analyzed by chi-square (2 x 2) with two levels of group (PD Off and NC) and two levels of movement (single and double). Data were analyzed 1) across target types (explicit and inferred) and target change conditions (like to like and like to unlike target change conditions), 2) across target types broken down by like to like and like to unlike target change
conditions, and 3) by target type broken down by *like to like* and *like to unlike* target change conditions.

Chi-square assumptions were met. Observations were measured as frequencies. Each observation fell in only one cell of the design and each observation was independent of every other observation. In addition, the observed values of \( x^2 \) with one degree of freedom were corrected for continuity via the Yates correction (Shavelson, 1996).

**Results.** There were significant differences between groups in rates of single versus double movements across target change conditions and target types (\( x^2 = 37.52, \text{df} = 1, \ p = 0.000 \)). Specifically, the PD Off group produced a higher rate of single movements (observed count = 92, expected count = 66) and the NC group produced a higher rate of double movements (observed count = 99, expected count = 73).

There were also significant differences between groups in shifts from 1) *like to like* \( (x^2 = 25.06, \text{df} = 1, \ p = 0.000) \), and 2) *like to unlike* targets \( (x^2 = 12.28, \text{df} = 1, \ p = 0.000) \). More specifically, the PD Off group produced a higher rate of single movements and the NC group produced a higher rate of double movements. This pattern occurred in shifts from the *inferred to inferred* target \( (x^2 = 14.26, \text{df} = 1, \ p = 0.000) \), the *explicit to explicit* target \( (x^2 = 10.06, \text{df} = 1, \ p = 0.002) \), the *inferred to explicit* target \( (x^2 = 13.66, \text{df} = 1, \ p = 0.000) \), and the
explicit to inferred target ($\chi^2 = 0.88$, df = 1, p = 0.34), although statistical significance was not reached in the latter. These results suggest that, in PD Off patients, the critical time period involved in specifying trajectory (CTP$_{\text{final}}$) generally did not occur within the 500 ms time window.

Double trajectory interval level data were analyzed with repeated measures ANOVA with two levels of group (PD Off and NC) and two levels of shifting condition e.g., like to like and like to unlike. The homogeneity of variance assumption was met (Bartlett-Box test). PD Off and NC groups had equivalent variances on premotor RT$_{\text{second}}$ in the like to like shifting condition (sd: PD Off = 129, NC = 85, p = 0.32) and on premotor RT$_{\text{second}}$ in the like to unlike shifting condition (sd: PD Off = 119, NC = 77, p = 0.31). Intraclass correlations were 0.76 in the PD Off group and 0.79 in controls.

First, data were analyzed across target types broken down by shifting condition. In the like to like shifting condition, data points for the explicit to explicit and inferred to inferred target changes were combined into median premotor RT$_{\text{second}}$ scores whereas in the like to unlike shifting condition, data points for the explicit to inferred and inferred to explicit target changes were combined into median premotor RT$_{\text{second}}$ scores. Next, data were analyzed by target types separated by like to like and like to unlike shifting conditions. For instance, in the inferred loop, median premotor RT$_{\text{second}}$ in the like final target
(inferred) and unlike final target (explicit) were compared. In the explicit loop, median premotor RT_{second} in the like final target (explicit) and unlike final target (inferred) were compared. Lastly, data were analyzed by final target type broken down by initial target type. For example, median premotor RT_{second} in a final inferred target were compared when the prior target was inferred and when the prior target was explicit. Also, median premotor RT_{second} in a final explicit target were compared when the initial target was inferred and when the initial target was explicit.

Findings Across Target Types Broken Down by Shifting Condition

The hypothesized interaction between the PD Off group and the like to unlike shifting condition was not statistically significant, F (1, 12) = 0.47, p = 0.5; Eta^2 = .03; power = 0.09. A statistically significant interaction may have occurred with an effect size of 0.5 and sample size of 20 (power level = 0.56) (NCSS PASS, 1992). A main effect for Group occurred. PD Off patients had longer premotor RT_{second} regardless of shifting condition, F (1, 12) = 9.9, p = 0.008, (PD Off M = 458 ms; NC M = 307 ms). A main effect for Shifting Condition was not significant. Premotor RT_{second} were similar in the like to like (M = 362 ms) and like to unlike (M = 403 ms) shifting conditions, F (1, 12) = 1.8, p = 0.19, power = 0.23.
Findings by Target Type Broken Down by *Like to Like* and *Like to Unlike* Shifting Conditions

**Inferred Loop.** The hypothesized interaction between the PD Off group and the *like to unlike* shifting condition (i.e. prior *inferred* target and final *explicit* target) was not statistically significant, $F(1, 12) = 2.2, p = 0.16; \eta^2 = .15; \text{power} = 0.278$. However, a main effect for *Group* occurred. PD Off patients had longer premotor RT$_{\text{second}}$ regardless of shifting condition, $F(1, 12) = 8.6, p = 0.01$, (PD Off M = 515 ms; NC M = 327 ms). In addition, a main effect for *Shifting condition* occurred. Premotor RT$_{\text{second}}$ were longer in the *like to like* (inferred to inferred) shifting condition, $F(1, 12) = 6.0, p = 0.03$, (*Like to like* M = 468 ms; *like to unlike* M = 374 ms).

**Explicit Loop.** The hypothesized interaction between the PD Off group and the *like to unlike* shifting condition (i.e. prior *explicit* target and final *inferred* target) was not statistically significant, $F(1, 12) = 0.36, p = 0.56; \eta^2 = .03; \text{power} = 0.085$. A main effect for *Group* occurred. PD Off patients had longer premotor RT$_{\text{second}}$ across shifting conditions, $F(1, 12) = 6.3, p = 0.03$, (PD Off M = 436 ms; NC M = 312 ms). In addition, a main effect for *Shifting Condition* occurred. Premotor RT$_{\text{second}}$ were longer in the *like to unlike* (explicit to inferred) shifting condition, $F(1, 12) = 30.1, p = 0.00$, (*Like to unlike* M = 449 ms; *like to like* M = 278 ms) (see figure 19).
Findings by Final Target Type Separated by Initial Target Type

**Final Inferred Target.** Median premotor $RT_{second}$ to a final *inferred* target were compared when the prior target was *inferred* in contrast to when the prior target was *explicit*. An interaction between *group* and *shifting condition* was not significant, $F(1, 12) = 2.8, p = 0.11$; $\eta^2 = .19$; power = 0.34.

**Final Explicit Target.** Median premotor $RT_{second}$ to a final *explicit* target were compared when the prior target was *inferred* in contrast to when the prior target was *explicit*. Premotor $RT_{second}$ tended to be longer across groups to a final *explicit* target, when the prior target was *inferred* (Target effect), $F(1, 12) = 4.2, p = 0.068$, power = 0.457, (*explicit to explicit* $M = 278$ ms; *inferred to explicit* $M = 353$ ms) (see figure 20).

**Summary**

PD Off patients were hypothesized to have disproportionately prolonged premotor $RT_{second}$ in shifts involving the *like to unlike* shifting condition. This was not supported. However, PD Off patients had prolonged premotor $RT_{second}$ across target types and regardless of shifting condition (Main effects). In addition, premotor $RT_{second}$ were prolonged across groups to a final *inferred* target irrespective of the prior target type (Main effects). For example, premotor $RT_{second}$ were significantly longer in 1) the *like to unlike* shifting condition involving a prior *explicit* and final *inferred* target (explicit loop), and 2) in the *like*
Figure 19. Like to Unlike Shift Condition: Second Premotor Reaction Time (ms)
Figure 20. Different Initial Targets to Final Explicit Target: Second Premotor Reaction Time (ms)
to like shifting condition involving a prior inferred target and final inferred target (inferred loop). Yet, premotor RT\textsubscript{second} were not significantly prolonged in the like to unlike shifting condition involving a prior inferred target and final explicit target (inferred loop). This suggests that a set effect from a prior explicit target type in the like to unlike shifting condition (explicit loop) did not contribute to prolonged premotor RT\textsubscript{second} to the final inferred target.

Target Change Task: Go Time 0-Target Change 700 (Initial target presents simultaneously with go signal; 700 ms later the initial target is extinguished and a second target appears)

Nominal level data were analyzed in this condition. Second premotor reaction time (premotor RT\textsubscript{second}) could not be calculated for statistical analysis. The kinematic landmarks employed in previous task conditions could not be used to accurately demarcate the end of the first movement and the beginning of the second movement.

Nominal level data were analyzed by chi-square (2 x 2) with two levels of group (PD Off and NC) and two levels of movement (single and double). Data were analyzed 1) across target types (explicit and inferred) and target change conditions (like to like and like to unlike target change conditions), 2) across target types broken down by like to like and like to unlike target change
conditions, and 3) by target type broken down by *like to like* and *like to unlike* target change conditions.

Nominal level data were also analyzed by chi-square (2 x 2) with two levels of target change condition (*like to like* and *like to unlike*) and two levels of movement (single and double). This analysis was done by group and across groups.

Chi-square assumptions were met. Observations were measured as frequencies. Each observation fell in only one cell of the design and each observation was independent of every other observation. In addition, the observed values of $\chi^2$ with one degree of freedom were corrected for continuity via the Yates correction (Shavelson, 1996).

**Results**

There were significant differences between groups in rates of single versus double movements across target change conditions and target types ($\chi^2 = 3.98, \text{df} = 1, p = 0.046$). Specifically, the PD Off group produced a higher rate of single movements (observed count = 41, expected count = 33.4) and the NC group produced a higher rate of double movements (observed count = 114, expected count = 106.4). However, PD Off patients produced 70.5% double movements in this condition (98/139) compared to 81.4% in controls (114/140). In addition, PD Off patients produced only 29.5% single movements in this
condition (41/139) compared to 66.2 % in Target Change 500 (92/139) and 87.7 % in Target Change 300 (135/154). Furthermore, the PD Off and NC groups produced similar rates of single and double movements in shifts from 1) like to like ($\chi^2 = 1.9, df = 1, p = 0.168$), and 2) like to unlike targets ($\chi^2 = 1.54, df = 1, p = 0.214$). In specific, this pattern occurred in shifts from the inferred to inferred target ($\chi^2 = 2.0, df = 1, p = 0.153$), the explicit to explicit target ($\chi^2 = 0.249, df = 1, p = 0.618$), the inferred to explicit target ($\chi^2 = 3.665, df = 1, p = 0.056$), and the explicit to inferred target ($\chi^2 = 0.000, df = 1, p = 1.0$). These results suggest that, in PD Off patients, the critical time period involved in specifying trajectory (CTP$^{\text{tral}}$) occurred within the 700 ms time window. Table 5 summarizes the results of testing hypothesis 3.

**Research Question 1**

The critical time period involved in specifying trajectory (CTP$^{\text{tral}}$) to the inferred target location will significantly differ from the CTP$^{\text{tral}}$ to the explicit target location in PD Off patients compared to NC participants.
Table 5
Findings per Task and Condition for Hypothesis 3
INF: Inferred Target, EXP: Explicit Target, PD Off: Parkinson’s disease patients off medication, NC: Controls

<table>
<thead>
<tr>
<th>Task</th>
<th>Condition</th>
<th>Analysis</th>
<th>Dependent Variable</th>
<th>Relationship To Hypothesis</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target Change</td>
<td>Go Time</td>
<td>Repeated Measures</td>
<td>Premotor RT&lt;sub&gt;second&lt;/sub&gt;</td>
<td>Few double trajectories available in PD Off. Premotor RT&lt;sub&gt;second&lt;/sub&gt; not obtainable.</td>
</tr>
<tr>
<td></td>
<td>0</td>
<td>Anova</td>
<td>Movement Double or Single</td>
<td>A statistically significant difference occurred between groups (BG). PD Off produced a higher rate of single movements and NC produced a higher rate of double movements 1) across target type &amp; target change condition, and 2) in shifts from like to like &amp; like to unlike target types.</td>
</tr>
<tr>
<td></td>
<td>Target</td>
<td>Chi-square</td>
<td>Movement Double or Single</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Change 300</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| Target Change | Go Time   | Repeated Measures  | Premotor RT<sub>second</sub> | Group effect: prolonged in PD Off across shifts from like to unlike and like to like target types  
|               | 0         | Anova              | Movement Double or Single | No Interaction effect: tended to be prolonged in PD Off in target change involving a prior INF target & final INF target.  
|               | Target    | Chi-square         | Movement Double or Single | A statistically significant difference occurred between groups (BG). PD Off produced a higher rate of single movements and NC produced a higher rate of double movements 1) across target type & target change condition, and 2) in shifts from like to like & like to unlike target types. |
|               | Change 500|                    |                    |                                                                                           |
Table 5 - Continued
Findings per Task and Condition for Hypothesis 3
INF: Inferred Target, EXP: Explicit Target, PD Off: Parkinson’s disease patients off medication, NC: Controls

<table>
<thead>
<tr>
<th>Target Change</th>
<th>Go Time 700</th>
<th>Repeated Measures</th>
<th>Premotor RT&lt;sub&gt;second&lt;/sub&gt;</th>
<th>Premotor RT&lt;sub&gt;second&lt;/sub&gt; not obtainable.</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Anova Chi-square</td>
<td>Movement Double or Single</td>
<td>PD Off and NC groups produced a similar rate of single &amp; double movements in shifts from like to like &amp; like to unlike target types.</td>
</tr>
</tbody>
</table>


Research question 1 was analyzed in late target changes involving a double movement (Target Change task e.g., Go time 0 coupled with Time of Target Change at 300 ms, Go time 0 coupled with Time of Target Change at 500 ms, Go time 0 coupled with Time of Target Change at 700 ms).

Target Change Task: Go Time 0-Target Change 300

Data were analyzed by chi-square (2 x 2) with two levels of group (PD Off and NC) and two levels of movement (single and double). Data were also analyzed by group using chi-square (2 x 2) with two levels of initial target type (explicit and inferred) and two levels of movement (single and double). Each initial target type included like to like and like to unlike target conditions.

Chi-square assumptions were met. The observed values of $x^2$ with one degree of freedom were corrected for continuity via the Yates correction for continuity (Shavelson, 1996).

Results. There were significant differences between groups ($x^2 = 37.07$, df = 1, p = 0.000). Specifically, the PD Off group produced a higher rate of single movements (observed count = 135, expected count = 111) and the NC group produced a higher rate of double movements (observed count = 67, expected count = 43).

A single movement indicated that commitment to the initial target had not occurred and that trajectory to the initial target was not yet specified whereas a
double movement indicated that commitment to the initial target had already occurred and that the trajectory to the initial target had been specified. Thus, a higher rate of double movements in controls suggests the NC group had specified trajectory to the initial target. In contrast, in PD Off patients, commitment to the initial target did not occur in the majority of trials. These findings indicate that the CTP\textsuperscript{traj} in the NC group occurred within 300 ms of target presentation whereas in PD Off patients, the CTP\textsuperscript{traj} did not occur within the 300 ms time window.

Results also showed that the initial target type was not related to movement type (single vs double) in either the NC or PD Off groups (within groups). Specifically, there were no significant differences in rates of single versus double movements to the explicit versus inferred targets in the NC group (χ² = .01, df = 1, p = .91) or in the PD group (χ² = 1.2, df = 1, p = .27). This finding suggests that at Go Time 0-Target Change 300, CTP\textsuperscript{traj} to the inferred target does not differ from CTP\textsuperscript{traj} to the explicit target in the NC or PD Off groups.

Target Change Task: Go Time 0-Target Change 500

Data were analyzed by chi-square (2 x 2) with two levels of group (PD Off and NC) and two levels of movement (single and double). Data were also analyzed by group using chi-square (2 x 2) with two levels of initial target type.
(explicit and inferred) and two levels of movement (single and double). Initial target type included like to like and like to unlike target conditions. Chi-square assumptions were met.

Results. There were significant differences between groups in rates of single versus double movements ($\chi^2 = 37.52$, df = 1, $p = 0.000$). Specifically, the PD Off group produced a higher rate of single movements (observed count = 92, expected count = 66) and the NC group produced a higher rate of double movements (observed count = 99, expected count = 73). The findings suggest that in PD Off patients, the CTP$^{trial}$ did not occur within the 500 ms time window.

Results also showed that the initial target type was not related to movement type (single versus double) across groups ($\chi^2 = 1.4$, df = 1, $p = .23$) or in the PD Off group ($\chi^2 = 0.004$, df = 1, $p = .95$). However, in the NC group, initial target type was related to the type of movement produced ($\chi^2 = 4.5$, df = 1, $p = 0.03$). Controls produced a higher rate of double movements when the initial target was inferred (observed count = 56, expected count = 49.9) and produced a higher rate of single movements when the initial target was explicit (observed count = 26, expected count = 19.9). The findings suggest that at Go Time 0-Target Change 500, CTP$^{trial}$ to the inferred target differs from CTP$^{trial}$ to the explicit target in controls.
Data were analyzed by chi-square (2 x 2) with two levels of group (PD Off and NC) and two levels of movement (single and double). Data were also analyzed by group using chi-square (2 x 2) with two levels of initial target type (explicit and inferred) and two levels of movement (single and double). Initial target type included like to like and like to unlike target conditions. Chi-square assumptions were met.

**Results.** There were significant differences between groups in rates of single versus double movements across target change conditions and target types ($X^2 = 3.98, df = 1, p = 0.046$). Specifically, the PD Off group produced a higher rate of single movements (observed count = 41, expected count = 33.4) and the NC group produced a higher rate of double movements (observed count = 114, expected count = 106.4). However, PD Off patients produced 70.5% double movements in this condition (98/139) compared to 81.4 % in controls (114/140).

Results also showed that the initial target type was not related to movement type (single versus double) across groups ($X^2 = 2.94, df = 1, p = 0.086$) or in the PD Off group ($X^2 = 0.003 df = 1, p = .956$). However, in the NC group, initial target type was related to the type of movement produced ($X^2 = 5.715, df = 1, p = 0.017$). Controls produced a higher rate of double movements
when the initial target was inferred (observed count = 63, expected count = 57) and produced a higher rate of single movements when the initial target was explicit (observed count = 19, expected count = 13). The findings suggest that at Go Time 0-Target Change 700, CTP^\text{traj}_t to the \textit{inferred} target differs from CTP^\text{traj}_t to the \textit{explicit} target in controls. Table 6 summarizes the results of testing research question 1.

\textbf{Research Question 2}

Second premotor reaction time (premotor RT_{\text{second}}) will be positively related to perseverative errors on measures of cognitive shifting capacity (e.g., Wisconsin Card Sort Test (WCST), Trailmaking Test (TMT) Part-B) in PD Off as compared to NC participants.

This was analyzed with Kendall's Tau in the Target Change Task coupling go time 0 and target change 500. Premotor RT_{\text{second}} were calculated by target type in the \textit{like to unlike} shifting condition. For example, premotor RT_{\text{second}} were calculated in 1) the \textit{like to unlike} shifting condition involving a prior \textit{explicit} and final \textit{inferred} target, and in 2) the \textit{like to unlike} shifting condition involving a prior \textit{inferred} and final \textit{explicit} target.
Table 6
Findings per Task and Condition for Research Question 1
INF: Inferred Target, EXP: Explicit Target, PD Off: Parkinson’s disease patients off medication, NC: Control Group

The critical time period involved in specifying trajectory (CTP[Inf]) to the inferred target will significantly differ from the CTP[Exp] to the explicit target in PD Off compared to NC group.

<table>
<thead>
<tr>
<th>Task</th>
<th>Condition</th>
<th>Analysis</th>
<th>Dependent Variable</th>
<th>Relationship To Research Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>Target</td>
<td>Go Time 0</td>
<td>Chi-square</td>
<td>Movement type: Single vs Double</td>
<td>A statistically significant difference occurred between groups. PD Off produced higher rate of single movements and NC produced higher rate of double movements.</td>
</tr>
<tr>
<td>Change</td>
<td>Target Change</td>
<td>300</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>There was no relationship between initial target type and movement type by group. Therefore, CTP[Inf] to INF target did not differ from CTP[Exp] to EXP target in PD Off or NC groups.</td>
</tr>
<tr>
<td>Target</td>
<td>Go Time 0</td>
<td>Chi-square</td>
<td>Movement Single vs Double</td>
<td>A statistically significant difference occurred between groups. PD Off produced higher rate of single movements and NC produced higher rate of double movements.</td>
</tr>
<tr>
<td>Change</td>
<td>Target Change</td>
<td>500</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Initial target type was not related to movement type in PD Off. NC group produced a higher rate of double movements to INF target and higher rate of single movements to EXP target. Thus, CTP[Inf] to INF target may differ from CTP[Exp] to EXP target in NC group.</td>
</tr>
<tr>
<td>Target</td>
<td>Go Time 0</td>
<td>Chi-square</td>
<td>Movement Single vs Double</td>
<td>NC group produced higher rate of double movements to INF target and higher rate of single movements to EXP target. Thus, CTP[Inf] to INF target may differ from CTP[Exp] to EXP in NC group.</td>
</tr>
<tr>
<td>Change</td>
<td>Target Change</td>
<td>700</td>
<td></td>
<td>Initial target type was not related to movement type in PD Off.</td>
</tr>
</tbody>
</table>
Analysis was conducted by group because there was a difference in means between groups in perseverative errors (PD Off \( M = 19 \), NC \( M = 12 \); \( t(11) = 2.0, P = 0.03 \)) and in premotor RT_{second} (PD Off \( M = 468 \) ms, NC \( M = 337 \) ms).

A difference in means might produce a misleading correlation coefficient. In addition, if the relationship between variables was different in each group this might affect the correlation coefficient. Kendall’s Tau was used because the distributions of scores for premotor RT_{second} were skewed. Extreme scores may affect the correlation coefficient especially with the small sample size (\( n = 14 \)).

Results

**PD Off group.** Premotor RT_{second} were not related to perseverative errors on the WCST. Specifically, the observed correlation between premotor RT_{second} (in the like to unlike shifting condition, explicit to inferred target) and perseverative errors was not statistically significant, \( r = -0.46, p = 0.09 \). In addition, the observed correlation between premotor RT_{second} (in the like to unlike shifting condition, inferred to explicit target) and perseverative errors was not statistically significant, \( r = -0.20, p = 0.28 \). Furthermore, premotor RT_{second} were not related to performance (time in seconds) on the TMT Part-B (premotor RT_{second} in explicit to inferred shift, \( r = -0.33, p = 0.17 \); premotor RT_{second} target in inferred to explicit shift, \( r = -0.33, p = 0.17 \).
NC group. Premotor RT\textsubscript{second} in the *like to unlike* shifting condition from the *explicit to inferred* target were related to perseverative errors on the WCST (*r* = 0.52, *p* = 0.04). However, the observed correlation between premotor RT\textsubscript{second} (in the *like to unlike* shifting condition, *inferred to explicit* target) and perseverative errors was not statistically significant, *r* = 0.33, *p* = 0.15. Furthermore, premotor RT\textsubscript{second} were not related to performance on the TMT Part-B (premotor RT\textsubscript{second} in *explicit to inferred* shift, *r* = -0.43, *p* = 0.08; premotor RT\textsubscript{second} target in *inferred to explicit* shift, *r* = 0.05, *p* = 0.44).

**Summary**

Fourteen persons, seven with idiopathic PD off medication and seven neurologically intact controls participated in this research. A reaction time paradigm was used to access the pattern of cognitive operations that underlies movements. Specifically, participants employed rapid arm extension movements to explicitly identified targets (explicit target) and targets inferred from indirect cues (inferred target). In addition, participants completed measures of cognitive shifting capacity such as the Wisconsin Card Sort Test (WCST) and Trailmaking Test Part-B (TMT Part-B).

This research investigated the effects of explicit and inferred targets on movement initiation and execution. The findings indicated that persons with PD off medication are impaired in initiating and executing movement to cognitively
derived targets as measured by prolonged premotor reaction times and movement times. The research also investigated the timing involved in the program that specifies trajectory to the explicit and inferred targets. The findings suggested that persons with PD off medication might have deficits in programming trajectory to the explicit and inferred targets.

Finally, the research tested the effect of expectancy from a prior target type on initiation to a subsequent target type. The findings showed that persons with PD off medication are impaired in initiating movement to a final target when shifting from a prior target. Set from a prior target type did not exclusively inhibit cognitive processing to an unlike final target type. Lastly, prolonged second reaction times to an unexpected final target type (e.g., explicit to inferred) were expected to correlate with higher scores in the WCST and the TMT Part-B, however, this was not supported. Table 7 summarizes the results of testing the hypotheses and research questions.
Table 7
Summary of Findings  PD Off: persons with idiopathic Parkinson's disease off medication, NC: Control group

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Summary</th>
<th>Conclusions</th>
</tr>
</thead>
<tbody>
<tr>
<td>One</td>
<td>Partially supported</td>
<td>PD off persons are impaired in initiating movement across targets containing different attributes as measured by prolonged premotor reaction times.</td>
</tr>
</tbody>
</table>
| Two         | Partially supported | PD off persons are impaired in executing movement to targets containing different attributes as measured by prolonged movement times.  
PD Off persons may use simplified movement strategies to cognitively derived targets as measured by equivalent movement times to explicit versus inferred targets. |
| Three       | Partially supported | PD off persons are impaired in initiating movement to a final target type when shifting from a prior target (as measured by prolonged second premotor reaction times across shifts from like to unlike and like to like target types). |
| Research Question 1 | Partially supported | The program involved in specifying trajectory may be impaired in PD Off persons. The critical time period involved in specifying trajectory (CTP^{traj}) differed in PD Off and NC groups. In controls, the CTP^{traj} occurred within 300 ms of target presentation. In PD Off, the CTP^{traj} occurred between 500 ms and 700 ms of target presentation.  
Initial target type was related to movement type in NC group suggesting the CTP^{traj} to inferred versus explicit targets differed in the NC group. The CTP^{traj} to inferred target did not differ from the CTP^{traj} to explicit target in the PD Off group. |
CHAPTER V
DISCUSSION OF FINDINGS

Introduction

The goal of this study was to investigate cognitive processes involved in the generation of movement. Persons with idiopathic Parkinson's disease (PD), a disorder of the basal ganglia, were the probe to understanding cognition in motor control. Cognitive changes in PD may be related to dysfunctional basal ganglia-thalamocortical circuits linking the basal ganglia (BG) to the frontal lobes (Alexander, Delong, & Strick, 1986; Middleton & Strick, 1994). The BG thalamocortical circuits are involved in: planning, problem solving, flexibility, motivation, initiation of behavior, preparation to move and execution of movement. Lesions of the striatum may interfere with functioning of these circuits and with the cognitive functions they support (Dubois et al. 1995).

A reaction-time paradigm was used in this study. The approach was to design two tasks with kinematically similar motor requirements (i.e., the sequence and pattern of joint angle rotations to the desired target) but that differed in the level of cognitive processing required. In this study, movement kinematics were controlled, thus, removing kinematics as a confounding variable. Therefore, differences in performance, as measured by reaction times (RT) and movement times (MT), related to a difference in the cognitive operations involved
in generating movement to the target type rather than kinematic differences in the task.

In agreement with other studies (Evarts et al., 1981; Sheridan, Flowers, & Hurrel, 1987; Stelmach, Teadale, & Phillips, 1992; Waters & Strick, 1981; Weis, Stelmach, & Heffer, 1997) movements times were longer in the PD group. Reaction times, however, were not. Previous research has been inconclusive about differences between Parkinsonian patients and controls in RTs which may be related to methodological differences among studies. These include the control of medications that affect motor performance, the type of target used, the amount of time subjects are allowed to practice performance tasks, selection criteria, sample size, and the partitioning of RT into a premotor and motor component. In this study even though RTs were not prolonged in the PD group, premotor RTs were longer. Thus, RT needed to be partitioned into premotor and motor RT in order to detect differences between PD patients and controls. The PD effect on premotor RT may not have been detected had only RT been measured.

Movement Initiation

In this study, movement initiation was measured by premotor RT which reflects the time involved in cognitively inferring the target destination. Study findings showed that in the NTC-GO-0 task, PD Off patients had significantly
longer premotor RT\textsubscript{single} across target types. The two target types, the explicit and inferred targets, had differing levels of cognitive complexity. It was thought that the increased cognitive complexity associated with the inferred target might contribute to prolonged response time particularly in PD. Presumably, combining and relating the individual features of the inferred target would be more cognitively demanding compared with processing the explicit target.

Although the hypothesized interaction between group and target type (inferred vs explicit) was not statistically significant, PD Off patients tended to have longer premotor RT\textsubscript{single} to the inferred target. Figures 13 and 14 plot premotor RT\textsubscript{single} against movement time (MT)\textsubscript{single} at Go time 0 for the inferred target by group. Note that median scores in figure 13 and corresponding raw scores in figure 14 are distributed toward longer premotor RT\textsubscript{single} in the PD Off group. This differs from figures 15 and 16 that plot median and corresponding raw premotor RT\textsubscript{single} against MT\textsubscript{single} for the explicit target. Note that premotor RT\textsubscript{single} to the explicit target in PD Off and NC groups is similar in duration. In Figure 7, median premotor RT\textsubscript{single} is plotted for the inferred versus explicit targets by group. Notice that several PD Off patients have disproportionately longer premotor RT\textsubscript{single} to the inferred target whereas NC subjects show similar premotor RT\textsubscript{single} to the inferred and explicit targets. These results suggest that
persons with PD off medication may be more impaired in initiating movement to a cognitively complex target such as the inferred target.

When comparing performance at Go time 0 and Go time 1000, no PD group effect occurred at Go time 1000 and PD patients tended to benefit from the 1000 ms interval of time particularly to the inferred target. Figure 12 plots premotor RT single for the explicit and inferred targets by group for the NTC-GO-0 and NTC-Go-1000 tasks. Note that premotor RTs are shorter at Go time 1000 compared to Go time 0 and that the PD Off and NC groups have similar premotor RT single at Go time 1000. However, both groups also tend to have shorter premotor RT single to the inferred target at Go time 1000. This suggests that the 1000 ms time interval between target presentation and go signal may have particularly benefited initiation to the inferred target and that persons with PD can benefit from advanced information in preprogramming movements to cognitively complex targets. Thus, cognitively inferring the target destination (premotor RT), and mobilizing the musculature to lift the stylus (motor RT) may be completed in advance and it may only be necessary to detect the stimulus to trigger the response.

Set Shifting

Cognitive processes in movement also refers to a prior state affecting the processing of subsequent information in the notion of expectation and set. One
aspect of expectancy is manifested in the phenomena of set and shifting capacity. In this study, PD patients demonstrated diminished shifting capacity as seen in an increased number of perseverative errors on the Wisconsin Card Sorting test. In addition, diminished shifting capacity may have been manifested in prolonged second RTs to the final target in the target change task.

In this study, a weighting towards the "no target change " task was expected to produce a response bias. Presumably, a change in one's response bias was required when a shifting requirement occurred. In particular, shifting to an unexpected target type would raise task difficulty to a level at which performance became significantly impaired in patients with PD. Therefore, PD patients were expected to have disproportionately prolonged second RTs when shifting to an unexpected final target. This was not supported.

Persons with PD had deficits initiating movement (prolonged second premotor RTs) to both the unexpected and expected final target type. Across groups, second premotor RT were longer in the like to unlike shift condition involving a prior explicit and final inferred target compared to a shift from a prior inferred to a final explicit target (see figure 19). If set from a prior target type affected cognitive processing to an unexpected final target type, then it should not depend on the direction of change. For instance, the set effect of a like to unlike final target type should not occur only when the initial target is explicit and
final target is inferred. It's unlikely that an inhibitory effect of set from a prior explicit target accounted for the longer second premotor RTs to the final inferred target. More likely, the cognitive complexity associated with the final inferred target accounted for the longer second premotor RT to the inferred target.

Perhaps a prior state affected the processing of subsequent information in the notion of set. Analyses were conducted breaking the final target type by initial target type (i.e. prior explicit to final explicit target and prior inferred to final explicit target). The effect of the prior target type on premotor $RT_{second}$ to a final explicit target approached a target effect ($p = 0.068$). Across groups, premotor $RT_{second}$ tended to be longer in a final explicit target when the prior target was inferred (353 ms) as opposed to when the prior target was explicit (278 ms) (see figure 20). This suggests that a prior inferred target may have inhibited processing of a final explicit target thus contributing to prolonged second premotor RTs to the explicit target.

Diminished shifting capacity may not have contributed to lengthened second premotor RTs in the PD group. PD patients had significantly longer premotor RTs relative to controls in the Target Change task and in the No Target Change task which did not involve a shift. Thus, persons with PD showed deficits initiating movement to the final submovement in a two-movement sequence (TC task) and in a single movement task (NTC task). Additionally,
second premotor RTs to the unexpected target type did not significantly correlate with scores in measures of cognitive shifting suggesting that second premotor RTs were not related to decreased shifting capacity. However, the small sample size \((n = 7)\) might have accounted for the insignificant correlation.

In summary, persons with PD showed deficits in initiating movement to a final target when shifting from a prior target. Possibly, diminished shifting capacity prolonged initiation to the final submovement in the two-movement sequence.

**Movement Execution**

**Movement Strategy**

Cognitive abnormalities in generating movement may be more apparent when target demands limit the range of behaviors that are effective and require the use of an optimal strategy. It was hypothesized that cognitive abnormalities in persons with PD would manifest in the use of a simplified strategy “default” movement strategy to both target types. Based on the movement time data, this was supported. It was also hypothesized that neurologically intact controls would use an optimal movement strategy to the explicit target. Presumably, aiming the stylus at the center of the square containing the explicit target would require an optimal strategy involving accuracy, whereas, placing the stylus on
the square indicated by the inferred target would not. This was not supported. Controls moved similarly to both target types.

Controls. Based on this line of reasoning, controls failed to use an optimal movement strategy. However, movement times may not have been the best measure of movement strategy and this may account for why control participants seemingly employed a simplified strategy to the two target types. Another movement parameter such as velocity profile may have better indexed movement strategy. Deceleration or peak velocity may have shown differences in movement strategy to the two target types. For example, deceleration time may have been longer to the explicit target if participants carefully aimed and directed the stylus to the center of the explicit target. Time to peak velocity may have been longer to the inferred target if participants began executing movement to the inferred target (due to the orienting cues of the inferred target) before trajectory was fully specified. Prolonged deceleration to the explicit target and longer time to peak velocity to the inferred target would tend to equalize movement times to the two target types, suggesting that controls moved similarly to the explicit and inferred targets.

The effects of practice may also account for why control participants seemingly employed a simplified strategy. Moving similarly to both targets suggests that controls did not trade speed for accuracy when placing the stylus
on the explicit target and that controls benefited from the practice session. In practice sessions, participants were instructed to place the stylus anywhere on the square containing the explicit target rather than aiming for the center of the plus sign.

In order to determine the contribution to MT due to a speed-accuracy tradeoff, the study design should have included a control session where participants moved to a highlighted square on the 3x3 matrix that did not contain a cognitive target (control trials). That would enable comparison between MTs to the explicit target with MTs in control trials. Longer MTs to the explicit target compared to control trials implies that speed might have been traded for accuracy when moving to the explicit target.

**Parkinsonian patients.** Based on movement time data, patients with PD also moved similarly to the explicit and inferred targets. However, there is some suggestion that patients with PD may have pronounced deficits in programming movement to the inferred target. Although a significant group-target interaction was not present, PD Off patients tended to have longer $MT_{\text{single}}$ to the inferred target. Figure 18 plots $MT_{\text{single}}$ for the explicit and inferred targets by group for the NTC-GO-0 and NTC-Go-1000 tasks. Note that PD Off patients tend to have longer MTs to the inferred target whereas in the NC group, MTs to the explicit and inferred target are equivalent.
Prolonged MTs to the inferred target may indicate that, in PD, the underlying program for movement is defective. PD patients may have started executing movement to the inferred target before they had completely programmed the movement (e.g., trajectory, velocity) because the vertical and horizontal bands "oriented" the patient to the general target destination. Subsequent programming may have been completed as the movement was being executed thus prolonging movement times (Kaszniak, personal communication, March, 1998). In addition, relying on the visual cues to guide movement may have slowed movement times. In contrast, controls may have completed programming prior to executing movement to the inferred target thus resulting in shorter movement times.

PD patient's reliance on visual cues to guide movement may reflect underlying deficits in the movement program involved in specifying target acquisition. Defective motor planning may account for why PD involves a change from programmed to visually guided movements. Visual guidance enables movements to be controlled during execution (Flowers, 1976; Stelmach, 1989). Visual cues can potentially be used to improve gait in Parkinsonian patients. A pattern of visual cues placed on the floor (e.g., horizontal stripes, sheets of white writing paper, triangular rods) has beneficial effects by helping
PD patients initiate walking and increase stride length (Bagley et al., 1991; Dunne, Hankey, & Eddis, 1987; Purdon-Martin, 1967).

In summary, cognitive abnormalities in generating movement may be more apparent when target conditions require the use of an optimal strategy. Movement times may not be the best measure of movement strategy. Rather, velocity profile may better index movement strategy.

The PD patient's reliance on visual cues may reflect underlying impairment in the movement program to a desired target. In this study, PD patients tended to have longer MTs to the inferred target compared to explicit target in a kinematically equivalent task. The visual cues in the inferred target may have aided construction of the movement program during movement execution. This implies that motor programming is not limited to a RT period and might occur during movement execution in a ballistic task.

**Specifying Trajectory**

Based on the method used to determine when trajectory was specified, the critical time period involved in specifying trajectory differed between patients with PD and controls. Findings indicated that controls specified trajectory within 300 ms of target presentation whereas PD patients specified trajectory between 500 and 700 ms of target presentation. Furthermore, findings indicated that controls produced a higher rate of double movements when the initial target was
inferred suggesting that the trajectory to the inferred target may have been specified at a different time than the trajectory to the explicit target. Controls may have benefited from the "orienting" cues of the inferred target in specifying trajectory to the inferred target and quite possibly, the program involved in specifying trajectory to the inferred target occurred at an earlier point in time than the program for the explicit target. The implication is that the program involved in specifying trajectory is impaired in patients with PD.

A sequencing deficit in PD may have confounded the method used in this study to determine when trajectory was specified. The method required participants to produce two consecutive movements in a sequence. The ability to produce two consecutive movements might be confounded by a deficit in sequencing, which is reported to occur in PD patients in nonmotoric and motoric tasks. Whereas PD patients produced a preponderance of single movements in the TC task, controls produced predominately double movements, suggesting that a sequencing deficit may have affected movement execution during the two-movement task.

**Methodologic limitations**

The central limitation in this study was the small sample size. A larger sample size would have resulted in increased power. Post-hoc power analyses indicated that low power levels might have contributed to nonsignificant findings.
Therefore, the researcher could not conclude that the means of the PD Off and NC groups were equal (Type II error) when higher power might have shown a statistically significant difference.

Another major limitation in this study was the method used to determine scores for the RT data. Several factors affected reliability of RT scores that probably increased the variability of RT scores beyond their "true" variability. The source of unreliability in the RT data came primarily from estimating the onset of the go signal. The data analysis program did not display onset of the go signal; therefore, the researcher had to determine when the go signal began based on other landmarks displayed. Additionally, the researcher may have introduced error when determining the first burst of EMG activity. This would have affected the length of the premotor RT period.

If RT data were more reliably measured, then potentially larger power levels would have resulted, as occurred in the movement time data. Unreliability of RT scores might have been reflected in large variability of scores about the mean contributing to a larger standard deviation. Even with a large effect size, it would not be detected (Type II error) because of the large variability on the dependent measure. To combat the effect of large variability, a larger sample size was needed. Increasing the sample size would decrease the standard error of the mean thus allowing better estimation of population characteristics.
Methodological Changes Recommended

1) The inferred target may need to be modified in order to make it more
cognitively demanding. Effect sizes were small in this study. One possibility
is that the inferred target was not sufficiently demanding for the PD group.
The absence of a target effect at Go time 0 suggests the explicit and inferred
targets were not sufficiently different in the level of cognitive processing
required. Piloting in order to determine the effect size is recommended
before proceeding with a more extensive investigation.

2) Practical constraints should be considered in the data collection phase
including the total amount of data points acquired, the length of individual
sessions, and the total number of sessions. It is recommended that the
collection of data points be limited to those needed to answer the hypotheses
in the study. In the present study, redundant data points were collected.
Consequently, data collection involved four, three to five hour-long, sessions
per participant. Individual sessions were excessively long which may have
fatigued participants. In addition, the sample size was small (n = 14).
Potentially, twenty-eight subjects per group could have been sampled had
collection of data points been limited to that necessary to answer the
hypotheses.
3) Limit each data collection session to one hour or less. The task in this study required vigilance and attentiveness. Participants reported they were bored. The consequences are that participants could develop aversion to the task, which could impact a reaction time paradigm (G. Ahern, Personal communication, July, 1998). In addition, some of the controls engaged in conversation while performing the task. Engaging in a secondary activity such as conversation could potentially affect RTs.

Nursing Science

Findings in this study suggest that cognitive processes in movement may occur during movement initiation or movement execution. More specifically, the findings imply that movement programming may be a serial or parallel process, is modifiable and responsive to target conditions and demands. This is contrary to a basic assumption of the motor program concept that the program is set up prior to onset of movement. The reaction time to begin movement is thought to reflect the time to construct the appropriate motor program (Schmidt, 1988).

Movement programs are abstract central representations that are thought to regulate movement in space to reach the desired destination. This involves timing the execution of movement to the right place at the right moment and at the right pace (Marsden, 1982). If movement programs exist, they probably do
not develop in a vacuum but rather in an ecological context through experience acquired in person-environment interactions.

Viewing the development of motor programs from a contextual perspective expands a traditional view of motor plans and programs as fixed, unmodifiable structures that occur prior to onset of movement irrespective of target conditions. Contextualism acknowledges the person-environment interaction in producing movement pattern. Within contextualism, the individual's movement pattern reflects cognitive processes, motivational state, and the interaction of the individual with objects in the context. Although stanch ecological theorists may deny the existence of motor programs, a central representation such as a motor program is compatible within a contextual worldview given the assumption that central representations develop through person-environment interaction. A presumption is direct experience with objects result in object knowledge being acquired and, in turn, these central representations are used when the appropriate context is presented (Martenuik, MacKenzie & Leavitt, 1988). This notion of central representations reflecting person-object interactions is compatible with Klatzky et al., (1993), who suggests cognitive representations of interactions with objects, such as motor plans and motor programs, result in motor strategies specific to the object. For instance,
different motor strategies would be employed when grasping an apple as opposed to a ripe tomato.

**Nursing Implications**

Though this research did not test interventions, the research findings may be clinically relevant. Findings from this research suggest that an individual's movement patterns are tailored to target attributes and that the brain may incorporate these cognitive aspects into planning movements. Many disabling symptoms in PD related to gait disorders are not relieved by medication. This opens up possibilities for new therapies such as manipulating target attributes to help persons with PD initiate and execute movement.

The drawbacks to several previous studies are that the research did not systematically investigate aspects of target attributes that lead to improvement in movement. Future studies would need to systematically examine aspects of target attributes such as the optimal target size, contrast between target with background, optimal distance between targets placed along a walkway, strategic placement of targets in the patient's environment, and aesthetic properties. Targets should not be indiscriminately placed throughout the patient's environment but rather can be strategically placed at the end of a hallway, entrance to a closet, or other areas that are particularly problematic for the patient. In addition, the patient's determination of the target's efficacy needs to
be evaluated. Furthermore, the target's aesthetic qualities also need to be considered in terms of acceptability to the patient and family. For instance, a target might be more readily accepted if it fit within the decor of the patient's home and was not obtrusive in the home environment.

The cognitive aspects of movement generation can also be communicated through inservices for clinical nursing. This would sensitize nursing professionals to the "not so obvious" cognitive component in motor control. This might lead to some innovative ways to capitalize on cognitive aspects of movement in alleviating altered movement in afflicted patients.

**Summary**

The goal of this study was to investigate cognitive processes involved in the generation of movement. Chapter 4 addressed the results of the study related to the research hypotheses and research questions. This chapter addressed interpretation of findings, methodologically limitations, and nursing science. In addition, nursing implications and potential clinical relevance of the findings were addressed.
Idiopathic Parkinson's disease is characterized by three of the cardinal symptoms: tremor, bradykinesia, rigidity, or postural instability and a history of levodopa responsiveness (Calne et al., 1992). Pathologically, dopaminergic degeneration of cells of the substantia nigra pars compacta and dopaminergic cells of the ventral tegmental area occur.

Kinetics refers to the forces (muscles, gravity, external resistance) that produce motion, stop motion, or change motion of bodies. Kinetics involve the time course of joint angle rotations.

Kinematics refer to the sequence and pattern of joint angle rotations to a desired target.

Cognitive operations underlying motor function can be studied using mental chronometry, defined as "the time course of information processing in the human nervous system". Reaction time is used to infer the time course of mental processing. It is defined as the measured time between two events, the stimulus and the response (Posner, 1978). In this study reaction time represents the time involved in cognitively inferring target destination and initiating the movement.

Basal ganglia refers to the caudate nucleus, putamen, nucleus accumbens, globus pallidus, subthalamic nucleus, and substantia nigra.

Brown and Marsden's (1990) maintain a distinction between internal/active/effort-demanding tasks and external/passive/automatic tasks. In internal/active/effort-demanding tasks, the patient must generate a solution and develop his own response strategy whereas in external/passive/automatic tasks, the material is presented in an organized form or patient is given explicit guidelines against which to check progress. Automatic processes are thought to use little mental capacity whereas effortful processes consume more brain capacity. Automatic processes are considered easy; called on quickly and carried out concurrently. Attentive or effortful processes are considered difficult, time consuming and easily disrupted (interfered with). This is tested when doing two tasks at one time in a dual task paradigm (Haberlandt, 1994).

Brown and Marsden maintain that this distinction can be applied to any task where cognitive control comes primarily from the subject (e.g., recall memory) or where a cue or guidance is provided by the experimenter or stimulus configuration (e.g., recognition memory). Brown and Marsden (1990) extend
their internal-external distinction to the internal versus external control of attention. According to Sanes (1985), patients with PD may not process an equivalent amount of information per unit time as do controls, due to depleted processing resources. The assumption is the human information-processing system has a limited capacity to perform mental work. A theory based on depleted central processing resources may account for impaired performance of PD patients in a cognitively demanding task in which patients have to rely on internal control; if resource demands exceed those available, a performance deficit would be observed. For example, a shifting requirement might place more demands on central processing resources of the PD patient by introducing an effort demanding component that exceeds resources available (Richards, Cote, & Stern, 1993).

More specifically, the planning of movement involves assembling the instructions needed to put together the package of motor actions needed to execute the movement (i.e., how to act). To achieve the objective of movement, motor programs need to be assembled that enable one to move in space to reach the desired destination (i.e., where to act). This involves timing the execution of movement to the right place at the right moment and at the right pace (i.e., when to act), (Marsden, 1982; Marsden, 1984).

The individual parts of the motor plan are called motor programs. The motor program is responsible for the precise spatial and temporal patterns of muscle behaviors that are needed to carry out the necessary motion. Motor plan can be distinguished from motor program by the difference between writing a phrase on a blackboard as opposed to a pad on a desk. In both instances the relative motions are the same (i.e., motor plan), producing a characteristic writing style. However, different muscle activities are necessary in both conditions suggesting involvement of different motor programs (E. Montgomery, Personal communication, 1993).

Motor sequencing operations. Memory impairment may affect performance on a sequencing task. Subjects must compare the responses they have made with those that still remain to be carried out; therefore, sequencing tasks not only require an organized strategy but also an accurate memory (Kolb & Whishaw, 1996). Sullivan et al., (1985) assessed sequencing ability, removing memory as a confound. Fifteen patients with PD, 15 patients with Alzheimer's disease, and 15 controls were compared on the Picture Arrangement Subtest of the Weschler Adult Intelligence Scale (PAS-WAIS) (Wechsler, 1955). The PAS-WAIS requires a series of cartoon pictures to be placed in an order that tells a sensible story. The pictures are all present as the patient orders them; this minimizes demands
on memory and decreases the likelihood that memory impairment systematically impacts picture ordering. Only the PD patients showed deficits in sequencing pictures in the PAS-WAIS, even when time was not used in scoring.
APPENDIX A

DESCRIPTION OF NEUROPSYCHOLOGICAL TASKS (ALPHABETICAL)
Appendix A

Description of Neuropsychological Tasks (alphabetical)

Brooks (1968) spatial and nonspatial (verbal) memory tasks
The spatial memory task requires remembering number-word pairs by mentally placing the numbers in a imagined 4X4 matrix. The nonspatial (verbal) memory task requires remembering number-pairs as paired associates.

California Verbal Learning Test (Delis, Kramer, Kaplan, & Ober, 1983)
Is a word list learning test that measures recognition memory, immediate and delayed recall memory.

Delayed alternation task (Kolb & Whishaw, 1990)
In delayed response, the animal is shown where food is located (e.g., under one of two cups) but is preventing from responding for a few seconds. After the delay, the animal is allowed to respond, and his accuracy in choosing the correct hiding place for the food is measured. Even with short delays, chimpanzees with frontal lesions may not be able to remember which cup the food is under. In delayed alternation, the location of the food is alternated from one side to the other, with a brief delay between trials.

Mirror Drawing task (Kolb & Whishaw, 1990)
This test requires the participant to trace a line between the double outline of a star while seeing the star and his pencil in a mirror.

Odd-Man-Out (Flowers and Robertson, 1985)
Subjects are asked to indicate which of a set of letters or numbers is different from the others on two series of cards, using two rules of classification alternately on successive trials. The number of correct choices on each trial and the kind of errors made, indicate the ability of subjects to apply a concept consistently and to alternate between one response set and another. Response set is defined as a state of brain activity which predisposes a subject to respond in one way when several alternatives are available.

Sternberg paradigm (Sternberg, 1975)
is a short term memory scanning task: The subject is shown a memory set of varying size and then a single target digit. The subject has to decide whether or not the target digit is a member of the memory set; he indicates his decision by pressing one of two keys: a "yes" key and a "no" key. Both response speed and accuracy are recorded.
**Stroop test** (Stroop, 1935)
In this task, the subject is given a list of color names. He must either read the words or name the color of the printed words. Reading is easy in the congruent situation when color name is printed in the same ink color (word red is printed in red). Reading is still fairly easy in the incongruent situation, when color names are printed in different colors (word red is printed green). However, when the subject must name color the words are printed in, rather than reading the words, condition is very difficult. The subject must say "green" when he sees the word "red" printed in green. One cannot ignore reading the word which interferes with naming the color. The highly practiced skill of reading interferes with the less practiced task of naming colors. This interference effect is referred to as the "Stroop" effect.

**Tower task** (e.g. Tower of Hanoi Puzzle)
It involves the movement of disks from one location to another (peg 1 to peg 3) constrained by several rules. There are three pegs. Only one disk may be moved at one time and smaller disks must always be placed on larger disks. In this puzzle, the problem solver must keep each goal, the sequence of subgoals, and the moves to be made in working memory. Difficulty arises when one cannot remember the goals, and his/her current place in the sequence of goals (Haberlandt, 1994).

Working memory is tested by the Tower of Hanoi Puzzle. Working memory contains the plan used to solve a problem. Sequencing, transformations, and intermediary results are held in working memory for easy access. Patients inability to plan and organize is seen in impaired performance on the Tower of Hanoi test (Haberlandt, 1994).

**Trailmaking Test** (Army Individual Test Battery, 1944)

Part A: Subjects are asked to connect consecutively numbered circles in ascending order as quickly as possible. This task assesses sequencing and visuomotor ability.

Part B: Subjects are asked to connect consecutively numbered and lettered circles in ascending order as quickly as possible; Subjects must alternate between numbers and letters, e.g., 1-A-2-B-3-C. This task assesses sequencing, shifting, and visuomotor ability.
Verbal fluency (Kolb & Whishaw, 1996)
requires the subject to say or write as many words as possible beginning with
a given letter in 5 min, then as many four letter words beginning with a given
letter in 4 min.

Vocabulary and Naming
Vocabulary is assessed by presenting each subject with 10 sheets containing
4 outline drawings of common objects and asking the subject to point to the
object named by the experimenter. In the naming task, subjects are asked to
name 10 outline drawings of common objects. Impairment on these tasks
may indicate visual agnosia (inability to recognize objects or their pictorial
representation, or to draw or copy them), anomia (difficulty in finding words,
especially those naming objects) or both (Kolb & Whishaw, 1996).

Wisconsin Card Sorting Test (Heaton, 1981)
Subjects sort cards containing stimuli that differ by three physical criteria:
color, shape, and number. The subject must shift between these criteria as
the basis for sorting but is not warned that there will be a shift in sorting
criteria. After one criteria for sorting is established, the examiner shifts to
another rule without informing the subject. The subject must then shift to the
new criteria.
APPENDIX B

HUMAN SUBJECT'S APPROVAL AND CONSENT FORM
I am being invited to voluntarily participate in the research project entitled “Motor control in Parkinson’s and Alzheimer’s disease.” The purpose of the project is to study the problems of movement control in patients with Parkinson’s and Alzheimer’s disease. Recent research suggests that Parkinson’s disease patients may perform differently from normal subjects on tasks where there are changes in size and the type of the target for movement. If this is found to be true, we may then understand Parkinson’s disease better and find better ways of testing patients so as to give better treatment. Many patients with Alzheimer’s disease develop symptoms similar to patients with Parkinson’s disease. This study will provide an opportunity to carefully compare Parkinson’s disease patients to those with Alzheimer’s disease. Ten normal, 10 parkinsonian features, and 10 Alzheimer’s patients without parkinsonism will be asked to participate over a one year period.

My participation will not affect any treatment that I might be receiving except to delay the first morning dose of medications for Parkinson’s disease, if any.

If I agree to participate, I will be asked to agree to the following:

I will have stopped any medications used to treat my Parkinson’s disease at midnight before the morning of my testing. Then I will perform the following movement tests in the Neurology Department. These will last approximately one hour. Then I will restart my Parkinson’s medication, wait one hour, and repeat the tests.

(a) I will be sitting in a chair at a table. There will be a light panel with touch sensors in front of me. The light panel will indicate what touch sensor I am to touch with my right index finger. Electrodes, similar to those used in taking a heart tracing, will be placed on my skin over the muscles in my forearm and arm. There will be no puncturing of the skin. In this way, electrical activity of my forearm and arm muscles can be recorded. Potentiometers, devices that measure a joint’s position in space, will be placed at my right elbow and wrist.

(b) While sitting in a chair at a table, I will be asked to trace eight figures on a board in front of me as quickly and as accurately as I can. This task will be timed.

(c) While sitting in a chair at a table, my hand would be placed in a device which measures movement of the wrist. Electrodes will be placed as described in paragraph (a) above. I will move my wrist back and forth in response to instructions.
(d) While sitting in a chair, I will be asked to look at different spots of light. I will be wearing eyeglasses that will measure eye movements. These glasses will not contact or irritate the eyes.

I understand there are certain risks and discomforts that might be associated with this research:

(a) There is a risk of electrical shock through the electrodes used to record the muscle activity. The risk of electrical shock is the same as any household electrical appliance. All electrical equipment has been checked to comply with departmental biomedical standards.

(b) Worsening of the symptoms of Parkinson's disease, as a result of the antiparkinsonian medicines being withheld for one evening and night.

(c) Although every effort will be made to ensure my confidentiality, there is still the risk of exposure.

I understand that the possible benefits to myself and society are greater understanding of how Parkinson's or Alzheimer's disease affects movement and the possible development of testing which may aid in the management of Parkinson's disease. I understand that I will not receive any financial remuneration for my participation.

I understand that the investigator and the University will take all reasonable measures to protect the confidentiality of my records and my identity will not be revealed in any publication that may result from this project. Only Dr. Erwin Montgomery, or those specifically designated by him, will have access to my records. I understand there is a possibility that my medical record, including identifying information, may be inspected and/or photocopied by officials of federal and state government agencies during the ordinary course of carrying out their functions.

I understand that there is no cost to participate in this research project and that I will not be paid to participate.

I understand that side effects or harm are possible in any research program despite the use of high standards of care and could occur through no fault of mine or the investigator involved. Known side effects have been described in this consent form. However, unforeseeable harm may also occur and require care. I understand that money for research-related side effects or harm, or for wages or time lost, is not available. I do not give up any legal rights before signing this form. Necessary emergency medical care will be provided without cost. I can obtain further information from Dr. Erwin B. Montgomery, Jr., M.D., at 626-2319. If I have any questions concerning my rights as a research subject, I may call the Human Studies Committee office at 626-6721.
BEFORE GIVING MY CONSENT BY SIGNING THIS FORM, THE METHODS, INCONVENIENCES, RISKS AND BENEFITS HAVE BEEN EXPLAINED TO ME AND MY QUESTIONS HAVE BEEN ANSWERED. I UNDERSTAND THAT I MAY ASK QUESTIONS AT ANY TIME AND THAT I AM FREE TO WITHDRAW FROM THE PROJECT AT ANY TIME WITHOUT CAUSING BAD FEELINGS OR AFFECTING MY MEDICAL CARE. MY PARTICIPATION IN THIS PROJECT MAY BE ENDED BY THE INVESTIGATOR OR THE SPONSORS FOR REASONS THAT WOULD BE EXPLAINED. NEW INFORMATION DEVELOPED DURING THE COURSE OF RESEARCH PROJECT WILL BE GIVEN TO ME AS IT BECOMES AVAILABLE. I UNDERSTAND THAT THIS CONSENT FORM WILL BE FILED IN AN AREA DESIGNATED BY THE HUMAN SUBJECTS COMMITTEE WITH ACCESS RESTRICTED TO THE PRINCIPLE INVESTIGATOR, ERWIN B. MONTGOMERY, JR., M.D., OR AN AUTHORIZED REPRESENTATIVE OF THE NEUROLOGY DEPARTMENT. I UNDERSTAND THAT I DO NOT GIVE UP ANY OF MY LEGAL RIGHTS BY SIGNING THIS FORM. A COPY OF THE SIGNED CONSENT FORM WILL BE GIVEN TO ME.

________________________________________________________
Subject's Signature Date

________________________________________________________
Parent/Legal Guardian (if necessary) Date
INVESTIGATOR'S AFFIDAVIT

I have carefully explained to the subject the nature of the above project. I hereby certify that to the best of my knowledge the person signing this consent form understands clearly the nature, demands, benefits, and risks involved with his/her participation and that his/her signature is legally valid. A medical problem, language or educational barrier has not precluded this understanding.

Signature of Investigator ___________________________ Date ___________________________
April 26, 1994

Erwin B. Montgomery, M.D.
Department of Neurology
Arizona Health Sciences Center

RE: HSC A90.120 MOTOR CONTROL IN PARKINSON'S DISEASE AND ALZHEIMER'S DISEASE

Dear Dr. Montgomery:

We received your 25 April 1994 letter requesting that Berta Leis [predoctoral student] be added as assistant to the above referenced project. Approval for this change is granted effective 26 April 1994.

The Human Subjects Committee (Institutional Review Board) of the University of Arizona has a current assurance of compliance, number M-1233, which is on file with the Department of Health and Human Services and covers this activity.

Approval is granted with the understanding that no further changes or additions will be made either to the procedures followed or to the consent form(s) used (copies of which we have on file) without the knowledge and approval of the Human Subjects Committee and your College or Departmental Review Committee. Any research related physical or psychological harm to any subject must also be reported to each committee.

A university policy requires that all signed subject consent forms be kept in a permanent file in an area designated for that purpose by the Department Head or comparable authority. This will assure their accessibility in the event that university officials require the information and the principal investigator is unavailable for some reason.

Sincerely yours,

William F. Denny, M.D.
Chairman
Human Subjects Committee

cc: Departmental/College Review Committee
Explicit-inferred PD Project Protocol
Berta Leis

You will be seated in front of a screen that looks like a T.V. screen. On the screen are nine squares arranged like a tic tac toe board. In this task you are being asked to take a pencil and move it as fast as possible to a target that appears on the tic tac toe board.

Begin by holding the pencil in your dominant hand at the starting point located on the table. On the upper right hand side of the screen is a green light. When the green light blinks, press the pencil down the starting point. Wait for a beep to sound and then release the pencil and move as quickly as possible to the target that appears on the tic tac toe board.

There are two types of targets: 1) the first is shaped like a plus sign ( + ) that identifies the exact location of the target: 2) the second contains two cues, a vertical and a horizontal band ( _ | ) which are used to determine its precise location.

*Move to any portion of the square in both types of targets:* you do not need to move to the “center” of the plus sign or the center of the square located on the tic tac toe board.

*Place the tip of the pencil squarely (not sideways) on the screen* as if throwing a dart. Remember to move as fast as possible to the target once you hear the beep.

Once you have hit the target, *bring the pencil back to the starting point at your leisure* and wait for the green light to blink before pressing the pencil down again.

Sometimes when you are moving to a new target, the target will change location. Move to the new location as quickly as possible.

*Again the steps are:* green light blinks, press pencil down, wait for beep, quickly move to target.

Finally, this task requires concentration so *remember to break* at least every 10 to 15 minutes or as often as needed to maintain your concentration.
References

Aldridge, J., Anderson, R., & Murphy, J. (1980). The role of the basal ganglia in controlling a movement initiated by a visually presented cue. Brain Research, 192, 3-16.


NCSS PASS (1992). Hintze, J.


